Internationales Symposion
INTERPRAEVENT 2004 – RIVA / TRIENT

ENVIRONMENT-ORIENTATED CONTROL MEASURES IN TORRENTS – DESIGN PRINCIPLES AND LIMITS

UMWELTGERECHTE WILDBACHVERBAUUNG PLANUNGSGRUNDSÄTZE UND ANWENDUNGSGRENZEN

Joerg Heumader[1]

ABSTRACT

As response to the growing disapproval of public opinion with mere technical countermeasures torrent engineers try to plan and implement „near-nature“ control techniques, but up till now principles how to do this have been laid down only insufficiently. This report tries to define targets and principles for such works in a broader environmental context. Additionally to the main goal "Protection of people from flood and sediment disasters", environment-orientated countermeasures have the target "As little negative influence on environment and landscape as possible" as far as that can be done without interfering with the main goal. Such techniques cannot be used in torrent reaches, where debris flows may occur, and their application is restricted in densely settled or urbanized areas. The report gives an overview on environment orientation targets, including landscape and recreation, and discusses some aspects of mountain-stream ecology, the knowledge of which is essential. As a result the report lists up principles for the design of environment-orientated defense measures in torrents and gives some examples.

Key words: Near-nature control techniques, environment-orientated control measures, mountain-stream ecology

ZUSAMMENFASSUNG

Rein technische Schutzmaßnahmen in Wildbächen werden durch die Öffentlichkeit zunehmend kritisch beurteilt. Als Reaktion darauf werden seitens der Wildbachverbauer verstärkt „naturnahe“ Techniken eingesetzt, aber bis jetzt gibt es wenig grundsätzliche Überlegungen hiezu. Dieser Beitrag versucht, Ziele und Grundsätze für solche Techniken auf Basis umweltrelevanter Fakten zu definieren. Zusätzlich zum Hauptziel „Schutz der Menschen vor Wildbachkatastrophen“ haben umweltgerechte Verbauungsmaßnahmen das Ziel „So wenig nachteilige Auswirkungen auf Umwelt und Landschaft wie möglich“, so weit dadurch das Hauptziel nicht be-

[1] Gebietsbauleiter, Forsttechnischer Dienst für Wildbach- und Lawinenverbauung, Gebietsbauleitung Oberes Inntal, Langgasse 88, A-6460 Imst, Österreich (Tel.: +43-5412-66531; FAX: +43-5412-6653123; E-mail: joerg.heumader@wlv.bmlf.gv.at)

einträchtigt wird. Derartige Techniken können in Wildbachstrecken, wo Muren auftreten, nicht eingesetzt werden und ihre Anwendung ist in dicht besiedelten Gebieten nur eingeschränkt möglich. Der Beitrag gibt eine Übersicht über Ziele im Interesse der Umwelt, einschließlich Landschaftsbild und Erholung, und erörtert einige Zusammenhänge aus der Ökologie von Gebirgsbächen, deren Kenntnis von besonderer Bedeutung ist. Als Ergebnis werden Grundsätze für die Planung von umweltgerechten Verbauungsmaßnahmen aufgelistet und einige Beispiele präsentiert.

INTRODUCTION

The rapid technical progress in building materials and construction equipment, together with the growing public prosperity in industrial countries after the second world war enabled and enforced technical countermeasures. After decades of such more or less mere technical torrent control measures public opinion looks at such works with growing disapproval. Environment and its protection rank high in peoples minds and are of considerable social and political value.

GENERAL REMARKS

Since several years torrent control engineers like to use the term “near-nature techniques” for their control measures (“naturnahe Verbauung” in German), but nobody seems to know definitely what that means. The term “near-nature techniques” is somehow misleading, because it is impossible to plan or implement control works in a torrent channel, so that it will resemble a natural and untouched mountain stream afterwards. Man is part of the evironment - the author therefore prefers the term “environment-orientated”, including not only ecological, but also socioeconomic and cultural aspects. These terms are often confused with “soil bioengineering techniques”, although the two conceptions obviously are not the same. In combination with technical measures soil bioengineering methods are important for “environment-orientated” countermeasures, but they are only tools to reach the aspired target.

LIMITS OF APPLICATION

Because the expectations people put in environment-orientated techniques are very high, it is absolutely necessary, that the experts on the field of torrent control and defense lay emphasis on the fact, that such measures have distinct limits:

- **They cannot be used in torrents or torrent reaches, where debris flows may occur.**
- **They need definitely more space than mere technical countermeasures, therefore their application normally is very restricted in densely settled or urbanized areas.**

Accordingly it is very important to classify torrents or torrent reaches as “flood creeks”, “bedload-transporting torrents” or “debris-flow torrents”. With enough space for control works such techniques can be used for flood creeks and bedload-transporting torrents or comparable torrent reaches. In this connection we should not overlook the fact, that the characteristics of torrent reaches can be changed by upstream countermeasures (e.g. from a debris-flow reach to a flood reach with little or no sediment transport by the implementation of a debris retention basin).

GENERAL TARGETS

Environment-orientated control measures try

- to protect people and their activities from flood and sediment disasters as main goal **and**
- to diminish negative influences of defense works on environment and landscape as far as that secondary target can be reached without interfering with the main goal.

ORIENTATION TARGETS

Designing and implementing environment-orientated control measures has to take into account

- the ecology of running waters (especially of mountain streams)
- the special situation of each catchment
- the natural channel morphology
- the natural streambank and floodplain vegetation
- the special forms of natural or cultivated landscapes
- the demands of people for recreation
- the needs of preservation of endangered species

It is to emphasize, that

- normally not all of these targets can be reached and that they can also exclude one another.

REMARKS ON MOUNTAIN-STREAM ECOLOGY

Torrent control engineers normally know little of mountain-stream ecology, although a basic knowledge of that is essential for a successful planning and implementing of environment-orientated control works.

The ecosystem "mountain stream" is a principally open system without distinct boundaries to neighbored ecosystems.

Most important parts are:

- The water body,
- the channel including the banks,
- the hyporheic habitat, that is the gap system in the sediment of the channel bottom, connected with the groundwater
- the strips on both banks, which are influenced by the stream
- the plants and animals living there.

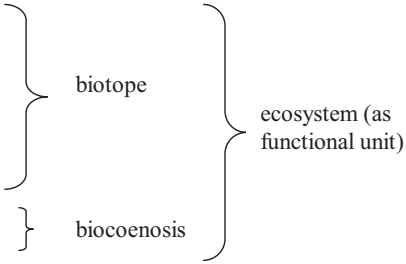

Fig. 1. shows schematically the interactions in a mountain-stream ecosystem.

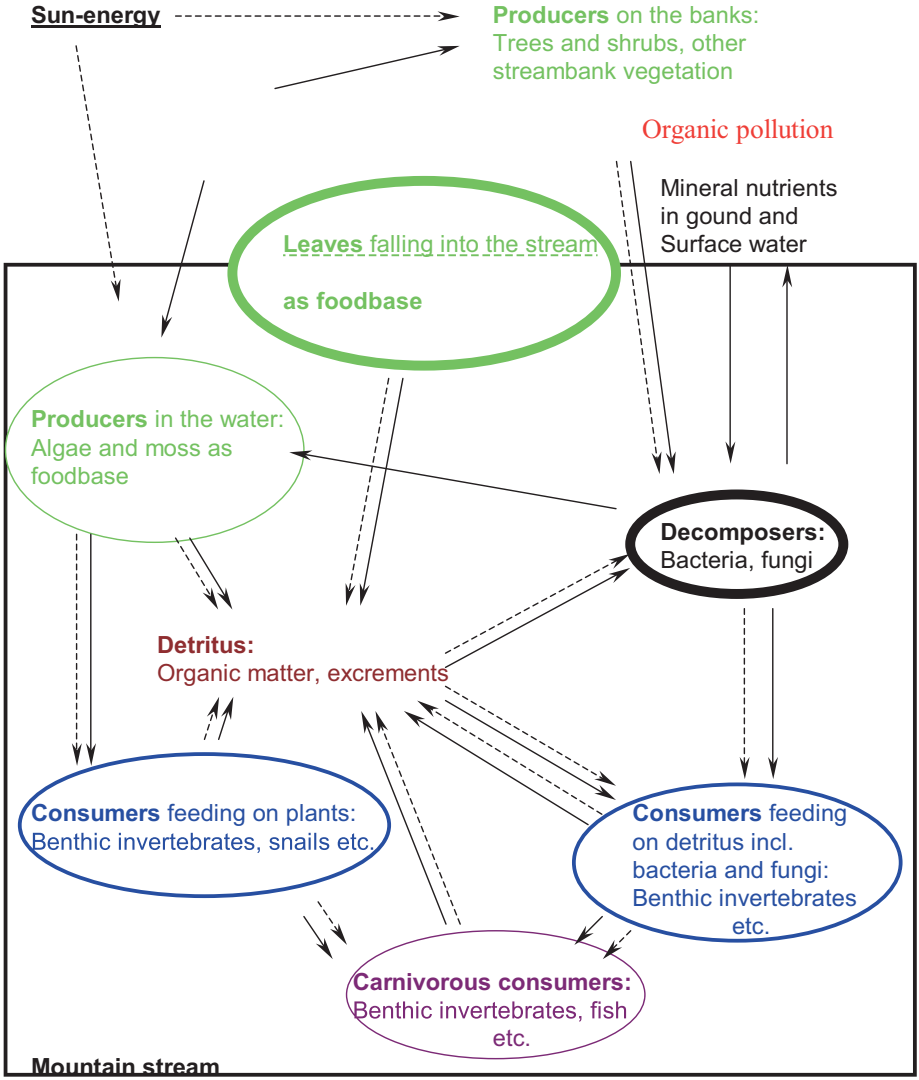

Fig. 1: Substance-transport and energy–flow in a mountain-stream ecosystem (HEUMADER 1985, modified).

Substance-transport
Energy–flow

There are three levels of substance transport and energy flow:

Producers (plants):
The most important foodbase in mountain streams are not algae as primary producers but leaves and plant particles falling from the streambank vegetation into the water.
Planting or preservation of streambank vegetation therefore is a very important part of environment-orientated control works (HEUMADER 1985).

Consumers (animals):
They are feeding either as primary consumers on algae, moss and detritus (e.g. benthic invertebrates) or live as secondary carnivorous consumers (e.g. benthic invertebrates, fish). They need richly structured banks and stream beds; most important is a natural, not fixed channel bottom, because most of them live in the gap system of the bed sediment (hyporheic habitat). Different current velocities, water depths, microhabitats etc. enhance the living conditions for subaquatic animals.

Fish need special conditions like different water currents and stillwater areas, different water depths and deep enough pools even in case of low water levels, suitable spawning sites and only low barriers with a concentrated low-water runoff, which do not hinder upstream migration.

Decomposers (bacteria and fungi):
They are decomposing not only dead organic matter especially leaves falling into the water, but also sewage in case of water pollution with the help of oxygen, therefore they play an important role for the self-purification ability of mountain streams. Decomposers need richly structured subaquatic surfaces on stones, dead wood, plants and roots to grow on or they live in the gap system of the bed sediment. Especially in case of purifying waste water they have a high need of oxygen, therefore the oxygen intake by the mixing of water and air in case of different currents and of water falling across sills and dams and plunging into pools is very important.

PRINCIPLES FOR ENVIRONMENT-ORIENTATED CONTROL WORKS

Torrent defense works in steep middle or upper reaches have certainly positive effects on the reaches downstream (also with regard to the ecosystems there), but normally they are and have to be above all technical constructions (consolidation dams, retention dams, debris-flow breakers etc.).

These principles therefore are formulated especially for regulation, channel and retention works in lower reaches, on alluvial fans and in redepositional reaches.

- **With regard to mountain-stream ecology:**

Principles and details for ecology-orientated torrent control measures have been published in Austria by HEUMADER (1978), MERWALD (1987, 1994) and VEREIN DER DIPLOMINGENIEURE DER WILDBACH- UND LAWINENVERBAUUNG ÖSTERREICHS (1994).

We have to accept the fact, that the implementation of control works will lead unavoidably to changed new bed structures and therefore new habitats (biotopes). If these man–made habitats are richly structured, nature will reconquer these heavily disturbed or new torrent reaches in a very short time. The unfounded statement of conservative limnologists, that all changes or disturbances by man in an uncontrolled stream reach have principally negative influences on its "ecological capability" cannot be accepted in this connection (HEUMADER 1995).

The following aspects are important:

- Natural, "open" streambed.
  If control of depth erosion is necessary, it should be done punctually by sills and low dams.
- Different channel widths, channel depths, bank inclinations and cross sections,
  resulting in different currents, water depths and sediment deposits.
- Natural bank development
  as far as possible. For that purpose defense measures against lateral erosion should be only punctual, for example by spurs or groynes, or only in especially endangered sections, e.g. outer curves of a channel.
- Use of natural building materials like stones and boulders, timber and plants as far as possible or additionally to technical measures for bank and channel protection works. For that purpose soil bioengineering with its well-tried methods is of great use.
- Structuring the stream channel
  using boulders, wood stumps and plants, but only if they cannot be negative obstacles in case of high-flood runoff.
- Planting structured streambank belts
  using streambank and floodplain tree and shrub species suited for the site. Some sections should be left bare to natural revegetation. Streambank vegetation is not only important as foodbase, but also because by shadowing mountain streams it prevents negative high water temperatures in case of low water runoff, because it is a habitat especially for insects and birds and because it functions as a buffer zone against intensively used agricultural areas and negative inputs of fertilizers, herbicides and others.
- Structuring sediment and debris retention basins
  by secondary channels, stillwater ponds, boulders, stone heaps and tree stumps despite the fact, that such structures will be destroyed by the next debris deposition. The basins should not be planted but left to natural revegetation.

- **Additional with regard to mountain-stream fishes:**

- Implementation of low-water level structures
  like channels or transverse structures with double sections
- Deep enough pools in case of low-water runoff
  They can be built artificially or are forming naturally downstream sills and dams, which should have no or deep-lying base protections for that purpose.
- No barriers for fish migrations
  Sills and other transverse structures should concentrate low-water runoff and not be higher than 0,3 – 0,8/1,0 m; this depends on the fish species. In some cases the building of slanting ramps instead of dams should be considered. Retention dams should be constructions with openings reaching down to the channel bottom.
- Installing fish passes (ladders) in case of too high check dams
  Such fish ways should be built by using the described techniques as far as possible.

- **With regard to landscape protection:**

- Design of control works according to similar natural streams or torrent reaches
  Typical forms and structures of natural stream sections (straight or meandering courses, braided sections, steep or gently inclined banks etc.) should be used as design models if possible.
- Planting or preserving shrub groups or tree groves near the channel
  in addition to the streambank vegetation
- Use of natural building materials as far as possible**.**
  Mere technical works and artificial building materials like concrete and steel should be used only if absolutely necessary or in combination with natural materials.
- Necessary technical constructions built of concrete or in combination with steel elements should not be too dominating.
  For that case special dam constructions should be used or they should be covered or hidden by soil, riprap or vegetation as much as possible.
- Characteristic landscape elements, either natural or originating from cultivation by man, should be preserved or reconstructed.
  Such structures and landscape elements are for example debris-flow lobes and boulders deposited by disasters of the past on stone heaps and rows originating from cultivating fields and meadows.
- Preservation or reconstruction of natural or artificial secondary channels, e.g. for sawmills, irrigation or other purposes. Sometimes such secondary channels can be adapted also as fishways.
- Preservation of old defense works of historical value
  Torrent defense works of historical value should be preserved as a sort of cultural heritage and integrated in new defense conceptions as far as possible.

- **With regard to recreation necessities:**

- Installing recreation facilities
  like walking paths and sitting places including information boards on the special mountain stream environment and control measures.
- Implementation of water playgrounds for children near and in the streambed.
  For that special purpose streambed adaptions with regard to children's safety are necessary.

- **With regard to wildlife preservation:**

- Preserving wildlife habitats of endangered species
  Sometimes natural streambeds and areas in the neighborhood are habitats for endangered plant or animal species. Control works should avoid such sites or try to reduce negative impacts as far as possible. Additionally it can be tried to enhance the conditions of endangered species by the implementation of special habitat structures and microsites. People should be kept off by densely planted brush belts or fences from such sites.

CONCLUDING REMARKS

Environment-orientated control works are without doubt of great importance because of urgent public demands on the one hand; on the other hand their possibilities and limits are tested each year on different sites in many countries. For the future an intensified exchange of experiences with such techniques is necessary to learn about their functional limits with the goal of further progress on that field.

Some possible solutions for channel works and retention basins are shown in the Fig. 2 – 8.

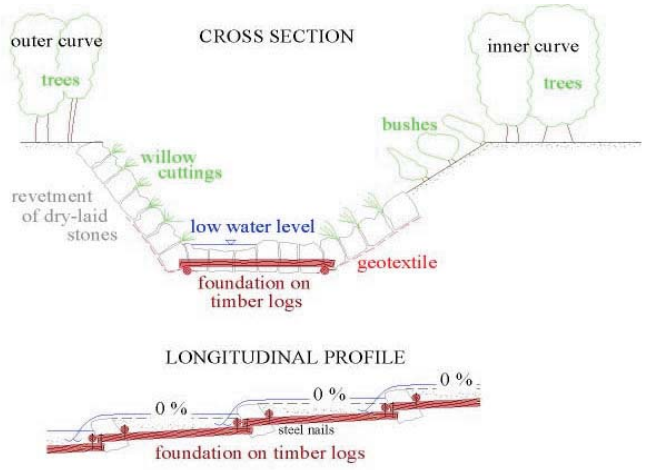

Fig. 2:
Environment-orientated channelwork for flood creeks and bedload–transporting torrents
Low sills of boulders and large stones, founded on and fixed by timber logs, nailed together.
Revetments of dry-laid stones, at the lower half underlaid by a geotextile to prevent outwash of fine material

Fig. 3:
Channelworks in a bedload-transporting torrent reach constructed after the method shown in Fig. 2 after some years with low runoff.
Remarks on environment orientation:
+ Stream bottom remains natural and the hyporheic habitat intact.
+ Use of natural building materials
± The banks are structured by stones, but are not left natural
+ Concentration of low-water runoff by irregular sill crowns
+ Different currents and water depths (step-pool-structure)
+ Sills can be jumped by fish
± Streambank vegetation of planted and natural origin, but not dense enough
+ Good oxygen intake by the water-air-mixture resulting from overfalling water

Fig. 4:
Channelwork controlling a small flood creek in a settled area. The stream bottom is fixed by low sills as shown in Fig. 2, the banks are protected by walls made of dry-laid stones.

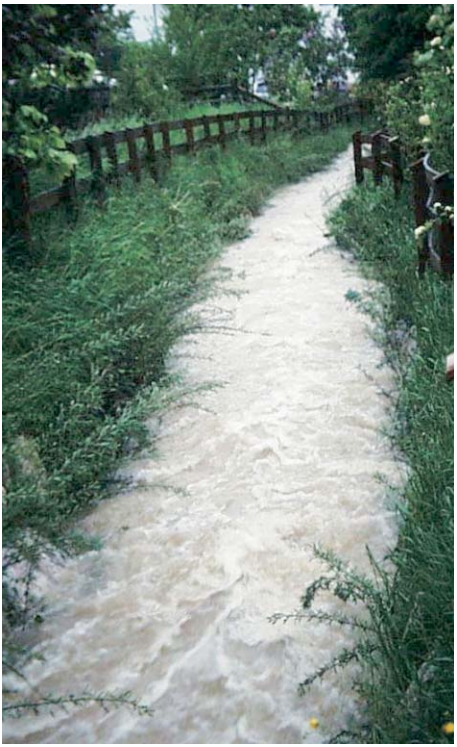

Fig. 5:
The same reach only 1 year later with high-flood runoff.

+ Dense streambank vegetation by fast-growing willows (*Salix sp.*)

Remarks on environment orientation:

+ Use of natural building materials (stones, timber, willow cuttings)
+ Structuring the bottom by wooden piles and small tree stumps
+ Different current patterns
+ Good fish habitat
± Unnatural steep stone walls on both banks, due to the restricted possibilities in the settled area

This reach has not only a good population of brown trout (*Salmo trutta f. fario*), but also of crayfish (*Astacus astacus*).

Fig. 6 and 7:
Debris retention basin shortly after excavation and 5 years later.
Remarks on environment orientation:
+ Structuring the basin by a small channel and two ponds
+ Creating a new habitat for stillwater and floodplain species
+ The basin bank slopes have been left unprotected
+ The basin has not been revegatated, resulting in a dense natural floodplain vegetation
+ Landscape improvement of the surrounding intensively used agricultural area
+ Only the outlet dam at the lower end of the basin is a technical construction

Fig. 8:
Widening of controlled channel adapted as playground for children
Remarks on environment orientation:
+ Recreation facility in the easily accessible stream bed
+ Stream bottom remains natural and the hyporheic habitat intact
+ Use of natural building materials
+ Rich structure by tree stumps embedded into the stream bottom
± The banks are structured by stones, but are not left natural

REFERENCES:

HEUMADER J. (1978): *Wildbachverbauung, Gewässerschutz und Fischerei.* Wildbach- und Lawinenverbau 1/1978.

HEUMADER J. (1985): *Die Bedeutung von Ufergehölz und Uferbepflanzung an Wildbächen*. Wildbach- und Lawinenverbau 100.

HEUMADER J. (1995): *Ist hohe "ökologische Funktionsfähigkeit) grundsätzlich an den "natürlichen Fließgewässerzustand" gebunden?* Österr. Wasser- und Abfallwirtschaft, 5/6, 47. Jhg.

MERWALD I. (1987): *Untersuchung und Beurteilung von Bauweisen der Wildbachverbauung in ihrer Auswirkung auf die Fischpopulation*. Forstl. Bundesversuchsanstalt Wien 158 (Bd. I und II), Österr. Agrarverlag.

MERWALD I. (1994): *Leitfaden für einen ökologischen Schutzwasserbau (Teil 1), Kriterien für die ökologische Bewertung von Schutzwasserbauten (Teil 2).* Fischereiverband I Krems.

VEREIN DER DIPLOMINGENIEURE DER WILDBACH- UND LAWINENVERBAUUNG ÖSTERREICHS – Hrsg. (1994): Wildbachverbauung und Gewässerökologie. Wildbach- und Lawinenverbau 58.