Niujuangou Gully, China

Flash flood monitoring and risk management

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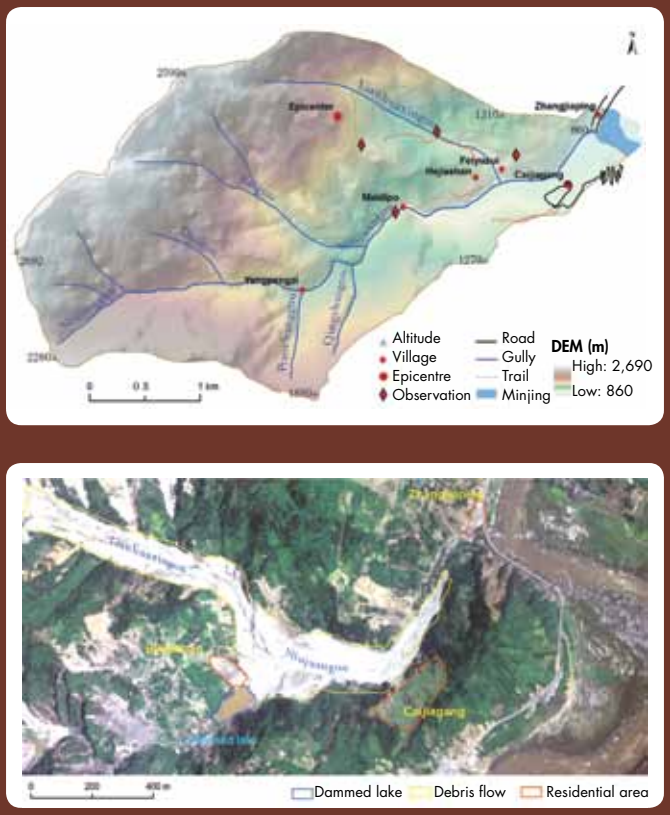
The Wenchuan earthquake completely changed the topography of the Niujuangou gully. The processes and formation mechanisms that could now lead to flash floods in the area must be understood to assess altered vulnerability and risk. Research into the hydrological process and monitoring are needed to understand the critical rainfall that would trigger a flash flood so that floods can be forecasted and an early warning system developed.

Figure 24: **3D digital map of the study area (top) and ADS40 areal image of the study area (bottom)**



Introduction

Niujuangou gully is located in Yingxiu town, Wenchuan County, Sichuan Province (E103°25′12″ to 103°28′31″ and N31°01′21″ to 31°03′16″), 78 km from Chengdu. The terrain of the study area is low in the southwest and high in the northeast, ranging from 860 m above mean sea level to 2,693 m above mean sea level, a difference of 1,833 m. The gully is flanked by high mountains with steep slopes and a deep valley with a mean gradient of 3.16 per cent. It has a total drainage area of 10.46 km^2 and main channel length of 5.8 km. The gully contains six branches and is 3.77 km in length. Niujuan gully is part of the Minjiang River system (Figure 24).

The study area has a subtropical moist climate, with high annual rainfall. It has long-term annual mean rainfall of 1,253 mm, annual maximum rainfall of 1,688 mm, and daily maximum rainfall of 270 mm. Sixty-eight per cent of the annual precipitation falls from June to September.

Flash floods in the study area are caused by intense rainfall, earthquakes, and landslide dam outbursts. Intense rainfall is perhaps the most common cause of flash floods. The topography, geology, and land use in the study area make it particularly prone to flash floods. Abrupt slope gradients and poor and fragile watersheds in the hills produce very high flow velocities and centralized discharge. The study area was at the epicentre of the Wenchuan earthquake in 2008, which radically changed the natural conditions triggering rock falls, landslides, debris flows, and dammed lakes (five in Niujuan gully alone), making the area more prone to flash floods. The mechanisms for the formation of flash floods and the critical level of rainfall to trigger a flood event in the post-earthquake environment are different from that

before the earthquake. Flash floods are occurring in new gullies with low frequency, but on large scale. For example, as a result of the flash flood in Zhouqu County on 8 August 2010, 1,510 people died, 255 people went missing, 47,000 people were affected, and 6,000 houses were damaged (Figure 25). This natural disaster was the most serious flash flood since 1949. A flash flood also occurred in the Hongchun gully on 13 August 2010, which killed more than 200 people and destroyed Yingxiu town (Figure 25). There had never been a flash flood in this gully before the earthquake.

Economic and social factors, including the development of local society and the economy, also contribute to flash flood risk and vulnerability. There are two towns in the study area, Yingxiu and Xuankou, and three villages, Zhangjiaping, Caijiagang, and Hejiasha. The population lives in mostly rural areas and consist of Han Chinese and Tibetan people. The Wenchuan earthquake seriously damaged the socioeconomy of the study area. Before the earthquake, Zhangjiaping village had 389 people in 105 households, with 0.4 ha of farmland per capita, annual income per capita of RMB 6,000–7,000 (USD 953–1,112), and five pigs per household. The earthquake killed 52 people and injured 120; it also led to the loss of all but 90 of the village's 1,800 sheep, and destroyed all of the houses and arable land rendering the villagers homeless. Before the earthquake, Caijiagang village had a population of 279 in 68 households, with farmland per capita of 0.2 ha, annual income per capita of RMB 1,000 (USD 159), two pigs and five chickens per household, and more than 300 sheep. The earthquake killed 16 people and injured 48; it also killed about 10 per cent of livestock, and destroyed more than 40 ha of farmland, all houses, and all schools rendering the villagers homeless.

The study was conducted to:

- summarize flash flood control measures and practices in the study area;
- establish flash flood monitoring and early warning;
- share information and disseminate knowledge;
- build the capacity of stakeholders in the flash flood risk zone; and
- implement flash flood risk management.

Method and Approach

Data collection

A large amount of data were collected for the study including spatial data, attribute data, time data, thematic data, socioeconomic data, statistics, and loss and damage data. Secondary data were collected through a review of literature on flash floods from China and abroad. Experts, scholars, and professionals were also approached for data and reports. This was supplemented by local government documents and materials from the study area. Large-scale digital maps and high-resolution remote sensing images were also purchased. Field surveys, observations, and investigations were used to obtain primary disaster data, meteorological and hydrological parameters for flash flood monitoring, data for warning and forecasting, and data for risk assessment and mapping. A questionnaire survey was conducted to obtain socioeconomic data and disaster-loss data, and assess the needs of

Figure 25: **Flash floods in Zhouqu County on 8 August 2010 (left)** and **Yingxiu town on 13 August 2011 (right)**

stakeholders and identify gaps for flash flood capacity building. Local residents and stakeholders were also interviewed to document local knowledge and practices. In addition, experts were commissioned to prepare some of the materials for capacity building.

There were some problems and constraints in the course of data collection. For example, it was difficult to obtain government data, relevant research reports, large-scale geologic maps, and high-resolution images. The language barrier made it difficult to communicate with minority nationalities and isolated residents, making it difficult to understand and document indigenous knowledge and practices.

Stakeholder participation

The stakeholders involved in the study included local government, private enterprises, financial institutions including banks and insurance companies, non-governmental organizations, and local residents (Table 10).

Activities

The project worked with and through the local communities, government and other local stakeholders to implement its activities. Community-based preparedness and risk management is a separate policy for managing floods and flash floods in the study area. The community participates in flood risk identification, prioritization, plan formulation, implementation, monitoring, and evaluation. The community and the local government are involved in all aspects of flash flood management.

Activities undertaken as part of the study include:

- **Awareness raising:** Awareness raising of flash flood risk was conducted at the community level through the dissemination of booklets and posters, lectures, expert consultations, and knowledge contests. Information on flash flood risk was also incorporated into the primary and middle school curriculum (Figure 26).
- **Capacity building:** Community members participated in flash flood control drills and flash flood prevention training, workshops, and forums.

Table 10: **Stakeholders and their role in flash flood management in the study area**

Stage	Government	Private enterprises	Financial institutions	Residents
Rescue and relief work	Conducting rescue and relief work, provision of emergency living allowance	Relocation of enterprise property to safe zone and self-help	Banks, insurance companies, tax department, and flood risk investment companies donate funds for emergency rescue	Self-help
Recovery	Disaster investigation, formulate plans, provide funds for recovery operations	Raise funds and resume production	Provision of materials, social mobilization	Recovery of property and rebuilding of lives and livelihoods
Development	Development of the economy, improving risk awareness, and building the capacity of stakeholders	Improving economic capacity and contributing to economic resilience	Building the capacity of stakeholders to enhance their risk awareness of flash flood	Participation in training, community-based risk management, and disaster reduction activities
Flood prevention and mitigation	Construction of flood prevention and mitigation projects	Contribute to prevention capacity by storing and allocating flood prevention goods and materials and by putting in place own structural engineering measures	Offer social security and disaster relief, including relief payments, disaster insurance, reconstruction funds, financial transfer payments, and tax-exemptions.	Involved in monitoring, early warning, and water conservancy project construction
Flood preparedness	Organizing materials, technology and manpower for flood preparedness, forecasting and warning and building a materials reserve base for flood prevention and control	Provision of equipment for flash flood preparedness	Provision of facilities and reserves of materials and medicines for preparedness	Involved in risk awareness raising and prevention work
Roles and contribution to the study	Provision of leadership and decision-making, support for activities, administrative management	Provision of funds and data support, participation in capacity building and risk management	Provision of financial assistance, disaster insurance, tax policy, and fund audits	Major participants/ stakeholders, contribution of local knowledge and practices

Figure 26: **Creating awareness among school children**

- **Warnings:** As part of the project, flash flood warnings are disseminated through television and radio broadcasts, by email, mobile telephone text messages, the Internet, blogs, and satellite telephones. In the local area, communities use fireworks, smoke, warning lights, torches, signal lights, flag signals, audio frequency amplifiers, gongs/drums, and public announcements .
- **Flood risk mapping:** A flood survey was conducted in the study area, flood data were collected and processed, and a database was established. This was used to calculate the flood submerging range, assess flood disaster loss, and conduct flood risk mapping. The project produced eight map groups with 40 sheets of maps: hazard-inducing environment map group, flash-flood investigation map group, post-flood reconstruction map group, flood-control engineering map group, monitoring and warning map group, risk management map group, capacity building map group, and information-sharing and knowledge-dissemination map group. This series of maps demonstrates the status, achievements, and needs in relation to flash floods in the pilot site as well as the outcomes and effects of the cooperative project from different angles.
- **Impact evaluation:** A hazard assessment, vulnerability assessment, risk assessment, and assessment of loss and damage were conducted to evaluate the potential impact of a flash flood on the study area.

Flash Flood Management in the Study Area

Flash flood management in the study area combines structural engineering measures with non-structural measures including capacity building.

Structural measures

Structural engineering is the major measure taken to prevent and control flash floods in the study area. After the Wenchuan earthquake, large-scale structural engineering reconstruction was conducted including the construction of sand-sediment dams, check dams, dikes, drainage canals, culverts, and slope land control engineering (Figure 27). Slope land control and soil conservation engineering measures, for example, have been undertaken at the source of the gully. Two check dams with 2–5 step dams are being built in the upper stream of the Lianhuaxin channel and in the major Niujuangou channel to stabilize the slope and channels. Three large sand-sediment dams are being built in the middle reaches and three small-scale sand dams have already been built in the lower reaches to block and deposit sediment. A 1.8-km dike in the downstream reaches of Niuguangou gully and 3.5 km dike along the Minjiang River are in place to control flash floods and protect Caijiagang village, Zhangjiaping village, and Yingxiu town. A 1.2-km drainage canal is currently under construction in the downstream reaches of Niujuangou to control debris flow.

Despite the existence of these measures, the standard of existing structural engineering is low. The flood control capacity of cities and important towns is only defensive against floods of 3–20 year frequency and the drainage ability of those cities or towns is only defensive against floods of 3–8 year frequency. There is no structural engineering in most of the riverine and mountain areas in the study area. In addition, some channels are severely silted and flood levels are increasing.

Non-structural measures

Non-structural measures are also in place in the study area and supplement structural engineering measures by restricting human activities and harmonizing the relationship between man and nature. The major non-structural measures in place include integrated watershed management to control flood-inducing processes through land

Figure 27: **Structural measures for flash flood control, Niujuangou gully, Wenchuan County, China**

Dam construction

Check dam

Sand sediment dam construction

use management, forest conservation, ecological rehabilitation, reconstruction and land use planning; resettlement; the provision of support by developed provinces to affected counties with counterpart aid (e.g., Shanghai helped to reconstruct affected areas in Guangdong Province); the adjustment of industrial structures; and supply of labour. Preparedness measures have been undertaken including flood risk assessment, socioeconomic flood hazard mapping and assessment, monitoring, forecasting, and warning, and emergency relief planning. Response measures in place include evacuation plans, search and rescue plans, the placement of temporary shelters, and health measures.

Post-disaster measures are in place for damage and needs assessment, recovery and rehabilitation, and evaluation. Originally, stations and equipment for flash flood monitoring and alarms were scarce, and almost all of them were destroyed by the Wenchuan earthquake. New techniques and equipment for flash flood monitoring and warning were adopted and installed in only a few important sites/gullies (Figure 28). Most of the risk zones in areas severely afflicted by the Wenchuan earthquake lack flash flood monitoring and warning.

A Flash Flood Risk Management Committee was established in the study area with 15 members elected by a general assembly and representatives from different sectors. There are seven work teams in the committee including a flood management headquarters team, consultant team, flood monitoring team, communication team, emergency response team, hydrologic and meteorological team, and logistics team. The committee operates at the village/community level and takes the lead in organizing, coordinating, and implementing flash flood management in its jurisdiction.

Capacity building activities

Capacity building activities for flash flood risk reduction in the study area include:

- **Emergency response plans:** There are three types of emergency response plans at the county, town and community/village levels. In addition, there are special emergency response plans for schools, key zones, and key units. All of these plans comprise a comprehensive emergency response network.
- **Emergency response drills/exercises:** Emergency response drills are conducted once

Figure 28: **Alarm system installed in the headwaters of Niujuangou gully**

or twice a year by the local government for local residents, units, and volunteers. Community emergency rescue teams have been set up and are comprised of members of the armed forces, local community members, administrative staff, and volunteers. The needs of vulnerable groups such as children, the elderly, pregnant women, and people with disabilities are considered and incorporated into drills and evacuation plans.

- **Evacuation and rescue:** In order to move people away from flooding and associated hazards and minimize loss and damages, emergency response teams under the Flash Flood Risk Management Committee, together with local community members and government staff, have determined three safe areas, set up five evacuation camps and temporary shelters, prepared socioeconomic flash flood risk maps, and marked alternative evacuation routes. The plan is clearly explained using cards and caution boards.
- **Victim-aid system:** The victim-aid system mainly consists of local reserve storehouses, emergency material supply stations, disaster-relief resources, emergency equipment, and emergency reserve funds. This system was established by local governments, communities, non-governmental organizations, adjacent communities, and volunteers.
- **Awareness raising, education and training:** Two information and education centres were built in the study area to carry out education, training, and information sharing about floods. Activities conducted at the centres by the project team and local government include display and distribution of popular science knowledge booklets and posters, primary and middle school classroom instruction, local television announcements, videos, training classes, knowledge contests, interviews, and consultations. The anniversary of the Wenchuan earthquake is used to raise awareness about disaster prevention and mitigation.
- **Monitoring and warning:** With the help of local communities and local government, the project team purchased flash flood monitoring and warning instruments, set up one field surveying network and four automatic weather stations, and developed and established two flash flood warning systems. In addition, three community-based flash flood preparedness teams have been formed with professional and amateur members.

Outcomes and Results

The project achieved five major outcomes:

- **Database:** A comprehensive database was set up by collecting and compiling data, materials, practices, literature, and indigenous knowledge on flash floods in the study area. The project summarized national and regional flash flood policies, strategies, plans, and countermeasures, and documented indigenous knowledge and practices, to produce an enormous database including maps.
- **Piloting and installation of an early warning system:** A flash flood monitoring and early warning system was piloted in the study areas and encompasses weather monitoring, water and soil monitoring, field surveys, flash flood forecasting, and flash flood warning. One automatic meteorological station, two automatic rain gauges, three soil moisture sensors, three water level measurements, and one video camera have been installed as part of the system. The system has a signal transmission instrument to notify communities of a flash flood event, together with an operating system and information management system.
- **Flash flood information management system:** A flash flood information management system was developed and implemented for flash flood data storage, risk mapping, information sharing, and knowledge dissemination.
- **Flash flood risk maps:** Hazard maps were developed for eight map-groups containing a total of 40 sheets of maps.

- **Capacity building**: Capacity building was conducted at the community level including awareness raising through the distribution of booklets and posters; lectures on relevant topics; professional consultations; a knowledge contest on flash floods; programmes for primary and middle school students; training and drills for local residents and volunteers on flash flood risk and preparedness; and knowledge dissemination and information sharing. Communities were provided with materials on flash floods including popular-science booklets, records, videos, and reports, as well as tools kits contained equipment for use in the event of a flash flood event (emergency bags) and information cards explain how to use the equipment and what to do.

As a result of these five outcomes, the project contributed to:

- **Reducing vulnerabilities**: The project contributed to reducing the vulnerability of people in the study area to flash floods by conducting flash flood risk assessment and management, raising risk awareness, building the response capacity of the community, and through risk sharing and risk transfer.
- **Community resilience**: The project contributed to community resilience to flash floods by mobilizing communities for mitigation and recovery with the use of local resources and labour for reconstruction, and by facilitating and strengthening linkages and partnerships for external support and relief.

Lessons Learnt

- The processes causing flash floods in the study area have changed since the Wenchuan earthquake. There is a lack of relevant research and findings on these processes making it difficult to forecast flash floods and identify potential flash flood gullies in the study area.
- Indigenous knowledge and local practices are important, but often overlooked by external agencies and governments who tend to favour scientific and specialized knowledge, most of which is not in tune with local contexts and realities. The majority of the people in the study area live in remote villages and suburbs of Yingxiu town and are usually the first victims of flash floods. Ignoring their knowledge and practices may cause serious social and economic loss in the future, and result in the failure of some flash flood management projects and activities.
- Existing structural measures are inadequate for flash flood prevention and control, and capacity to manage flash flood risk is limited.
- There is a lack of technology and equipment for flash flood monitoring and warning systems in the affected areas.
- Diversity between stakeholders in the study area and differences in their needs is a challenge in implementing integrated flash flood risk management. For instance, local residents need a safe settlement or shelter far from flash floods, while governments have focused on large-scale restoration and reconstruction, which was finished three years after the Wenchuan earthquake, but without thorough scientific planning. The residents in and near Yingxiu town have greater awareness and capacity to deal with flash flood risk, while those in remote and isolated areas have less, making it difficult to identify common gaps and demands in capacity and to design capacity-building modules.

Recommendations

- Conduct new assessments of flash flood processes and formation mechanisms, as well as vulnerability, after major natural disasters such as earthquakes.
- Monitor flash floods and determine the critical rainfall and soil moisture levels. Based on this, develop an effective flash flood monitoring, forecasting, warning, and alarm system for the whole catchment area, which includes Niujuangou gully in Wenchuan County, Beichuan County, and the city of Dujiangyan. This requires strengthening the national and local network of hydrological and meteorological observations, weather radars, the acquisition and processing of modern satellite derived products, and field surveys and experiments.
- Stimulate the government and local communities to be actively involved in flood management and capacity building. Actively strive for external support and cooperation at the local, government, and organizational levels.
- Combine advanced science, technology, and equipment with indigenous knowledge and local practices that take into account local contexts and realities.
- Develop a standard methodology and format for documenting flash flood events.
- Strengthen structural measures of flash flood management and enhance defensive standards in the study area.
- Strengthen non-structural measures of flash flood management, including raising awareness and building the capacity of communities to manage flash floods.