Attabad landslide crisis in Hunza, Pakistan – lessons for the management of valley blocking landslides

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Focus Humanitarian Assistance, Pakistan

Durham University

http://blogs.agu.org/landslideblog/

The Boulby Geoscience Facility

Schedule of talk

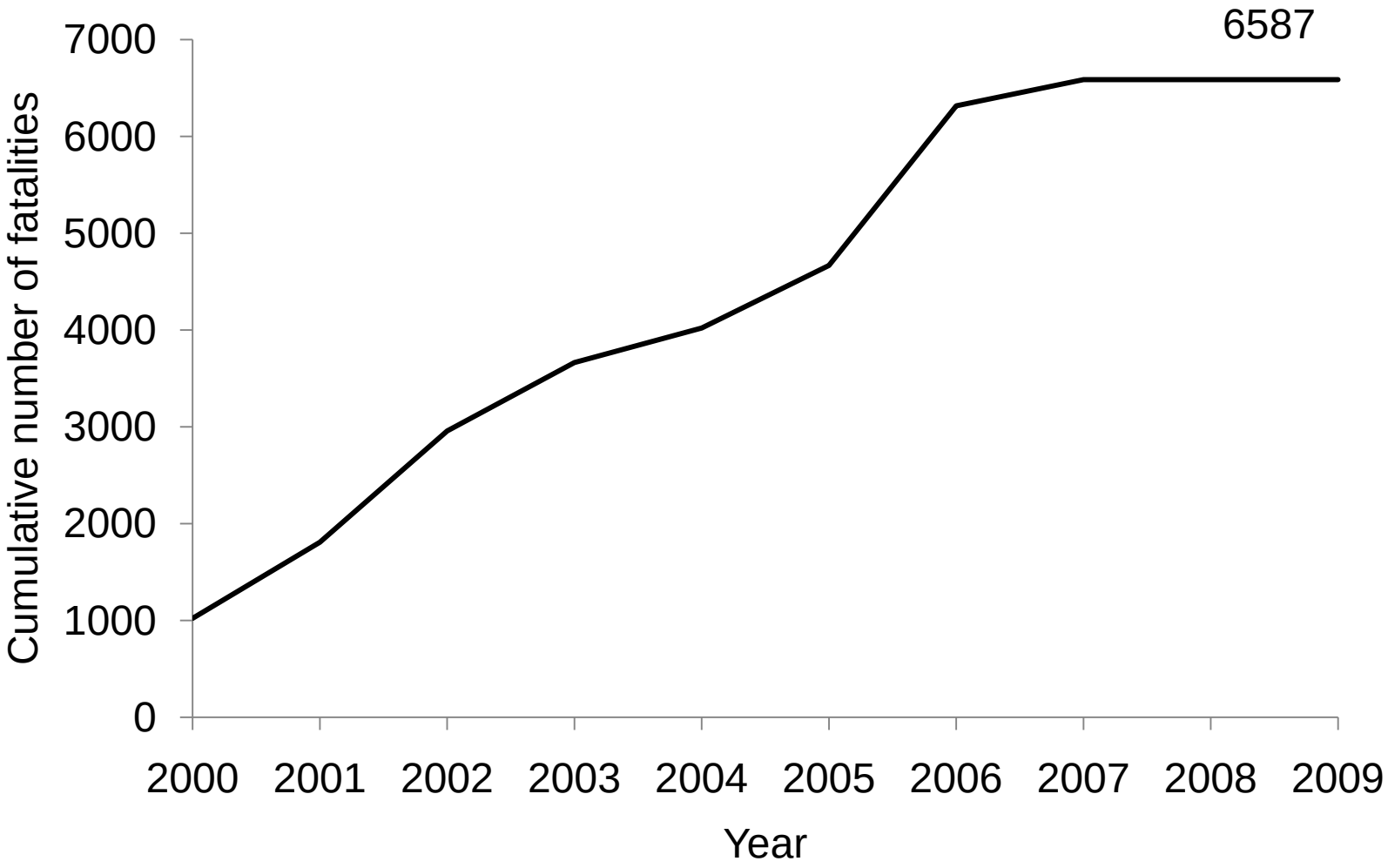
- Global landslide mortality hazard and risk
- Landslide mortality hazard and risk along the Himalayan Arc
- The 2010 Attabad landslide, Hunza, Pakistan

Powerpoint file on my AGU hosted blog at:

http://blogs.agu.org/landslideblog/

Google: “landslide blog AGU”

CRED data for landslide fatalities

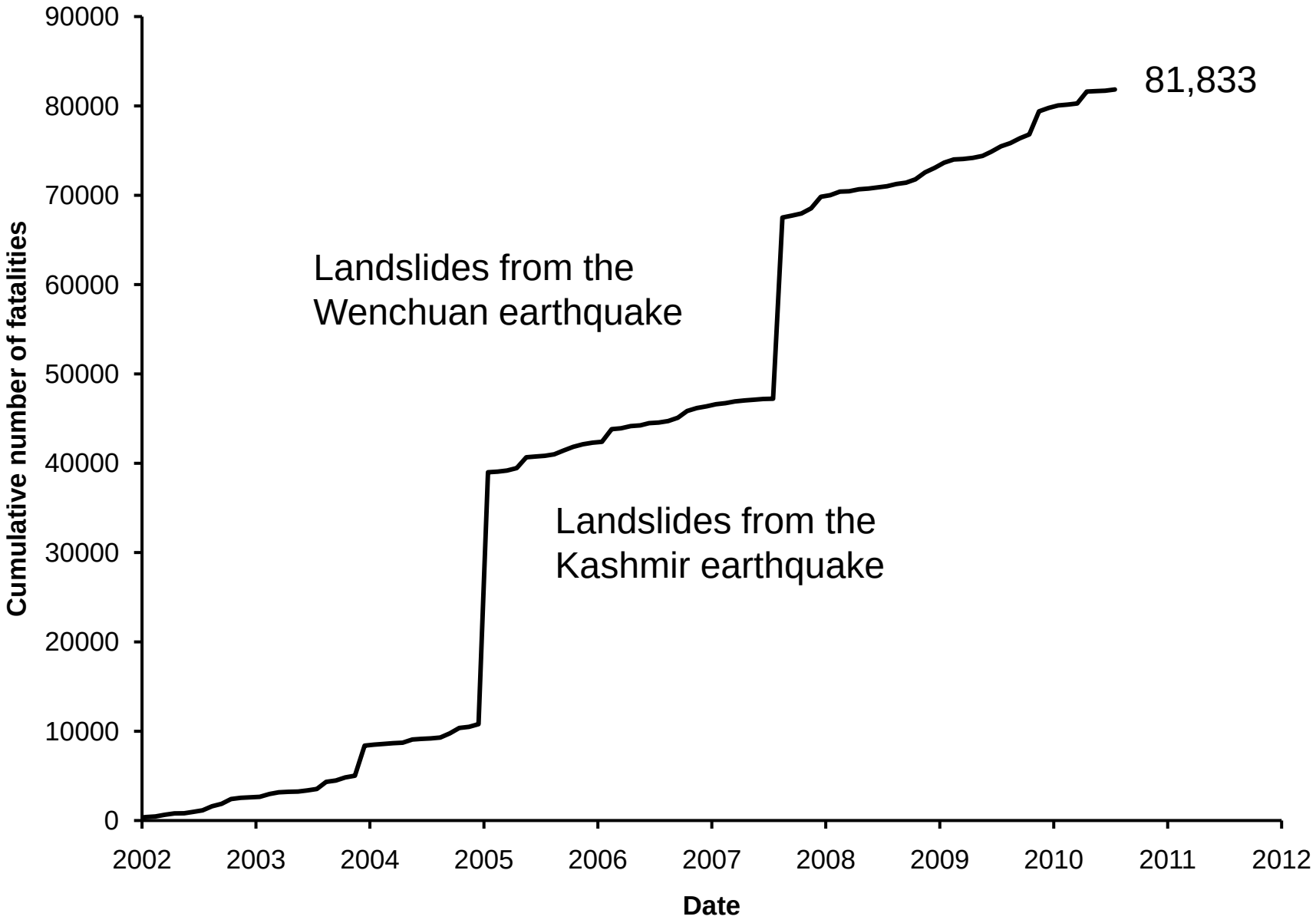


Other disasters 2002-2009 (CRED database)

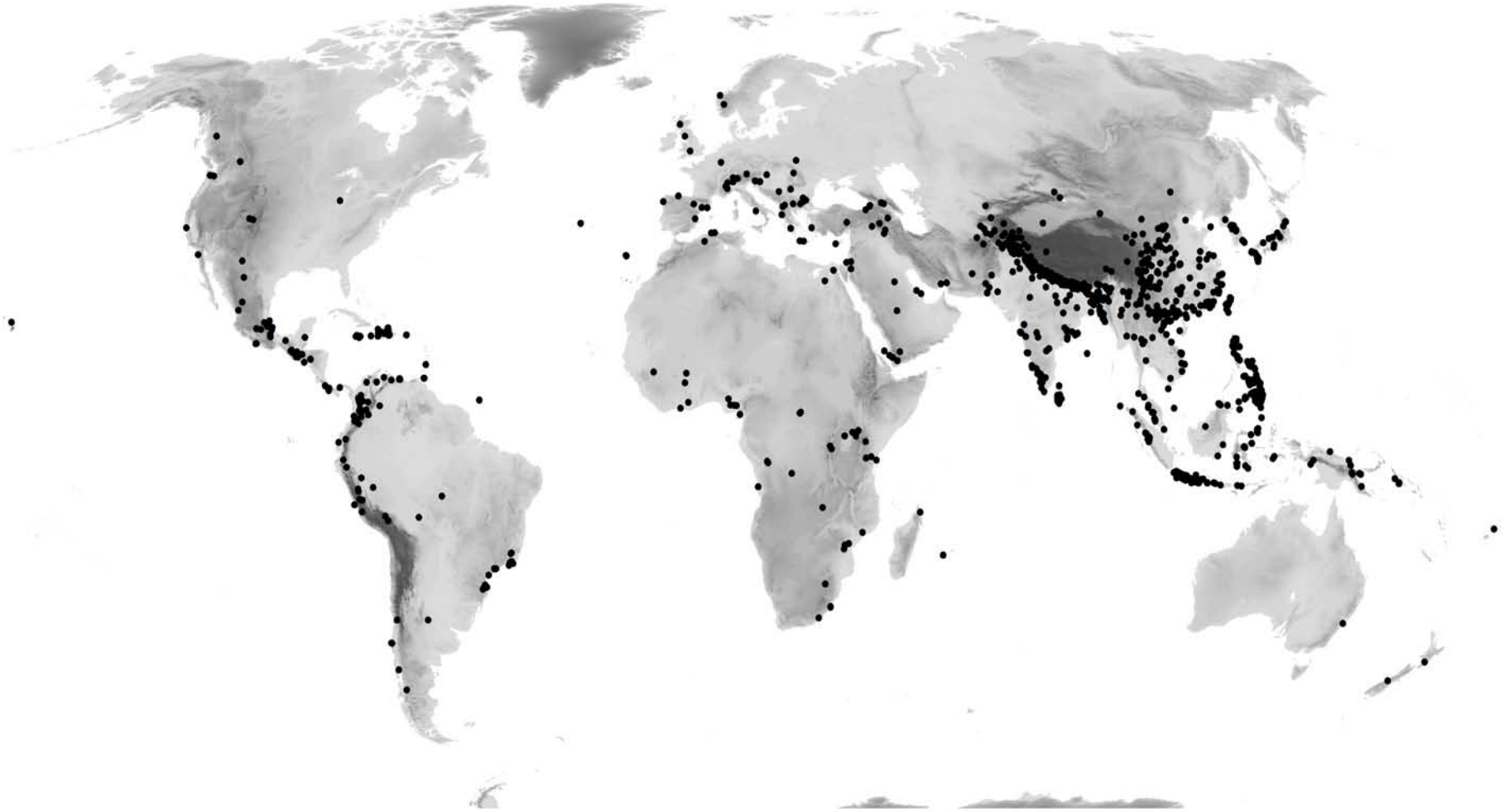
Earthquake: 429,877 River flood: 37,860

Storm: 166,410 Volcano: 221

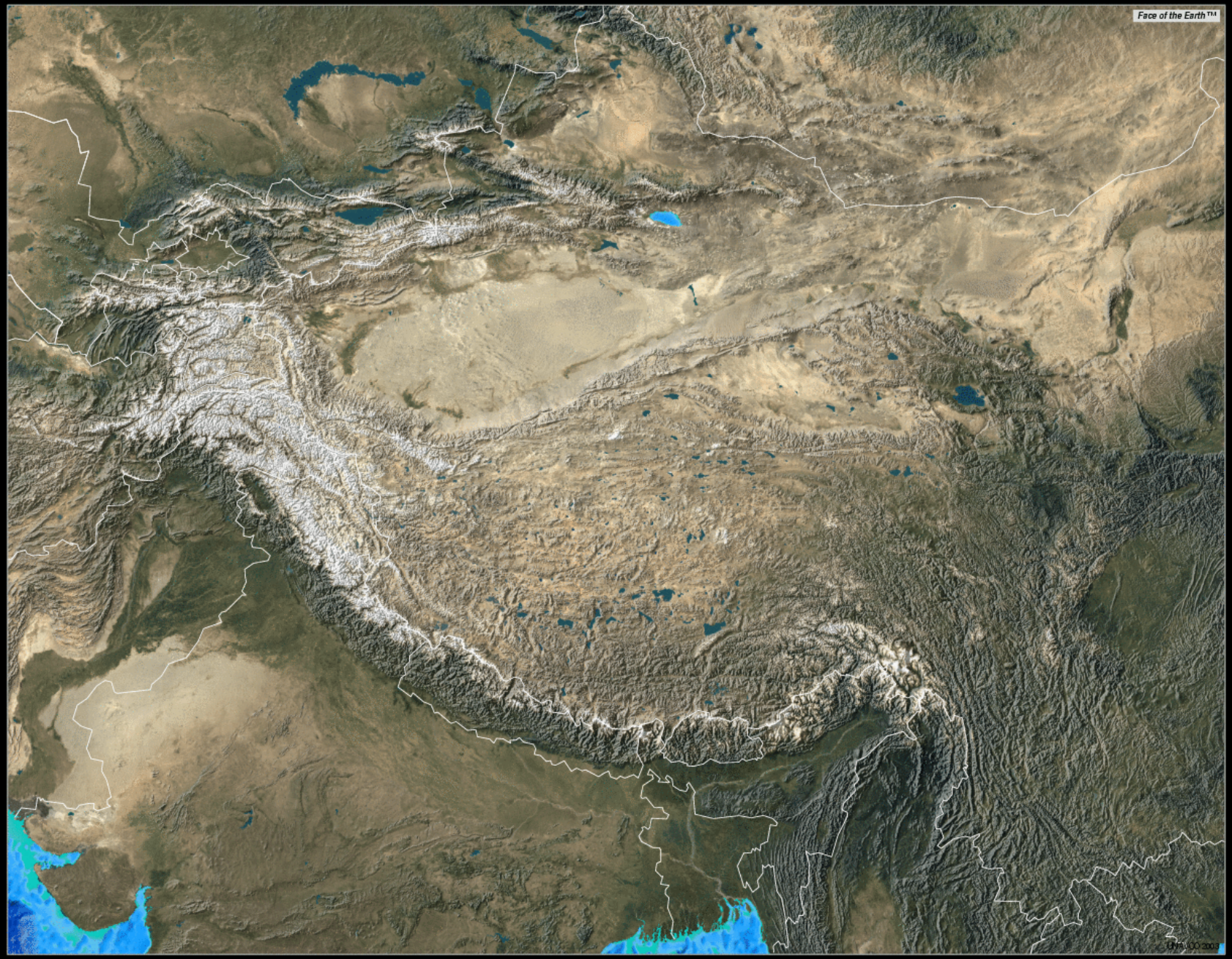
The (more) true human cost of landslides



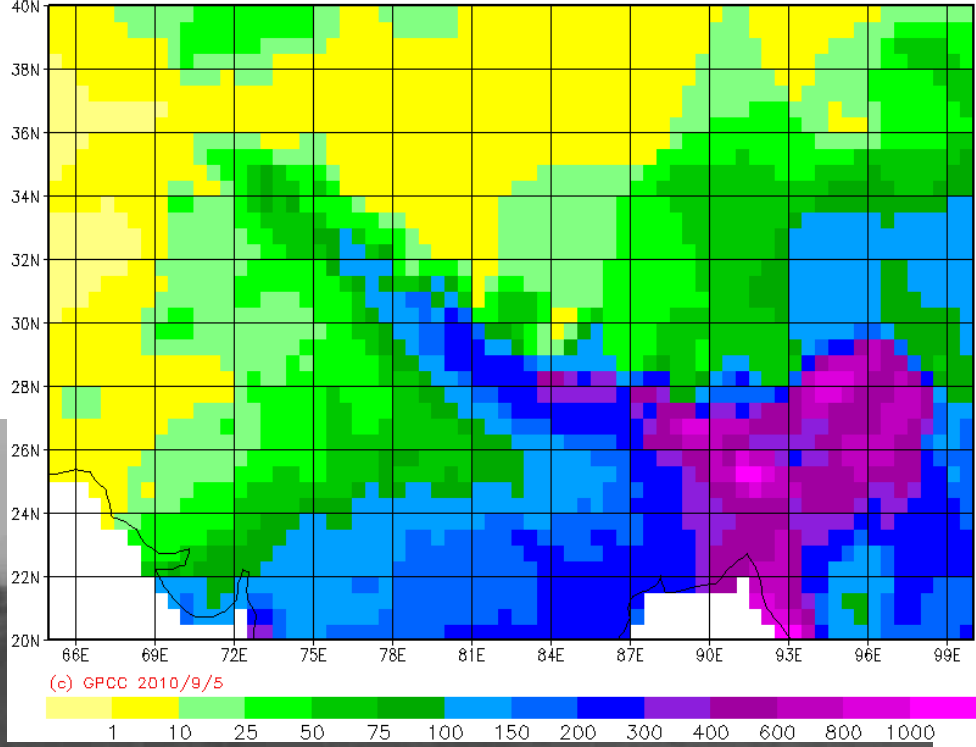
Global fatal rainfall-induced landslides – 2006 to 2009



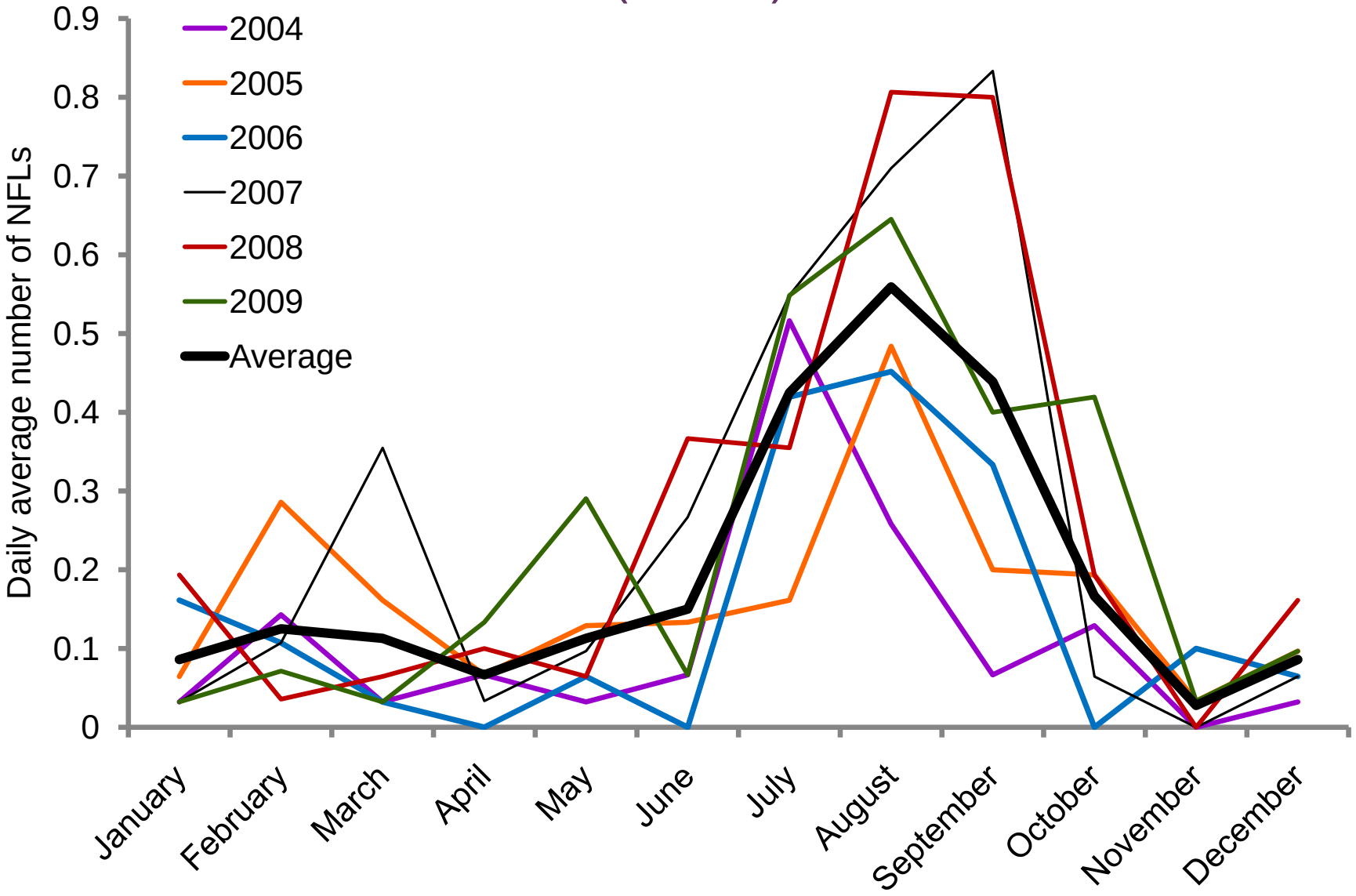
Himalayan Arc



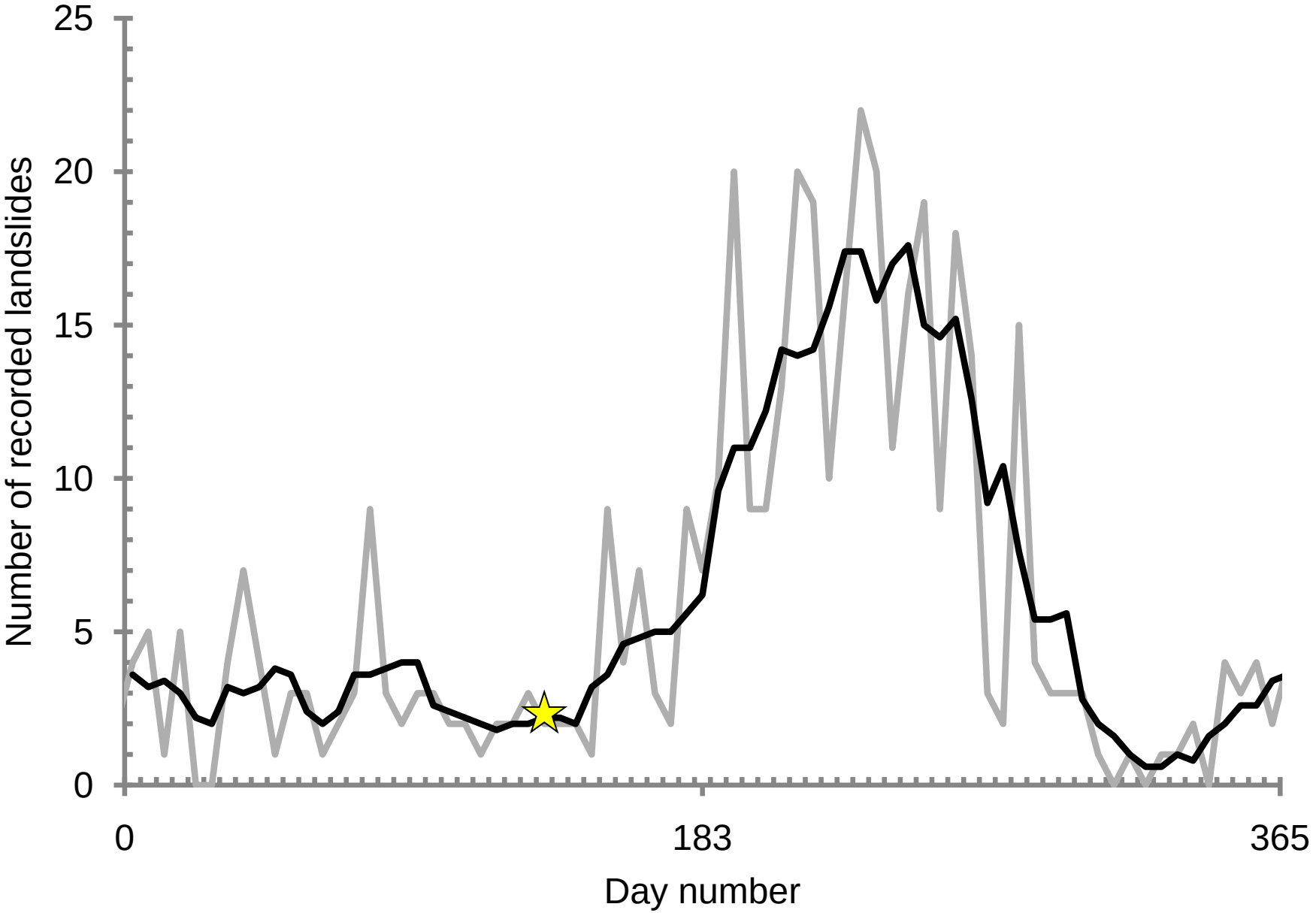
Himalayan Arc – 2004 to 2009



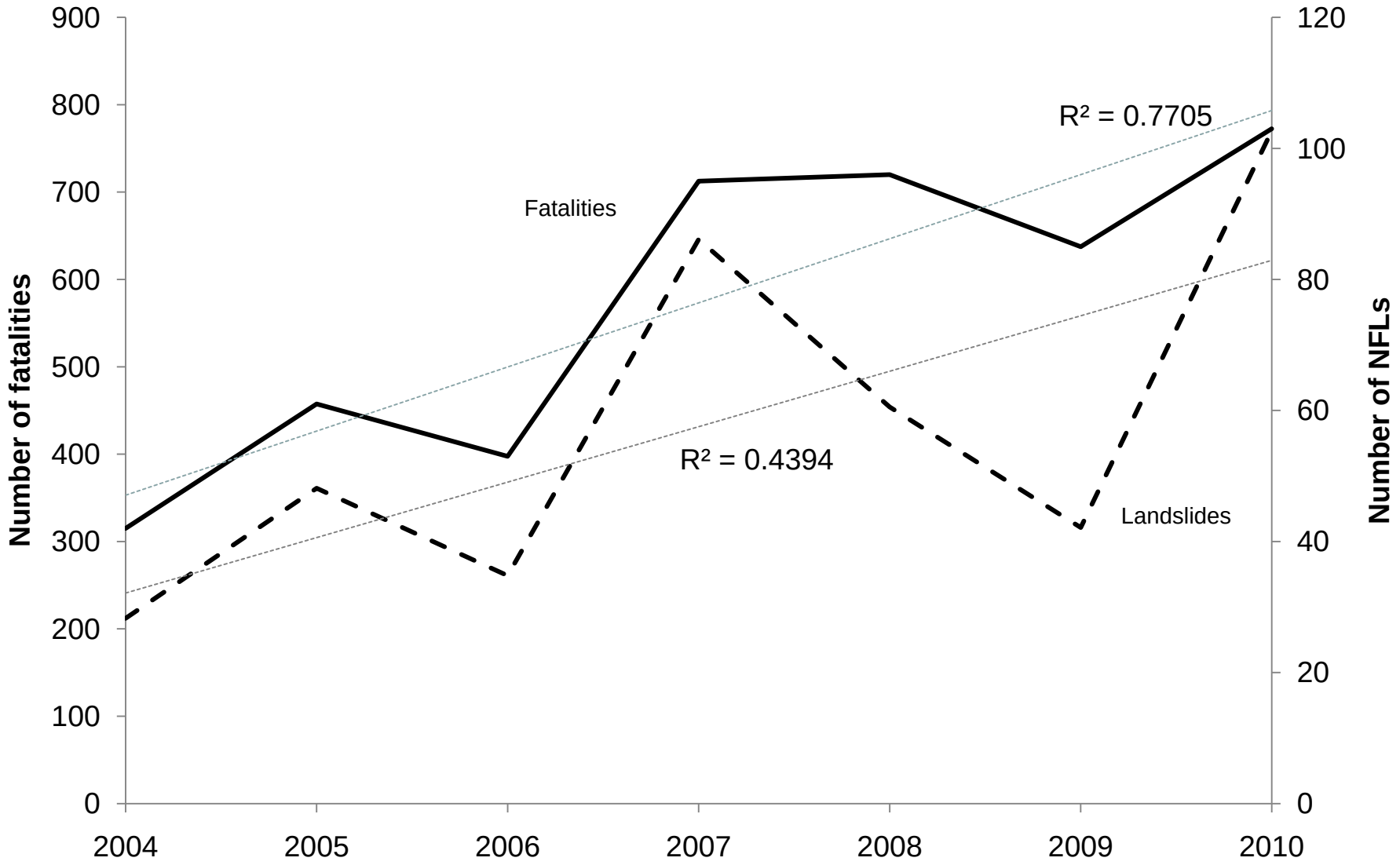
Monthly occurrence of non-seismic fatal landslides (NFLs)



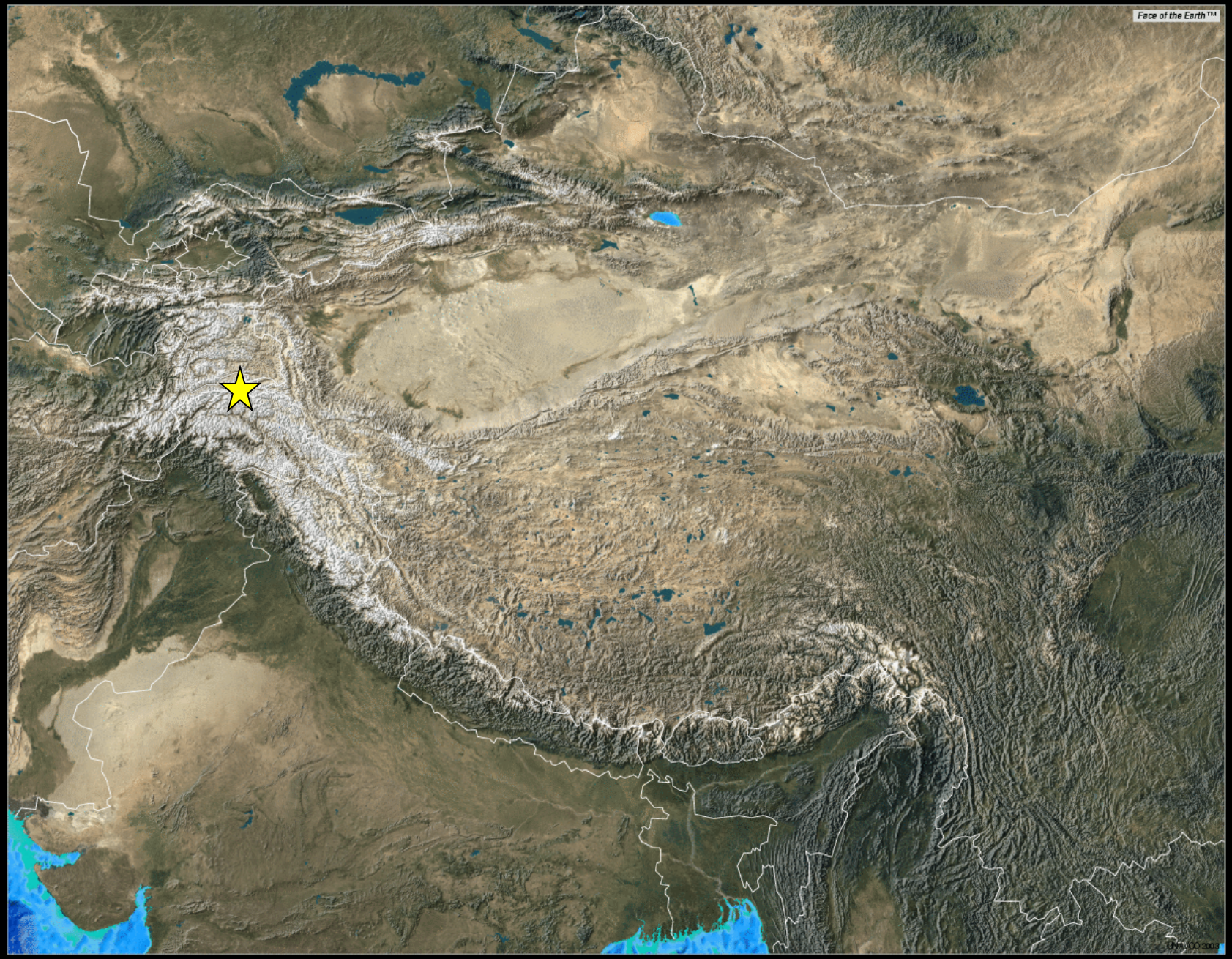
Annual cycle in pentads (five day bins)

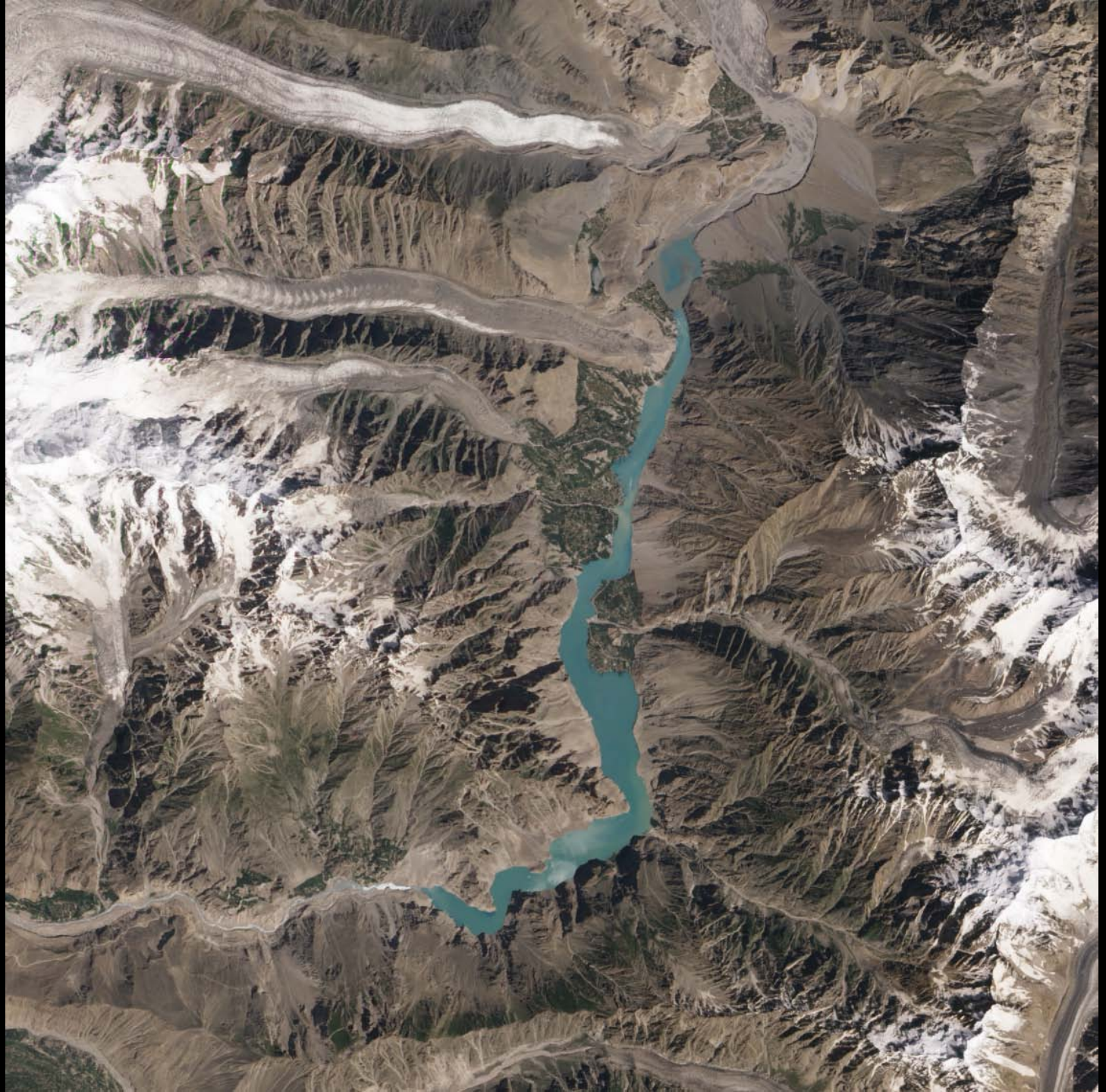


Trend in occurrence?



Attabad





Slope identified as unstable in 2003

Durham University

Collapse event: 4th January 2010

1. Progressive failure over >7 years, scar height = 1175 m

2. Catastrophic failure event in Jan 2010 with no trigger

Cross valley runout = 1300 m
Deposit height = 120 to 200 m

3. Emplacement of rockslide onto lake sediments triggered secondary high velocity mudflow event

1858 landslide dam

Wenchuan Earthquake barrier lake risk table

Table 1 Standard for breach risk evaluation of Quake lakes

Influence factors	Risk level			
	Extremely high risk	High risk	Medium risk	Low risk
Endangered lives in downstream area (thousand)	>1000	500–1000	100–500	<100
Materials and structure of landslide dam	Mostly soils, loose structure	Soils with massive rubble, medium loose structure	Massive rubble with soils, dense structure	Mostly massive rubble, with gaps
Maximum probable storage capacity (1000 m^3)	10^5	10^4–10^5	10^3–10^4	<10^3
Quake lake catchment area (km^2)	>1000	100–1000	50–100	<50
Landslide dam height (m)	>100	50–100	25–50	<25

Yang *et al* 2010

Data driven flood estimation

TABLE 6. SUMMARY OF REGRESSION EQUATIONS TO PREDICT PEAK DISCHARGE FROM THE FAILURE OF EARTH- AND ROCK-FILL, LANDSLIDE, MORAINE, AND GLACIER DAMS

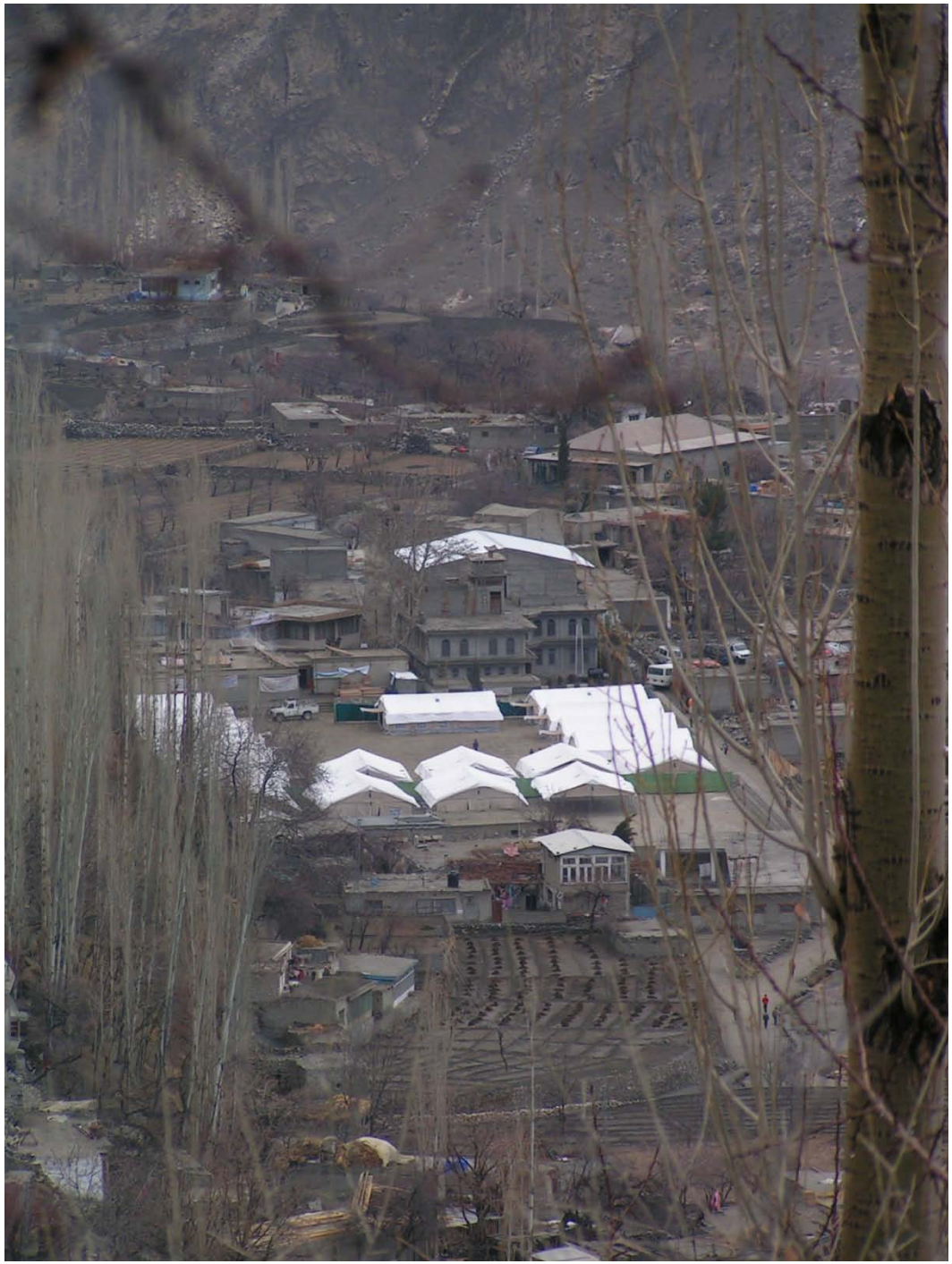
Type of dam	Equation	Number of data points	Coefficient of determination (r^2)	Standard error (%)
1. Earth- and rock-fill	$Q = 0.0184(PE)^{0.42}$	26	0.75	91
2. Landslide	$Q = 0.0158(PE)^{0.41}$	12	0.81	185
3. Moraine	$Q = 0.00013(PE)^{0.60}$	8	0.78	92
4. Glacier	$Q = 0.0000055(PE)^{0.59}$	11	0.80	64

Note: Q = peak discharge (m^3/s); PE = potential energy (joules).

- Typical values of maximum discharge using this approach:
  - 14,000 cumecs (Costa and Schuster 1986)
  - 12,000 - 26,000 cumecs (Walder and O'Connor 1997)

Management of the hazard

- Initial management response was the construction of a spillway.
  - Original intention: 30 metres deep
  - Actual depth at time of overtopping: 15 metres
  - Final spillway was very narrow and unlined

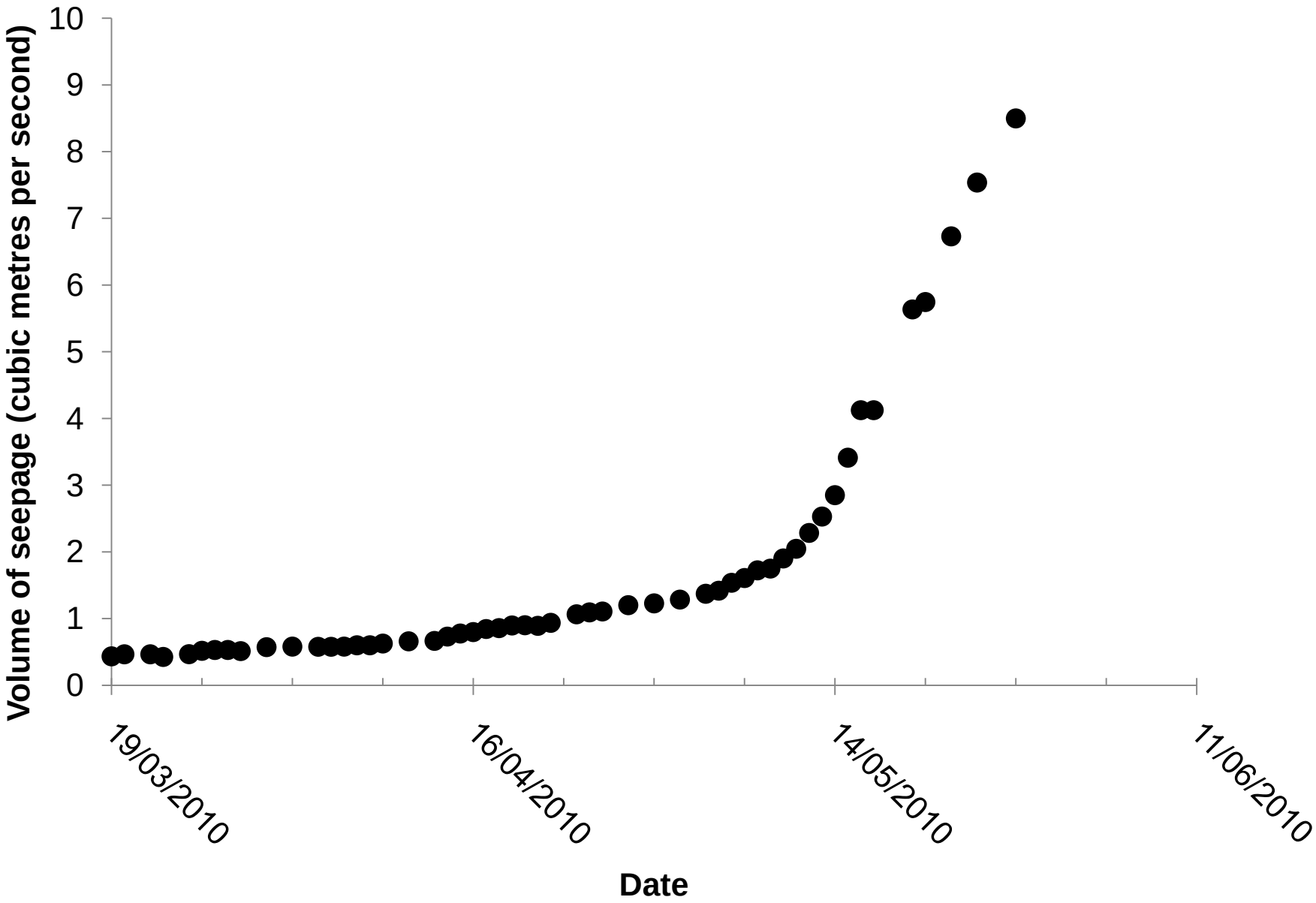


Evacuations

- After the landslide, Focus installed sirens in 15 villages
- People in most hazardous areas relocated into camps
- Boat service established on lake, but enormous hardship upstream
- One month before overtopping NDMA evacuated 15,000 people downstream of barrier

Seepage

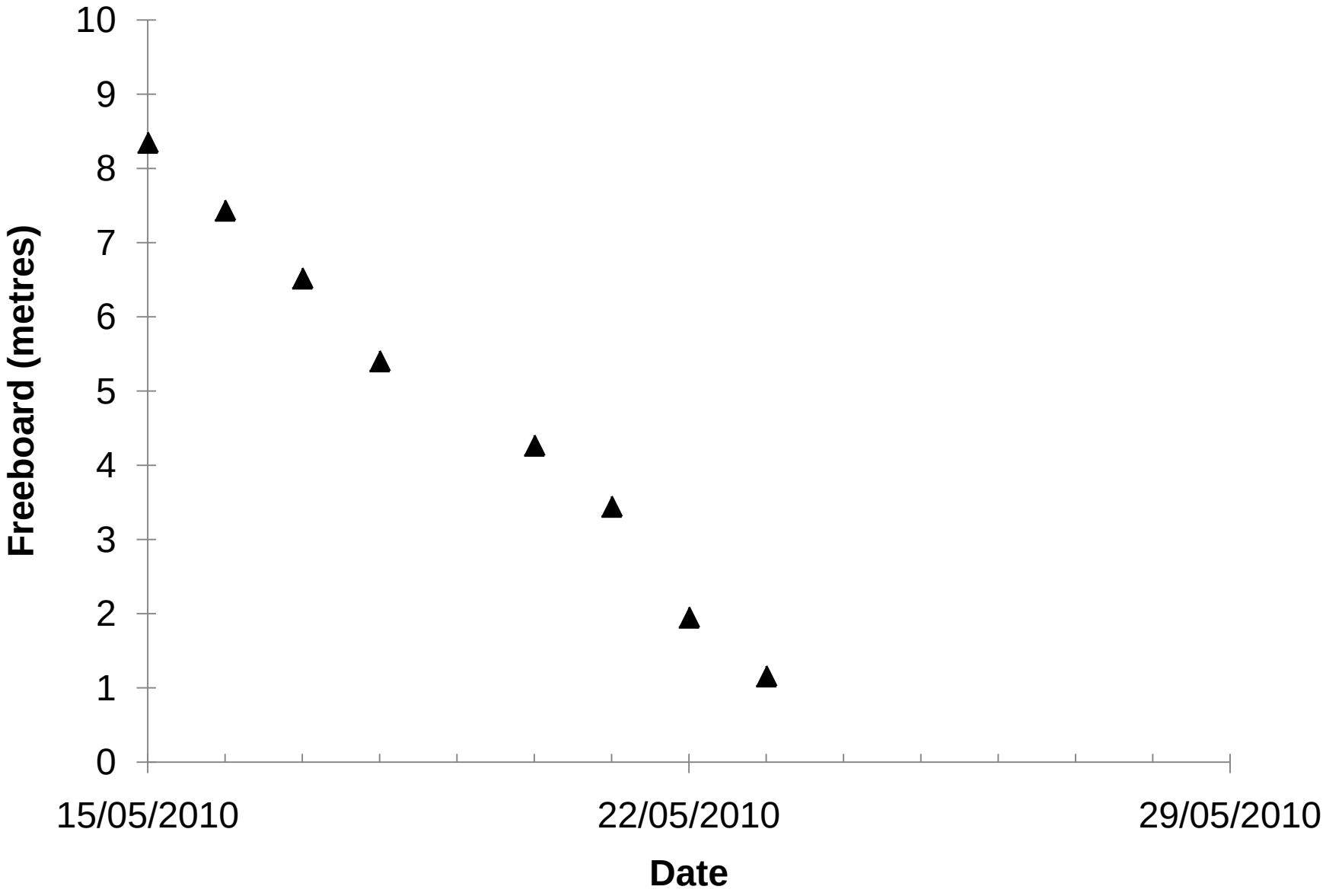
Seepage development

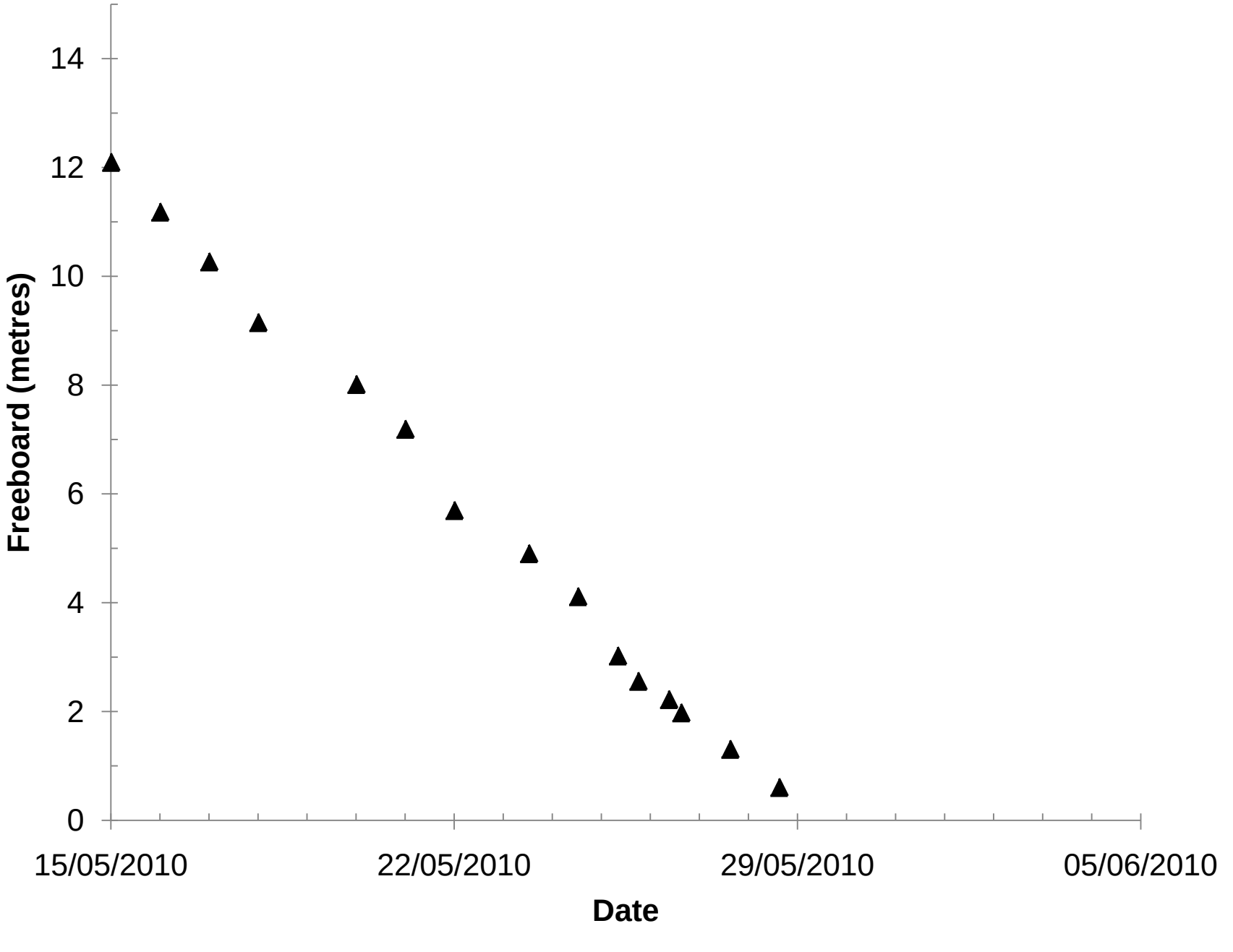


Prediction of date of overtopping

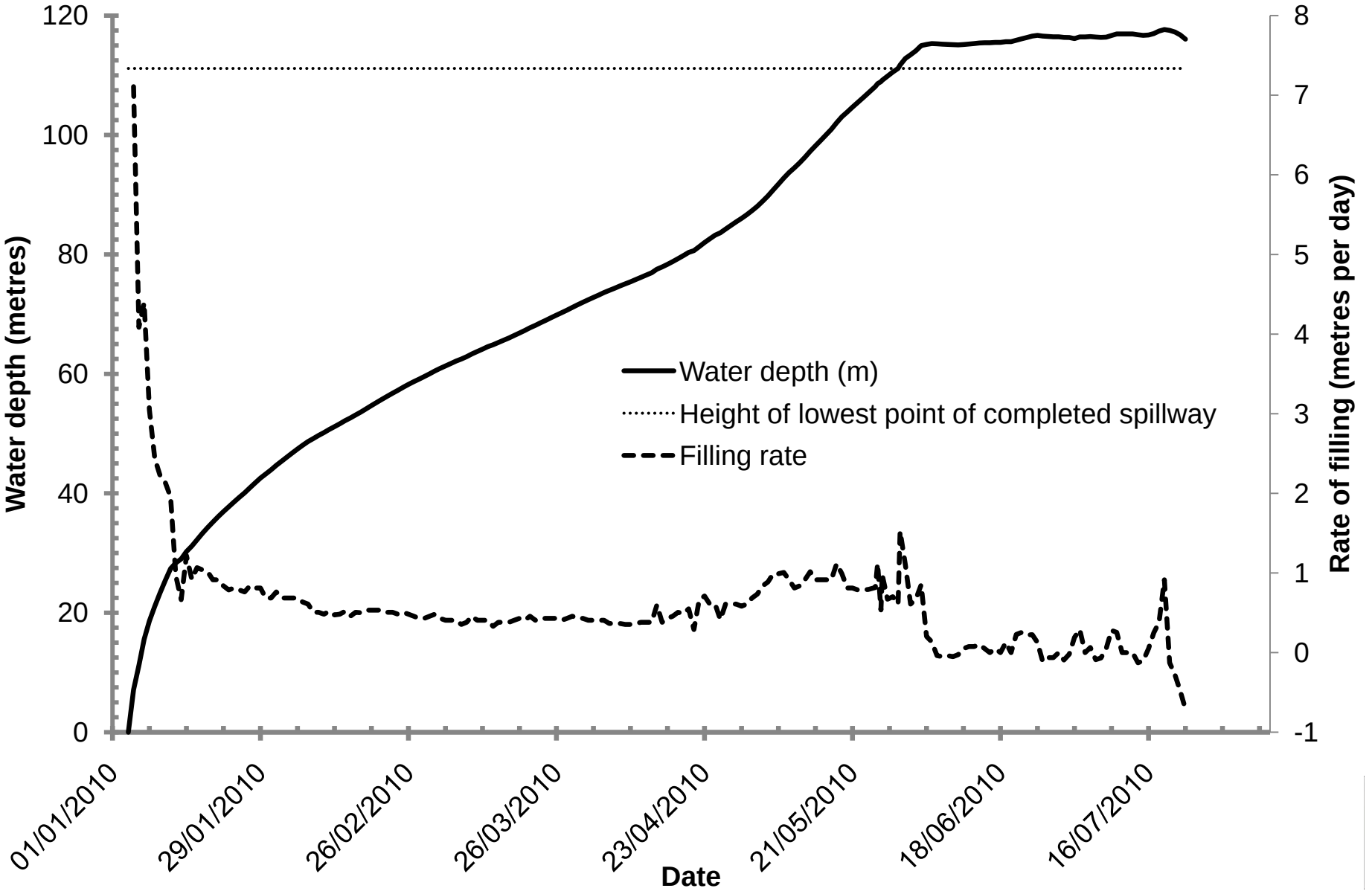
- NDMA consistently predicted the date of overtopping incorrectly (repeatedly predicted overtopping too early)

- However, final overtopping occurred later than expected because the lacustrine silts deformed, raising the floor of the channel

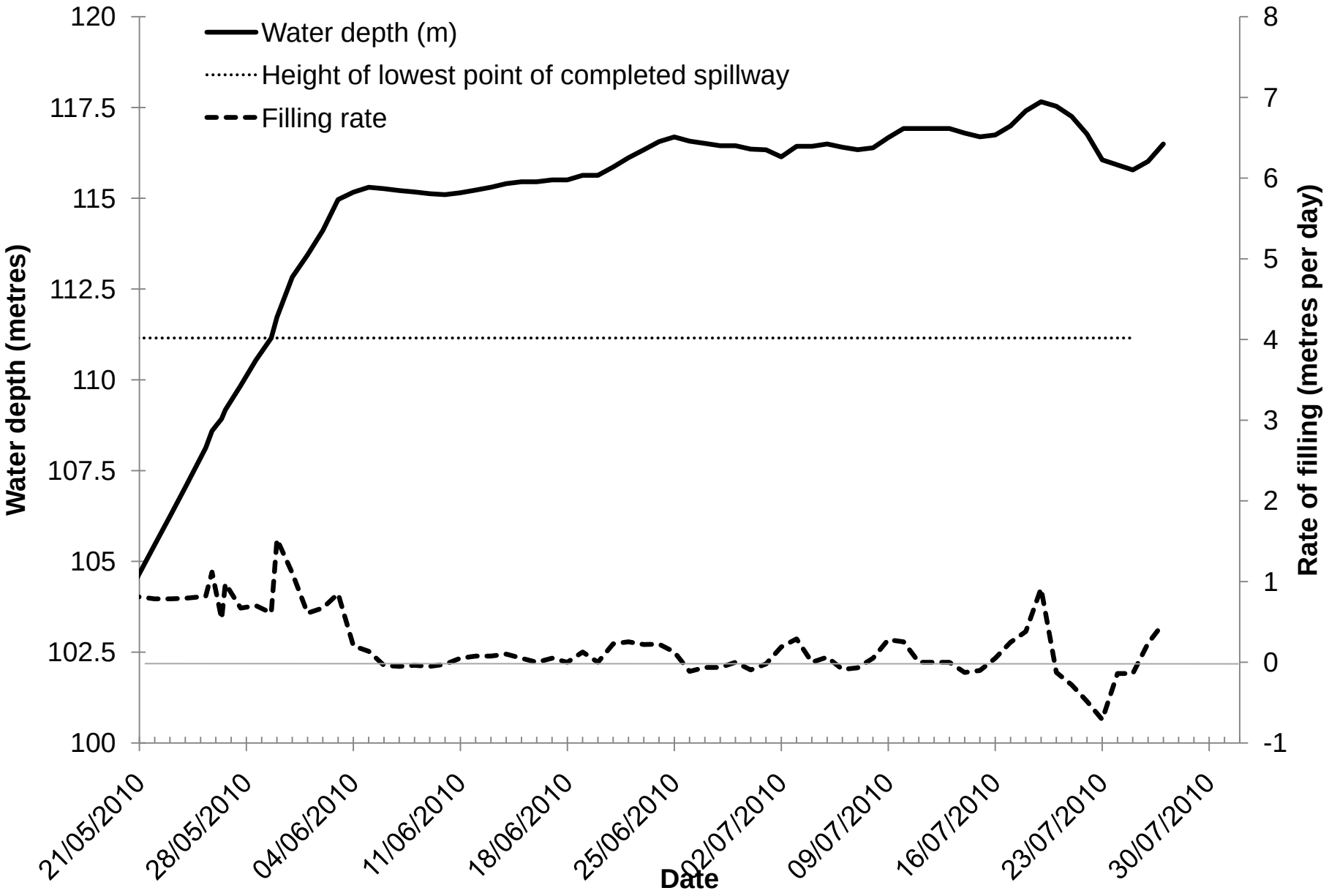

10
9
8
7
6
5
4
3
2
1
0
Freeboard (metres)
15/05/2010
22/05/2010
29/05/2010
Date


14
12
10
8
6
4
2
0
Freeboard (metres)
15/05/2010
22/05/2010
29/05/2010
05/06/2010
Date

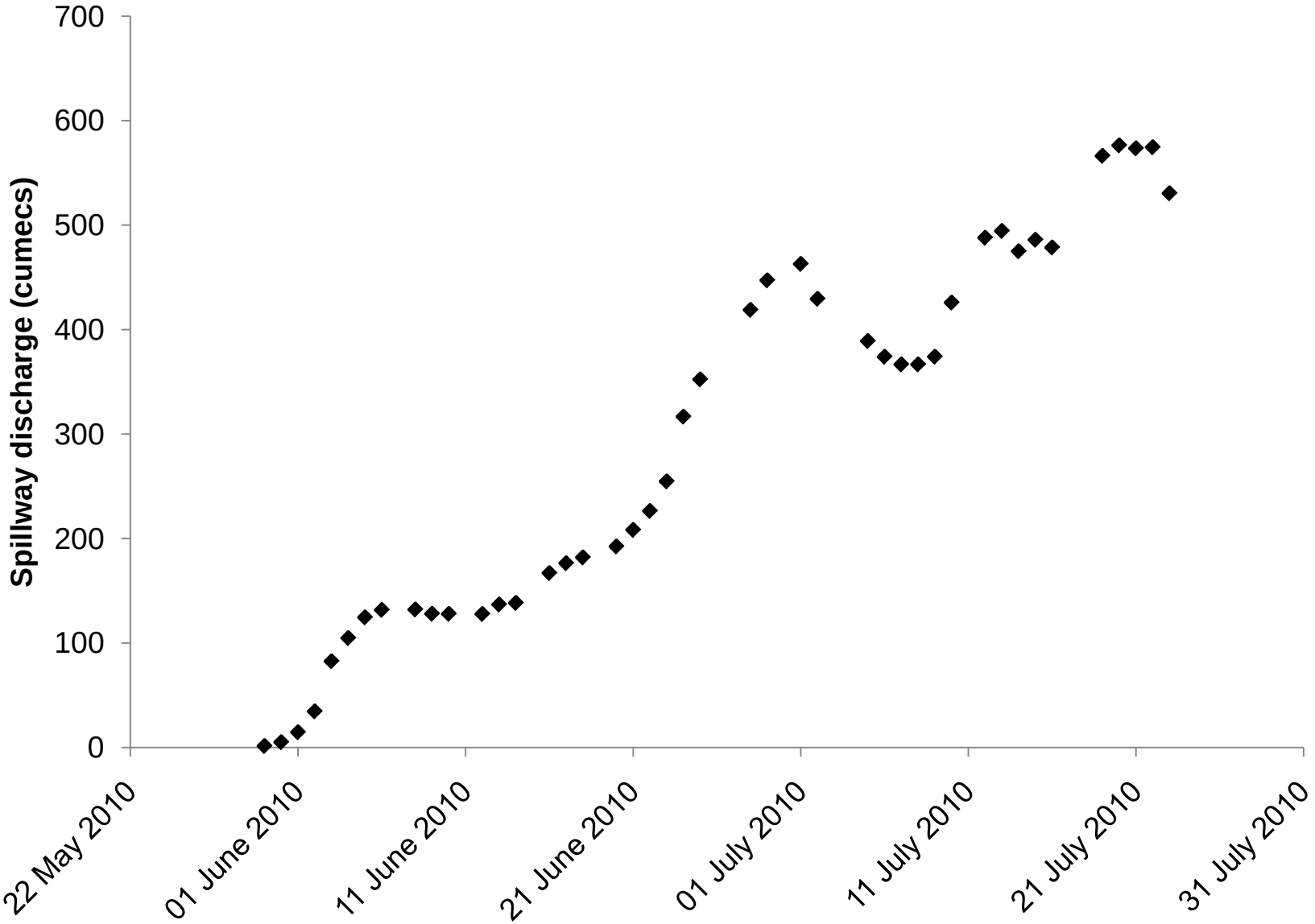
Water level rise



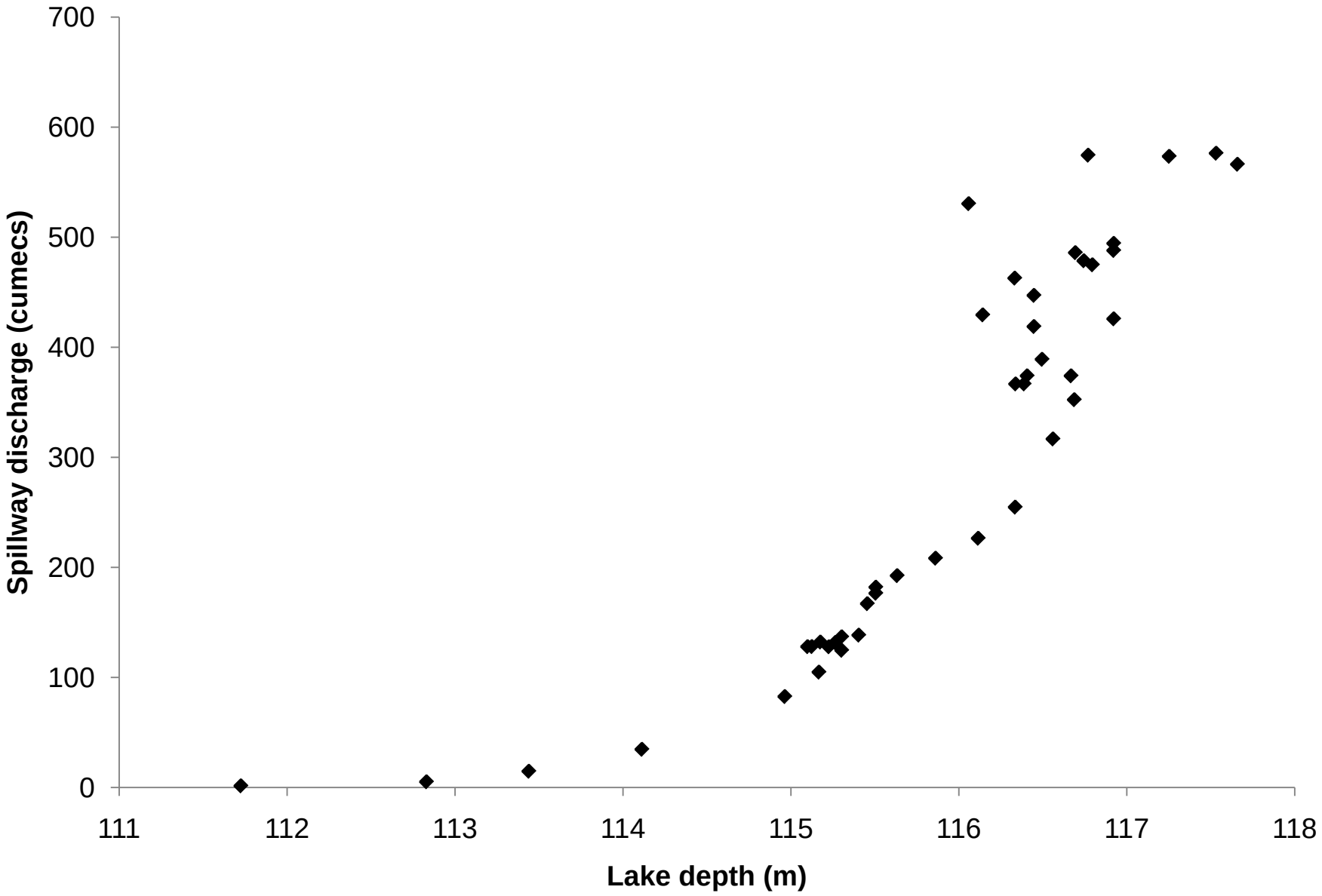
Overtopping behaviour



Evolution of spillway discharge



Spillway discharge – depth relationship



Spillway evolution

Management problems

- Karakoram Highway remains blocked
- In 2010 floods, Gilgit-Baltistan was cut off to north and south
- Loss of productive land
- Loss of cash crop markets
- Landslide hazard remains
  - Progressive failure
  - GLOF
  - Seismic event
  - Landslide into lake

- Should the lake level be lowered?
  - FWO attempt through the winter aimed to reduce the spillway elevation by 35 metres, but achieved less than 4 metres
- 2011 monsoon will start in about six weeks

Conclusions

- Impacts of landslides much higher than conventionally considered
- Strong component is from the Himalayan Arc
- Attabad landslide event
- Long term management problems
  - Should the dam be left alone, strengthened or lowered?