

Landslide Hazard Management and Control in Pakistan A Review



M.H. Malik
and
S. Farooq

Copyright © 1996

International Centre for Integrated Mountain Development

All rights reserved

Cover Photograph: Plane failure in schists at Lower Gali, Muzaffarabad

Inset: Movement of scree slope blocking the road between
Muzaffarabad and Garhi Habib Ullah.

Published by

International Centre for Integrated Mountain Development
G.P.O. Box 3226,
Kathmandu, Nepal

ISBN 92-9115-483-0

The views and interpretations in this paper are those of the author(s). They are not attributable to the International Centre for Integrated Mountain Development (ICIMOD) and do not imply the expression of any opinion concerning the legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries.

Landslide Hazard Management and Control in Pakistan

A Review

The inherently unstable nature of mountain areas of the Hindu Kush-Himalayas is well recognized. The steep slopes, unstable geology, and frequent earthquakes combine to make the Hindu Kush-Himalayas one of the most hazard-prone areas in the world. Landslides of varying intensity have occurred frequently in the past in Hindu Kush-Himalayas. In recent years, there has been an increase in human settlement of hazard-prone areas as a result of population pressure, as well as improvements in accessibility by road and the onset of other infrastructural developments. Consequently, natural and man-made disasters are on the increase and each event affects an even greater number of people than before. Floods and landslides during the monsoon season are the most common natural disasters affecting this region, often resulting in substantial economic and environmental losses and causing great suffering to many people.

Despite all this the present levels of understanding and systematic analysis of these disastrous events are very poor and data bases are non-existent. No monitoring activities are carried out even in cases where such monitoring can be of direct benefit to project-related management activities. Investments in developing practical guidelines for managing such events as well as in forecasting them have been inadequate.

Since its inception, ICIMOD has been promoting the development of a better understanding of natural hazards. Various activities have been undertaken so far. These include several training programmes dealing with mountain risk engineering, focussing on improving road construction along unstable mountain slopes, a series of landslide hazard management activities in China, and field assessment of landslides and flood hazards in south central Nepal following the extreme climatic events that took place in July 1993.

One of the goals set by ICIMOD in its Mountain Resources Programme is to "improve the management of mountain resources and environments and eventually reversing their degradation." Various activities envisaged to achieve this goal are directed to:

- identification of measures to mitigate different types of natural hazards which result in the loss of natural resources;
- promotion of skills and methodologies for natural hazard assessment; and
- improvement of public awareness for better disaster preparedness in mountain areas.

ICIMOD's programme on "Landslide Hazard Management and Control" focusses on these concerns to help protect valuable natural resources from different types of natural hazards. This programme is based on activities already introduced at ICIMOD in 1994 with support from the Government of Japan.

This programme is concerned not only with examining the types and extent of landslide events but also with measures for their mitigation and control; and in addition the skills and methodologies needed for natural hazard assessment.

To improve the knowledge base on Landslide Hazard Management and Control, state-of-the-art reviews were commissioned in four countries of the Hindu Kush-Himalayan Region. These countries are China, India, Nepal, and Pakistan.

Suresh Raj Chalise of the Mountain Natural Resources Division at ICIMOD coordinated the work carried out on these reviews and the current document entitled "Landslide Hazard Management and Control in Pakistan: A Review" was prepared by M.H. Malik, and Saqeb Farooq of the Institute of Geology, Punjab University. Mr. Malik and Mr. Farooq have produced a comprehensive document on a topic that is crucial to the development of mountain areas and the wellbeing of mountain inhabitants.

February 1996

International Centre for Integrated Mountain Development
Kathmandu, Nepal

Preface

Abstract

The inherently unstable nature of mountain areas of the Hindu Kush-Himalayas is well recognised. The steep slopes, unstable geology, and intense monsoon rains combine to make the Hindu Kush-Himalayas one of the most hazard-prone areas in the world. Although natural hazards of varying intensity have occurred frequently in the past in Hindu Kush-Himalayan countries, more recently there has been an increase in human settlement of hazard-prone areas as a result of population pressure, as well as improvements in accessibility by road and the onset of other infrastructural developments. Consequently, natural and man-made disasters are on the increase and each event affects an even greater number of people than before. Floods and landslides during the monsoon season are the most common natural disasters affecting this region, often resulting in substantial economic and environmental losses and causing great suffering to many people.

Despite all this the present levels of understanding and systematic analysis of these disastrous events are very poor and data bases are non-existent. No monitoring activities are carried out even in cases where such monitoring can be of direct benefit to project-related management activities. Investments in developing practical guidelines for managing such events as well as in forecasting them have been inadequate.

Since its inception, ICIMOD has been promoting the development of a better understanding of natural hazards. Various activities have been undertaken so far. These include several training programmes dealing with mountain risk engineering, focussing on improving road construction along unstable mountain slopes, a review of landslide hazard management activities in China, and field assessment of landslides and flood events in south central Nepal following the extreme climatic events that took place in July 1993.

One of the goals set by ICIMOD in its Mountain Natural Resources' programme is to "Improve the conditions of mountain resources and environments by halting and eventually reversing their degradation." Programme activities envisaged to achieve the above goal are directed to:

- identification of measures to mitigate different types of natural hazards which result in the loss of natural resources;
- promotion of skills and methodologies for natural hazard assessment; and
- improvement of public awareness for better disaster preparedness in mountain areas.

ICIMOD's programme on "Landslide Hazard Management and Control" focusses on these concerns to help protect valuable natural resources from different types of natural hazards. This programme is based on activities already introduced at ICIMOD in 1994 with support from the Government of Japan.

This programme is concerned not only with examining the types and extent of landslide events but also with measures for their mitigation and control; and in addition the skills and methodologies needed for natural hazard assessment.

To improve the knowledge base on Landslide Hazard Management and Control, state-of-the-art reviews were commissioned in four countries of the Hindu Kush-Himalayan Region. These countries are China, India, Nepal, and Pakistan.

Suresh Raj Chalise of the Mountain Natural Resources' Division at ICIMOD coordinated the work carried out on these reviews and the current document entitled "**Landslide Hazard Management and Control in Pakistan : A Review**" was prepared by M.H. Malik, and Saeed Farooq of the Institute of Geology, Punjab University. Mr. Malik and Mr. Farooq have produced a comprehensive document on a topic that is crucial to the development of mountain areas and the well-being of mountain inhabitants.

Contents

Abstract

Introduction

This country review on landslides in Pakistan deals with all the aspects of landslides, their types; causative factors; their relation to geology, earthquakes, monsoons, and deforestation; their impact; and possible studies to overcome disasters and control. This paper systematically identifies the problem areas and gives details of the historical background clearly establishing the connection with certain natural (earthquakes, lithology) and man-made (excavations and indiscriminate construction) causative factors.

The northern parts of Pakistan, i.e., the mountainous regions of the Himalayas, the Karakoram, and the Hindu Kush, have a high incidence of landslides. Though this part of the country is not highly-populated, nevertheless, the impact of landslides is felt severely. More so, because this part of the country is bordered by China, India, and Afghanistan and is, therefore, of considerable strategic importance.

The extent of the impacts of landslides depends upon various factors such as the depth and rate of movement, stresses from the environment, volume of materials involved, and, most importantly, the proximity to settlements and structures. The author quotes instances where more than half a village has been wiped out or where powerhouses/dams have been damaged.

Dealing with the diversity of causes, the author scientifically enumerates aspects of geology, such as lithological distribution, bedding, joints, foliation, and schistosity, that lead to landslides. Causative factors relating to surface and groundwater and the effect of saturation on strength, temperature variations, earthquakes and vibrations, and effects of vegetation and deforestation have been dealt with in the context of Pakistan.

The text is further substantiated with figures, tables, and photographs.

Bibliography

List of Plates

11	Plate 1: Geology of Pakistan
12	Plate 2: Landslides in Pakistan
13	Plate 3: Landslides in Pakistan
14	Plate 4: Landslides in Pakistan
15	Plate 5: Landslides in Pakistan
16	Plate 6: Landslides in Pakistan
17	Plate 7: Landslides in Pakistan
18	Plate 8: Landslides in Pakistan
19	Plate 9: Landslides in Pakistan
20	Plate 10: Landslides in Pakistan
21	Plate 11: Landslides in Pakistan
22	Plate 12: Landslides in Pakistan
23	Plate 13: Landslides in Pakistan
24	Plate 14: Landslides in Pakistan
25	Plate 15: Landslides in Pakistan
26	Plate 16: Landslides in Pakistan
27	Plate 17: Landslides in Pakistan
28	Plate 18: Landslides in Pakistan
29	Plate 19: Landslides in Pakistan
30	Plate 20: Landslides in Pakistan
31	Plate 21: Landslides in Pakistan
32	Plate 22: Landslides in Pakistan
33	Plate 23: Landslides in Pakistan
34	Plate 24: Landslides in Pakistan
35	Plate 25: Landslides in Pakistan
36	Plate 26: Landslides in Pakistan
37	Plate 27: Landslides in Pakistan
38	Plate 28: Landslides in Pakistan
39	Plate 29: Landslides in Pakistan
40	Plate 30: Landslides in Pakistan
41	Plate 31: Landslides in Pakistan
42	Plate 32: Landslides in Pakistan
43	Plate 33: Landslides in Pakistan
44	Plate 34: Landslides in Pakistan
45	Plate 35: Landslides in Pakistan
46	Plate 36: Landslides in Pakistan
47	Plate 37: Landslides in Pakistan
48	Plate 38: Landslides in Pakistan
49	Plate 39: Landslides in Pakistan
50	Plate 40: Landslides in Pakistan
51	Plate 41: Landslides in Pakistan
52	Plate 42: Landslides in Pakistan
53	Plate 43: Landslides in Pakistan
54	Plate 44: Landslides in Pakistan
55	Plate 45: Landslides in Pakistan
56	Plate 46: Landslides in Pakistan
57	Plate 47: Landslides in Pakistan
58	Plate 48: Landslides in Pakistan
59	Plate 49: Landslides in Pakistan
60	Plate 50: Landslides in Pakistan
61	Plate 51: Landslides in Pakistan
62	Plate 52: Landslides in Pakistan
63	Plate 53: Landslides in Pakistan
64	Plate 54: Landslides in Pakistan
65	Plate 55: Landslides in Pakistan
66	Plate 56: Landslides in Pakistan
67	Plate 57: Landslides in Pakistan
68	Plate 58: Landslides in Pakistan
69	Plate 59: Landslides in Pakistan
70	Plate 60: Landslides in Pakistan
71	Plate 61: Landslides in Pakistan
72	Plate 62: Landslides in Pakistan
73	Plate 63: Landslides in Pakistan
74	Plate 64: Landslides in Pakistan
75	Plate 65: Landslides in Pakistan
76	Plate 66: Landslides in Pakistan
77	Plate 67: Landslides in Pakistan
78	Plate 68: Landslides in Pakistan
79	Plate 69: Landslides in Pakistan
80	Plate 70: Landslides in Pakistan
81	Plate 71: Landslides in Pakistan
82	Plate 72: Landslides in Pakistan
83	Plate 73: Landslides in Pakistan
84	Plate 74: Landslides in Pakistan
85	Plate 75: Landslides in Pakistan
86	Plate 76: Landslides in Pakistan
87	Plate 77: Landslides in Pakistan
88	Plate 78: Landslides in Pakistan
89	Plate 79: Landslides in Pakistan
90	Plate 80: Landslides in Pakistan
91	Plate 81: Landslides in Pakistan
92	Plate 82: Landslides in Pakistan
93	Plate 83: Landslides in Pakistan
94	Plate 84: Landslides in Pakistan
95	Plate 85: Landslides in Pakistan
96	Plate 86: Landslides in Pakistan
97	Plate 87: Landslides in Pakistan
98	Plate 88: Landslides in Pakistan
99	Plate 89: Landslides in Pakistan
100	Plate 90: Landslides in Pakistan

1	Introduction
2	The Landslide Issue
3	1.1 Landslides in Pakistan
4	1.2 Landslides in Pakistan
5	1.3 Landslides in Pakistan
6	1.4 Landslides in Pakistan
7	1.5 Landslides in Pakistan
8	1.6 Landslides in Pakistan
9	1.7 Landslides in Pakistan
10	1.8 Landslides in Pakistan
11	1.9 Landslides in Pakistan
12	1.10 Landslides in Pakistan
13	1.11 Landslides in Pakistan
14	1.12 Landslides in Pakistan
15	1.13 Landslides in Pakistan
16	1.14 Landslides in Pakistan
17	1.15 Landslides in Pakistan
18	1.16 Landslides in Pakistan
19	1.17 Landslides in Pakistan
20	1.18 Landslides in Pakistan
21	1.19 Landslides in Pakistan
22	1.20 Landslides in Pakistan
23	1.21 Landslides in Pakistan
24	1.22 Landslides in Pakistan
25	1.23 Landslides in Pakistan
26	1.24 Landslides in Pakistan
27	1.25 Landslides in Pakistan
28	1.26 Landslides in Pakistan
29	1.27 Landslides in Pakistan
30	1.28 Landslides in Pakistan
31	1.29 Landslides in Pakistan
32	1.30 Landslides in Pakistan
33	1.31 Landslides in Pakistan
34	1.32 Landslides in Pakistan
35	1.33 Landslides in Pakistan
36	1.34 Landslides in Pakistan
37	1.35 Landslides in Pakistan
38	1.36 Landslides in Pakistan
39	1.37 Landslides in Pakistan
40	1.38 Landslides in Pakistan
41	1.39 Landslides in Pakistan
42	1.40 Landslides in Pakistan
43	1.41 Landslides in Pakistan
44	1.42 Landslides in Pakistan
45	1.43 Landslides in Pakistan
46	1.44 Landslides in Pakistan
47	1.45 Landslides in Pakistan
48	1.46 Landslides in Pakistan
49	1.47 Landslides in Pakistan
50	1.48 Landslides in Pakistan
51	1.49 Landslides in Pakistan
52	1.50 Landslides in Pakistan
53	1.51 Landslides in Pakistan
54	1.52 Landslides in Pakistan
55	1.53 Landslides in Pakistan
56	1.54 Landslides in Pakistan
57	1.55 Landslides in Pakistan
58	1.56 Landslides in Pakistan
59	1.57 Landslides in Pakistan
60	1.58 Landslides in Pakistan
61	1.59 Landslides in Pakistan
62	1.60 Landslides in Pakistan
63	1.61 Landslides in Pakistan
64	1.62 Landslides in Pakistan
65	1.63 Landslides in Pakistan
66	1.64 Landslides in Pakistan
67	1.65 Landslides in Pakistan
68	1.66 Landslides in Pakistan
69	1.67 Landslides in Pakistan
70	1.68 Landslides in Pakistan
71	1.69 Landslides in Pakistan
72	1.70 Landslides in Pakistan
73	1.71 Landslides in Pakistan
74	1.72 Landslides in Pakistan
75	1.73 Landslides in Pakistan
76	1.74 Landslides in Pakistan
77	1.75 Landslides in Pakistan
78	1.76 Landslides in Pakistan
79	1.77 Landslides in Pakistan
80	1.78 Landslides in Pakistan
81	1.79 Landslides in Pakistan
82	1.80 Landslides in Pakistan
83	1.81 Landslides in Pakistan
84	1.82 Landslides in Pakistan
85	1.83 Landslides in Pakistan
86	1.84 Landslides in Pakistan
87	1.85 Landslides in Pakistan
88	1.86 Landslides in Pakistan
89	1.87 Landslides in Pakistan
90	1.88 Landslides in Pakistan
91	1.89 Landslides in Pakistan
92	1.90 Landslides in Pakistan
93	1.91 Landslides in Pakistan
94	1.92 Landslides in Pakistan
95	1.93 Landslides in Pakistan
96	1.94 Landslides in Pakistan
97	1.95 Landslides in Pakistan
98	1.96 Landslides in Pakistan
99	1.97 Landslides in Pakistan
100	1.98 Landslides in Pakistan

Contents

Introduction	1	Bibliography	57
The Landslide Issue	1	List of Plates	59
Description and Types	1		
<i>Rockfalls</i>	7	List of Figures	
<i>Topples</i>	7	1: Road Map of Northern Pakistan	2
<i>Slides</i>	7	2: Geological Map of Kohala- Muzaffarabad Area (Kohala to Dulai) showing Landslide Risk Zones	3
<i>Flows</i>	11	3: Different Types of Landslides and Slope Failures	4
<i>Creep</i>	11	4: Statistical Distribution of Various Types of Landslides in Different Areas	5
Impact of Landslides	13	5: Geological and Landslide Inventory Map of Abandoned Road between Khera Gali and Changla Gali.(Hazara)	8
Factors Causing Landslides	14	6: Stability Assessment along part of the Karakoram Highway from Thakot to Batgram (28km) using the Stereoplotting Technique	9
Geology and Landslides	14	7(a): Typical Circular Failure in Soils	10
<i>Engineering-Geological Properties</i>	14	7(b): Nomenclature Used to Describe Landslides (Varnes 1978)	10
<i>Geological Structure</i>	15	8: Wedge Failure, Plane Failure, Circular Failure, Creep Flow, Shetan Pari to Aliabad Hunza (65km) Karakoram Highway	12
<i>Stresses and Geological History</i>	17	9: Sketch of Kohala Landslide along with Cross-sections, Stereoplot and Test Results	16
Earthquakes and Landslides	24	10: Joint Frequency vs Lithology	19
Monsoon Rains and Landslides	32	11: Joint Frequency vs Clay Fraction in Claystone Beds	19
Sloping Terraces and Landslides	33	12: Joint Frequency vs Bed Thickness	20
Deforestation and Landslides	33	13: Average Joint Frequency vs Distance from a Small Fault	20
Reducing Impacts from Landslide Disasters	46	14: Tectonic Map of Northern Pakistan	21
Landslide Studies and Hazard Mapping	46	14(a): Seimotectonic Provinces of Pakistan	22
Landslide Monitoring and Warning Systems	49	14(b): Sketch Map Showing Areas which have Suffered Earthquake Damage	23
<i>Optical Methods</i>	49	15: Macro-Earthquake Events and Major Thrusts	25
<i>Mechanical Methods Used for Rock Mass</i>	49	16: Slides Recorded on Murree- Muzaffarabad Road - New Slides and Reactivated Slides (Murree 1988)	34
Landslide Control Works	49	17: Slides Recorded on Murree- Muzaffarabad Road - New Slides and Reactivated Slides (Murree 1989)	35
<i>Changing the Geometry or Shape of the Slope</i>	52	18: Slides Recorded on Murree- Muzaffarabad Road - New Slides and Reactivated Slides (Murree 1990)	36
<i>Rock Bolting</i>	52	19: Slides Recorded on Murree- Muzaffarabad Road - New Slides and Reactivated Slides (Murree 1991)	37
<i>Drainage</i>	52		
<i>Retaining Walls</i>	52		
<i>Vegetation</i>	52		
Methods of Preventing Flooding caused by Landslide Dams	52		
Landslide Control in Watersheds	53		
<i>Planning and Survey</i>	53		
<i>Afforestation</i>	53		
<i>Structural Control</i>	53		
<i>Treatment of Landslides</i>	53		
Increasing Public Awareness	53		
Technical Consulting Services	54		
Insurance Programme	54		
Institutions Dealing with Landslides	54		
Role of Public Agencies	54		
Role of Research Institutions	54		
Role of Provincial and Local Governments	54		
Role of NGOs and Scientific Societies	54		
Overall Conclusions and Recommen- dations for a Practical Training Programme	55		
Conclusions	55		
Recommendations	55		

20: Slides Recorded on Murree- Muzaffarabad Road - New Slides and Reactivated Slides (Murree 1992)	38
21: Slides Recorded on Murree- Abbottabad and Murree-Muzaffarabad Road - New Slides and Reactivated Slides (Kakul 1988)	39
22: Slides Recorded on Murree- Abbottabad and Murree-Muzaffarabad Road - New Slides and Reactivated Slides (Kakul 1989)	40
23: Slides Recorded on Murree- Abbottabad and Murree-Muzaffarabad Road - New Slides and Reactivated Slides (Kakul 1990)	41
24: Slides Recorded on Murree- Abbottabad and Murree-Muzaffarabad Road - New Slides and Reactivated Slides (Kakul 1991)	42
25: Slides Recorded on Murree- Abbottabad and Murree-Muzaffarabad Road - New Slides and Reactivated Slides (Kakul 1992)	43
26: Relationship of Angle of Slope (Terraces) with Stability Number	44
27: Sketch of the Sehr Bagla Potentially Unstable Zone Along with Cross- section, Stereoplot and Test Results	47
28: Stereoplot Showing Joint Sets and Direction of Principal Stress	48
29: Brief Sketch of the Simbal Slide (Motorway M1) showing Monitoring Pegs	50

List of Tables

1: Abbreviated Classification of Landslides (After Varnes 1978)	6
2: Features and Triggering Factors of Major Landslides in Pakistan	6
3: Field Measurements and Evaluations of Discontinuity Parametres	18
4: Chronological Catalogue of Non- instrumental (Intensity) Data	27
5: Instrumental Data List of Macro- Earthquakes (1904-1977)	29
6: Instrumental Data	29
7: Earthquakes Felt at the Tarbela Dam Project	30
8: Landslides Related to Major Earthquakes	31

9: Land Area under Forests in Different Countries	45
10: Monitoring Data of Simbal Landslide on the M1 Motorway between Lahore and Islamabad - June 1994	51

List of Plates

1: Medium-sized gabion structure showing deformation due to creep	59
2: Landslide between Muzaffarabad and Garhi Dupatta (Failure is within the ancient landslide)	59
3: Downslope failure of the retaining wall due to landslide as a result of saturation	60
4: Failure of retaining wall due to slump failure	60
5: Reconstruction of retaining wall after landsliding along the Murree- Muzaffarabad Road	61
6: Backfilling behind the retaining wall along the Murree-Muzaffarabad Road	61
7: Subsidence of metalled road near Kohala	62
8: Initiation of failure of downslope due to absence of retaining wall	62
9: Landslide due to deforestation	63
10: Tilting of trees due to landslide	63
11: Plane failure in schists at Lower Gali near Muzaffarabad	64
12: Movement of scree slope blocking the road between Muzaffarabad and Garhi Habib Ullah	64
13: Small-scale landslide caused by making a path for a newly-built house	65
14: Widening of road by blasting (may cause threatening slope ultimately)	65
15: Plane table mapping in critical areas	66
16: Point load testing of rock at site	66
17: Landslide activity in Aug. 1994 shows slip surface in background and cracks in displaced material along the M1 Motorway, Lahore-Islamabad	67
18: Fresh slip surface (Aug. 1994) along the M1 Motorway (Simbal landslide) between Lahore and Islamabad	67
19: An experiment for protection of excavated slope by plaster covering plates	68
20: Failure of experimental plaster covering due to swelling of shales	68

Acronyms

K.K.H.	Karakoram Highway
C	Cohesion
MC	Moisture Content %
LL	Liquid Limit
PL	Plasticity Limit
PI	Plasticity Index
rb	Bulk Density
rd	Dry density
ϕ	Angle of Internal Friction
Gs	Specific Gravity
p	Density
JRC	Joint Roughness Coefficient
JCS	Joint Wall Compressive Strength
ϕ_r	Angle of Residual Friction
n	Normal Load