# FISCHBACH, Tyrol, Austria

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<th>Mitigation measures</th>
<th>Open check dam with small slots; armoured channel</th>
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### Open check dam
- Masonry dam made from boulders between 0.3 and 0.5 m in diameter. Crest width of 2.5 m. Vertical upstream slope; downstream slope transitions from sloped at base to vertical near the top.

### Outlet structure
- Three slots, left slot is 2 m wide and right slots are 1 m wide. Currently only the bottom 1-2 m is open. Horizontal

### Spillway
- Located on the left side of the dam; 30 m wide; spills over dam into a floodplain area protected by riprap

### Construction
- Built in 1923; vertical bars added more recently

### Geomorphology
- D50: sand or 2-3 mm. D90: 0.3 m. Dmax: up to 0.5 m (unless this reach has been altered by cleaning). Gradient upstream of barrier: 7.5 degrees.

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Satellite image from Google Earth Pro, dated 2015

Site photographs by author, June 2016
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**Material and armouring**
Concrete and masonry check dam abutments; concrete pillar in mid-stream with natural stone facing. Armouring of the channel base is not visible, but appears to be concrete as well, based on the small step-down sub-dam a few metres downstream.

**Outlet structure**
18 m wide rack with two large openings. Possibly intended for large wood? Currently clean.

**Spillway**
On the right abutment. Armoured with masonry.

**Construction**
Designed by WLV. Age unknown. Some evidence that current configuration is new: some concrete is visibly newer, whereas other sections are weathered and chipped.

**Geomorphology**
Channel D90 = 0.5 m

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Satellite image from Google Earth Pro, dated 2015

Site photographs by author, June 2016
## LATTENBACH, Tyrol, Austria

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<td>Unstable watershed; one of the first sites where monitoring was implemented.</td>
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**Closed check dams**
Reinforced concrete with masonry armouring. Spacing is variable: between 15 m and approximately 50 m. Slope instability in the watershed is causing encroachment over some of the check dams.

**Monitoring**
Monitoring systems in middle reach and in village. All systems include flow depth sensors, geophones and video cameras. Middle reach stations also include infrasound and 2D laser. Middle reach systems are used to trigger alerts; collect data once per 5 minutes until alert thresholds are reached. During alerts, data collection is 2 times per second at all stations.

**Armoured channel**
Concrete and masonry; 9 m deep and 6 m wide with 70-80 degree side slopes.

**Confluence**
Issues with sediment blockage, like in other areas. When debris flows are observed by the monitoring station, the upstream hydro project releases all the water to ensure remobilization of the sediment at the bottom of Lattenbach.

Site photographs by author, May 2016

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![Slope instability covering closed check dam in watershed](image1.jpg)

![Confluence of Lattenbach with the main river](image2.jpg)

![Closed check dams in middle reach](image3.jpg)

![Lattenbach in village](image4.jpg)
MASONBACH, Vorarlberg, Austria

Mitigation measures
Large closed check dam and open check dam combination

Process type (and basis)
Debris flow

General notes
In 1995 a debris flow from Masonbach in Innerbraz hit a train, which was passing the bridge over the Masonbach. 3 passengers died, 8 passengers were severely injured. In the meantime 3 retention basins were built and the stream bed and the banks in the settlement area were stabilized (from WLV Vorarlberg).

Closed check dam and basin
Reinforced concrete check dam located on fan. Basin created using earthfill berms with keyed-in boulder armouring; no visible masonry.

Open check dam
Vertical upstream and downstream slopes; 1.5 m wide crest. Outlet is 4 m wide with 10 horizontal beams, approximately 20 x 40 cm.

Spillway
Over the barriers. No armouring on the open check dam crest; possible steel plate armouring on the closed check dam.

Construction
Construction finished in 2013; designed by WLV.

Geomorphology
D50: sand. D90: 0.3 or 0.4 m. Stream flow depth of 0.3 m.

Looking upstream at closed check dam

Satellite image from Google Earth Pro, dated 2015

Site photographs by author, June 2016

Looking downstream at open check dam
PETTNAU AM ARLBERG, Tyrol, Austria

Mitigation measures
Open check dam with large basin; channel stabilization with closed check dams; lower open check dam

Process type (and basis)
Debris flow

General notes
Large basin partially created from earthfill berm

Upper check dam
Reinforced concrete with near vertical upstream and downstream slopes. 8.5 m high.

Outlet structure
Two openings with horizontal bars. Openings are about 6.8 m high and 4.3 m wide with 0.7 m vertical gaps between beams. Steel beams are approximately 20 x 40 cm.

Right abutment berm
Earthfill berm approximately 120 m long with a 36 degree slope (although variable). Maximum height of 20 m, pinching to 10 m high where it meets natural ground. Berm height seems disproportionate (unnecessarily tall) compared to the outlet structure.

Spillway and armouring
Spillway over top of barrier—the entire crest is slightly sloped. Downstream of barrier is armoured with boulders set in concrete, then closed check dams.

Construction
Looks old—maybe in the 1980s.

Geomorphology
D50: 0.05 m. D90: 0.4 m up to 0.8 m. Gradient upstream of upper barrier: 7 degrees.

Site photographs by author, June 2016

Satellite image from Google Earth Pro, dated 2015
RENNEBACH, Tyrol, Austria

Mitigation measures: Upper barrier with benches; armoured channel; lower barrier

Process type (and basis): Debris flow (based on watershed)

General notes: Addition of berms and steps within basin—interested to see how they perform.

Upper barrier: Concrete and steel outlet structure with earthfill berm basin. Outlet concrete is 9.5 m high; opening is 8 m wide at crest and narrows slightly to base. Unknown whether there is a concrete core through the abutments. Armoured with inset riprap and masonry. Crest is ~5 m wide. Two diversion berms and two benches added to basin; intended to promote deposition.

Channel: Partially armoured channel between basins. At inlet to lower basin, channel is 6 m deep and 10 m wide with 70-80 degree side slopes armoured with inset riprap (Dmax = 1 m). Gradient is 7 degrees upstream of bridge and 20 degrees at basin inlet.

Lower barrier: Concrete and steel outlet structure with earthfill berm basin. 5.5 m to top of outlet grate; 7 m to top of concrete, plus additional 2 m of earthfill. Armoured with inset riprap. Steel grate at 45 degree angle. Vertical beams are 12 x 12 cm; horizontal beams are 20 x 35 cm. Openings are 80 x 60 cm.

Construction: Timing unknown. WLV and BOKU were involved in adding the berms to the upper basin recently—2015?

Site photographs by author, June 2016
Mitigation measures

12 closed check dams; open check dam; armoured channel

Process type (and basis)

Debris flows

General notes

See related case study in Chapter 6

Old barrier

There was an old barrier, which was overtopped/outflanked and then removed. The old barrier had a concrete outlet structure with earthfill abutments. Constructed in the 1990s. Captured an event a few years ago, which filled 1/3 of the basin. Initial hazard map estimate was 1500 m$^3$.

2015 event

The event started as sediment transport, and was depositing in the basin at a 20% gradient—very steep, but not yet a debris flow. Local evacuations started, then debris flow occurred in the middle of the night. Triggered from a watershed landslide.

New barrier construction

One of the biggest building sites in Austria in the summer of 2016. Using 8000 m$^3$ of concrete, with 100 kg of steel per m$^3$ according to new regulations (previously 30 kg/m$^3$). Thought to make it more aesthetic, but too expensive and there are space constraints. €4 million ($XX CAD) for barrier and €10 million ($XX CAD) for system.

New barrier

Reinforced concrete. Three openings approximately 1 m wide with single steel bar (for reinforcement, not debris capture). Spillway over crest.
**SCHNANNERBACH, Tyrol, Austria**

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<tr>
<td>Process type (and basis)</td>
<td>Hybrid debris flow and debris flood (based on size of watershed); also avalanches</td>
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<td>General notes</td>
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**Open check dam**
Arch dam with four horizontal slits. Balloons installed to block slots. Designed to be inflated sequentially and remotely, with water from a gravity-fed holding tank. Mayor and professionals receive rainfall and water level warnings and decide whether to block the slots. Constructed in 1991.

**Closed check dam**
Built and filled prior to the construction of the open dam. Date unknown.

**Armoured channel**
Narrow, deep channel in village with low check dams. Masonry.

**Confluence**
Capacity improved after sediment deposition and backup issues during the 2005 event. Also changed the inflow angle.

**Maintenance**
Required every event; 6 events in the last 7 years. Costs €60k to €70k per cleaning ($90k—$1.3 million CAD). Material is considered as waste by EU regulations—need to do chemical tests.

![Site photographs by author, May 2016](image1)

![Satellite image from Google Earth Pro, dated 2015](image2)
### SONNENHALB, Vorarlberg, Austria

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<th>Mitigation measures</th>
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<td>Debris flow (based on watershed size)</td>
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<td>General notes</td>
<td>Typical old Austrian style barrier</td>
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**Open check dam**
Reinforced concrete barrier with outlet structure. Abutments are earthfill over a concrete core wall that appears to extend to bedrock. 8-9 m tall with a 2.2 m crest. Concrete fins create three openings—two are 5 m wide and one (inactive channel) is 10 m wide. Vertical bars are 0.8 m apart. Vertical steel beams are 20 x 40 cm; horizontal beams are 35 x 60 cm.

**Spillway**
Over the barrier. Steel lip on downstream edge of crest.

**Erosion protection**
Downstream side of dam is elevated a few metres from the stream bed (see photograph). Erosion protection is not visible because of water, but likely present (concrete plinth? Boulders in concrete?)

**Downstream**
No additional structures observed

**Construction**
Unknown

**Geomorphology**
D50: 0.03 m. D90: 0.4 m. Stream flow depth: 0.4 m. Basin gradient: 7 degrees.

![Site photographs by author, June 2016](image)
STARKENBACH, Tyrol, Austria

Mitigation measures  Closed check dam; ongoing quarrying of sediment and slide debris

Process type (and basis)  Debris flow; rock avalanche

General notes  Site of a major rock avalanche in 1999

Rocks avalanche  The 1999 rock avalanche had a volume of 3 million m³ and formed a deposit 80 m deep. A lake formed above the deposit and outflow stopped for 48 hours. Concerns of a landslide dam outbreak flood prompted downstream evacuation.

Mitigation  A spillway was dug across the debris to lower the lake for initial management of the hazard. Longer term management involved trenched installation of two pipes across the debris, 60 to 80 m in length. The pipes were manufactured locally, so this was a popular option. The closed check dam was also built at this time. Total cost of 30 million Austrian schillings ($3.2 million CAD). The pipes were destroyed in a storm in 2005.

Quarry operation  Sediment is sent to other areas and countries. Transport of 1500 tonnes per year.

Closed check dam  Built for channel consolidation purposes. 13 m wide; crest is armoured with stones. Potential for outflanking.
SUGGADINBACH, Vorarlberg, Austria

Mitigation measures
Armoured channel; 5 closed check dams; retention/regulation basin; open check dam

Process type (and basis)
Debris flood (based on size of watershed and low channel gradient)

General notes
Typical example of an Austrian-type outlet structure

Material and armouring
Barrier abutments are earth berms with reinforced concrete core walls (1 m wide) and keyed-in boulders for armouring; crest at outlet is ~2 m wide; basin is armoured with keyed-in boulders; channel immediately downstream of outlet is concrete with boulder inlay

Outlet structure
Two 6 m wide openings split into 0.6 m wide segments; angle of the outlet grill varies—~60 degrees at steepest, transitioning to ~10 degrees. Vertical bars are 20 cm wide and 40 cm deep. Large horizontal bar is 60 x 70 cm.

Spillway
14 m base width and 22 m top width. Armoured with a steel plate. 2 m crest at spillway.

Construction
Designed by WLV. Check dams constructed between February and July 2013.

Geomorphology
D50: sand. D90: 0.15 m. Upstream slope (in basin): 2 degrees

Satellite images from Google Earth Pro

Site photographs by author, June 2016
Mitigation measures: Series of closed check dams of varying age and repair; highway bypass under creek

Process type (and basis): Debris flow

General notes: Channel stabilization with closed check dams

List of structures:
- Upstream to downstream: 2 upstream dams; large closed check dam; older check dam with pipe; masonry check dam; four dams (newish) upstream of village bridge; at least nine more downstream

Spacing:
- Variable. Upstream dams are about 50 m apart. Larger dams in middle reach are between 100 and 200 m apart.

Construction:
- Reinforced concrete check dams with steel armoured dam crests. Some have slots or pipes for drainage.

Geomorphology:
- D50: 0.02—0.03 m. D90: 0.5 m. Flow depth: 0.3 m. Upstream and downstream slopes around large dam: 12 degrees

Site photographs by author, June 2016

Satellite image from Google Earth Pro, 2014.
Mitigation measures | Large open check dam in watershed
---|---
Process type (and basis) | Debris flow
General notes | Example of building high in the watershed rather than on the fan

**Barrier**
- Reinforced concrete. 10.5 m high above left abutment, 6 m from downstream channel walls. Crest is 1.2 m wide.

**Outlet structure**
- Outlet has 14 horizontal steel bars, 30 x 30 cm. The grid is 7.5 or 8 m high. The opening is 4 m wide.

**Spillway**
- Over barrier. 11 m wide at top and 6 m wide at base with 45 degree side slopes.

**Erosion protection**
- Concrete is protected with steel plates. Downstream of the barrier, the channel is armoured with large boulders (up to 1.5 m) set in cement. There are also inset boulders to protect the upstream left abutment.

**Construction**
- Built in 2015 after a damaging debris flow in 2010.

**Maintenance**
- Road constructed into upper watershed for construction and maintenance

**Additional mitigation**
- Nothing additional observed downstream
### ZURSBACH, Vorarlberg, Austria

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<td>Similar design to Waldtobel</td>
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**Barrier**

Standard barrier with vertical rake, similar to Waldtobel but with two outlets. Crest is 2-2.5 m wide. Barrier is 11.5 m tall at the maximum, and 7-8 m tall at the outlet.

**Outlet structure**

Two slots about 5 m wide with 13 visible horizontal bars. Bars appear to be hooked into place, possibly to facilitate repair.

**Spillway**

Over the barrier. No steel plate for erosion protection

**Construction**

Construction completed in 2006.

![Looking upstream](image1)

![Looking upstream](image2)

![Looking downstream](image3)

![Satellite image from Google Earth Pro, dated 2015](image4)

*Site photographs by author, June 2016*