

DAMAGE ASSESSMENT OF ANNAPURNA REGION NEPAL - JULY 15, 2015



ACKNOWLEDGMENT

The assessment of the Annapurna region's main trekking routes for structural and geotechnical earthquake-related damage was funded by SAMARTH-NMDP, a program supported by UKAID, and conducted on behalf of the Government of Nepal through the Ministry of Culture, Tourism and Civil Aviation. The assessment of the popular tourism treks was proposed by Intrepid Travel. Intrepid proposed an assessment of the two most popular tourist treks in Nepal to better assess safety as well as to assure travelers and the tourism industry. We would also like to express our sincere thanks to the Department of Tourism, Nepal Tourism Board and the Tourism Recovery Unit, the many members of Nepal's Tourism Industry and, in particular, the Annapurna Conservation Area Project (ACAP), which contributed to and provided their strong support to this project.

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EXECUTIVE SUMMARY

The Annapurna region, the most popular tourism destinations of the country, is located in the Himalayas in north-central Nepal. Following the powerful earthquakes of April and May 2015, the extent and severity of earthquake-related structural damage and geologic hazard were widely believed to be limited, but remained unknown.

With funding from SAMARTH-NMDP and on behalf of the government of Nepal through the Ministry of Culture, Tourism and Civil Aviation, an assessment team was dispatched from June 25 to July 2, 2015 to this region to observe and record seismic damages that occurred along the main trekking routes and select villages as a result of the earthquakes.

The team was comprised of a structural engineer and an engineering geologist, supported by a professional mountain guide and local conservation officer familiar with the region. The objective of the rapid reconnaissance of the region was to a) develop a baseline understanding of the extent of earthquake-related damage, b) advise on the overall trekking safety of the region's routes and c) provide recommendations on repairs or risk mitigation that will inform tourism recovery and commercial readiness strategies that are currently being developed by the government, its international development partners, and Nepal's tourism industry at large. The aim of these efforts is to promote tourism back to Nepal which will support the nation's economic recovery. The findings of the structural and geotechnical rapid assessment of the region are summarized in this report.

METHODOLOGY

A mix of helicopter flyover and trekking was used to access and assess the Annapurna region. The assessment began at Pokhara; from there 31 villages and approximately 220 km of trails were assessed, the majority of the trail by helicopter and most of the structures on foot.

The methodology applied to conduct the structural damage assessment was a rapid visual assessment per ATC-20 damage-assessment methodology and Department of Urban Development and Building Construction (DUDBC) guidelines. A total of approximately 30 bridges and 30 villages with a total of approximately 250 accommodations were assessed in the Annapurna region.

A visual reconnaissance of the areas of concern for potential geologic hazards such as rockfall, landslides, debris flows and other related steep terrain hazards was conducted to rapidly assess earthquake-related geologic damage and risk in the region.

Figure 1: Site Area Plan



Our reconnaissance was focussed on the Annapurna Circuit and Annapurna Sanctuary trekking routes (figure 2).

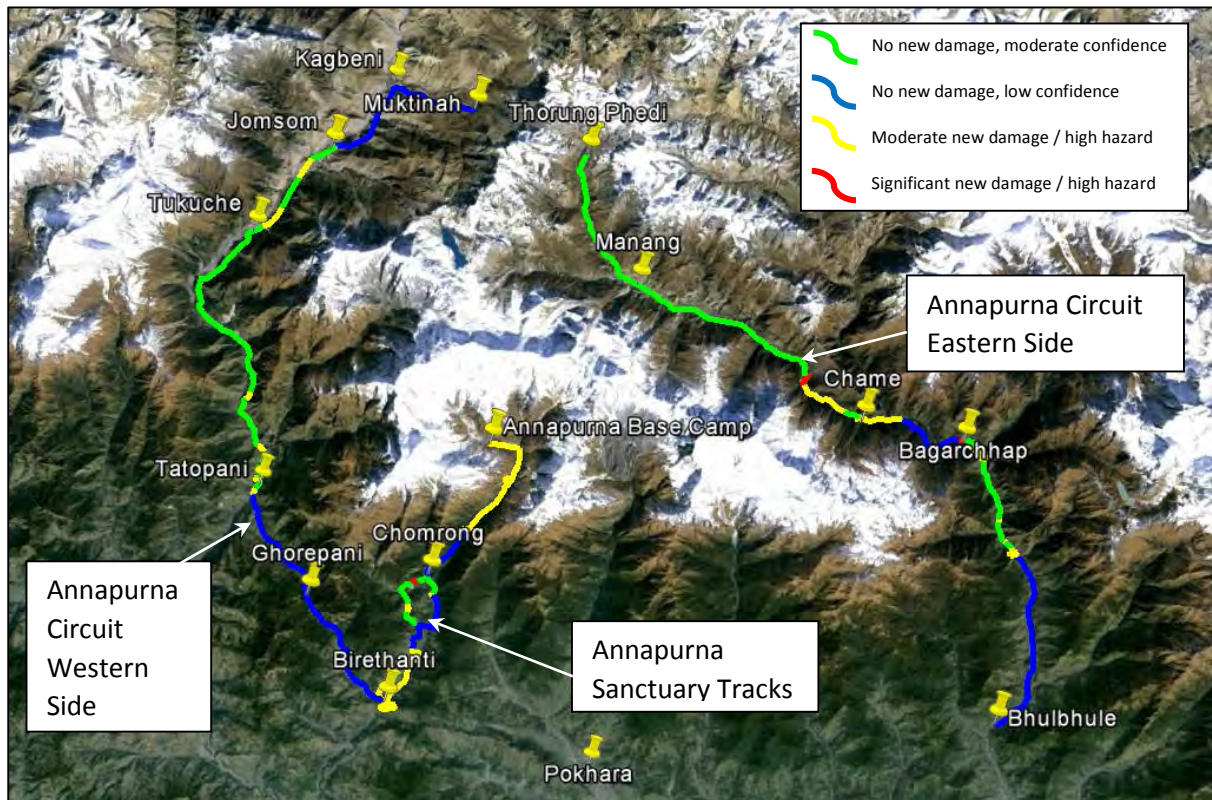
Villages and track locations were identified to us by the pilots and/or Annapurna Conservation Area Project (ACAP) staff traveling with us.

We have mapped areas of observed damage, areas of no observed damage and areas of high or heightened hazard over a Google Earth satellite image. The track areas we assessed are coloured to show observations as follows:

- Green** Areas of no observed new damage, moderate confidence of observations
- Blue** Areas of no observed new damage, low confidence of observations
- Yellow** Areas of moderate observed new damage and/or high level of existing hazard
- Red** Areas of significant observed new damage and/or high level of existing hazard

Our confidence of observations relates to how sure we are of having covered the area relatively accurately. Areas of low confidence are typically where the weather inhibited a clear view of the whole area and/or the flight speed was very high. As such the likelihood of having missed or misinterpreted some features is relatively higher in these areas, compared to areas with moderate confidence.

Figure 2: Trekking Route Location Plan



The Thorung La Pass between Thorung Phedi and Muktinah was not covered due to weather constraints. This section involves a high mountain pass and is likely to have a very significant level of landslide and avalanche hazard. However, we expect that the natural hazards in this area have not significantly increased as a result of the earthquake.

For the purpose of discussion in this report, the trail covered has been roughly divided into the following six sections:

Southwest Sector – Birethanti to Tukuche

Northwest Sector – Tukuche to Muktinah

Southeast Sector – Bhubhule to Chame

Northeast Sector – Chame to Thorung Phedi

South Central Sector – Birethanti to Bamboo

North Central Sector – Bamboo to Annapurna Base Camp (ABC)

The tracks and villages in the southern areas are typically well forested with significant soil cover whereas the northern sections are typically more barren and dominated by bare rock and scree. On the Eastern and Western Sectors, this change is largely attributable to crossing the main mountain divide which brings drastic climatic changes. In the Annapurna Sanctuary area (South Central and North Central Sectors), the change is due to elevation, climate and recent glaciation.

3. Geology

Parsons et al (2012-2013¹) have compiled a 1:200,000 scale geological map of the Annapurna area that includes our study area. There is a series of major northwest – southeast trending thrust faults through the study area with basement rock typically including sandstone/mudstone sequences, limestone and metamorphic rocks ranging from shale to gneiss. The geology is complex and varies significantly within the study area. The Parson et al. geological map should be referred to for details of specific areas.

4. Field Assessment and Discussion

Our reconnaissance focus was on identifying new landslide damage that could be attributed to the April and May 2015 earthquakes. The rapid nature of the reconnaissance means that the level of detail is broad and in some areas, our confidence in observations is low. Data collection comprised helicopter flyby observations at varying speeds and altitude, as well as foot based observation at a number of villages. The damage observed and reported is not intended to be a comprehensive survey of earthquake damage but rather a rapid assessment of areas of apparent new damage.

In addition to areas of new damage, some select areas of considerably high existing landslide hazard have been identified. Some of these areas may have worsened due to recent earthquake shaking.

The damage is discussed in relation to the individual sectors of the study area discussed in Section 2 of this report and individual villages.

In some locations, we have recorded a shadow angle behind buildings. This is the angle between the building or developed area and the base of a slope considered to present a landslide or rockfall hazard. This does not include other factors such as source area and material or local ground geometry. A detailed hazard and risk assessment is required to determine these factors and understand the level of risk.

Southwest Sector – Birethanti to Tukucho

Track Birethanti to Tatopani - the trail in this area is typically located on the side of moderate to steep, well vegetated slopes. The trail climbs up to Ghorepani then down to Tatopani. No apparent new landslide damage was observed between Birethanti and the River crossing south of Tatopani. There is some new rock and debris on and near the track in some locations south of Tatopani (between the river crossing and Tatopani).

¹ Parsons A.J.; Law R.D.; Searly M.P.; Phillips R.J.; Lloyd G.E. (2012-2013), *Geology of the Dhaulagiri-Annapurna-Manaslu Himal, Western Region, Nepal 1:200,000*.

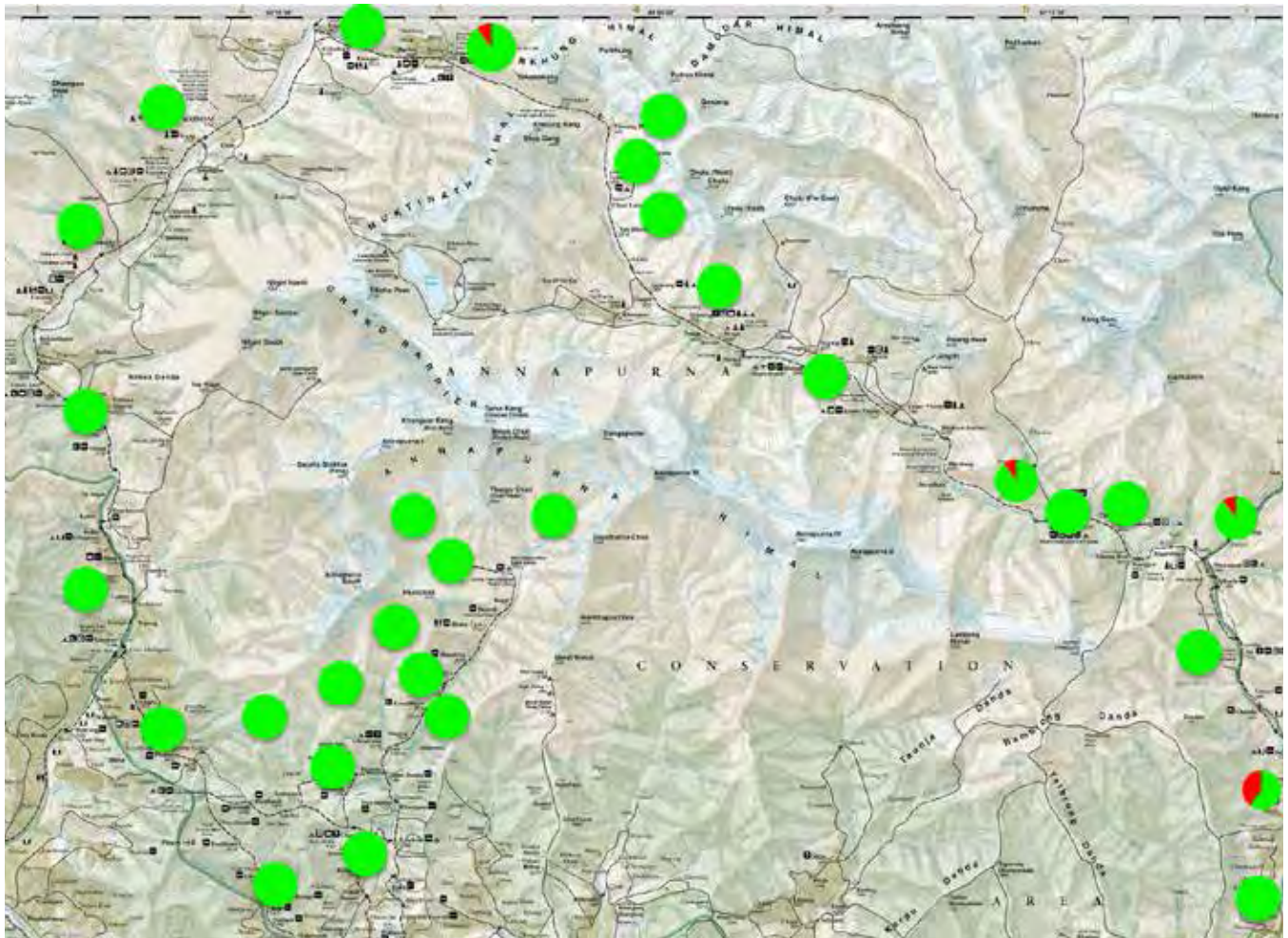


Figure 1. ABOVE - The green marks the percentage of undamaged structures and the red marks the percentage of earthquake-damaged buildings in the 15 villages that were assessed following the April and May 2015 earthquakes.



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STRUCTURAL ASSESSMENT RESULTS

The Annapurna-area building and bridge-damage assessment included the Annapurna Circuit trek area from Bhulbhele to Birethanti and the Annapurna Sanctuary trek area from Pothana to Annapurna Base Camp. Approximately 30 bridges and 30 villages with approximately 250 accommodations were assessed in the Annapurna region.

Out of approximately 250 accommodations assessed, structurally concerning earthquake damage was observed at only six accommodations.

Damage included large cracks in concrete columns (one hotel), settlement of building at edge of river and stone wall cracking (one hotel bathroom structure) and out-of-plane wall failure of stone walls (four hotels). The majority of damage was noticed on the eastern part of the Annapurna Circuit, which is closer to the M7.8 epicenter and experienced higher ground accelerations as reported by USGS.

Bridges assessed had no structural earthquake damage. One bridge located approximately one kilometer of a mile north of Chame had soil erosion concern where edge of river bank is approaching the bridge abutment. Overall, there is very little damage in the Annapurna region; only 3 percent of accommodation buildings had damage.

Buildings damaged can be repaired easily. Stone building wall damage should be replaced with stone and cement mortar. The concrete column damage can be repaired; it should be inspected for rebar damage and repaired with high-strength repair mortar.

GEOTECHNICAL ASSESSMENT RESULTS

The Annapurna Circuit and Annapurna Sanctuary trails and villages covered in this study appear largely undamaged by landslides following the April and May 2015 earthquakes. This is consistent with the relatively low ground accelerations we understand were experienced in the area.

We identified some areas that did not show evidence of recent failure, but have a particularly high hazard levels due to their existing features or geometry (for example, very high rock slopes and areas with evidence of historic large rockfall and slope instability).

In order to manage the risks associated with the hazards identified in the report, we recommend completing a detailed risk-assessment study. This will include assessment of likelihood of failure, occupancy of specific areas of trail and villages and combining these with hazard to assess the risk.

Once the risk is assessed, we recommend that a tolerable level of risk is defined by the Nepal Government, including consideration of the likelihood of loss of life and a comparison with hazards elsewhere in the country and international standards.

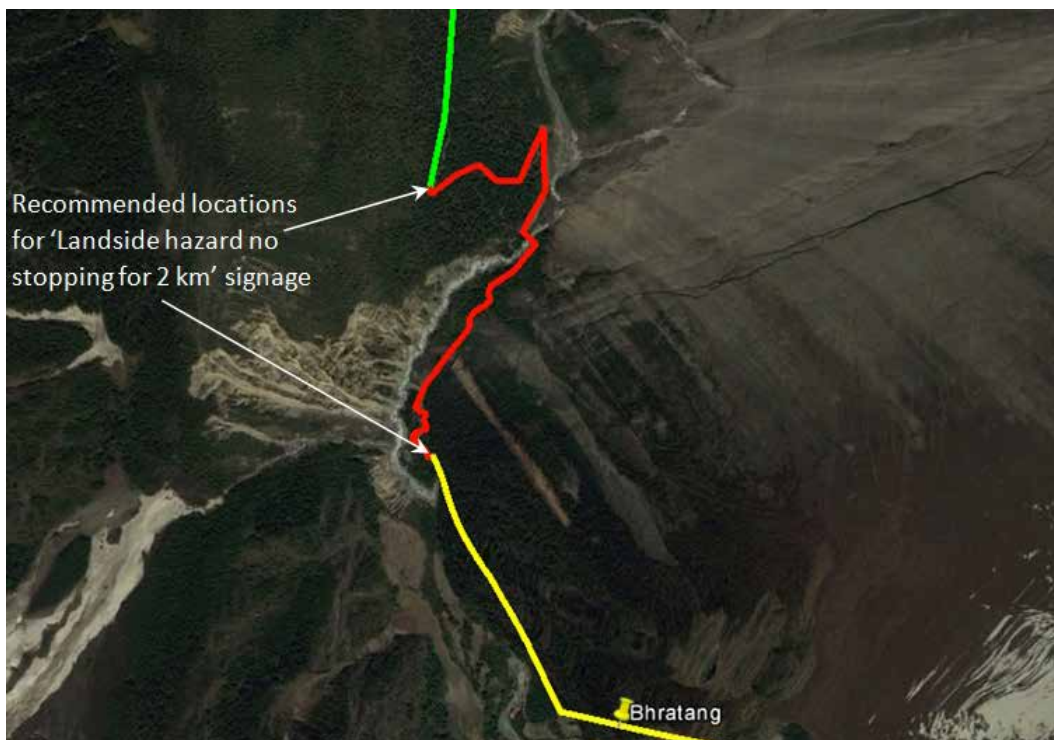
Upon definition of intolerable hazards, which we anticipate will include the main four hazard areas identified during the assessment – namely Bagarchhap; Bhratang; Kagbeni; and between Kimrong and Chomrong / Jhinu Danda (southern part of Annapurna Sanctuary tracks) – the Eliminate, Isolate or Minimize (E/I/M) hierarchy should be used as described below.

RECOMMENDATIONS

The best method for risk management is to eliminate the risk and, if this is not possible, isolating the hazard is preferred; only if this is not possible is minimizing the hazard acceptable.

In addition to the specific recommendations, all geotechnical risks in the area should be reduced to a level that is As Low As Reasonably Practical (ALARP). This is discussed after the recommendations.

- We recommend a detailed hazard and risk assessment is undertaken at Bagarchhap to better understand the slope stability / rapid deposition risk to villagers and tourists staying in the area. Until such time as this is complete, we recommend that the risk present at the village is considered intolerably high for overnight occupancy.
- We recommend placing 'Landslide Hazard No Stopping for 2 km' signage on either side of the new regolith landslide north of Bhratang. The location of the high-hazard area, as shown in the photograph below, extends from the hairpin turns in the track south of the landslide to the hairpin turn at the top of the hill on the north side of the river – where the track turns north again. This area should be considered to have a heightened chance of future landslide failure and people should be encouraged to walk through the area without stopping to reduce the track occupancy time in the area.



- We recommend a detailed assessment of the gravel cliff stability on the north side of Kagbeni as it may affect the buildings near the crest. There is one building we understand to be a hotel (there may be more) located at or very near the cliff edge. Given the apparent cliff instability, we consider the risk of using this building may be unacceptably high in its current state. The adjacent area around the blue handrail is also considered to be at high risk of failure as it is already undermined. While this track is not strictly part of the Annapurna Circuit track, we recommend another route is used.

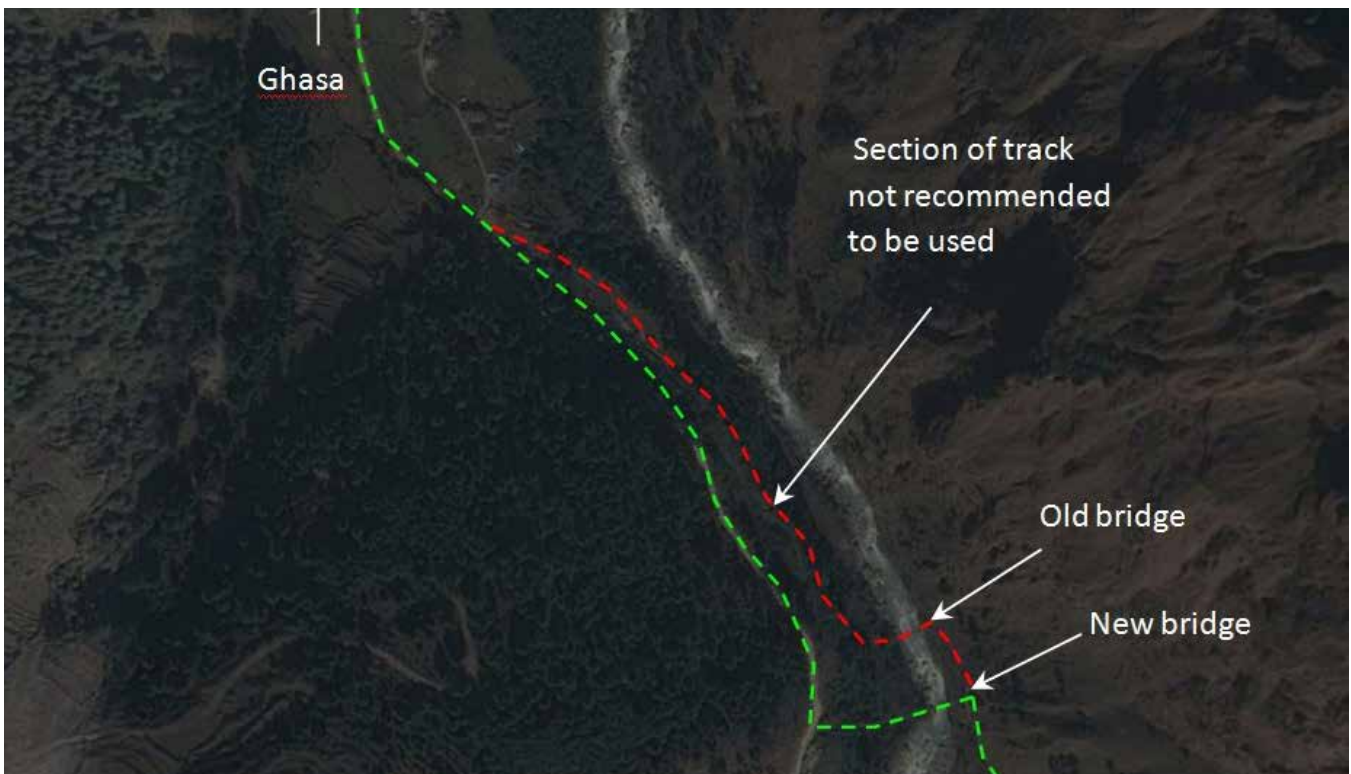


Recent failure near hotel, track undermined (not Annapurna Circuit) Track undermined, no support at edge

- We recommend re-routing the section of track that is located at the scarp of the large rockslide between Kimrong and Chomrong / Jhinu Danda (southern part of Annapurna Sanctuary tracks). The track is located within 2 m from the edge of the failure and a building is within approximately 20 m of the edge. The track should be located at least 100 m upslope from the edge of the failure. The section of track that requires re-routing is approximately 250 m long and can tie back into the existing trail where it is located further back from the failure. Warning signage should be placed on the track near the edge of the failure indicating 'Danger cliffs and landslide hazard' or similar so it is clear to use the new section of track. We recommend that the building in close proximity to the headscarp is assessed in detail to determine the level of landslide risk to any occupants.



- We recommend the older section of trail south of Ghasa that leads to the old foot bridge (bridge nearest Ghasa) be abandoned in favor of the road located further west that leads to the newer bridge as discussed in previous sections. Signage should be placed on the track to the old bridge indicating there is a landslide hazard.



- We recommend that rockfall hazard signage be placed between Bamboo and Annapurna Base Camp.
- The following villages were identified as having a relatively high level of existing hazard based on the historic rockfall or slope instability around the buildings. More detailed information on this is provided in the report. We did not undertake a detailed hazard assessment and this is not a comprehensive list of hazardous areas. A detailed risk assessment of villages should be considered to determine the level of risk to occupants. In the interim, we recommend 'Rockfall Hazard Area' or 'Landslide Hazard Area' signs be placed on the trail at each end of the villages as appropriate.
 - Tatopani – Existing rockfall hazard.
 - Ghasa – Some existing rockfall hazard.
 - Tukuche – Existing dropout/cliff collapse hazard particularly to the northeast.
 - Kagbeni – Gravel cliff erosion/cliff collapse hazard on northern part of village.
 - Chamje – Existing rockfall hazard.
 - Dharapani – Existing rockfall hazard.
 - Bagarchhap – Existing debris flow hazard is high, as discussed above.
 - Chame – Existing slope failure and cliff collapse hazard on north side of river.
 - Bhratang – Existing rockfall hazard. It is unclear if there is accommodation at this location.
 - Bamboo – Existing rockfall/wedge failure hazard (may have worsened).
 - Deurali – Existing rockfall hazard.
 - Machhapuchhre Base Camp – Existing rockfall hazard.
- We recommend abandoning or repairing the damaged toilet/bathroom block identified on the north side of the river at Chame. Detailed assessment of slope stability and scour below the structure should be undertaken if repairs to the building are being considered.
- All the frequently used tracks should be checked for new failures and rockfall following monsoon rains each year. It is likely that some form of inspection like this already happens as the tracks are used by many people, not just trekkers, and we saw repairs in many locations.
- Bridges on the tracks should be checked every year during floods and after flood waters recede to look for damage or undermining from river scour and erosion.
- Communication between villages regarding landslides, particularly any landslides that block rivers, should be encouraged and maintained. If a river is dammed, ACAP and government geologists should be informed immediately so an assessment of severity can be undertaken and evacuation precautions taken, if necessary.
- We recommend information posters showing common landslide hazards such as rockfall and slope instability are displayed in prominent locations such as ACAP check posts. Information could include areas not to stop and signs of slope instability to look out for.

ALARP PRINCIPLE

In areas of the trail other than those that have been discussed specifically, we recommend that risks are managed using the ALARP principle.

There are a number of relatively low-cost measures to reduce the risk to occupants of the area that should be considered:

1. Seasonal closure of the trail during the monsoon may be considered, as it is most likely that rockfall and landslides will occur during the wet months. While closures might work for tourists, special consideration should be extended as to how it would impact locals.
2. The occupancy of hazard areas should be reduced as much as possible in order to reduce the likelihood of loss of life in the event of rockfall or landslides. This should be applied to all areas mapped as yellow in this study. Reducing occupancy may be achieved by locating lodges and houses away from the hazard areas or reducing use in these areas, and liaising with trekking companies to adjust their itineraries to reduce the risks. If this is undertaken, government assistance may be required to aid those businesses and people affected to relocate their business to safer areas.
3. Hazard areas should be signed and communicated to both locals and visitors. This may include signage at the beginning and end of the hazard areas using universal signage, such as that adopted on roads, to encourage people not to stop in these areas.
4. A communication program may be initiated, and may include meetings or radio broadcasts for locals combined with posters presenting the hazard for visitors. Many of the ACAP checkpoints and offices have posters describing local wildlife and areas of specific interest, and we recommend preparing a poster on natural hazards in the area to accompany the existing posters.

CONCLUSION

Following the April and May 2015 earthquakes, observed structural earthquake-related damage in the Annapurna region was very limited (3 percent of total buildings stock and 0 percent of bridges assessed). Similarly, it appears that the Annapurna Circuit and Annapurna Sanctuary trails covered in this study are largely undamaged by landslides after the earthquakes. However, there are some areas that have been identified as having a particularly high hazard level due to their existing features or geometry. For example, very high rock slopes and areas with evidence of historic large rockfall and slope instability. A detailed risk-assessment study of these areas is recommended. This will include assessment of likelihood of failure, occupancy of specific areas of trail and villages, and combining these with hazard to assess the risk.



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