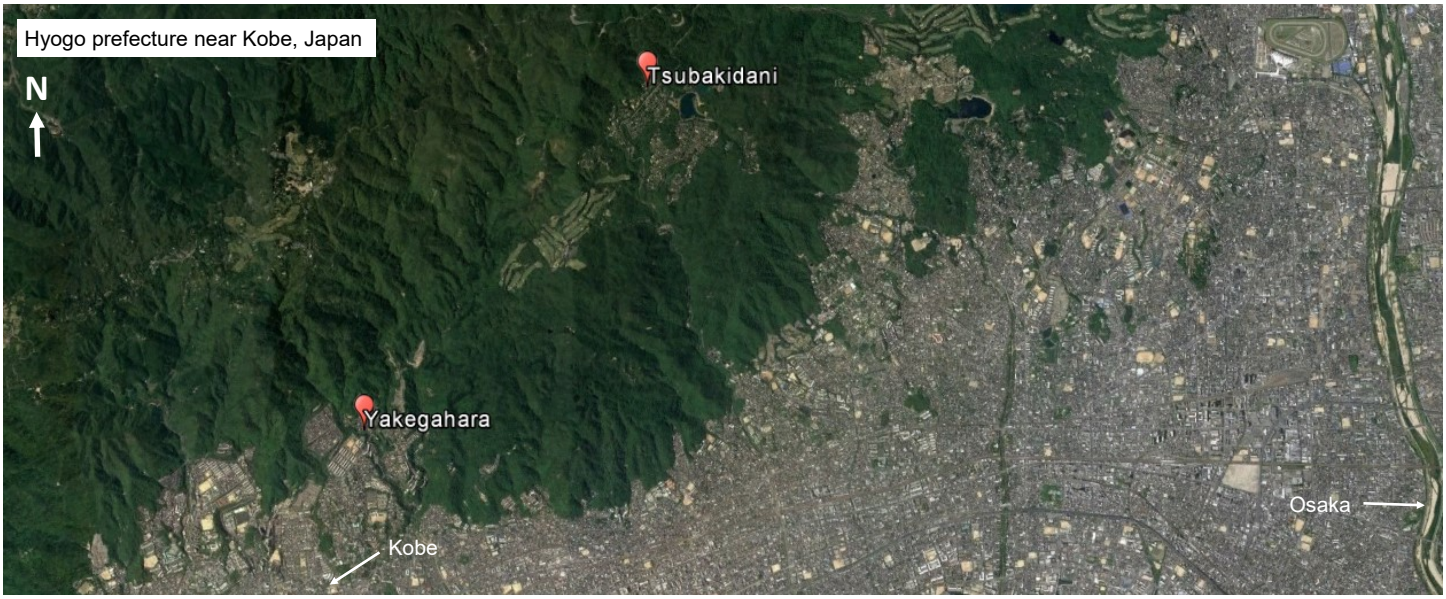
LOCATIONS OF SELECTED MITIGATION SITES IN JAPAN



YAKEGAHARA, near Kobe, Hyogo, Japan

Mitigation measures	Consolidation dam and concrete-lined channel
Process type (and basis)	Debris flows; consolidation of landslide sediment
General notes	Built after a landslide, but there has been little (no?) sediment transport since

Consolidation dam	Concrete barrier with granite facing for decoration and aesthetics. 14 m high because of the 15 m seismic requirements. 4 m crest width. Two steel grids to block inlets to basin. Basin is concrete-lined.
Basin	Concrete-lined. About 30 m deep and 100 m wide
Maintenance	Culverts under the barrier are cleaned by excavator. Will require a crane for access; has not been done yet. Inspections completed every year.
Armoured channel	Concrete-lined, with steps
Construction	Built in 1998. Cost of about 300 million yen (in 1998?) - $3.4 million

From Google Earth Pro, dated 2016


Concrete channel


Downstream face with granite decoration


Dam crest and left inlet


Basin and right inlet

Site photographs by author, September 2016

TSUBAKIDANI, near Kobe, Hyogo, Japan

Mitigation measures	Open check dam with concrete sidewalls and a grid outlet structure
Process type	Debris flows.
General notes	Used to be a closed dam (built in 1968); recently renovated to incorporate the grid (2013). Dam is 12.5 m tall. Cost of $770,000 CAD for the renovation. No maintenance since renovation.

Photograph by D. Stead, September, 2016

SHINOBU, near Takayama, Gifu, Japan

Mitigation measures	Closed check dam and fish bypass weir
Process type (and basis)	Sediment transport,; possibly debris floods
General notes	Constructed in the 1980s. Includes a park and a tunnel under the dam, to attract tourists. Dam is vegetated and appears very natural; no concrete or grout visible.

Closed check dam with natural boulder appearance

Fish bypass

Site photographs by author, September 2016

DOKANMATSU, near Takayama, Gifu, Japan

Mitigation measures	Closed check dam; swale bridge with culverts; fish weir; monitoring
Process type (and basis)	Debris floods; bedload transport (watershed size)


Swale bridge below the check dam (inset: grouted riprap)


Closed check dam and subdam for erosion protection

Site photographs by author, September 2016

“GREAT WALL” dam, near Takayama, Gifu, Japan

Mitigation measures	Open check dam with large arch openings and decorative stone facing.
Process type (and basis)	Debris flows from an eruption of Mount Yake
General notes	Japanese name not recorded. Intended for debris flow attenuation after volcanic eruptions.


Looking at upstream face

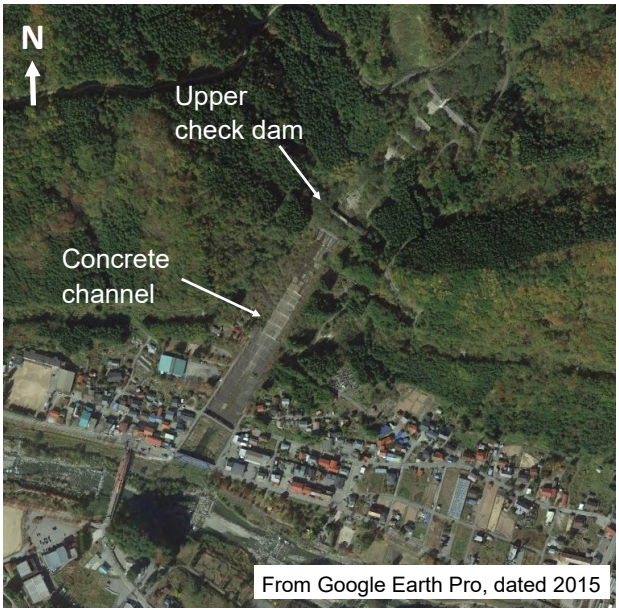

Looking at downstream face

Site photographs by author, September 2016

TOCHIO, near Takayama, Gifu, Japan

Mitigation measures	Flexible debris net and articulated concrete mats
Process type (and basis)	Debris floods—major event in June 2013
General notes	Short-term mitigation system, to be replaced with a larger barrier

Previous event	In 1980, there was a large debris flow that broke damaged the highway bridge in town. Significant sediment deposition and 3 people were killed including tourists. This created a lot of impetus for a large, effective solution. Constructed in 1983.
Lower concrete channel	Massive concrete structure. Check dams approximately 20 m apart. Concrete in the middle channel. The edges of the channel have grouted riprap panels.
Upper check dam	Two culvert outlets, one flowing. Crest about 3 m wide. Dam has about 5 m of freeboard above current sediment. Additional closed check dams observed upstream, but not visited.
Geomorphology	D50: 0.03 m. D90: natural up to 1.5 m. As observed in the upper check dam basin.



From Google Earth Pro, dated 2015


Upper check dam looking upstream


Concrete channel


Upper check dam looking downstream

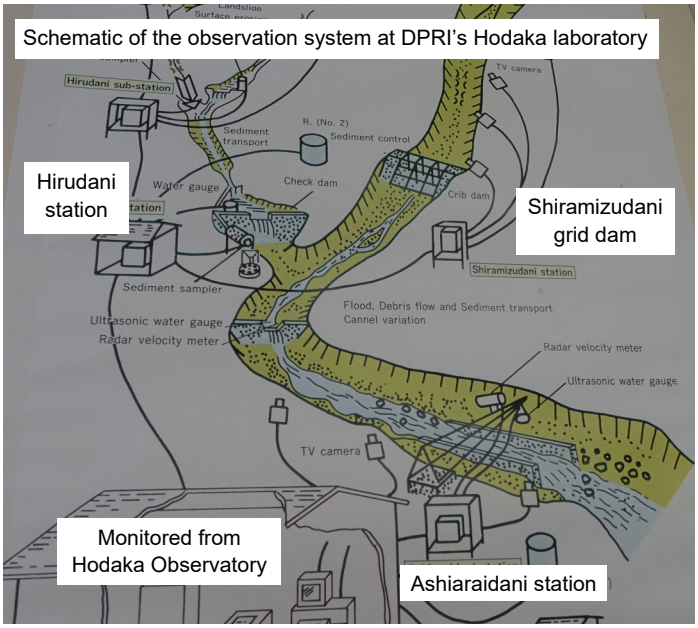

Armouring in lower channel

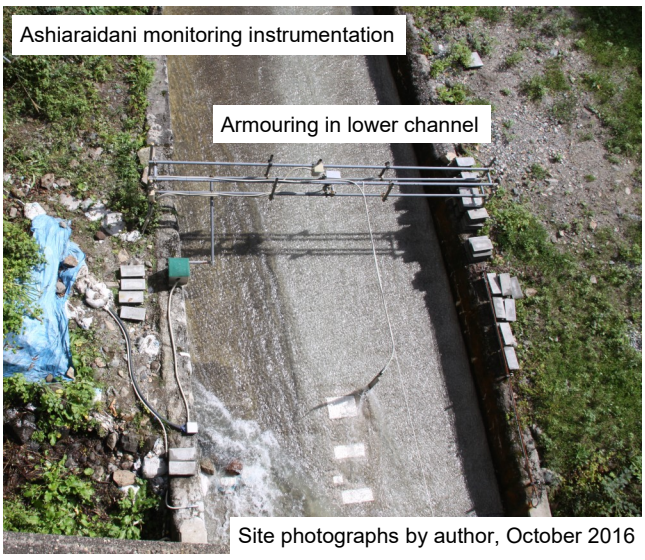
Site photographs by author, September 2016

SHIRAMIZUDANI, HIRUDANI and ASHIARAIDANI, Nakao, Gifu, Japan

Mitigation measures	Grid dams, open check dams and sediment observation system
Process type (and basis)	Debris flows off Mount Yake
General notes	Location of DPRI Hodaka Sediment Observatory

Shiramizudani grid dam	Completed in 1980, constructed by Kobe Steel Company. Design discharge: 94 m^3/s. Height: 14.75 m. 4395 m^3 of concrete and 242 tonnes of steel. 4 x 4 m openings in the middle, 3 x 4 m openings on sides. Used to use 2x D90 in the 1980s. Maintained 2 or 3 times since construction. 21,000 m^3 capacity.
Hirudani	Completed in 1975. Empty basin by opening slots approximately every year. Approximately 50 m^3 per year. Using TDR sensors to monitor sedimentation.
Ashiaraidani channel	Installation of Swiss plate geophones, and Japanese microphone plates.
Check dams	Large check dams in upper watershed; open dam under construction in village.





Site photographs by author, October 2016

KAMIKOCHI GRID DAM, near Takayam, Gifu, Japan

Mitigation measures	Open check dam and erosion protection
Process type	Debris flows
General notes	Active construction site on the access road to Kamikochi National Park


Grid dam and channel


Grid dam

Photograph by D. Stead, September, 2016

KAMIKOCHI CHECK DAMS, near Takayama, Gifu, Japan

Mitigation measures	Closed check dams
Process type (and basis)	Unknown (debris flows?)
General notes	Check dams created from steel posts, filled with cobbles and boulders from the stream


Looking upstream


Steel grid gabions

Site photographs by author, September 2016

KAMIKAMIHORI DEBRIS BREAKER, near Takayama, Gifu, Japan

Mitigation measures	Closed check dams (one previously with debris net); debris breaker; another low closed dam
Process type (and basis)	Debris flows; DPRI professors shared videos from the 1990s
General notes	Debris breaker test case. Now partially dismantled.

Background	This is an experimental site, with no elements at risk. Used to have 3 events per year, now there hasn't been an event in 3 years.
Debris breaker	About 3 m high from base to top of grill. Other geometry information not available because the grid has been removed. It was stressed that the sidewalls are very important to prevent overtopping and avulsion.
Monitoring	The current system includes a load cell and water level sensor to estimate water content and sediment load (fines). There are 11 trip wires upstream; the sensors turn on after at least 2 trip wires are triggered.


Load cell


Looking upstream


Looking downstream

Site photographs by author, October 2016

TATEYAMA CALDERA, near Toyama, Toyama, Japan

Mitigation measures	Several hundred structures, mostly closed check dams with some open check dams
Process type	Debris flows (in tributaries); debris floods; landslide dam outbreak floods
General notes	Refer to Hayashi et al (2014) and thesis (Shiraiwa, Hongu, shutter dam) for additional information

System	Sabo works initiated after the 1858 landslide dam earthquakes. Environmental restrictions are now more strict for sabo, but Tateyama works are still permitted. Approximately 60% of the structures that are planned have been constructed.
Shutter dam	14.5 m high, 120.5 m long crest, about 15,000 m^3 of concrete and 227,000 m^3 of storage. Shutter is intended to attenuate the dosing process (test case) - to be opened after peak and closed when the water level is back to normal. Optimized with physical models.
Sabo dam 12	17.5 m high. Regulations require that dams larger than 15 m are founded on bedrock. Not possible here, so foundation is grouted. Spacing determined by the extent of sediment deposition upstream of the lower dam, assuming 1/2 the natural bed slope.


Shiraiwa dam, looking downstream


Unconsolidated landslide dam sediments


Shutter dam


Under construction


Sabo dam 12 (left) and additional works (upstream)

Site photographs by author, October 2016