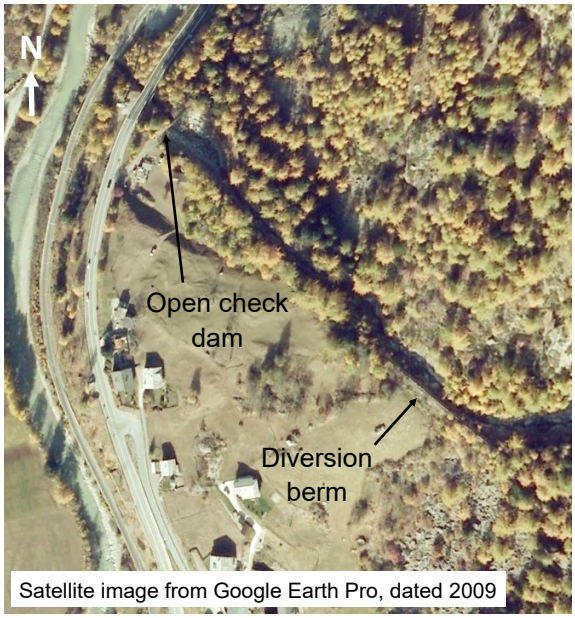
LOCATIONS OF SELECTED MITIGATION SITES IN SWITZERLAND

BIELZUG, Canton of Valais, Switzerland

Mitigation measures	Diversion berm, armoured channel, open check dam
Process type (and basis)	Debris flow
General notes	Small basin being expanded to improve capacity

Upgrade project	Current basin capacity is 5000 m^3, being upgraded to 20,000 m^3 (30 year event). 100 year event is 80,000 m^3. A warning system is also installed because this capacity does not meet the protection targets; the village is still at risk from 300 year and extreme events. The system includes geophones in the watershed, linked to lights on the road and in the village. Cost of 1.8 million CHF ($2.4 million CAD) and a cost benefit ratio of 2.9. Designed by the consulting firm wasser/schnee/lawinen.
Diversion and channel	Channel berms are between 2 and 4 m high. Side walls constructed from reinforced concrete. Lower channel armoured with inset boulders.
Open check dam	Outlet is 3 m wide with removeable horizontal beams. New concrete cap to increase check dam height.
Geomorphology	Some blocks up to 1 m.



Satellite image from Google Earth Pro, dated 2009

Construction to upgrade diversion berm and channel


Looking upstream at check dam

Looking upstream at check dam

Site photographs by author, June 2016

DORNIBACH and DORNIURSE, Canton of Schywz, Switzerland

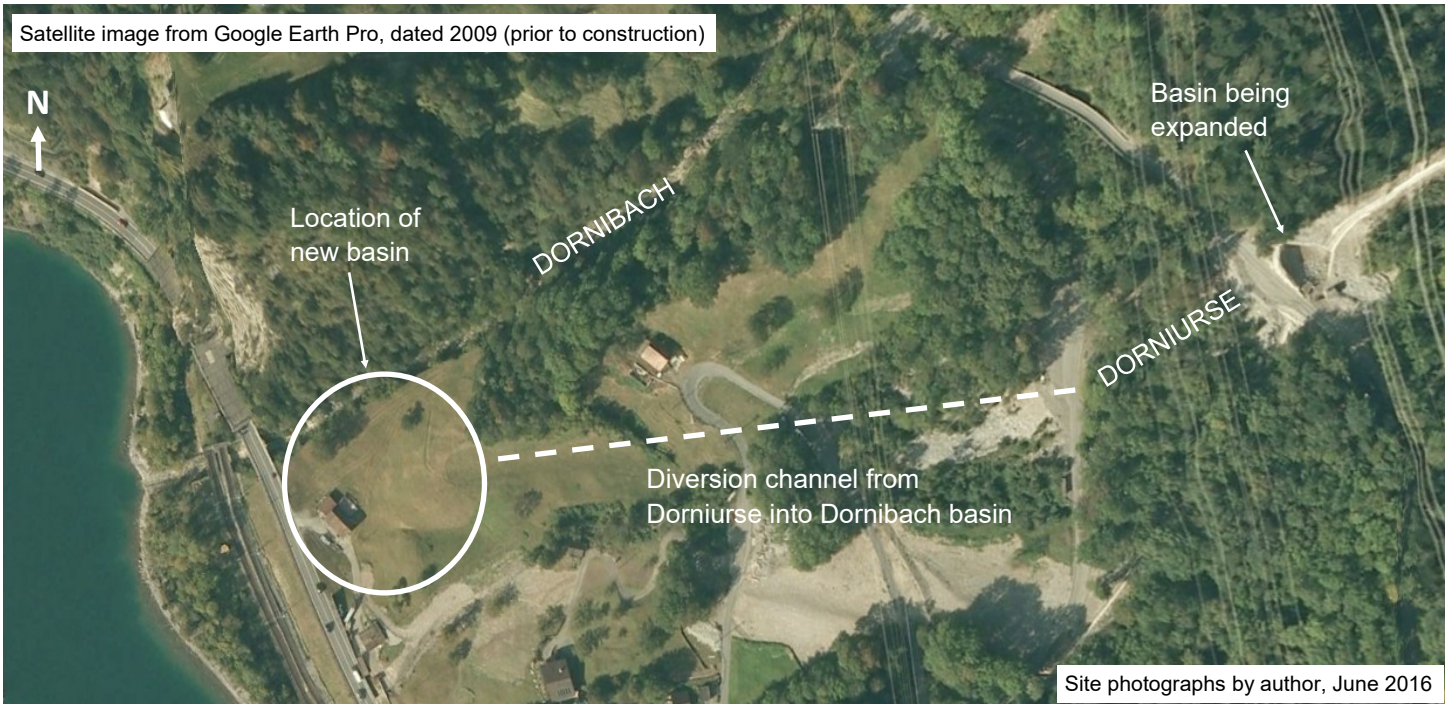
Dorniurse mitigation	Basin; diversion berm
Dornibach mitigation	Energy dissipation structure; basin and open check dam
Process type (and basis)	Debris flows
General notes	Two creeks managed through a combined system

Dorniurse mitigation	There was a 5000 m^3 rockfall in the ravine in 2009, which destroyed to old retention basin and a house in the village. New basin is planned with a 4000 m^3 capacity. Enough to hold the 30 year event; larger events will be diverted to Dornibach. Debris gates across the road need to be closed manually by the fire brigade.
Dornibach mitigation	Basin and energy dissipation structure installed just above the railway. The design was tested with physical model. Breaker required to slow the flow and direct material into the basin. Estimated maximum velocity of 25 m/s; breaker slows flow to 12 m/s. Outlet opening is 7 m wide and 5-6 m high. Openings are 0.4 m wide, between 0.3 m I-beams.
Construction	Designed by a private Swiss firm. Cost of 7 million CHF ($9.5 million CAD); cost benefit ratio of 1.1.

Dornibach outlet structure


Dorniurse diversion channel and gates to block road


Dornibach basin and debris barrier



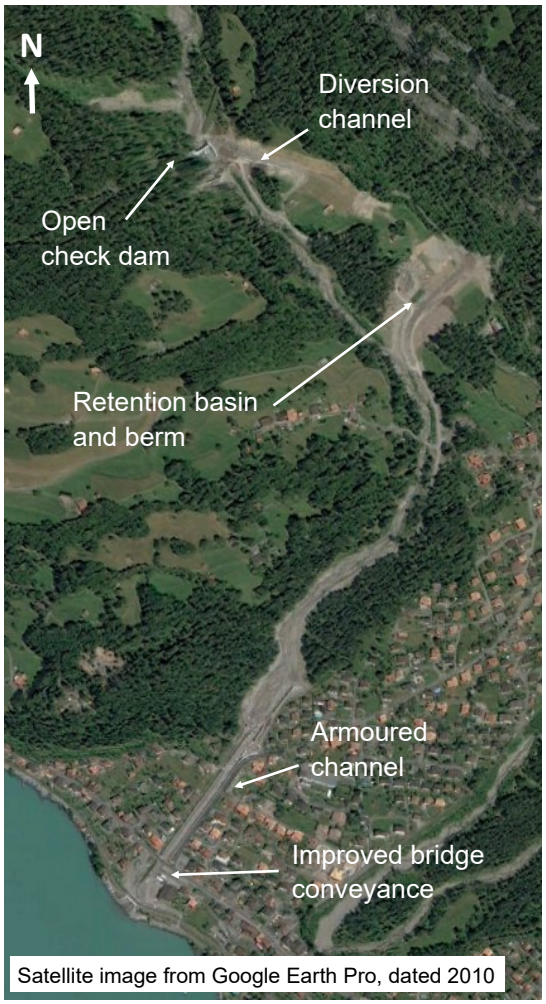
Satellite image from Google Earth Pro, dated 2009 (prior to construction)

Site photographs by author, June 2016

GLYSSIBACH, Brienz, Canton of Bern, Switzerland

Mitigation measures	1) Open check dam, 2) diversion channel, 3) retention basin and berm, 4) armoured channel, 5) improved bridge conveyance
Process type (and basis)	Debris flow; damaged during 2005 event
General notes	Excellent example of the functional chain concept

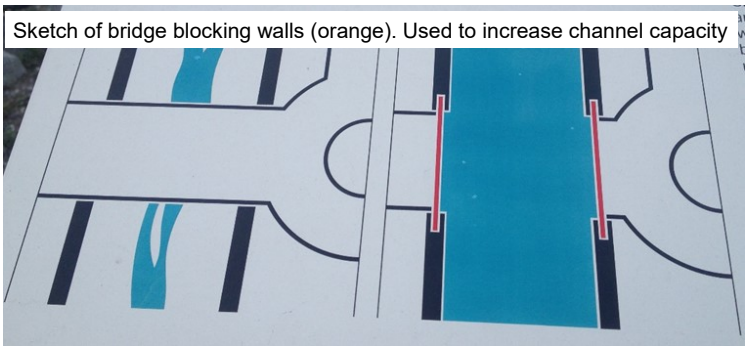
Open check dam	Foundation consists of a 1.5 m thick, 17 m wide and 40 m long concrete slab. The barrier is 2 m thick, and is composed of 2680 m^3 of concrete and 222 tonnes of steel rebar. The downstream fins stabilize against tilting and sliding. Intended to pass small events (up to 25,000 m^3); larger events are diverted into the retention basin.
Retention basin	Capacity of around 75,000 m^3. The tallest section is about 15 m high.
Additional notes	Available in German from site visit; can be translated if more technical specifications are required.



Satellite image from Google Earth Pro, dated 2010


Open check dam looking upstream


Diversion channel looking downstream


Sketch of bridge blocking walls (orange). Used to increase channel capacity

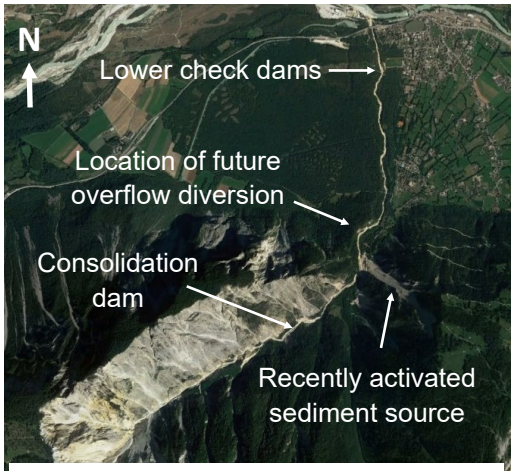

Armoured channel

Site photographs by author, June 2015

ILLGRABEN, Canton of Valais, Switzerland

Mitigation measures	Large closed check dam in upper watershed; series of check dams; monitoring system. Plan to add overflow weir and diversion structure (Berger et al., 2016).
Process type (and basis)	Debris flow, currently 3-5 per year but up to 7/year
General notes	One of the most (the most?) heavily monitored debris flow watershed in the world

Historical construction	In 1961, a 500,000 m^3 debris flow prompted the construction of 30 check dams in the channel and a large consolidation dam (40 m high) in the upper watershed. Decreased frequency for a while.
Monitoring	WSL monitoring started in 1999. System inclues: rain gauges in the upper watershed; geophones; depth sensors; force plate; erosion sensors; and instrumented wall with force plates and geophones. There is also an alert system near the channel, with lights and sirens. If an alert is triggered at the upper consolidation dam, there is 5-10 minutes to escape.
Erosion	Very large variation in channel bed. For example, 6 m between two seasons.
Planned diversion	Overflow structure planned at the first dogleg below the fan apex. Intended to pass smaller events and divert larger events onto the western, undeveloped portion of the fan



Satellite image from Google Earth Pro, dated 2016


Recent landslide source


Check dam profile, mostly buried in sediment


Middle reach between apex and check dams


Closed check dam near confluence


Closed check dam

Site photographs by author, June 2016

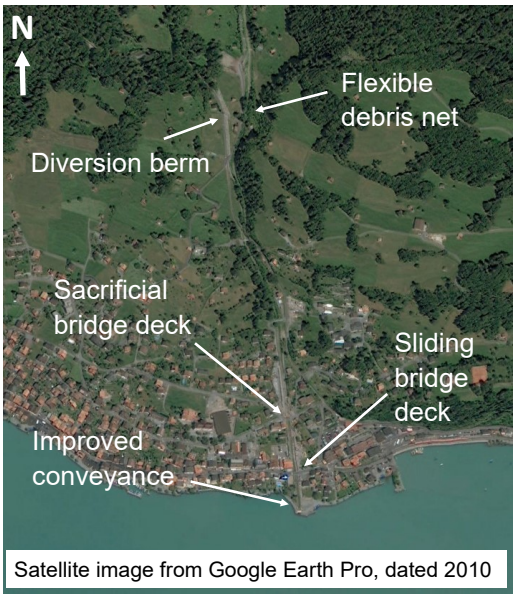
TASCHBACH, Canton of Valais, Switzerland

Mitigation measures	Check dams in upper watershed; open check dam; masonry armoured channel
Process type (and basis)	Debris flows, disasters in 1957 and 2001 (according to sign posted on the dam).
General notes	Downstream side of check dam is vegetated. Spillway is about 15 m wide.

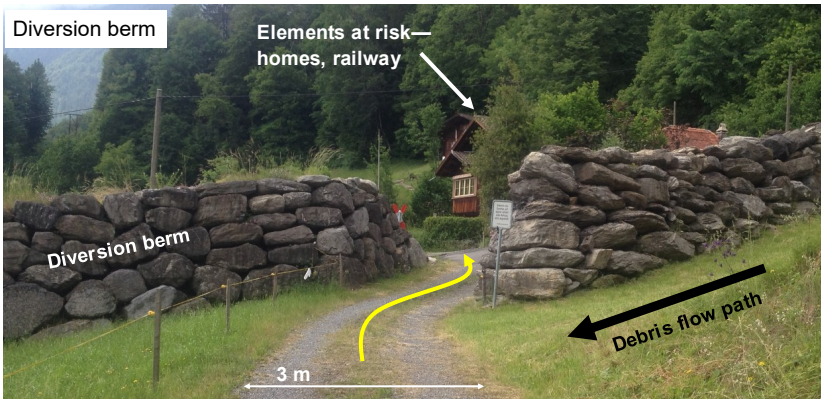
Site photographs by author, June 2016

TRACHTBACH, Brienz, Canton of Bern, Switzerland

Mitigation measures	1) Flexible debris net, 2) armoured channel, 3) bridge with sidewalls that break when subjected to flows, 4) moveable bridge, 5) improved capacity at confluence
Process type (and basis)	Debris flows
General notes	Excellent example of the functional chain concept. Additional notes in German from site visit; can be translated if more technical specifications are required.



Satellite image from Google Earth Pro, dated 2010



Site photographs by author, June 2015