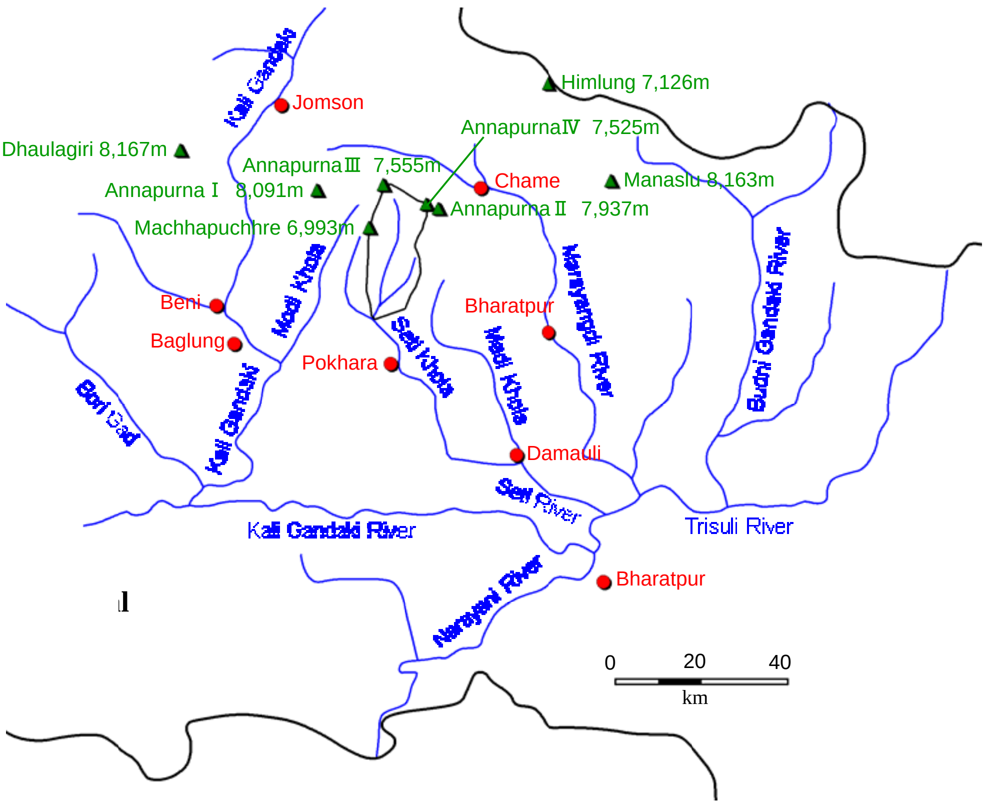
Survey Report on the Seti River Flood,Nepal（May 5, 2012）

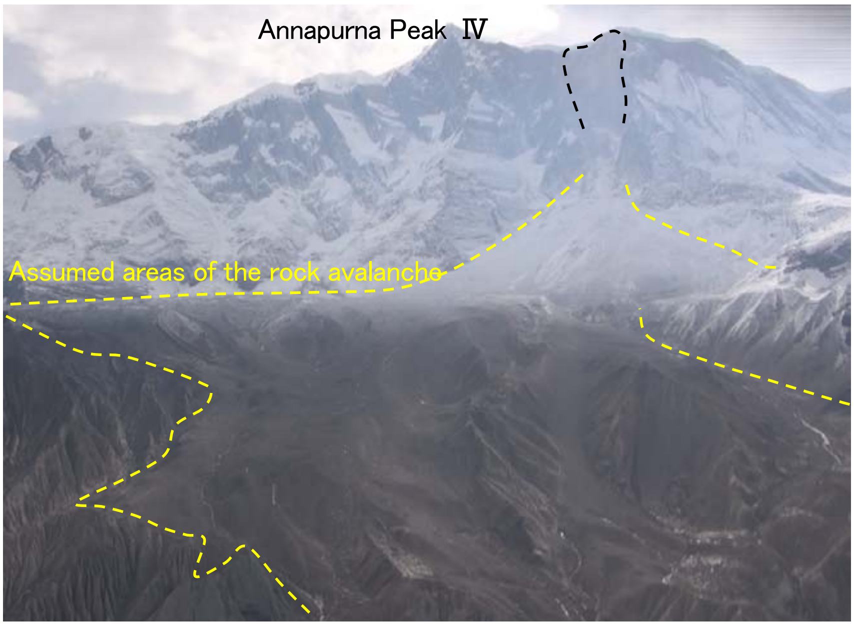
November 2012

The Japanese Disaster Survey Team for the Seti River Flood

Plate

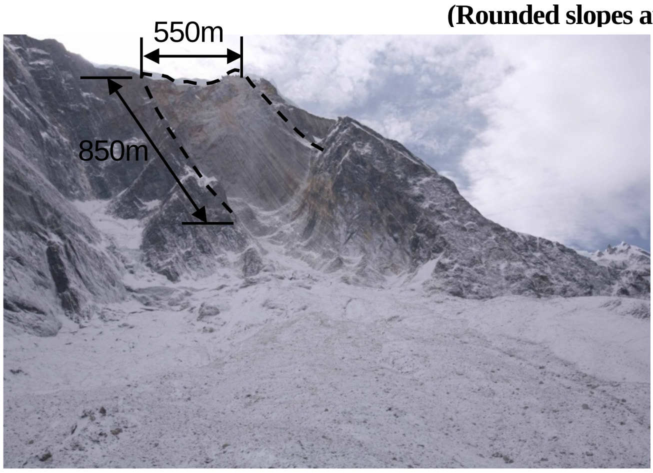
Bird's eye view of the Seti watershed (Modified from Google Earth)





Panoramic view of the rock slide on the west-facing slopes of Annapurna Peak IV (Gentle foot slopes can be seen in the center.)

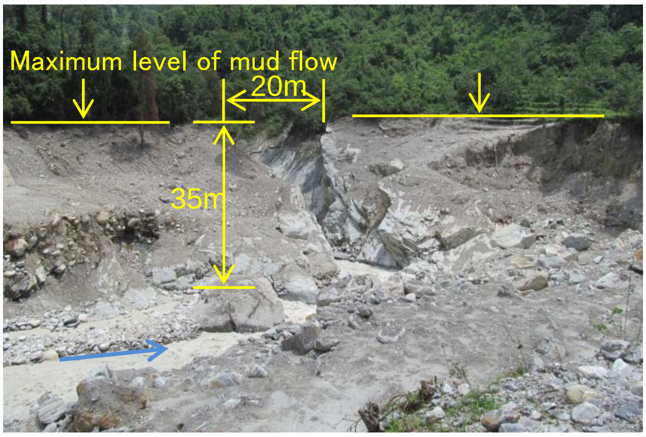
Earth pillars of lacustrine deposits
(Rounded slopes appear in the right section.)



Rockslide on the west-facing slopes of Annapurna Peak IV
(Collapsed slopes in the center right and fragmented debris can be seen on the foot slopes.)

The Seti Gorge formed in limestone
(Mud originating from the rock avalanche can be seen at the lower part.)

Seti Gorge channel way



Third bending point of Seti River at Kapuche (It breached after the temporary blockage.)

Trees falling toward downstream (There is mud clinging to them.)

River channel just downstream of the third bending point at Baraudi

Temporary damming-up area near Kapuche (Two houses remain on the lower terrace at Yomo.)

Disaster area around the suspension bridge at Karapani

(The flood overtopped the left-bank river terrace due to the momentary river blockage.)

Contents

1. Introduction

On 5 May 2012, a rockslide on the western cliff of Annapurna □ triggered floods[1)], which ran down the Seti Khola (River) causing serious damage to villages and tourist spots along the river. Information on damage, rescue operations, etc. was provided from time to time by the Japanese Embassy in Nepal and the NPO Disaster Information Research Institute as well as a series of OCHA Situation Reports.

Considering the seriousness of the disaster and the necessity to investigate the phenomena for disaster mitigation in Nepal in the future, the NPO Nepal-Japan Friendship Association for Water Induced Disaster Prevention (NFAD) dispatched a five member survey team from 2 to 10 June, 2012, just one month after the disaster.

There are many materials which are very useful for the preparation for the survey and analysis on the cause and process of the floods, such as a series of ICIMOD studies, Mr. Maximov's (pilot of Avia Club Nepal) Video, Dr. Petly's report, Dr. Fushimi's report, the Noguchi Ken office homepage, LANDSAT images, and so on.

The survey was carried out smoothly and satisfactorily owing to those materials and the kind cooperation of DWIDP[2)], ICIMOD[3)], and others. Good weather despite it being the rainy season and the carefully arranged logistic support also factored into this success.

The Helicopter survey focused on the western flank of Annapurna □ where the rock slides and rock avalanches occurred to trigger the disaster. Soil materials were collected for comparison with the deposits in the downstream areas.
Reconnaissance along the Seti Khola confirmed that there was damming up at Jomo and severe bank erosions at places along the river. The deposits along the river were confirmed to be the same materials as those collected during the helicopter survey.
Interviews at the affected villages, district offices, schools, etc. were very useful in understanding the real situation at the time of the disaster. Our questions were abrupt and without prior notice, but all interviewees responded kindly with a variety of information.

On 9 June, the day when we left Nepal for Japan, a meeting was held at the residence of the Japanese Ambassador to report on the survey results. Representatives of the government and international organizations were invited. We promised to send the survey report to concerned organizations for information sharing. We hope that hat the results of the survey would be shared by all concerned for further study to mitigate this type of disaster in Nepal

Himalaya in the future.

This report is a compilation of the data/information collected and studies conducted by individuals and organizations prior to our survey, and the findings made during our survey. We are certain that some progress has been made in the research on the mechanism of rock slides/rock avalanches/mud flows, especially through such practical approaches as helicopter survey, reconnaissance survey, and interviews. However, we recognize that there are still phenomena which have not yet been clarified, as listed in the Recommendations. We hope that this report will be useful in the further advancement of research to mitigate this type of disaster in Nepal in the future.

1) Hydraulic behavior varies from rock slides to rock avalanches, mud flows, flash floods, and floods as descending from upstream to downstream. Therefore, the word “flood” is used here as a general expression for such phenomena.

2) Department of Water Induced Disaster Prevention, Ministry of Irrigation

3) International Center for Integrated Mountain Development

2. Purpose and Approach

1) Purpose

① Investigation on the causes and mechanism of the disaster

② Investigation on the possibility of recurrence of the disaster in Seti Khola, and recommendations on early warning/evacuation to avoid damage in Seti Khola in the future

③ Investigation on the possibility of occurrence of similar disasters in other areas in Nepal Himalaya

2) Approach

The survey is to be conducted through the following approaches in principle.

① Practical field survey involving helicopter survey, reconnaissance survey, and interviews in affected areas.

② Close coordination with government organizations, international organizations, universities etc. for a variety of information and support.

③ Publicizing the survey results for information sharing among all concerned for the further advancement of research on this type of disasters in Nepal.

3. Survey Team

Hidetomi Oi, Director General of NFAD, President of International Sabo Association

Daisuke Higaki (Dr.): President of Japan Landslides Association, Professor of Hirosaki

University, Member of NFAD

Hiroshi Yagi (Dr.): Professor of Yamagata University, Member of NFAD

Nobuhiro Usuki: Asia Air Survey Co., LTD, Member of NFAD

Kosuke Yoshino: Asia Air Survey Co., LTD

4. Itinerary

	Yagi	Oi, Higaki, Usuki, Yoshino
6/2 (Sat)	Haneda 0 : 20 → BKK 4 : 50 TG661 BKK 10 : 15 → KTM 13:30 TG319 【Stay at KTM】	
6/3 (Sun)	AM Information collection	Haneda 0:20 → BKK 4:40 TG661 BKK10:15 → KTM 13:30 TG319
	PM Meeting with the helicopter pilot Visit of Ministry of Home Affairs (Emergency Operation Center) (Oi) 【Stay at KTM】	
6/4 (Mon)	Move by helicopter KTM 6 : 40 → Karuwa 7:30 Survey by helicopter 8:00 → 9:40 Reconnaissance survey in Kapuche and Sano Khobang (Site for relocation) 【Stay at Karuwa】	
6/5 (Tue)	Reconnaissance survey Interview with Machapuchare VDC staff 【Stay at Karuwa】	
6/6 (Wed)	6:30-8:00 Reconnaissance survey in Kapuche (Reconnaissance of the gorge was attempted but unsuccessful) AM Karuwa → Kharapani。 PM Reconnaissance survey in and around Kharapani 【Stay at Kharapani in tents】	
6/7 (Thu)	Kharapani → Pokhara (by land) Pokhara → KTM (by air) 【Stay at KTM】	AM Visit to an elementary school in Diplang PM Kharapani → Pokhara (by land)。 Visit to Sardi Khola VDC on the way to Pokhara。 【Stay at Pokhara】
6/8 (Fri)	KTM 13:30 → BKK 18:15 TG320 Leave BKK 22:10 TG640	AM Visit to Seti Khola gorge in Pokhara Pokhara → KTM (by air) PM Preparation of report 【Stay at KTM】
6/9 (Sat)	Arrive at Narita at 6:20	9:30 – 11:00 Meeting to report on the survey at the residence of the Japanese Ambassador KTM 13:30 → B KK 18:15 TG320 Leave BKK 22:10 TG640
6/10（日）		Arrive at Narita at 6:20

5. Damages and response of thegovernment and international organizations

1) Summary of damage (Source: Ministry of Home)

Dead and missing	Dead:40 persons including three foreigners from Ukraine Missing : 32 persons*
Houses and buildings	20 houses, 1 public building , 2 temples
Infrastructure	Road 500 meters, 2 suspension bridges, 2 water supply systems
Total economic loss	NRs 85,000,000**

*30 persons according to OCHA

** 49,628,000 NRs according to OCHA

2) Response of the government and international organizations

5 May	・ Central Disaster Relief Committee and Emergency Operation Center were activated. ・ Home Ministry /Army dispatched a helicopter and search/rescue teams. ・ Search/rescue operations started by Kaski District Disaster Rescue Committee in cooperation with the Army, the police, the Red Cross and international organizations.
6 May	・ The Prime Minister visited the incident sites accompanied by the Minister of Home and the leader of the Maoist Party. ・ Cash support for the affected people was announced: 125,000 NRs for families of each identified deceased persons, and 25,000 NRs for families who lost their homes.
8-9 May	・ Damage assessment jointly by DDRC, ICIMOD, the police, Red Cross and international organizations
9-10 May	・ Reconnaissance by ICIMOD experts accompanied by staff of the Ministry of Home

An OCHA Situation Report was issued four times, from No. 1 (6 May) to No. 4 (10 May). The Government of Nepal did not request foreign assistance through OCHA.

6. Outcome of the survey and recommendations

6.1. Preparation of the field study

Video images and press reports of the disasters induced by the debris-mud flow were distributed through the Internet just after its occurrence on 5th May. They indicated rock-wall collapse or gigantic-scale snow avalanches occurring on the west wall of Annapurna IV, from which the uppermost reach of the Seti River starts to flow. Based on such information, airborne research using a helicopter was planned in order to investigate the cause of the debris-mud flows along the Seti River, which also affected the city of Pokhara and its lower stream area.

Dr. Yagi, who visited Kathmandu earlier than when the other members arrived, met Dr. S. Bajracharya of ICIMOD, who visited the Seti River area in the middle of May, and interviewed with him about his opinion on the disaster.

6.1.1 Information collection in Kathmandu

Remarks that we should focus on after the interview with Dr. Bajyacharya were summarized as follows;

① Rock avalanches and the subsequent debris-mud flow, including rock flour that coincidentally occurred, flew into the Seti Gorge. However, the distribution area of the rock flour was quite limited and therefore, it is doubtful whether the volume of the rock flour could be enough to supply the total amount of fine materials. Consequently, we had to pay much attention to other factors such as erosion due to the passage of the rock-debris avalanches flowed upon the slope, strong blow due to it, or mass movement induced by the impact tremor induced by the rock-debris avalanches.

② Dr. Bajracharya saw the rock failure which occurred on the right bank of the Seti Gorge and which seemed to be choking the Seti Gorge. That might have caused the pulse waving of the debris-mud flow due to the damming of the stream.

③There remains another possibility of the pulse waving of the debris-mud flow along the main stream. Damming up of the tributaries by a counter-flow of the debris-mud flow is another possible cause. Therefore, we had to check for traces of such damming at the confluence of tributaries to the main stream.

We discussed the issues to be checked in the field research based on the interview with Dr. Bajracharya and decided on the subjects which we should focus on at the observation flight and how to implement our field study as follows;

① We had to reconsider another source of fine materials included in the debris-mud flow because it is too difficult to attribute the source of the fine sediments to those derived from the failure on the neighbouring slope along the stream that were induced by the tremor caused by the impact of the rock avalanches. There is also the possibility that the tremor caused liquefaction of the sediments distributed along the floor bed of the gorge. We had to pay a great deal of attention to slope failures along the gorge due to toe erosion by the passage of the debris-mud flow and to the change of the stream bed whether the severe incision occurred along the gorge and the surrounding slope on which the rock avalanches passed down.

② We should check whether the rockslide along the Seti Gorge was of great enough scale to dam up the stream.

③ We should also check for traces of the tributaries damming up due to the debris-mud flow.

Based on the above mentioned remarks, we implemented the field studies as:

1) An air-borne reconnaissance study

An air-borne study was carried out on 4th June. Its targets of observation were a rockslide source area on the west-wall of Annapurna IV, the gentle slope developing on the foot of the west-wall ranging 3500-5000m as the uppermost course of the Seti River, the Seti Gorge, and its lower course to Karapani village.

2) Field study

The study team visited the most severely affected sites such as Sadal (the uppermost village), Yomo, Kharapani (which belongs to Macchapuchhare VDC), and Purujung Khola (which belongs to Sardikhola VDC) from 4th to 7th June. An outline of the topography in and around the study area is shown **Fig.6.1.1** & **Fig.6.1.2**.

Fig.6.1.1 Location of the Annapurna Himal

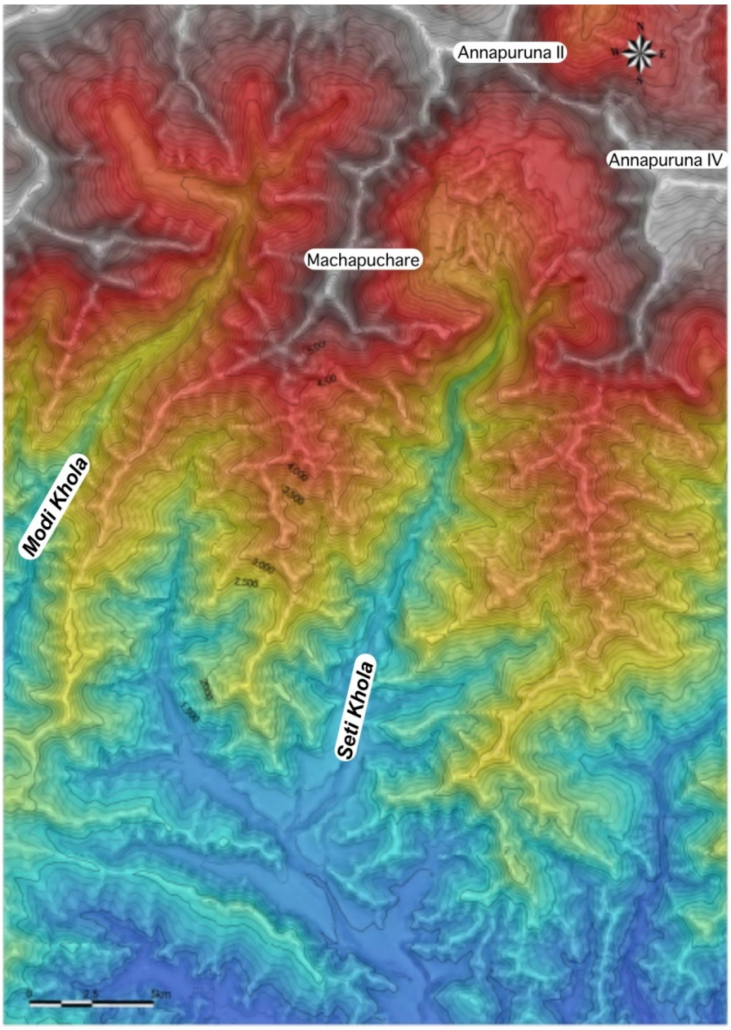


Fig.6.1.2 Topographic outline of the Annapurna Himal

6.2. Geomorphology, Geology, occurrences of rockslides and rock avalanches in the disaster affected area

6.2.1 Outline of Geomorphology and Geology in the uppermost course of the Seti River

The Annapurna Himal is one of the gigantic ranges in the Himalayas which consists of ten peaks higher than 7000m, and Annapurna I is a main peak at 8091 meters high. It continues 90 km east-westerly bordered by the Marsyandhi River to the east and the Kaligandhaki River to the west. The southern flank of the Annapurna Himal is a source of the Modhi and Seti Rivers. The uppermost course of the Seti River is a small round basin, with a diameter of 6 km, ranging from 3400m to 5000m a.s.l. (**Fig.6.1.2**). We are tentatively calling this basin the Annapurna Basin. Its southeastern fringe is cut by U-shaped valley along the Seti River at its outlet (**Image 6.2.1**). It is filled with well-stratified sediments of 1000m in thickness. The sediments are severely eroded, showing the unique badland topography of earth pillars or rough-edged earth screen-ridges (**Image 6.2.2**). This implies that the sediments are very muddy and of low permeability. Therefore, considering the distribution altitude as well, the sediments are thought to be paleo-glacial lake deposits. They are called “marl”, calcareous muddy sediments.

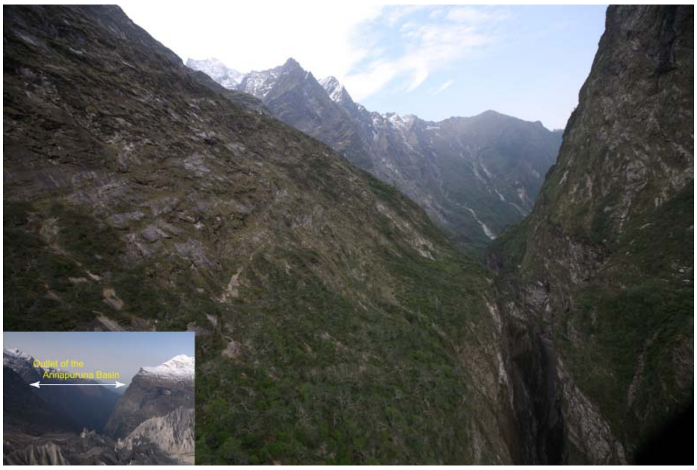


Image 6.2.1 Outlet of the Annapurna Basin

At the southeastern corner of the basin, a U-shaped valley develops as an outlet of the basin. The Seti River incises through the U-shaped valley,

Image 6.2.1 The earth pillars and earth screen-ridge in the Annapurna Basin

The paleo-glacial lake collapsed and caused GLOF in 12,000 yrs B.P. and 700 yrs B.P. (Yamanaka et al., 1982; Koirala, 1998), and the wide debris terraces on which the city of Pokhara is located were formed in the lower course along the Seti River.

The mountains surrounding the Annapurna Basin consist of carboniferous sedimentary rocks called the Tethys, ranging from the Ordovician to Devonian periods. They are composed of crystalline limestone, dolomite, calcareous shale, calcareous silt, dolomitic black shale and alternate of those strata with thin quartzite beds. Those strata are severely folded along the Annapurna Detachment, a normal fault declining to the north (Upreti & Yoshida ed., 2005). The Tethys overlay the Higher Himalaya crystalline rocks.

The present stream of the Seti River deeply incises the bottom of the U-shaped valley of the Last Glacial Age and formed a narrow gorge (**Image 6.2.1**). The marl distributed inside the Annapurna Basin is also cut deeply into its base. Furthermore, downward incision onto the Nirgili formation of the Ordovician period overlain by the marl has progressed, forming a slit-like karstic ravine of 200 m in depth (**Image 6.2.3**).

Image 6.2.2 Deep, a slit-like karstic ravine, incising calcareous sedimentary rocks called Niriglu formation

6.2.2 Rockslide and subsequent rock avalanche

The rock wall facing west just below the ridge between Annapurna IV and its southern sub-peak 6998 collapsed suddenly on 5th May, 2012 (**Image 6.2.4**). The maximum width and relative height of the rockslide are 500m and 1000m respectively. Blocks of the rockslide fractured at the foot of the wall and scattered on the glacier and subsequent rock avalanches run off on the glacier and the marl area (**Image 6.2.5**).

Image 6.2.4 Source area of rock failure just below the ridge top around Peak 6998

Light grey part is the source area of the rockslide.

Image 6.2.5 Passage area of the rock avalanches

Coincidentally, there was a big cloud of rock flour rolling. The average slope gradient from the foot of the wall to the inlet of the gorge is about 14 degrees. There is no gentle slope to reduce the speed of the rock-debris avalanches. The passage of high speed rock avalanches must have induced severe erosion on the glacier ice and the marl, because the surface of the glacier, the earth pillars and the rough-edged screen-ridges along the passage route of the rock avalanches looked rounded (**Images 6.2.6** & **6.2.7**). The height of the destructive blowing wind that caused severe erosion must have been up to 100m because a few rows of the earth pillars and screen-ridges in the eastern side were only rounded due to erosion, implying that they blocked the passage of the rock avalanches to the west by themselves.

Image 6.2.6 Eroded glacier surface

Note the glaring ice inside the yellow oval.

Image 6.2.7 Rounded earth pillars and screen-ridge due to passage of the rock-debris avalanches

Sticky mud flow lobes are also recognized along the stream floor.

Image 6.2.8 Slit inlet to the Seti Gorge

Some part of the debris avalanches over-jumped the ridges

Image 6.2.9 Rock-debris avalanches impact site just beside the Seti Gorge

Most of trees on the ridge were swept away by the main body of the debris avalanches and some of those distributed in its marginal parts were blasted out by the strong wind.

Yellow arrow indicates the direction of blasted trees.

Image 6.2.10 Coniferous trees blasted out by the accompanying strong wind with the debris avalanches on the right bank of the Seti gorge

6.2.3 Change from rock-debris avalanches to mud flow

Interviews with villagers showing that they felt cool wind during the passage of the mud flow, even in Pokhara, reveal that it included a great deal of ice fragments from the glacier and its melt-water inside. The rock avalanches involving ice, its melt-water, fine sediments and air had gradually turned into high-speed debris avalanches and jumped to fall into the Seti Gorge (**Image 6.2.8**).

It crashed into the ridge beside the gorge and its severe impact removed the trees there (**Image 6.2.9**). Strong blowing wind with muddy particles accompanying the debris avalanches also blasted out the coniferous trees distributed along the upper part of the gorge and the U-shaped valley (**Image 6.2.10**). Mud crusts are attached only to the upstream side of trees as if a muddy mist was sprayed in the same direction during the passage of the debris avalanches.

Some part of the fine sediments must have turned into mud flow because there are meandering lobes of mud flows remain along the stream floor between the earth pillars and rough-edged screen ridges (**Image 6.2.7**).

Such phenomena imply that in this event, there was a time series phase-change of mass movement in the order of rockslide, rock avalanches, debris avalanches and mud flows. Finally, the detritus that had flowed into the Seti River picked up a great deal water from the stream and ran a long distance as a mud flow of high water content.

6.2.4 Specifications of the rockslide

From the satellite photographs (Landsat 7) taken before and after the collapse shown in (**Image 6.2.11**), we can confirm the rockslide scar on the west slope of Annapurna IV and an extensive deposit of sediment directly beneath. The various elements of the scar (the width, depth and length of the collapse) are estimated based on the before and after satellite photographs observed by Landsat 7 and photographs taken from a helicopter. The analysis of the satellite photographs is shown in **Table 6.2.1** below.

Table 6.2.1 Dates of satellite images before and after the collapse

	Date of photograph
Before collapse	20/4/2012
After Collapse	6/5/2012

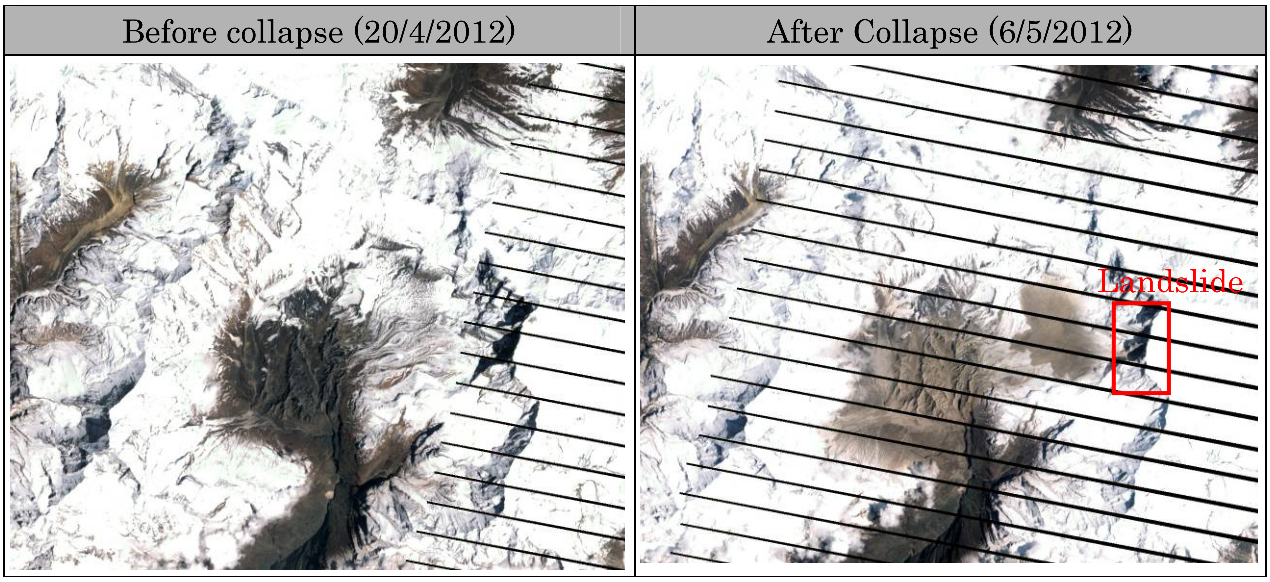


Image 6.2.11 Satellite images before and after the collapse (Landsat 7 image)

The estimated specifications of the denuded area are detailed in **Table 6.2.2** below.

Table 6.2.2 Specifications of the rockslide

	Measure (m)	Basis
① Width (B)	Approx. 550	Based on the satellite image
② Depth (D)	Max approx. 100 Average approx. 70	Based on the satellite image
③ Length (H)	850	Estimated from the helicopter images, based on a Width of 550m

① **Width**

The width of the collapse was measured using GIS to interpret the rockslide in the satellite images.

② **Depth**

The depth of the rockslide was measured in the same way, using GIS to interpret the landslide in the satellite images (**Image 6.2.12**).

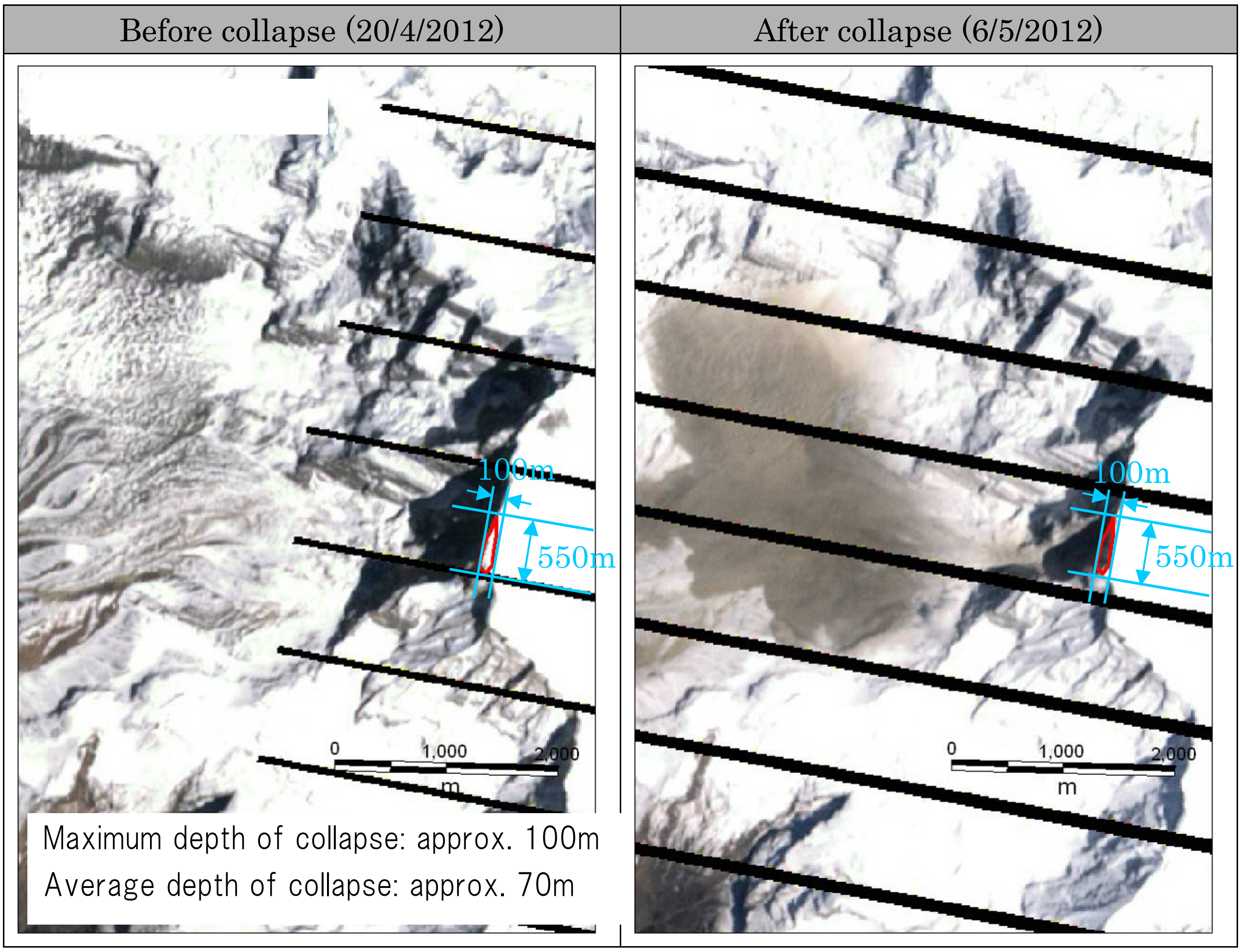


Image 6.2.12 Estimation of scale from the satellite images before and after the collapse

③ Length

Estimated from the helicopter photographs based on the breadth of 550m established above (**Image 6.2.13**).

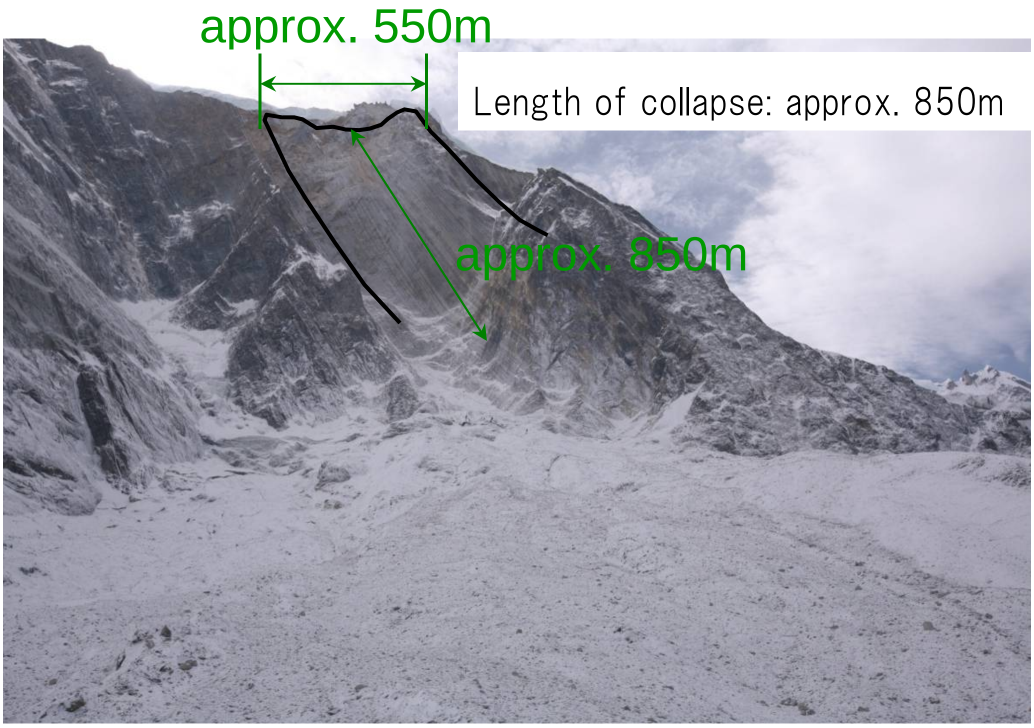


Image 6.2.13 Estimate of scale from the photos taken from helicopter investigation (04/06/2012)

④ Calculation of the volume of deposits

The volume of deposits V_1 was calculated per the formula below.

$$\begin{aligned} V_1(m^3) &= B(m) \times D(m) \times H(m) \\ &= 550(m) \times 70(m) \times 850(m) \\ &= 32{,}725{,}000(m^3) \end{aligned}$$

As a result, the volume of deposits from the western slope of Annapurna IV was calculated at about **<u>32,730,000m^3</u>.**

Estimation of the discharged debris

From the satellite images (Landsat 7) taken before and after the collapse shown in **Image 6.2.12**, we can confirm an extensive deposit directly beneath the western slope of Annapurna IV. The gradient of the area where the deposits of earth can be confirmed is comparatively gentle, and becomes much steeper further west from the deposition zone. That is to say, we can estimate that part of the debris that was produced by the collapse of the bedrock settled in the area of gentle gradient directly beneath the slope, and the rest flowed downwards as an avalanche. In the extensive deposits of earth in the image, it is estimated that there is also significant erosion of glacial and lacustrine deposits in the gentle gradient area due to high-speed rockslides or shock waves accompanying the avalanche described above.

Here, the volume of debris that flowed downstream and the volume of sediment that settled directly below the slope were estimated based on the hypothesized depth of deposit, and the deposit area was calculated using GIS.

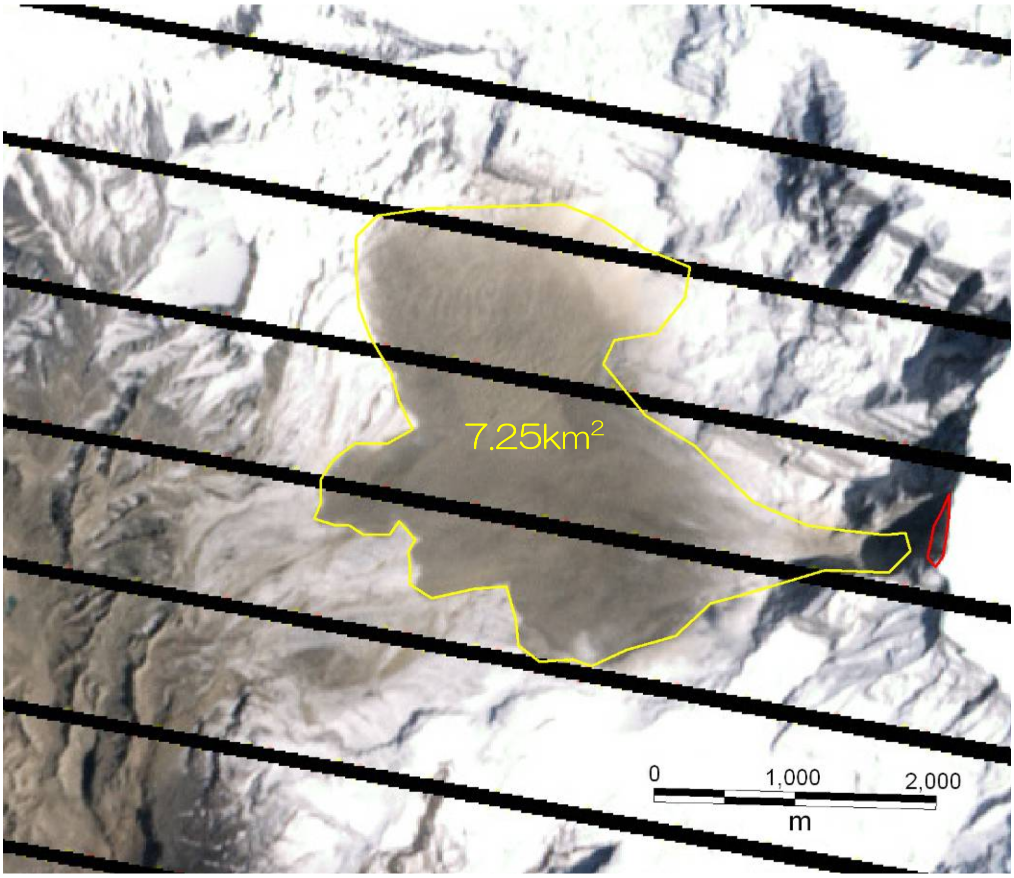


Image 6.2.14 The extent of deposition area

The status of the deposits could not be clearly confirmed even after checking video footage and the aerial images taken from a helicopter, as settled snow could be seen in the deposit area shown in yellow in **Image 6.2.14**. However, it could be seen from the ground that the deposits were formed of a thin layer of earth, so the average thickness was estimated to be around 2m.

The specifications of the deposition zone are shown in **Table 6.2.3** below.

Table 6.2.3 Specifications of the deposit zone

	Measure	Basis
① Deposit zone area (A)	7.25km²	Based on the satellite image
② Deposit zone thickness (h)	2m	Estimated from field survey

The volume of deposited earth V_2 and volume of downflow V_3 were calculated using the formula below.

Volume of deposit V_2

$$V_2(m^3) = A(m^2) \times h(m)$$
$$= 7{,}250{,}000(m^2) \times 2(m)$$
$$= 14{,}500{,}000(m^3)$$

Volume of downflow V_3

$$V_3(m^3) = V_1(m^2) - V_2(m)$$
$$= 32{,}725{,}000(m^3) - 14{,}500{,}000(m^3)$$
$$= 18{,}225{,}000(m^3)$$

From the above, the volume of debris including fine materials that was deposited directly beneath the western slope of Annapurna IV after the collapse was calculated at around **14,500,000m^3**, and the volume of debris which flowed into the Seti River was calculated at around **18,230,000m^3.** However, this value will change according to the estimate of the amount of change in terrain from the original topography, including erosion accompanying the debris flow.

6.3 The processes of rock avalanche and subsequent mud flows

The videos shot by A. Maximov, the pilot of an Avia Club Nepal light plane, have occasionally indicated the time of rockslide occurrence on the west-facing cliff of Annapuruna □ peak (Petley, 2012c). A big change was found among two video scenes with a shot time gap of 76 seconds (**Image 6.3.1**). Extreme dust smoke covering the southwest slopes of Annapurna □which was not seen in the former scene (left) appeared in the latter (right). S. G. Eksrom, a Columbia University geoscientists suggested that the local earthquake around this area indicates the occurrence of a landslide, and that the time was 9:09:56 AM (Nepal Local Time) on May 5 (Petley, 2012).

The duration of continuous shaking, which was recorded as 103 seconds, is expected to be the period between the collision of the rock and ice mass with the rocky flank slopes due to the rockslide and the termination of the rock avalanche in the deep parts of Seti Gorge. Based on these findings, the rockslide began at around 9:09 AM on May 5.

Image 6.3.1 Two video scenes taken by A. Maximov (Avia Club Nepal)

6.4 Mud flows from the Seti Gorge to Kharapani

Rock flour with a large amount of mud originating from both eroded marl deposits and the dust of rock fracturing due to the rock slide and rock avalanche was carried into the Seti Gorge and mixed with river water. Dust was often reported during the rock avalanche (Bandari and Kumar, 2000; Wieczorek, et al., 2000), and it was widely observed on the foot slopes of the rock slide area in the Landsat image taken on 6 May (Stark and Petley, 2012). Downstream from the fresh rock collapse, which was formerly believed to form the Seti River blockage (ICIMOD, 2012) (**Image 6.4.1**), continuous devastation of the forest along the river was observed, and the main process of transporting debris was by river water. The outer river bank of the two bending points of the Seti River just upstream of the narrow gorges was eroded up to 30m above the riverbed and some slope failures occurred (**Image 6.4.2**).

Image 6.4.1 Rock slide on the right bank slope of the Seti River

Image 6.4.2 River bank erosion and slope failure at the narrow bend of the Seti River

The river course from the Seti Gorge to the second bending point upstream side of Sadal is a segment where erosion was dominant.

The lower river terrace where Yomo Village had stood was covered with rather fine materials. The flood level indicated by the devastation of the river bank vegetation was 35m above the present riverbed at the third bending point just downstream of Kapuche (**Fig. 6.4.1**). Because of the narrow gorge about 20m wide and the steep bending at this point, temporary damming occurred during the flood. According to the interview, some people in Kapuche saw muddy flooding with a large amount of debris, and logs formed a lake-like situation (called “Saga” in the local language) there after around 5 minutes.

Fig 6.4.1 Riverbed conditions around and upstream of the third bending point

Since the riverbed gradient is about 5 degrees up to 1km downstream from the third bending point, breached materials from the temporary damming seem to have moved as a debris flow. The surge soon reached the Kharapani Bridge.

Some local eyewitnesses indicated that wood and debris were blocked by the bridge (**Image 6.4.3-A**) for very short time (less than 10 seconds) (**B**) and the water level rise that followed and the subsequent change in flow direction toward the public houses and restaurants (**C**) on the lower terrace of left bank resulted in washing away 7 houses for visitors, restaurants, and the campsite. The bath on the riverbed was also washed away. These may be the direct causes of the great casualties, at Kharapani.

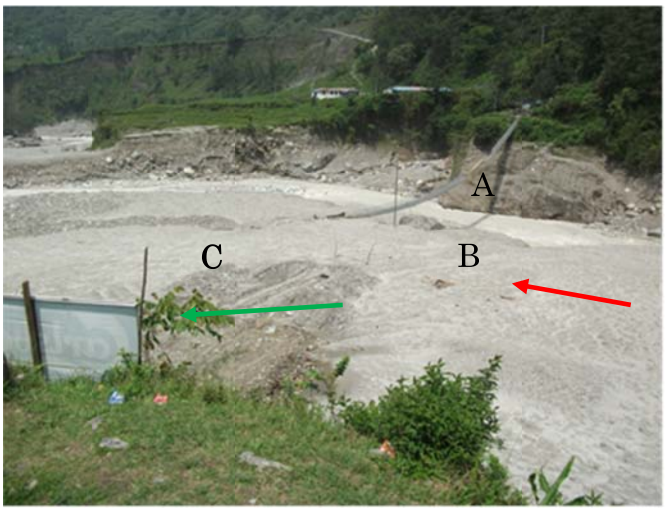


Image 6.4.3 Assumed processes of floods at Kharapani Bridge

In the flood deposits on the lower terrace, fine materials of less than 20cm in diameter such as gravels with mud, are dominant (**Image 6.4.4**). Gneiss and round gravels were not observed frequently. The main source of sediment was Tethys sediments and marl. The mud flow reached Kharapani at 9:38 (Dahal, 2012), so the travel time of the flood must have been around 30 minutes, indicating that the average speed from the origin to Kharapani was 60km/h. The high velocity surge was due to the gorge being strait and narrow with steep riverbeds from the reaching point of rock avalanche to the first river bending point. The large amount of logs which formed temporary dams at narrow or steep bends originated from the thick riparian forests along Seti Khola due to rare human intervention.

Image 6.4.4 Mud and gravel covering the lower river terrace (Baraudi)

6.5. Estimation of the peak flow

6.5.1 Examination of the cross-section

In order to estimate the peak flow at the time of the flood, a laser range finder was used on the flood marks in three areas of the Seti River to measure the breadth of the traces of the down-flow, the relative elevation from the riverbed and the bed slope. **Image 6.5.1** shows the places where the cross-section was measured, the measurements, and the calculated peak flow at each location.

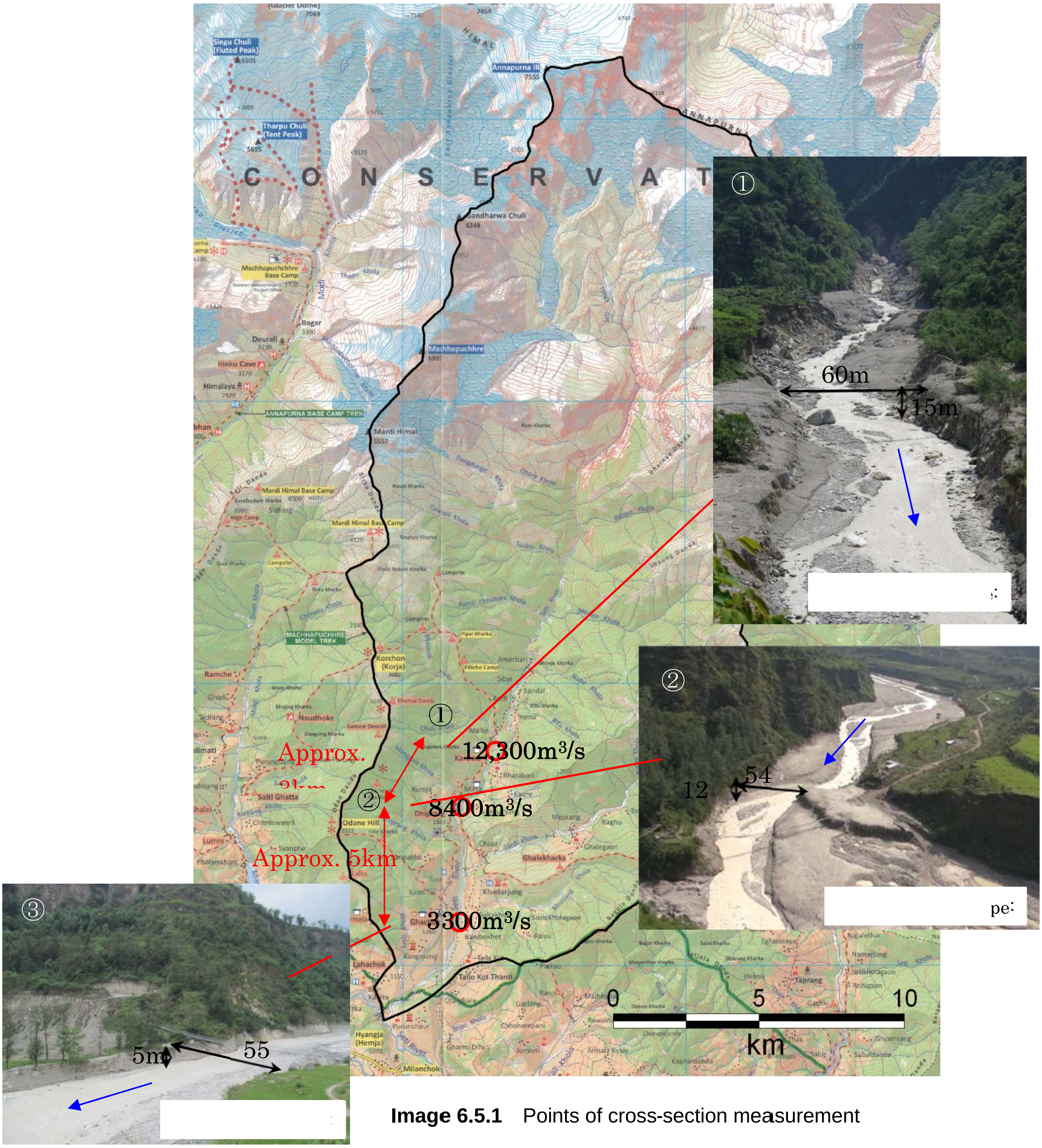


Image 6.5.1 Points of cross-section measurement

6.5.2 Analysis of video images

Based on the video images taken by the local people from the time of the arrival of the Kharapani mudflow (at the point ② in **Image 6.5.1)** obtained during the field study, an estimation was made of the average velocity of the head part of the mud flow (**Image 6.5.2**).

T=0s

T=5s

T=10s

T=15s

T=20s

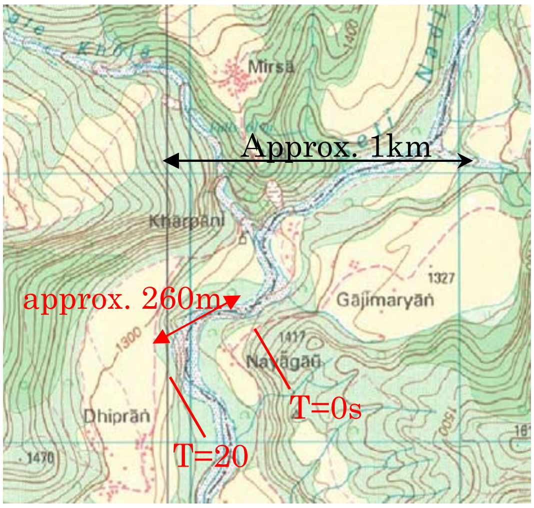


Image 6.5.2 Status of the arrival of the Kharapani mudflow

From the video analysis, the head part of the mudflow moved a distance of 260m (l) over 20 seconds, and its speed was calculated using the formula below.

$$
\begin{aligned}
v(m^3) &= l(m) \div T(s) \\
&= 260(m) \div 20(s) \\
&= 13(m/s)
\end{aligned}
$$

From this, the average speed of the leading edge of the Kharapani flood was calculated to be about **<u>13m/s (46.8km/h)</u>**. This is about the same range as the 7.8-13.6m/s of the Sakurajima Nojiri River, and faster than the observed speed of the avalanche at Kamikamihori Creek on Mount Yakedake in Japan.

6.5.3 Estimated peak flow

The Kharapani peak flow was calculated based on the results of the cross-section measurement and video analysis. Note that the flood marks were assumed to be the cross section at the time of the peak mudflow when calculating the peak flow volume.

$$
\begin{aligned}
Q_{\max}\left(m^3/s\right) &= a\left(m^2\right)\times v\left(m/s\right)\\
&= 648(m)\times 13(s)\\
&= 8{,}424\left(m^3/s\right)
\end{aligned}
$$

Here, a is the cross-sectional flow area.

From this, the Kharapani peak flow was calculated to be around **<u>8,400m³/s</u>.** Further, back calculating Manning's coefficient of roughness from this calculated peak gives an end result of 0.083. This is larger than the general value for mountain streams (0.03-0.05: Manual for River Works in Japan).

Peak flow was calculated other areas (① and ② from **Image 6.5.1**). Further, when Manning's formula is used, the roughness coefficient for ① is set larger than ② at 0.1, as it is the avalanche downflow section, and the coefficient for ③ is set at the typical value of 0.03, as it is the bedload transport section. Moreover, in all cases, both banks were calculated as a rectangular cross-section as they are virtually perpendicular benches.

① Cross-section

$$
\begin{aligned}
Q_{\max}\left(m^3/s\right) &= \frac{A}{n}\cdot R^{2/3}\cdot I^{1/2}\\
&= \frac{900}{0.1}\cdot\left(\frac{60\times 15}{2\times 15+60}\right)^{2/3}\cdot 0.087^{1/2}\\
&= 12{,}333\left(m^3/s\right)
\end{aligned}
$$

③ Cross-section

$$
\begin{aligned}
Q_{\max}\left(m^3/s\right) &= \frac{A}{n}\cdot R^{2/3}\cdot I^{1/2}\\
&= \frac{275}{0.03}\cdot\left(\frac{55\times 5}{2\times 5+55}\right)^{2/3}\cdot 0.052^{1/2}\\
&= 3{,}291\left(m^3/s\right)
\end{aligned}
$$

The peak flow of ① and ③ in Image 6.5.1 were respectively calculated at about **<u>12,300m³/s</u>** and **<u>3,300m³/s</u>.** The 12,300$m^{3/}$s peak flow of cross-section ① had attenuated to around 3,300m^3/s at cross-section ③ about 8km downstream.

6.5.4 The required volume of water to produce a mudflow

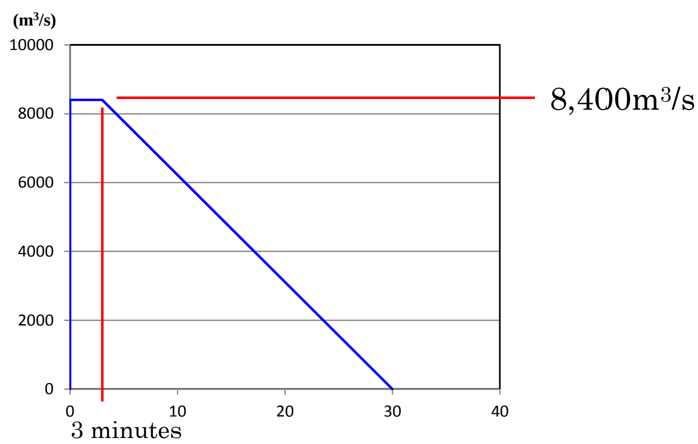
The field survey showed that there was hardly any debris remaining in the gorge near the source of the river, and although the source is unclear, it was accompanied downstream by a large volume of water. It is thought that this is what produced the large flood.

Here, the aggregate amount of water that flowed out was estimated from interviews on the ground.

Mr. Santos Rai (16), waiter in Kharapani.

- Immediately before the strong wind began and two women (college students) were blown off their feet, the roof of the building was blown away, and then the flood came.
- Some driftwood got caught up in the suspension bridge and blocked the river, and the flow turned around to the left bank.
- **<u>The flood ran along the bench for about three minutes. Then, it returned to its original water level about thirty minutes later.</u>**

According to the testimony above, the peak continued for three minutes and the mudslide continued for 30 minutes. This made it possible to create the hydrograph shown below.



From the formula below, the aggregate volume including earth was **<u>8,320,000m³</u>.**

From here, assuming the concentration of soil to be 10% gives an aggregate volume of water Q_w of **<u>7,480,000m³</u>.**

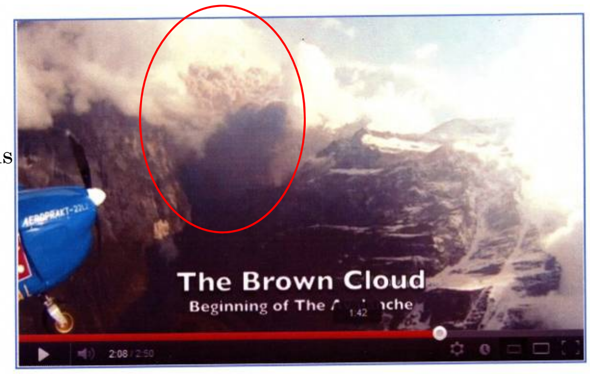
$$Q_w = Q \times 0.9 = 7,480,000 m^3$$

6.5.5 Estimating the velocity of the flood wave

Below are the times that each phenomenon occurred as understood from collected documents and local interviews. It is confirmed that a cloud of dust thought to be caused by the rockslide on the western slope face of Annapurna IV Peak arose at 9:09, and that earth flowed into the Seti River gorge three minutes later at 9:12. Another 26 minutes later at 9:38, the head of the mudflow reached in Kharapani in this image (Dahal, 2012 **Image 6.5.3**). Now, as shown in **Image 6.5.4**, the distance from Annapurna IV Peak's western slope to the Seti River gorge opening is about 10km, and the distance from the Seti River gorge opening to Kharapani is around 20km.

① 9:09 a cloud of dust confirmed at the source.

78 seconds



* Picture taken by A. Maximov (Avia Club Nepal)

↓ 3 minutes later

② 9:12 – Debris enters Seti River gorge.

↓ 26 minutes later

③ 9:38 – The flood wave arrives at Kharapani

Image 6.5.3 Status before and after the flood at Kharapani (Dahal, 2012)

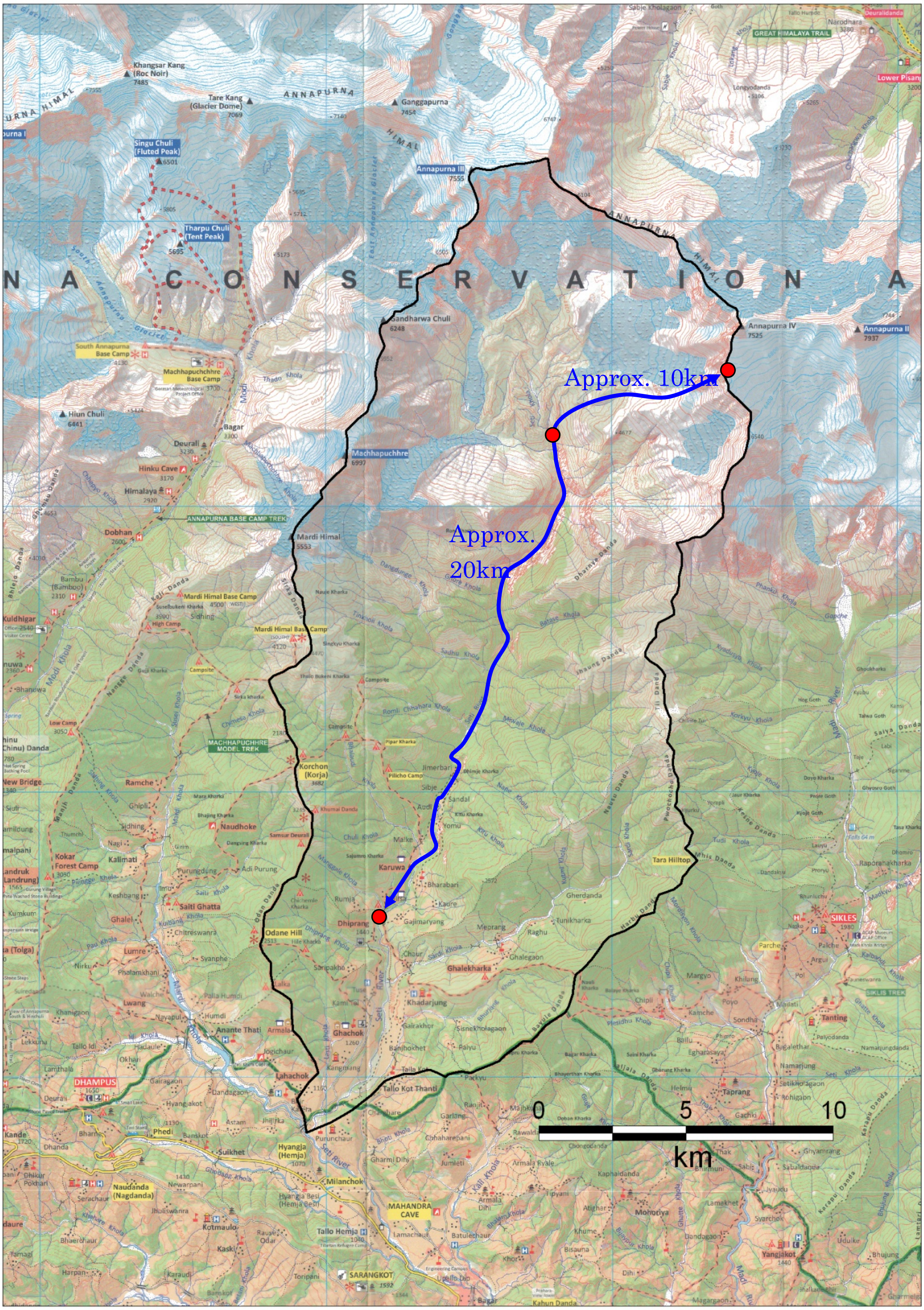


Image 6.5.4 Distance from Annapurna IV Peak western slope to Kharapani

(1) Estimated speed of the debris avalanche

From the above, the velocity of the avalanche (V_1) was calculated using the formula below, and the result is an estimated avalanche velocity of about **55.6m/s (200km/h)**

$$
\begin{aligned}
V_1(m/s) &= L(m)/T(s) \\
&= 10{,}000(m)/3 \times 60(s) \\
&\cong 55.6(m/s) = 200(km/h)
\end{aligned}
$$

(2) Estimating the speed of the flood wave

In the same way, the flood wave (V_2) was calculated using the formula below, and the speed has been estimated at around **12.8m/s (46.2km/h).** This is very similar to the velocity calculated in 6.5-2 (13.0m/s).

$$
\begin{aligned}
V_2(m/s) &= L(m)/T(s) \\
&= 20{,}000(m)/26 \times 60(s) \\
&\cong 12.8(m/s) = 46.2(km/h)
\end{aligned}
$$

The speed of the flood wave calculated from the video images was 13.0m/s, and the river bed is at a steep gradient upstream Kharapani, so it can be assumed that the speed of the water was high. That can be considered broadly correct from the perspective of information gathered from the local interviews to the effect that "flooding caused by the temporary damming lasted about five minutes."

6.6 Results of interviews with local people

The origin of floodwater whose peak discharge was estimated at 8,400m^3/s is not clear, and no big glacial lakes were found before the flood in the upstream area. Since the dominant agent of the rock avalanche was expected air blow, a main water source should have existed around the entrance of the Seti Gorge. One hypothesis is that the deep Seti Gorge had been blocked by the sediment transported from eroded fine materials and breached by the onslaught of rock avalanche debris. We interviewed the local people of Yomo, Kapuche, Baraudi, and Kharapani about the preceding phenomena of the Seti River.

According to the interviews, the phenomena and their occurrence time are as follows (**Fig. 6.6.1**).

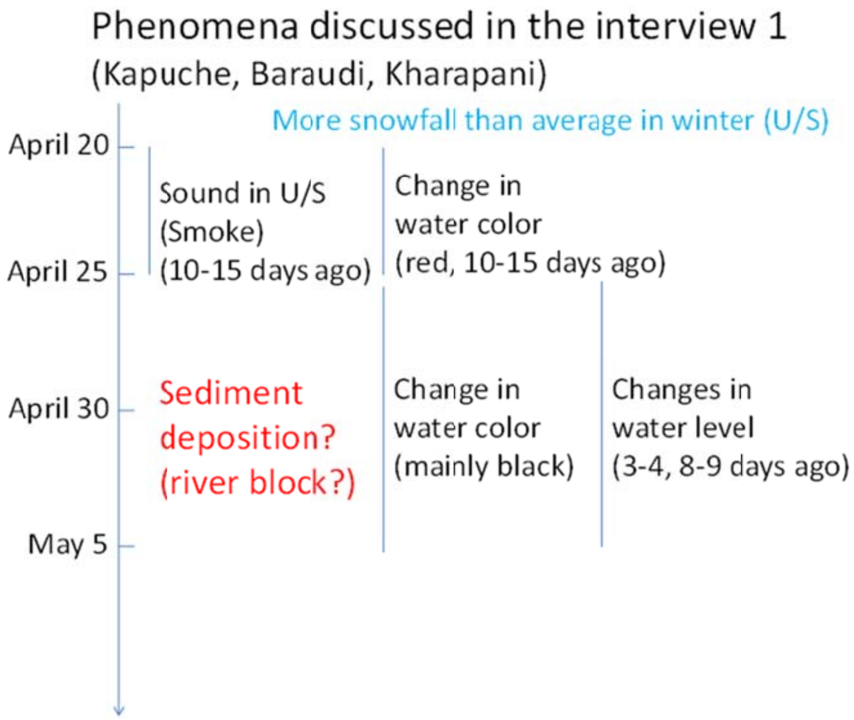


Fig. 6.6.1 Phenomena discussed in Interview 1 (Kabuche, Baraudi and Kharapani)

1) Snow depth in the Annapurna Mountains was greater than the usual in winter of this year (Yomo, Kapuche).
2) Rainfall occurred in late April (Yomo, Kapuche).
3) The color of the Seti River had changed to black and brown around 7-10 days before the flood (Kapuche, Yomo).
4) The water level of the Seti River had changed several times. It had become so low that people could cross the river (Baraudi).

Therefore there was more snowmelt water from the High Mountains than the usual in time preceding the flood. It may have activated surface erosion of former lake deposits in the foot area of Annapurna IV. The water color changes in late April are thought to be the result of surface erosion.

While many of the flood victims in the disaster occurred in Kharapani, the people of Kapuche, Kharapani area must have picked up on pre-cautionary phenomena because of the large amount of sediment which flew for the long distance to Kharapani. **Fig. 6.6.2** shows the results of interviews with local people about the pre-cautionary phenomena.

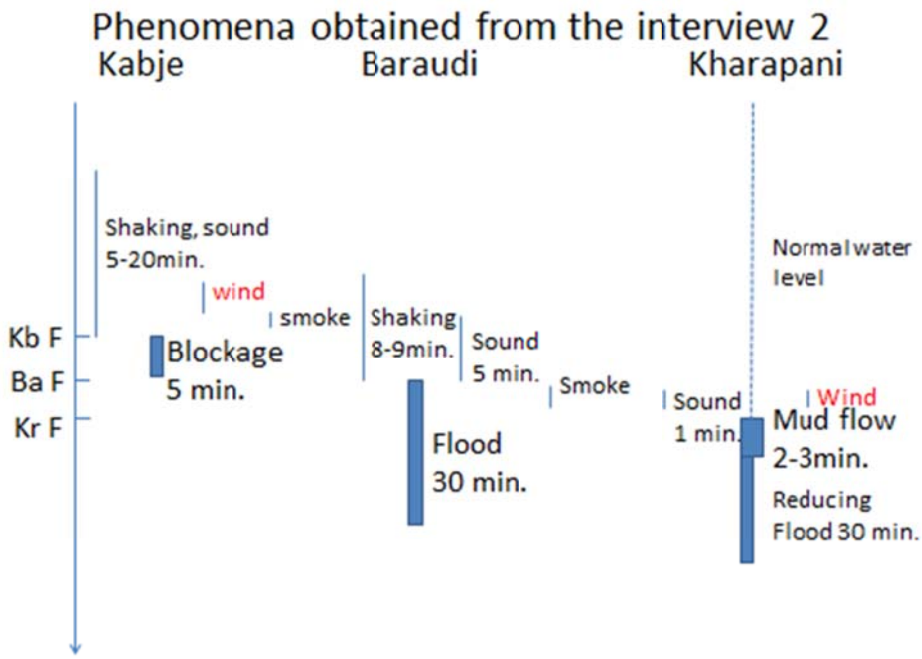


Fig. 6.6.2 The results of interviews to local people about the pre-cautionary phenomena

The people of Yomo and Kapuche noticed ground shaking and sounds like a flying helicopter from 5-20 minutes before the onslaught of mud flow. They also experienced strong wind and smoke in front of the approaching mud flow. The shaking and sound may have come from the approaching mud flow upstream. The smoke is assumed to have reisen and blown from the flood waves. Most of the people in Yomo immediately rushed to climb up the steep slopes to evacuate due to these phenomena.

At Baraudi and Kharapani, standing a short distance from the downstream side of the river bending points, people could only see the mud flow wave just before it approached. In Kharapani, however, some people noticed the ground shaking from around one minute beforehand. A few people also reported strong cold winds rushing in front of the mud flow. It is noteworthy that an old man living in Baraudi could see the approaching mud flow and informed his friend in Kharapani of the emergency via his mobile phone. However, this warning could not convince the visitors in the hot spring to evacuate because they could not believe it gicen the fine weather.

Based on the findings above, the hypothetical process of transition from the rock avalanche to the mud flow is assumed to be as follows.

The facies of remaining debris materials indicate that the rock avalanche partially changed into debris (mud) flow before arriving at the confluence of the Seti River. Possible origins of the water which formed the mud flow are thought to have been not only the stream water of torrents but the sudden failure of the ice caps which had covered the ridge slopes simultaneously with the rockslide. Fragmented ice blocks mixed with rock debris may have melted during the avalanche and provided water into the eroded fine marl materials. However, if the thickness, the area of collapsed ice, and the bulk density are 60m, 550*100m, and 0.9 respectively, the maximum volume of water from the ice, melting is assumed to be 3 million m^3. This is only 40% of the assumed volume of water mentioned in 6.5.4. The eroded ice of the debris-covered glacier on the foot slopes is not expected to be large in volume. The water from snowmelt and rainfall in late April and eroded fine materials from marl deposits may have caused a temporary blockage in the extremely deep and narrow gorge in of the Seti Khola limestone, and caused the color changes in the river water at Yomo and Kapuche and the remarkable decrease in the river water level one or two weeks before the flood. It is expected that the dammed-up water may have breached due to the falling materials of the rock-debris avalanche, thus formulating the mud flows. In this case, there were hardly any dammed-up materials remaining along the gorge.

6.7 Summary of survey results

Based on the field survey and analysis, the flood disaster of Seti Khola on May 5, 2012 is considered to have occurred as the following processes. Time series phase changes of mass movement occurred in this flood event.

1) A large-scale rockslide occurred on the west-facing walls of southwestern side of Annapurna □ at 9:09 AM on May 5. The ice cap on the ridge also fell down with it.
2) Rocky debris fractured at the foot of the wall and scattered on the glacier and subsequent rock avalanche run off on the glacier and the marl deposits in the Annapurna Basin. The marl deposits and glacier surfaces were eroded along the passage route of the rock avalanche and the accompanying blowing wind.
3) The rock avalanche gradually turned into debris flow due to melt-water from the ice what was involved and fell into the Seti Gorge. From there, mud flow moved downward, damaging the villages along Seti Khola and reached Kharapani at 9:38 AM, causing grat casualties.

The velocity of mass movements from the origin to Kharapani was approximately 60km/h. The studies on the seismic analysis and the observation by the pilot of a light plane indicated that the average velocity of the rock failure and rock avalanche reached around 200km/h (55.6m/s).

The scale of the rockslide was assumed to be approximately 850m in length, 550m in width, and 30 million m^3 in volume.

The interviews with local people and seismic observation data reveal that the rockslide was not caused by earthquakes, heavy rain, or snow melting. Dip slopes consisting of the Tethys sedimentary rocks may have induced rockslides. They also reveal that temporary damming up of the Seti River within five minutes had occurred at the narrow river bending point at Kapuche. Its bursting could have formulated a debris flow which may have increased the flow energy and changed into mud flow downstream, causing the catastrophic damages at Kharapani 3km downstream from the bursting point.

According to the local eyewitness a large amount of wood and debris at the front of mud flow were blocked by a bridge, thus causing changes in flow direction to the lower terrace of the left bank where the buildings for visitors had stood.

The video images taken at Kharapani indicate that the average velocity of the head part of the mud flow was about 13m/s (46.8km/h), which is almost same as that of the mud flow from Seti Gorge to Kharapani (46.2km/h). Estimated peak flow discharge by the field measurement of highest flood marks was 12,300 m^3/s at Yomo, 8,400 m^3/s at Kharapani, and 3,300 m^3/s at the point 5 km downstream of Kharapani.

The surficial flood deposits along the Seti River consist of fine silty and clayey materials with gravels. There fine materials are assumed to have originated from the dust of the rockslide, avalanche, and eroded marl deposits. The large amount of woody debris in the mud flow was from the dense riparian forests upstream.

According to local people, it is also expected that sediment concentration caused changes in river water color and decreased water levels downstream around two weeks before the flood on May 5. As the people also said that the High Mountain area of the Seti watershed had been covered with an unusually large amount of snow in last winter, excessive snow melting also may have induced sediment production in the marl areas. Recently, a scientific team of Nepalese and the University of Arizona pointed out via field survey that a landslide dam had been formed several weeks before the flood (AFP, 2012). Therefore the water source of the mud flows is not only the eroded glacier but also the possible bursting of the previous filling materials of the gorge (NFAD, 2012).

Several precautionary phenomena were also picked from the interview. People at Yomo and Kapuche had noticed ground shaking and strange sounds from upstream 5-20 minutes before the flood on May 5. Just before the arrival of the mud flow, they also saw smoke along the river. Such phenomena were caused by the approaching mud flow. However, the people of Baraudi and Kharapani recognized them much later because it was difficult to see far away due to the bending Seti River.

While many flood victims who came to Kharapani for picnics, baths, or to work in shops and stone quarrying, many of the upstream villages stood on the higher river terrace and sustained less damage than at Kharapani. Many of the people of Yomo, which stood on the lowest terrace and was completely overtopped by the mud flow, were able to escape up the slopes suddenly and survive because of the precautionary phenomena. However, the emergency information from Baraudi via mobile phone could not make the people in danger escape at Kharapani. Because of the fine weather, most visitors could not believe the loud voice calling for awareness of the big flood approaching.

Large-scale rockslides are not expected to occur frequently in High Himalaya, which consists of rather hard rocks. In the Annapurna Basin, where steep slopes with earth pillars are predomnant, large-scale mass movements seem uncommon.

However, steep rocky slopes formed by glacial erosion become unstable when the ice covering on the foot slopes melts (Ballantyne, 2002). Steep unstable slopes around marl deposits must be checked via air survey or high-resolution satellite images. It is also noticeable that the large amount of unstable sediments remaining from the flood on May 5 will be washed downstream easily, thus affecting the area around the Seti River.

Though the timing and location of similar flash flood disasters can hardly be forecasted, fine materials such as paleo-lake deposits, glacial deposits beneath the high steep slopes, or unstable large-scale landslide slopes that are actively dissected by torrents or rivers are prone to similar types of flash floods. In particular areas where there is less chance of humans being nearby like the uppermost basin of Seti Khola, should be monitored aerially or by special survey. Evidence of another recent rock collapse could even be observed on the steep slopes around the Annapurna Basin (**Image 6.7.1**).

Image 6.7.1 Evidence of recent rockslides on the east-facing slopes at the south of Annapurna III peak (Light brown part in the center)

6.8 Recommendations

1) Causes of large-scale rock slides and avalanches and detection of highly hazardous slopes

   The main cause of the rockslide on the ice-covered rocky mountain of 7,000m asl. should be examined as ice melting and earthquakes can hardly be expected in the Seti flood case. Any symptoms of rock slides such as cracks in glaciers or mountain slopes, should be detected by air survey in the High Himalaya.

2) Mechanisms of mud flow formulation

   The erosion volume of marl deposits due to the rock avalanche should be estimated by comparing the topography before and after the avalanche. Topographical maps may be prepared using the satellite. It may be also recommended to find evidence of temporary damming-up that lasted until the flood occurrence in the Seti Gorge.

3) Confirmation of the temporary damming at the narrow bending point upstream of Sadal which was reported in the interviews in Yomo and Kapuche.

4) Risk mapping of sudden flash floods in Nepal Himalaya

   Not only dangerous glacial lakes but wide distribution areas of thick marl deposits should be picked up below the large-scale rockslide prone slopes to perform risk zoning for sudden flash floods. Large-scale unstable landslides should also be picked up for landslide dam and burst risks. In particular, risky slopes in the outside areas of human activities, like the High Himalaya zone and mountains with dense forest cover, should be surveyed by air or satellite images because pre-caution by local people can not be expected.

5) Disaster preparedness education and simple early warning systems

   Direct oral and auditory recognition of the approaching floods helped the people escape suddenly in the Seti Flood Disaster. Mobile phones, which are widely used in Nepal, seem to be an important communication tool for early warning. Combining such an information system with disaster education from outside which helps the local people and visitors to reduce the risks associate with such floods. In the case of sightseeing areas like Kharapani, a TV monitor that monitors the upstream conditions of the risky river is useful for both sightseeing under normal circumstances and evacuation when floods occur.

6) Countermeasures against the unstable sediments of Seti River

   The areas along the Seti River have been highly susceptible to flood and sediment disasters due to the unstable deposits remaining from this flood. This is similar to the rivers affected by GLOFs and other big floods. Hazard zoning via aerial photo interpretation and field surveying, early warning through both education and rainfall monitoring, and river training works are recommended. Disaster preparedness and post-disaster restraint measures are recommended along the Seti River as a model case of disaster management against the sudden large-scale flash flood disaster. DWIDP may be one of the leading organizations for this.

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Annex 1: Interviews

4 June

An elderly person (74 years old) in Kabuche

- I have three sons (one is in Malaysia) and a daughter.
- I had never experienced such a big disaster as this in my life.
- In Yomo Village, located on the other side of the river, there were 13 houses. Eleven of them were completely washed away. Two remain but are uninhabitable. There was no damage in Kabuche.
- Twenty five minutes before the flood, people felt the ground shaking strongly like in an earthquake. I heard a roaring sound. I thought a big helicopter was approaching at a low altitude. I saw white smoke rising far away in the upstream area.

4 June

A middle aged person (50 years old) in Sano Khoban

(Sano Khoban is a place for relocation arranged by the government. It is located in a mountain area. We arrived there after walking a foot path for about one hour, struggling with leeches under incessant rain. Six families from Yomo were in a hut surrounding a wood fire.)

- I was born in Yomo. This is the first disaster like this in my life.
- People came to live in Yomo about 70 years ago. They cut trees and settled there. People were rich because the land was fertile and good for producing vegetables. Of the 13 families here, there came to settle in Yomo only three years ago from Dading District where they had been poor, suffering from frequent floods.
- Six families from Yomo are constructing houses here.
- All we received from the government was the land and two sacks of rice.

5 June

A boy in Kabuche.

- My house is one of the two which withstand the floods, but it is inhabitable due to extensive damage inside.
- I escaped to the mountain behind Yomo together with the people of village, and stayed there for two days. Only one of the person of the village died.

5 June

Mr. Arjun Bhandari, Sub-Secretary of Machapuchare VDC Tel: 9816101503

(We had informed Chairman of Machapuchare VDC of our visit in advance. He could not attend because of another appointment, but he was so kind as to send Mr. Bhandari to Karuwa to see us on his behalf. The VDC office is located in Diprang, about one hour on foot.).

・Seven people died in Machapuchare VDC: Yomo, 1), Diprang (2), Mirsa (4).

・ In Sano Khobang, the government provided land for 21 families, including families affected by the floods.

・Government support for affected families:

- Land to built a house
- 100,000 NRs for totally damaged houses 50,000 NRs for partially damaged houses

4 and 5 June

A young person in Karuwa, the uppermost place we stayed

(He could speak English fluently because he had worked in Qatar for four years. He guided us along the right bank of the river, upstream to the place in front of Yomo and downstream to the narrow gorge where sediment and wooden debris accumulated to form a temporary dam. Unfortunately, it was impossible to cross the river to Yomo because of the river water still flowing swiftly at a depth of more than one meter. According to Mr. Ram, our guide, the water of the river is relatively low in the morning because of the freezing in the high mountains, and high in the afternoon because of the melting there.)

・A suspension bridge connecting Jomo and Karuwa was washed away. A makeshift wooden bridge was constructed at the same place after the floods but was soon washed away as well.

・The color of the water of the river changed about one month before the floods. White smoke was seen upstream about 15 days before the floods.

・The river was blocked at the narrow gorge downstream of Yomo by sediment and wooden debris to form a lake-like situation (called “Saga” in the local language), which collapsed after about five minutes.

6 June

Ms. Dhul Maya Tamang (55 years old) in Chipreti/Sardi Khola (Ms. Tamang lives in a meager hut about one km downstream from Tatopani (Kharapani) and near the road leading to Pokhara.)

・My husband was killed by the floods while doing sand mining in the river. We have no children and I am alone now. We came here from Pokhara five years ago. I received 125,000 NRs from the government.

・On that day of the disaster, the river stopped flowing and dried up temporarily (for about five minutes)

6 June

The owner of Tatopani Riverside Viewpoint Restaurant, which is located on a higher river terrace of Seti Khola in Kharapani. The restaurant has a good view of the affected area in Kharapani. He opened the restaurant five months ago.

・I heard a roaring sound and felt the ground shaking like in an earthquake for about one minute.

・I received information about the flood from a person in an upstream village. I tried to communicate the danger to people in and around the river, but nobody believed me.

・ Three people from the UK were taking pictures of the whole process of the disaster beside the restaurant.

6 and 7 June (twice)

Mr. Santos Rai (16 years old), an employee of the restaurant mentioned above.

・Strong winds began suddenly. Two college girls walking on the suspension bridge were blown off into the river, the roofs blew off of every house and building, and the floods came.

・The flood flow was blocked by wooden debris at the suspension bridge, and the direction changed to the left bank side, where most of the tourism facilities such as restaurants, camping sites, etc. were located.

・The floods ran over the river terrace for about three minutes. The river flow became normal after about 30 minutes.

7 June

An elderly person in Kharapani,

The interview was performed on the higher terrace near the restaurant, looking down over the whole disaster area

・My parents and a laborer died, but their bodies have not been found yet. Without proof of their death, I cannot receive money from the government.

・The weather was fine on that day.

・The floods occurred only once. The river flow had been normal until just before the floods.

Another person joined the interview.

・I was working to construct walls on the left bank of the river in the upstream of the suspension bridge.

・The construction site was located in the upstream part of Kharapani, and I managed to notice the floods earlier than the others in the tourist places. I was able to narrowly escape the floods.

7 June 9:30-12:00

Visit to an elementary school (Shree Annapurna L.S. School) in Diprang.

We visited the school without a prior appointment, but Mr. Girdari Lamsal, (the principal, 46 years old) and several teachers kindly got together to tell us about their experiences in the disaster.

They have two videos of the disaster scene. One was taken by a teacher at he school and another by a person in the village. They promised to provide us with the videos later. (We received them later.)

There was a question from a teacher: “Another group of researchers said there were cracks in the glacier in the high mountains, which might cause similar disasters in the future. What do you think of this idea?” Our answer was “Our survey so far has not identified any phenomena that may cause similar disasters in the near future.”

7 June 15:00-15:30

Ms. Ganga Acharya, Sardi Khola VDC office staff

Ms. Acharia gave us the following summary of the casualties of Sardi Khola VDC.

・Dead and missing : 17 persons (The figure differs from the sum of the following)

Ward 1: 13 persons Gaina Khola(3), Bhurjung Khola(2), Koakarsari(4), Bajokhet(2), Chauva(2)

Ward 7: 3 persons

Ward 9:　2 persons

・Houses damaged : 12 houses

7 June　16:30-17:30

Mr. Santos Tamurakar, owner of a restaurant/hotel in Bhurjung Khola

・Many people of Bhurjung Khola are working in Tatopani as restaurant employees, sand mining laborers etc.

・My father’s body was found buried in the house. That’s how suddenly the floods came. My sister in law is still missing.

Annex 2: List of persons met

Japanese Embassy	Mr. Kunio Takahashi*	Ambassador
	Mr. Shuichi Sakakibara*	Minister-Counselor
	Mr. Hisashi Hoshino*	First Secretary
JICA Nepal Office	Mr. Mitsuyoshi Kawasaki*	Chief Representative
	Mr. Satoshi Fujii*	Senior Representative
Ministry of Home Affairs	Mr. Lakshimi Prasad Dhakal*	Joint Secretary
	Mr. Bal Krishna Panthi	Undersecretary
DWIDP	Er. Prakash Paudel	Director General
	Mr. Mathura Dangol	Deputy Director General
	Mr. Shanmukuhesh Chandra Amatya*	Chief, Landslide Section
	Mr. Kendra Bahadur Shrestha	Engineer
Tribhuvan Univ.	Dr. Bishunu Dangol*	Professor
UNDP	Ms. Shoko Noda*	Country Director
OCHA	Mr. Ram Prasad Luetel*	Disaster Response Specialist
	Mr. Andrew Martin*	
ICIMOD	Mr. Shamjwal Bajracharya*	Remote Sensing Specialist
	Ms. Nira Gurung	Communications Officer
Nepal Risk Reduction Consortium	Moira Reddick*	Coordinator
Shaplaneer	Ms. Hiromi Katsui	Chief, Nepal Office
Monta Dio Consulting	Mr. Kazuo Suganuma	

*Persons who attended the meeting at the official residence of the Japanese Ambassador on 9 June

Annex 3 List of reference materials

・Video1; Seeti ko Badi.mpg (20:30)　（Nepal Forum of Environmental Journalists (NEFEJ)）

・Video2; The front of debris flow (0:21)　(taken by a person in Diprang)

・Video3; The front of debris flow (01:25)　(ibid.)

・Map1; 1:50,000 (GHANDRUK, CHAME, LAMJUN HIMAL, TILICHO), Survey Department, Govt. of Nepal

・Map2; 1:25,000 (POKHARA(East), POKHARA(West), LAMACHAUR), Survey Department, Govt. of Nepal

S.S. Center Map House Thapathali, Ph.4264272

・Map3; ANNAPURNA

The Japanese survey team (leftmost: pilot)

Survey by short landing in the Annapurna Basin

Rockside can be seen at the center

Earth pillars consisting of the marl deposits

Bank erosion up to 30 m in height at the second bending point of the Seti River

Interviews with the people of Kapche

Sano Khobang as the land provided by the government for the evacuated people

Interviewing with the people of Sadal (Sano Khobang)

Upstream areas of the Seti River can be seen from Sadal due to a straight valley

Identification of the flood by the local eye witness (Kapche)

Strong bank erosion of consolidated gravel deposits by the mud flow (Baraudi)

Flood deposits of fine materials (Baraudi)

Upstream area of the Seti River cannot be seen from Kharapani due to river bending

Interviews with the teachers of the Shree Annapurna L.S. School (Diprang)

Coverage of mud flow deposits of fine materials on the lower river terrace (Kharapani)

Entrance of the gorge of Seti River in Phokara (toward downstream)

Entrance of the gorge of Seti River in Phokara (toward upstream)