



VISION FOR LANDSLIDE EARLY WARNING SYSTEMS IN NEPAL

**Practical
ACTION
CONSULTING**

About Practical Action

We are an international development organization putting ingenious ideas to work so people in poverty can change their world.

We help people find solutions to some of the world's toughest problems. Challenges made worse by catastrophic climate change and persistent gender inequality. We work with communities to develop ingenious, lasting and locally owned solutions for agriculture, water and waste management, climate resilience and clean energy. And we share what works with others, so answers that start small can grow big.

We're a global change-making group. The group consists of a UK registered charity with community projects in Africa, Asia, and Latin America, an independent development publishing company and a technical consulting service. We combine these specialisms to multiply our impact and help shape a world that works better for everyone.

About this report

Nepal is affected by multiple hazards, including rainfall-triggered landslides and the number of landslide induced disasters are increasing in Nepal. Local and provincial government agencies have reached out to Practical Action Nepal to **request help, advice and our expertise on developing landslide early warning to save people's lives and properties.**

Practical Action Nepal has worked on landslide early warning systems (LEWS) pilot studies in the past, but a **more rigorous and holistic assessment** was needed to understand if it would be feasible to develop a fully operational, sustainable LEWS, and what this would look like in Nepal.

The Practical Action Consulting International (PAC-Int) team are strongly involved in a LEWS project in India and are also involved in another LEWS project in Nepal. As a result of this work, PAC-Int have developed **extensive knowledge and networks** with key organisations involved in researching and implementing LEWS globally.

The increase in need and requests for LEWS within Nepal and the current work of the PAC-Int team provide an opportunity to **develop an informed strategy** as well as to explore potential areas of funding for Practical Action (PA) to take forward in developing a LEWS in Nepal. In developing this report, PAC-Int worked with the Nepal team to review current best practice, map out who is doing what on LEWS in mountain environments and make recommendations for Nepal.

Two knowledge products have been developed as a result of this work: an internal strategic piece which identifies opportunities for the Practical Action Group to enhance our programme offer in country; and an external vision for LEWS document (this document) which outlines recommended actions to build LEWS in Nepal, highlighting the key stakeholders, and indicating what can be achieved in the short and long term.

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SUMMARY

Landslide-induced disasters are **increasing in frequency** in Nepal. Between June and October 2020 alone, Nepal experienced significant impact with 285 people losing their lives due to landslides, and many more reported missing. This death toll is the worst attributed to disasters in recent years, including the floods in 2017 where 150 people lost their lives.

Landslide early warning presents an opportunity to **mitigate the impacts of landslides**, saving lives, reducing economic losses, and protecting development for communities in landslide-prone areas. Forecasting landslides is a difficult task, but by monitoring rainfall and other environmental conditions, it is possible to forecast the likelihood of landslides occurring in a particular region.

Landslide early warning systems can be developed at two scales: **local or regional**. At both scales, there are a number of ways forward which can be taken to develop and improve landslide early warning capacity. These steps include several recommended actions which can be implemented in the **short term**, as well as **longer term** actions which will be required to develop a holistic, sustainable, and effective landslide early warning system.

The section below outlines recommended actions aimed to build LEWS in Nepal, highlighting the key stakeholders, and indicating what can be achieved in the short and long term.

Regional to national level LEWS

**Improve use
of existing
knowledge
and
resources**

Recommended Actions

Target stakeholders:

- National, municipal, local government authorities
- Non-Government agencies and networks

Short term

Conduct assessment of the awareness and use of existing landslide forecasting and warning products

Identify the gaps and barriers to the uptake of these products

Identify information gaps in the available products

Localise hazard and susceptibility assessments

Recommended Actions

Target stakeholders:

- Municipal government authorities
- Humanitarian agencies and networks

Short term

Develop locally-specific and useful hazard, susceptibility and vulnerability maps

Integrate the use of these maps into municipal disaster management plans and activities

Develop impact-based forecasting

Recommended Actions

Target stakeholders:

- Department of Hydrology and Meteorology
- Department of Mines and Geology
- National, municipal, local government authorities
- Humanitarian agencies and networks
- NDRRMA

Short term

Collect and analyse data about historic impacts of landslide events

Collect and manage data about vulnerability and exposure

Long term

Develop collaboration and coordination between stakeholders in Nepal responsible for managing landslide risk

Improve forecast skill

Recommended Actions

Target stakeholders:

- Department of Hydrology and Meteorology
- Department of Mines and Geology
- National, municipal, local government authorities
- Humanitarian agencies and networks
- NDRRMA

Short term

Conduct a review of the accuracy of current forecast information provided by the DHM

Assess the utility of forecast information for decision-making

Long term

Develop and pilot a landslide forecasting methodology, adapting established effective practices

Establish clarity and coordination in governance

Recommended Actions

Target stakeholders:

- Department of Hydrology and Meteorology
- Department of Mines and Geology
- NDRRMA

Long term

Establish coordination between DHM and DOMG

Facilitate effective practices for data sharing

Incorporate inter-departmental collaboration into national DRM policies and plans

Establishment of a dedicated landslide forecasting centre

Increase data collection

Recommended Actions

Target stakeholders:

- Researchers
 - Department of Mines and Geology
 - Department of Hydrology and Meteorology
 - Non-governmental organisations
- Community stakeholders, e.g. CDMCs, schools, cooperatives, associations

Long term

Co-development of sustainable data collection methodology led by DOMG

Implementation of citizen science approach to the methodology design and application for meaningful engagement and collaboration with communities

Local level LEWS

Evidence-based locally-managed LEWS

Recommended Actions

Target stakeholders:

- Municipal and local government
- Community-based organisations
- Community stakeholders

Short term

Conduct a review of the accuracy and skill of local LEWS

Long term

Conduct a pilot to establish the accuracy, reliability, and appropriateness of different monitoring techniques and methodologies for the Nepal context

Conduct a cost-benefit analysis of local LEWS

LANDSLIDES IN NEPAL

Contributors to landslides

Both natural and human factors such as steep slopes, fragile geology, high intensity of rainfall, deforestation, unplanned human settlements are the major causes of landslide in Nepal (NDRRP, 2020). In Nepal, landslides are typically triggered by rainfall (for example during the monsoon), earthquake shaking, anthropogenic factors (such as cutting into the slope for construction purposes), and natural changes to slope gradient (for example caused by the rising of mountains due to tectonic forces).

Landslide-induced disasters are increasing in frequency in Nepal. Between June and October 2020 alone, Nepal experienced significant impact with 285 people losing their lives due to landslides, and many more reported missing. This death toll is the worst attributed to disasters in recent years, including the floods in 2017 where 150 people lost their lives.

The aim of an **early warning system** is to enable those at risk of hazards to receive appropriate information in advance of a hazard event, allowing sufficient time for them to act to reduce the possibility of injury, loss of life and damage to property and the environment. Successful development of flood early warning in Nepal has provided opportunities for people to take action to save lives and livelihoods. Landslide early warning presents an opportunity to mitigate the impacts of landslides, saving lives, reducing economic losses, and protecting development for communities in landslide-prone areas.

Forecasting landslides is a difficult task, but by monitoring rainfall and other environmental conditions, it is possible to forecast the likelihood of landslides occurring in a particular region.

Many initiatives to address landslide-related issues have been undertaken, but there is **not currently a fully functioning landslide early warning system in Nepal**. The Department of Hydrology and Meteorology are mandated to issue landslide early warnings, but the geological expertise required to link rainfall conditions to landslide risk is located in the Department for Mines and Geology, creating a gap between roles and capacity which affects the system.

Challenges for LEWS in Nepal

Landslide early warning systems can be developed at two scales: **local or regional**.

A **local LEWS** deals with a specific location or an individual slope. This system is based on the monitoring of conditions on the individual slope and the issuing of warnings when those conditions change.

A **regional LEWS** deals with the possible occurrence of multiple landslides over a larger geographical area, up to national scale. These systems are based on observed and forecast rainfall, and can provide forecast information with longer lead times for more people.

These systems are faced with specific challenges. Because local LEWS are based on monitoring conditions, key priorities relate to **monitoring technology**: solutions are needed which are accurate, appropriate, low-cost, and sustainable.

At the regional scale, forecasting is of key importance. Challenges facing these systems relate to the **skill and accuracy of forecasts**, including the need for access to free data, and the development of more geographically specific warnings. Another emerging priority is the shift towards impact-based forecasting, which combines weather information with information about exposure and vulnerability in an area to describe how the weather conditions will affect a population. These all require extensive **time and resources** to develop and implement.

For both systems, there are also challenges around providing decision-makers with **useful information** in a timely manner which supports effective preparedness and response.

Table 1: Comparison of local and regional scale LEWS

	Local scale LEWS	Regional scale LEWS
Spatial scales	Single slopes or landslides	Usually, regions up to national scale
Involved experts	Geologists, geomorphologists, engineering geologists	Meteorologists, statisticians, geographers
Landslide processes	All types	Shallow landslides, debris flows
Technical approach	Geotechnical monitoring systems, modelling approaches	Landslide triggering rainfall thresholds and rainfall forecasts
Monitoring methods	Geotechnical monitoring (e.g. crack meters, inclinometers)	Antecedent rainfall, rainfall forecasts, weather radar
Thresholds	Movement and triggers	Exceedance probability
Possible warnings	Automatic road closures, evacuations	“90% probability of (10 or more) landslides in the region “
Current research challenges	Low-cost approaches, integration of models with real-time data	Spatially explicit warnings, usage of free data

Opportunities

Triggers and thresholds for landslide early warning

Most landslide early warning systems for rainfall-induced landslides are based on the assumption that there is a relationship between environmental conditions (such as geology, soil type, vegetation cover, and slope angle), a trigger variable (such as rainfall amount or duration) and landslide occurrence. LEWS therefore develop “thresholds” which determine the minimum amount of the trigger variable (rainfall) for landslides to occur in susceptible environmental conditions.

Landslides are extremely **complex hazards** to forecast as so many different and widely varying factors need to be considered. Two slopes in the same area exposed to the same level of rainfall may have different types and levels of vegetative cover or land use, for example, which will influence if and how a landslide occurs.

However, by monitoring rainfall with other environmental conditions, the likelihood of a landslide occurring can be forecast. These forecasts are probabilities, estimated based on a combination of data and assumptions, so they are uncertain, but are also extremely useful for decision-making.

There are examples of operational regional LEWS which provide opportunities to learn from effective practices and apply these to the context of Nepal. There are currently only five nations, 13 regions, and four metropolitan areas benefit from territorial LEWSs (Guzzetti et al., 2020).

Table 2: Examples of regional LEWS from around the world

Location	Warning Issuer	Information communicated	Dissemination method	End user/ Stakeholder
El Salvador	Landslide Monitoring Center of the Ministry of Environment and Natural Resources & General Directorate of the Environmental Observatory	Levels of hazard warning: stable, low, medium, high	Website; App; special report; social networks	Civil defence; the public
Hong Kong	Hong Kong Geotechnical Engineering Office & Hong Kong Observatory	Alert if forecast is above a certain threshold number of landslides in a grid cell	Warning bulletin via media and internet	The public
Iceland	Icelandic Met Office	Colour coded levels of warnings; advice for local authorities and civil protection about evacuation and other actions	Press release; website	Local authorities; civil protection; the public

Italy	Consiglio Nazionale delle Ricerche	Probabilistic hazard forecast with colour scheme, divided into warning levels Auxiliary information available of previous landslide events in location, coupled with the same probabilistic information	Website; email bulletin	Civil protection agency at regional level
Japan	Ministry of Land, Infrastructure, Transport and Tourism & Japan Meteorological Agency	Levels of hazard, colour-coded	TV; radio; website	Local government officials; the public
Norway	Norwegian Water Resources and Energy Directorate	Traffic light hazard levels	Website; App; email (free subscription); SMS (free subscription); radio; TV	Local government officials; emergency authorities and media (free subscription); Norwegian Public Road Administration; Norwegian National Rail Administration; the public
UK	UK Met Office issues information (British Geological Survey develops forecast information)	Traffic light warning system (four levels of warning). Based on probability	Email bulletin	Local government officials; emergency authorities
USA: San Francisco Bay Area	US Geological Survey & National Weather Service	National Weather Service special weather statements	Radio; TV; SMS	The public
USA: Seattle	US Geological Survey, National Weather Service & City of Seattle	National Weather Service weather statements	Internet; radio; TV; Common Alerting Protocol; Disaster Management Information System	City officials; the public
USA: Southern California	US Geological Survey & National Oceanic and Atmospheric Administration	National Weather Service watches and warnings	Internet; National Oceanic and Atmospheric Administration weather radio; TV; Common Alerting Protocol; Disaster Management Information System	Emergency managers; the public

BUILDING A LEWS IN NEPAL: WAYS FORWARD

Building a LEWS in Nepal

The following are potential ways forward identified to develop LEWS in Nepal:

- Improve use of existing knowledge and resources
- Localise hazard and susceptibility assessments
- Develop impact-based forecasting
- Improve forecast skill
- Establish clarity and coordination in governance
- Increase data collection
- Evidence-based locally-managed slope-scale LEWS

There are a number of ways forward which can be taken to develop and improve landslide early warning capacity in Nepal. These steps include several recommended actions which can be implemented in the short term, leveraging and adapting existing resources, expertise and experience. These steps will contribute directly to improved landslide forecasting and early warning, as well as laying the groundwork for the longer term actions which will be required to develop a holistic, sustainable, and effective landslide early warning system.

Improve use of existing knowledge and resources

A range of projects focusing on landslide resilience and preparedness have been implemented in Nepal, producing different products designed to support decision-making in advance of and in response to landslide events. These products include hazard, susceptibility and vulnerability maps at national and local levels. Additionally, international and national forecasting agencies provide observational data and weather forecasts at different geographical and time scales.

There is a need to assess the use of existing products by those at national, municipal and local level, and to evaluate whether people are aware of and are using those products. Identifying the gaps and barriers to uptake of these resources, and missing resources required by stakeholders who manage, respond to, or prepare for landslides, will highlight clear priorities for how to access, use, develop, and improve existing knowledge and resources.

Recommended activities:

Achievable in the short term

- Conduct assessment of the awareness and use of existing landslide forecasting and warning products
 - Identify the gaps and barriers to the uptake of these products
 - Identify information gaps in the available products

Target outcomes

- Improved awareness, access and use of existing landslide-related products
- Development of recommendations for products and resources that are missing
- Identify information gaps in the available products

Target stakeholders

- National, municipal, local government authorities
- Humanitarian agencies and networks

Our expertise:

We have extensive experience of assessing early warning systems and use of risk information for practical application purposes. We can also provide learning and outputs from projects such as Landslide-EVO and LANDSLIP to contribute to the knowledge base of Nepal.

Localise hazard and susceptibility assessments

Hazard, vulnerability, and susceptible maps are essential tools for informed disaster risk management. The maps are available for Nepal, but they are provided at national level, meaning that they are less useful for municipal governments who need more specific information about hazard, vulnerability, and susceptibility in the areas they are mandated to reduce risk. There is a need for more locally specific and detailed information so that decision-makers can take action to reduce landslide risks in the short and longer term.

Recommended activities:

Achievable in the short term

- Develop locally-specific and useful hazard, susceptibility and vulnerability maps
- Integrate the use of these maps into municipal disaster management plans and activities

Target outcomes

- Disaster risk management for landslides at municipal level is strengthened with more relevant and useful information
- Municipal governments can make informed decisions about early actions to reduce landslide risks in their local areas

Target stakeholders

- Municipal government authorities
- Humanitarian agencies and networks

Our expertise:

We can provide a bridge to municipal government to facilitate the development, uptake and use of existing and new hazard and susceptibility maps and products.

Develop impact-based forecasting

The Department of Hydrology and Meteorology currently issues early warnings for landslides and floods when rainfall levels exceed standard thresholds. Developing forecast products which communicate the impacts of hazard events can improve the usefulness of forecast information for decision-making.

Impact-based forecasting in Nepal is being piloted by the UK Met Office, which is working closely with DHM and NDRRMA Nepal under the FCDO-funded Asia Regional Resilience to a Changing Climate Programme (ARRCC). The project aims to link weather forecasts with likely impacts (focusing on landslides), to produce forecast products and information that can be used by stakeholders to take action. Alongside this programme, the Sajaag-Nepal project is focusing on working with stakeholders to develop impact-based forecast information and potential early action protocols for three municipalities, including Karnali.

Recommended activities:

Achievable in the short term

- Collect and analyse data about historic impacts of landslide events
- Collect and manage data about vulnerability and exposure

Achievable in the long term

- Develop collaboration and coordination between stakeholders in Nepal responsible for managing landslide risk

Target outcomes

- Improved usefulness of forecast information to support decision-making for landslide risk reduction and management
- Strengthened flows of information, communication and decision-making between stakeholders

Target stakeholders

- Department of Hydrology and Meteorology
- Department of Mines and Geology
 - National, municipal, local government authorities
- Humanitarian agencies and networks

Our expertise:

We have significant experience with municipalities affected by flooding from the Karnali River, with strong, long-term relationships at local and municipal level. We also have significant knowledge of the FEWS, and are a project partner of the local landslide EWS Landslide-EVO project.

Improve forecast skill

The department of Hydrology and Meteorology currently issues early warnings for floods and landslides when rainfall levels are high. These warnings are based on a rainfall threshold developed in 2008, as well as data received from rainfall stations located across the country. The complex nature of Nepal's diverse climatic, weather, geological, and land use conditions means that localised differences are not captured in the collected data or represented in the forecasts. This affects the accuracy of forecasts. The DHM is able to state that landslides can be expected based on rainfall conditions, but is unable to state where these landslides will occur.

There is a need to develop a landslide forecast methodology for Nepal which can provide more specific, detailed, and certain information for decision-makers, in ways that are accessible, understandable, and actionable. This will require time, data, and cross-governmental collaboration, but can be supported by international knowledge and experience about landslide forecasting, drawing on learning from approaches that have been effectively applied and tested in different contexts.

Recommended activities:

Achievable in the short term

- Conduct a review of the accuracy of current forecast information provided by the DHM
- Assess the utility of forecast information for decision-making

Achievable in the long term

- Develop and pilot a landslide forecasting methodology, adapting established effective practices, linking all three tiers of government agencies working in DRRM and climate resilience.

Target outcomes

- Landslide forecasting skill in Nepal is enhanced, with greater accuracy, reliability, and specificity of forecast information
- Forecast information is provided in ways that are useful for decision-makers, responding to their needs and priorities

Target stakeholders

- Department of Hydrology and Meteorology
- Department of Mines and Geology
- National Disaster Risk Reduction and Management Authority (NDRRMA)
- National, provincial, municipal, local government authorities via NEOC, PEOC, DEOC, and LEOC
- Humanitarian agencies and networks

Our expertise:

We have significant understanding of holistic approaches to EWS and excellent connections to experts in the LEWS fields. We also have relevant expertise in data collection, governance, and user-centred communication of complex forecast information, as well as on piloting projects with a focus on legacy and sustainability.

Establish clarity and coordination in governance

There is currently no government department mandated for overseeing all aspects of landslides and early warning. The Department for Hydrology and Meteorology is responsible for issuing warnings, but lacks technical knowledge, and information on geology and geomorphology required to understand causative and triggering mechanisms to support landslide forecasting, while the Department of Mines and Geology collects landslide data and has governmental technical knowledge of landslides. However, there are no agreements or policies that facilitate collaboration, and the internal capacity to engage in such a way is limited.

There is a need to establish cross-departmental coordination, bringing together the experience, knowledge, and mandates of both departments for a coordinated and cohesive approach to collecting and sharing data, determining thresholds, and developing useful forecast products for landslide early warning. The NDRRMA has a key role to play in aligning these departments and integrating institutional arrangements and policies into existing disaster risk management policies and plans.

In the long term, the establishment of a dedicated landslide forecasting centre equipped with appropriate skills and resources would be required to implement an operational landslide early warning system for Nepal.

Recommended activities:

Achievable in the short term

- Establish coordination between DHM and DOMG
- Facilitate effective practices for data sharing
- Incorporate inter-departmental collaboration into national DRM policies and plans

Target outcomes

- DHM and DOMG work collaboratively to provide useful information and data for landslide forecasting and early warning
- National policies and plans include a roadmap to the establishment of a dedicated landslide forecasting centre

Target stakeholders

- Department of Hydrology and Meteorology
- Department of Mines and Geology
 - NDRRMA

Our expertise:

We can advise on potential appropriate governance structures for the establishment of an effective LEWS, drawing on our experience of flood EWS in Nepal, our knowledge of international best practice for LEWS and our role as a thematic committee member of NAP-DRM.

Increase data collection

The Department of Mines and Geology currently collects landslide observation data, while the Department of Hydrology and Meteorology collects rainfall and river level data. Various projects have collected databases of landslide observations, but to be able to forecast landslide likelihood in the future, dates and locations of landslide observations are needed to understand the relationship between rainfall conditions and landslide events.

There is a need to develop a sustainable methodology to collect the data that will facilitate the gathering of data which can be used for landslide forecasting in the long term, and which can be integrated with the existing practices of the Department of Mines and Geology. The approach will require collaborative efforts between government authorities, NGOs and communities to ensure adequate data collection.

Recommended activities:

Achievable in the long term

- Co-development of sustainable data collection methodology led by DOMG
- Implementation of citizen science approach to the methodology design and application for meaningful engagement and collaboration with communities

Target outcomes

- Application of a sustainable methodology for collection of required quantity and quality of data to support improved landslide forecasting
- Stakeholder awareness of, trust in, and uptake of landslide forecasts

Target stakeholders

- Department of Mines and Geology
- Department of Hydrology and Meteorology
- Non-governmental organisations
- Community stakeholders, e.g. CDMCs, schools, cooperatives, associations

Our expertise:

PA has extensive experience with citizen science approaches, data collection, and collaborative working across communities, NGOs and government authorities. Our experience here could be utilized to develop a pilot project to collect data, ensuring proof of concept is aligned with Nepal context and could be scaled up.

Evidence-based locally-managed slope-scale LEWS

There have been many initiatives to develop landslide early warning at local slope scales in Nepal. These projects have tested different methodologies for monitoring environmental conditions, and have conducted education and outreach about landslide risk. However, an assessment or evaluation of the benefits or accuracy of different monitoring methods for predicting landslides has not been undertaken. Another key challenge with these projects is sustainability: very few, if any, of these systems remain operational when the projects close. There is a need for evidence-based locally-managed landslide early warning systems which are able to continue issuing reliable warnings to communities in the long term, and which can provide a framework for other slope-scale LEWS to follow.

Recommended activities:

Achievable in the short term

- Conduct a review of the accuracy and skill of local LEWS

Achievable in the long term

- Conduct a pilot to establish the accuracy, reliability, and appropriateness of different monitoring techniques and methodologies for the Nepal context
- Conduct a cost-benefit analysis of local LEWS

Target outcomes

- The gaps and barriers to local LEWS and potential best practices to address these are identified and evaluated
 - Guidance is developed for sustainable, locally managed local LEWS which are based on community engagement
- Local LEWS are included in the mandate of government departments, providing effective governance, oversight and coordination

Target stakeholders

- Municipal and local government including Local Emergency Operation Center (LEOC)
- Community-based organisations such as Community Disaster Management Committees (CDJMC)
 - Community stakeholders e.g. CDMCs, schools, cooperatives, associations

Our expertise:

We can build on previous and current initiatives to develop collaboration for monitoring methods and community education and outreach. We also have expertise in conducting reviews to evaluate effectiveness and identify recommendation and lessons learned for moving forward.



**Together we can create a world
that works better for everyone.**

Contact us

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