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The 2020 glacial lake outburst flood at Jinwuco, Tibet: causes, impacts, and implications for hazard and risk assessment

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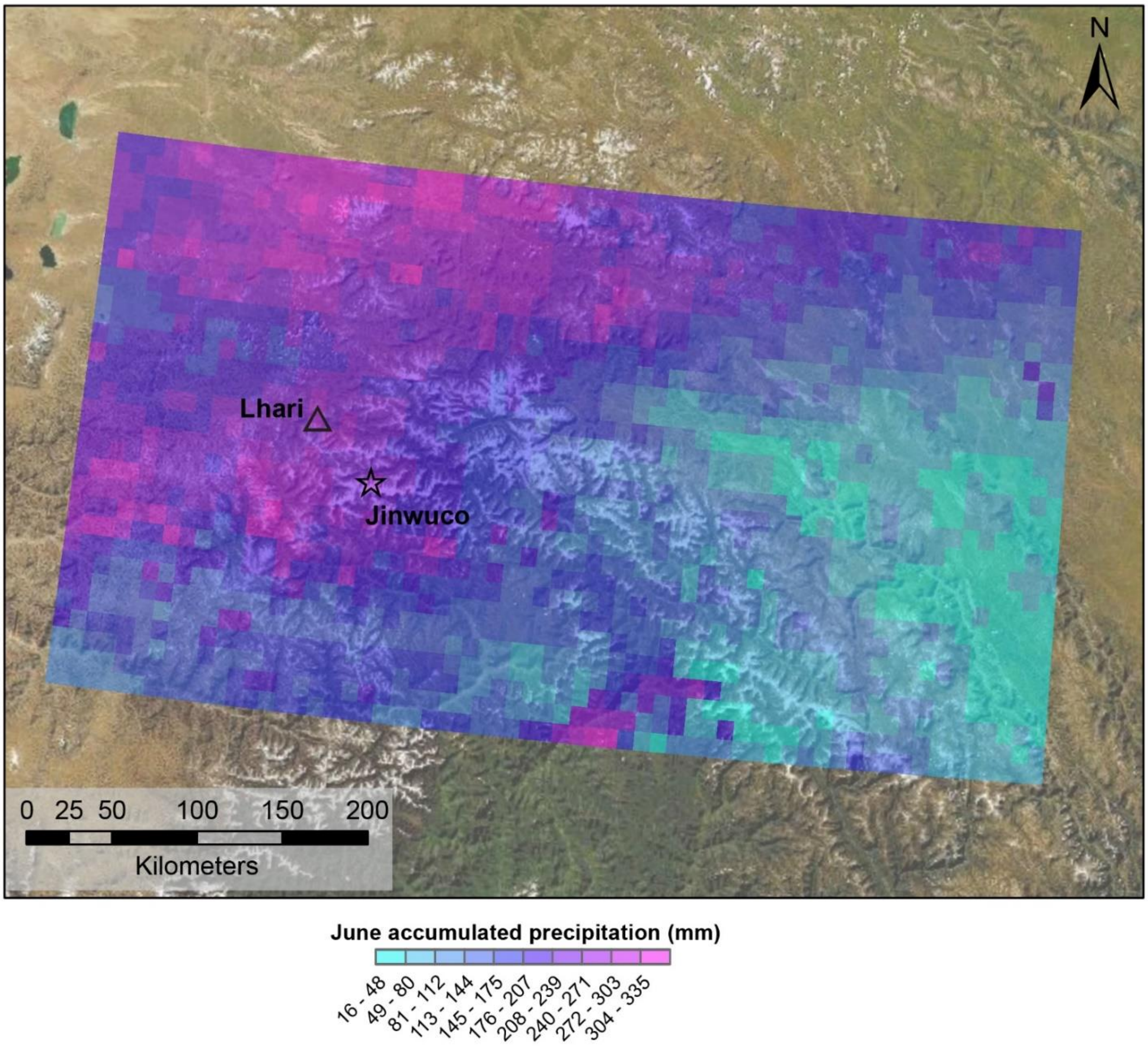
Supplementary Table 1. Detailed description of empirical equations used to estimate V, t_b and Q_p. All variables are in metric units (m, m^2, m^3), time t_b in hours and peak discharge Q_p in m^3/s unless otherwise stated.

Equation	**Description**	**Lake types**	**Reference**
Lake volume V:			
$V=0.035A^{1.5}$	A – lake area	Moraine dammed	Evans, 1986
$V=3.114A+0.01685A^2$	A – lake area	Moraine-dammed	O'Connor et al., 2001
$V=0.104A^{1.42}$	A – lake area	Moraine- and ice-dammed, thermokarst	Huggel et al., 2002
$V=0.0493A^{0.9304}$	A – lake area (in km^2); V – lake volume (in km^3)	Moraine-dammed	Yao et al., 2012
$V=0.0354A^{1.3742}$	A – lake area	Moraine-dammed	Wang et al., 2012
$V=A \cdot D$, where $D=0.087A^{0.434}$	A – lake area; D – mean lake depth	Moraine-dammed	Wang et al., 2012
$V=A \cdot D$, where $D=55A_{sqkm}^{0.25}$	A – lake area; A_{sqkm} - lake area in km^2; D – mean lake depth	Glacial lakes (various types)	Fujita et al., 2013
$V=0.2933A^{1.3324}$	A – lake area	Moraine- and ice-dammed	Loriaux and Casassa, 2013
$V=0.054393A^{1.483009}$	A – lake area	Moraine- and bedrock-dammed	Emmer and Vilímek, 2014
$V=A \cdot D$, where $D=0.1217A^{0.4129}$	A – lake area; D – mean lake depth (data replotted from Huggel et al. 2002)	Glacial lakes (various types)	Cook and Quincey, 2015
$V=A \cdot D$, where $D=0.5057A^{0.2884}$	A – lake area; D – mean lake depth (compilation including duplicate sites)	Glacial lakes (various types)	Cook and Quincey, 2015
$V=A \cdot D$, where $D=0.1746A^{0.3725}$	A – lake area; D – mean lake depth (compilation excluding duplicate sites)	Glacial lakes (various types)	Cook and Quincey, 2015
$V=A \cdot D$, where $D=0.3211A^{0.324}$	A – lake area; D – mean lake depth (compilation including duplicate sites and Huggel et al. 2002 data)	Glacial lakes (various types)	Cook and Quincey, 2015
$V=A \cdot D$, where $D=0.1697A^{0.3778}$	A – lake area; D – mean lake depth (compilation excluding duplicate sites and Huggel et al. 2002 data)	Glacial lakes (various types)	Cook and Quincey, 2015
$V=0.036A^{1.49}$	A – lake area	Moraine- and bedrock-dammed	Kapista et al., 2017
$V=A(0.041L_w+2)$	A – lake area; L_w – lake width	Moraine- and ice-dammed	Muñoz et al., 2020
Breach time t_b:			
$t_b=0.0179V_{er}^{0.364}$	V_{er} – volume of material eroded from the dam	Not specified	MacDonald and Langridge-Monopolis, 1984

t_b=1008A/(B_d·B_{w_avg})$^{0.5}$	A – lake area in acres; B_d – breach depth in feet; B_{w_avg} – average breach width in feet (calculated for both $B_{w\_avg\_v}$ and $B_{w\_avg\_t}$)	Not specified	Costa, 1985
t_b=0.011B_{w_avg}	B_{w_avg} – average breach width (calculated for both $B_{w\_avg\_v}$ and $B_{w\_avg\_t}$)	Not specified	Bureau of Reclamation, 1988
t_b=0.015B_d	B_d – breach depth (for highly erodible dam)	Not specified	Von Thun and Gillette, 1990
t_b=0.020B_d + 0.25	B_d – breach depth (for erosion resistant dam)	Not specified	Von Thun and Gillette, 1990
t_b=B_{w_avg}/4B_d	B_d – breach depth; B_{w_avg} – average breach width (for erosion resistant dam; calculated for both $B_{w\_avg\_v}$ and $B_{w\_avg\_t}$)	Not specified	Von Thun and Gillette, 1990
t_b=B_{w_avg}/(4B_d + 61)	B_d – breach depth; B_{w_avg} – average breach width (for highly erodible dam; calculated for both $B_{w\_avg\_v}$ and $B_{w\_avg\_t}$)	Not specified	Von Thun and Gillette, 1990
t_b=0.00254(V_{GLOF})$^{0.53}$·$B_d^{-0.9}$	V_{GLOF} – released volume; B_d – breach depth	Not specified	Froehlich, 1995
Peak discharge *Qp*:			
Q_p=1.268(B_d+0.3)$^{2.5}$	B_d – breach depth	Not specified	Kirkpatrick, 1977
Q_p=8/27·$g^{0.5}$·$B_b^{1.5}$·(0.4 $B_{w\_base\_t}$ +0.6 B_{w_max})	g – gravitational acceleration; B_d – breach depth; $B_{w\_base\_t}$ – breach width at the base; B_{w_max} – maximum breach width	Not specified	Price et al., 1977
Q_p=16.6$B_d^{1.85}$	B_d – breach depth	Not specified	Soil Conservation Service, 1981
Q_p=0.54($B_{w\_base\_t}$ · B_{w_max})$^{0.5}$	$B_{w\_base\_t}$ – breach width at the base; B_{w_max} – maximum breach width	Not specified	Hagen, 1982
Q_p=19.1$B_d^{1.85}$	B_d – breach depth (envelope equation)	Not specified	Bureau of Reclamation, 1982
Q_p=13.4$B_d^{1.89}$	B_d – breach depth	Not specified	Singh and Snorrason, 1984
Q_p=1.776$V_{GLOF}^{0.47}$	V_{GLOF} – released volume	Not specified	Singh and Snorrason, 1984
Q_p=1.122$V_{GLOF}^{0.57}$	V_{GLOF} – released volume	Glacial lakes (various types)	Costa, 1985
Q_p=0.981(V_{GLOF}·B_d)$^{0.42}$	V_{GLOF} – released volume; B_d – breach depth	Glacial lakes (various types)	Costa, 1985
Q_p=2.634(V_{GLOF}·B_d)$^{0.44}$	V_{GLOF} – released volume; B_d – breach depth	Glacial lakes (various types)	Costa, 1985
Q_p=44$B_d^{1.63}$	B_d – breach depth	Glacial lakes (various types)	Costa, 1985
Q_p=325(B_d·V_{GLOF}·10^{-6})$^{0.44}$	B_d – breach depth; V_{GLOF} – released volume	Glacial lakes (various types)	Costa, 1985
Q_p=0.72$V_{GLOF}^{0.53}$	V_{GLOF} – released volume	Moraine-dammed	Evans, 1986
Q_p=1.154(B_d·V_{GLOF})$^{0.412}$	B_d – breach depth; V_{GLOF} – released volume	Not specified	MacDonald and Langridge-Monopolis, 1984
Q_p=3.85(B_d·V_{GLOF})$^{0.411}$	B_d – breach depth; V_{GLOF} – released volume (envelope equation)	Not specified	MacDonald and Langridge-Monopolis, 1984
Q_p=0.0048$V_{GLOF}^{0.896}$	V_{GLOF} – released volume	Moraine-dammed	Popov, 1991
Q_p=0.607($B_d^{1.24}$·$V_{GLOF}^{0.295}$)	B_d – breach depth; V_{GLOF} – released volume	Not specified	Froehlich, 1995



Supplementary Figure 1. Accumulated precipitation over Southeastern Tibet from the Global Precipitation Measurement (GPM_3IMERGDF v06). There is close agreement in accumulated totals between the location of the GLOF at Jinwuco and Lhari, where the climate station is located.