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On alert: RIS risk amid rash of earthquakes in China's Sichuan-Yunnan region

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On March 3, 2013, an M 5.5 earthquake occurred in Dali, Yunnan Province, causing the collapse of some 1,800 houses and the emergency relocation of 21,000 people. In all, 160,000 people were adversely affected. Significantly, the Dali earthquake was just the most recent in a string of moderate and strong earthquakes (with magnitudes from 4.5 to 6.0) that have occurred in the Sichuan-Yunnan region of China since June 2012.

According to the China Earthquake Networks Centre website, from June 2012 to the present, the following earthquakes have occurred in the Sichuan-Yunnan region with a magnitude greater than 4:

2013-03-19 09:47, a M 4.2 earthquake occurred in Ning'er Hani and Yi Autonomous County, Yunnan Province;

2013-03-09 20:23, a M 4.5 earthquake occurred in Wenchuan County, Aba Tibetan and Qiang Autonomous Prefecture, Sichuan Province;

2013-03-03 13:51, a M 5.5 earthquake occurred in Eryuan County, Dali Bai Autonomous Prefecture of Yunnan Province;

2013-02-22 05:55, a M 4.2 earthquake occurred in the border of Yongsheng County and Ninglang Yi Autonomous County in Lijiang City, Yunnan Province;

2013-02-20 13:12, a M 4.8 earthquake occurred in Mojiang Hani Autonomous County of Pu'er City, Yunnan Province;

2013-02-19, 16:06, a M 4.5 earthquake occurred in the border of Xingwen, Gongxian and Changning counties in Yibin City, Sichuan Province;

2013-02-19 10:56, a M 4.9 earthquake occurred in the border of Qiaojia County of Zhaotong City in Yunnan Province, and Ningnan County of Liangshan Yi Autonomous Prefecture in Sichuan Province;

2013-02-07 23:11, a M 4.2 earthquake occurred in Yanjin County of Zhaotong City in Yunnan Province;

2012-09-11 15:30, a M 4.9 earthquake occurred in Shidian County of Baoshan City, Yunnan Province;

2012-09-11 15:27, a M 4.5 earthquake occurred in Shidian County of Baoshan City in Yunnan Province;

2012-09-07 12:19, a M 5.6 earthquake occurred in Yiliang County of Zhaotong City in Yunnan Province;

2012-09-07 11:23, an M 5.7 earthquake occurred in the border of Yiliang County of Zhaotong City in Yunnan Province, and Weining Yi, Hui and Miao Autonomous County of Bijie prefecture in Guizhou Province;

2012-06-24 16:07, a M 5.7 earthquake occurred in the border of Ninglang Yi Autonomous County of Lijiang City in Yunnan Province, and Yanyuan County of Liangshan Yi Autonomous Prefecture in Sichuan Province.

Earthquakes can be divided into two categories: naturally occurring and human induced. With rapid economic and technological development in China, concerns have been growing that seismic activity may have been induced by human activity, such as the impoundment of large reservoirs, deep well water injection, mining, as well as nuclear explosions. For example, since the Wenchuan earthquake on May 12, 2008, many scientific studies have indicated a close connection between the filling and drawdown of the Zipingpu reservoir and the Wenchuan earthquake.

So far, there is no evidence that the recent string of strong earthquakes that have occurred in the Sichuan-Yunnan region were induced by reservoirs. However, such frequent seismic activity, both moderate and strong, indicates a geological background of the high-intensity seismic activity that exists in the region. Given this geological condition, the unchecked construction of a large number of giant, even super-sized, hydropower projects in the region is cause for heightened concern about reservoir-induced seismicity, especially the risk of strong RIS.

The government's ambitious plan to turn all natural rivers into reservoirs with the cascade-like positioning of hydro dams, built close together in sequence, is underway,

along the great rivers of Jinsha, Lancang-Mekong, Dadu and Yalong and their major tributaries in the Sichuan-Yunnan region. Many of these dams are huge in size: 200 and 300 metres, and even higher, with water storage capacities in the billions of cubic metres, sometimes more than ten billion cubic metres. As they are located in strongly active seismic hazard zones, there is a high probability they will both induce and be damaged by seismic activity. The next 10 years will be especially dangerous as these high dams are completed and their large reservoirs filled.

While scientists are still researching the process by which a reservoir induces earthquakes, they have observed that RIS is most likely to occur within the first few years after a dam is filled. This is because, in general, it takes a period of time for reservoir water to penetrate deep into seismic faults and fissures before it triggers seismic activity.

Take the case of the Pubugou Dam on the Dadu River (a tributary of the Yangtze) in Hanyuan County of Sichuan, which is 186 metres high with a storage capacity of 5.39 billion cubic metres and an installed capacity of 3,300 MW, and started filling in 2009. From October 14, 2006, and December 31, 2011, some 1,834 small earthquakes have been recorded in the region. According to analysis by experts in the Sichuan Seismological Bureau, these earthquakes have been concentrated in several places of the reservoir area — in the central part of the reservoir, near the dam itself, and downstream of the dam. Based on their preliminary analysis, those experts believe that these small earthquakes are not necessarily related to the filling of the reservoir. I believe, however, based on what we know about the probable timing of RIS, that it is too early to rule out the possibility of RIS in the Pubugou Dam area. For this reason, seismic activity in the Pubugou reservoir and surrounding area must be closely monitored for the next few years.

Another example is the Xiangjiaba Dam on the main stream of the lower Jinsha River. With a dam height of 162 metres, a storage capacity of 5.163 billion cubic metres and an installed capacity of 6,400 MW, the Xiangjiaba is China's third-largest hydropower station. The first phase of reservoir impoundments at Xiangjiaba was completed in October 2012. It is noteworthy, and of concern, that the reservoir water level was raised from 278 metres to 354 metres above sea level in just six days, from October 10 to 16 in 2012. This extremely rapid rise of 76 metres is unprecedented in the history of large reservoir impoundments, both in China and abroad. Scientists have observed that RIS is related to the filling and draw down of reservoirs and the rate at which it happens. Therefore, this practice at Xiangjiaba undoubtedly increases the risk of reservoir induced seismicity and other reservoir induced geological disasters (such as landslides and mountain collapses). More is to come: later this year, from September to December, the Xiangjiaba reservoir will rise another 26 metres to its normal pool level of 380 metres above sea level. As with Pubugou, the Xiangjiaba reservoir area is entering a dangerous period: RIS is most likely to occur in the next few years, even lasting for a decade or more. The situation must be closely monitored.

The following table, published by the author a few years ago, lists some high dams and large reservoirs on the major rivers in the upper reaches of the Yangtze River in China that have the potential to trigger strong earthquakes. The author attaches it here in an effort to alert authorities and the public to the grave risks of RIS in the regions of these mega-dams.

River	Dam	Dam Height (m)	Reservoir Storage Capacity (billion m ³)	Generating Capacity (MW)	Construction Status	Seismic Fault Belt Related	Maximum Magnitude Recorded in History
Jinsha River	Xiangjiaba	162	5.163	6,400	Under construction	Mabian-Zhaotong	7.1
	Xiluodu	278	11.57	12,600	Under construction		
	Baihetan	277	19.1	13,050	Under construction	Dongchuan-Songming	8.0
	Wudongde	240	4.0	8,700	Planned to build		
	Guanyinyan	168	2.072	3,000	Under construction	Yanyuan	6.7
	Ludila	140	1.693	2,100	Under construction	Zhongdian-Dali	7.0
	Jinanqiao	156	0.663	2,400	Under construction		
	Ahai	130	0.882	2,000	Under construction		
	Liyuan	155	0.891	2,400	Under construction		
Dadu River	Pubugou	186	5.39	3,300	Already built	Anninghe	7.5
	Dagangshan	210	0.775	2,300	Under construction	Xianshuihe	7.6
	Changheba	241	1.075	2,200	Under construction		
	Shuangjiangkou	312	3.115	1,800	Under construction	Maerkang	6.6
Yalong River	Ertan	240	5.8	3,300	Already built	Anninghe	7.5

	Guandi	168	0.783	2,400	Under construction		
	Jinping I	305	7.765	3,600	Under construction	Litang-Yanyuan	7.3
	Lianghekou	305	10.23	2,700	Under construction	Xianshuihe	7.6

An earlier version of this table can be found in the following [FACTBOX: Hydro development along the upper Yangtze and tributaries](#)