WP7

Pilot Case Study Monograph

Litzauer Schleife on Lech

Date
2011-07-5

Document version
v2

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SHARE - Sustainable Hydropower in Alpine Rivers Ecosystems
http://www.sharealpinerivers.eu
Project reference number: 14-2-3-IT
Priority 3 – Environment and Risk Prevention
Project duration : 36 months – 1/08/2009 – 31/07/2012

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Introduction

This monograph describes the pilot case study **Litzauer Schleife on Lech**. This case study aims to assess the hydropeaking effects on the fauna of one of a few last free flowing reaches of the Bavarian Lech. Litzauer Schleife has not only an outstanding ecological value, substantiated by its declaration to a Bavarian State conservation area and, as a constituent, to a NATURA 2000 Site of Community Importance (SCI) and Special Protection Area (SPA). It also represents the last unregulated river stretch within the Lech run-of-river hydropower cascade and has been originally reserved for the construction of a hydropower plant. The challenge of this study is to find an economically acceptable compromise between the needs of a hydropower production and mitigation alternatives aimed on the improvement of the ecological situation within the reach.

The monograph gives a general description of the whole Lech river catchment with its geological, land cover, climatic and hydrological characteristics. The emphasis lies however on the Bavarian part of Lech from the city of Füssen to Rain upon Danube (the so called Middle und Lower Lech), where Litzauer Schleife is situated. Detailed information on river quality, water uses, mitigation plans and WFD monitoring programs, specifically for the case study reach, is also given.

1. Pilot case study area

1.1 Geographic situation

The pilot case study **Litzauer Schleife** is an about 6 km long stretch of the Bavarian part of the river Lech. It represents the last unregulated reach within the Lech's hydropower cascade owned by the energy company E.ON. This cascade stretches over the nearly 100 kilometres of Lech's flow path from Füssen to Augsburg.

Figure 1. The view of Litzauer Schleife on Lech

The river Lech is a right tributary of the river Danube with a total length of 256 km. Originating in the northern Limestone Alps in Tyrol, Lech passes the Austrian-German border near the town of Füssen and joins the upper Danube east of Donauwörth (see **Figure 2**). Its largest tributary is the river Wertach with the confluence at Augsburg. The important cities on Bavarian Lech are Schongau, Landsberg and Augsburg.

The Upper (Austrian - Tyrolean) Lech to the Bavarian border at Füssen has a flow distance of 86 km and a catchment area of about 1200 km^2. For decades this region has been viewed as the last example of a natural and dynamic torrent landscape on the northern slopes of the Alps. The Bavarian

part of Lech is almost completely regulated for hydropower production and therefore shows a high degree of hydromorphological degradation.

Figure 2. River Lech catchment; case study reach Litzauer Schleife

1.2 Geological and land cover characterisation

Coming from the northern Limestone Alps, Lech runs through the Flysch zone, entering the area of the faulted Molasse sediments some kilometres northward of the geomorphological edge of the Alps and crossing the belt of the Pleistocene moraines and the gravel fields (see **Figure 3**). The substratum of the Lower Lech reaches is formed by sandy sediments of the Molasse trough [**GLA (1996)**].

The river Lech catchment basin is long and narrow with a maximum width of about 40 km and a total area of 3926 km². Northward from the town of Schongau up to Augsburg, the Lech has formed a terrace landscape by continuous incision into the Pleistocene gravel deposits.

According to CORINE 2000 (see **Figure 4**) the relevant part of the Lech catchment (from Füssen over Schongau to Landsberg) is mostly represented by pastures and agricultural lands with natural vegetation. Also, a large part of the catchment area is covered by forest. The region adjacent to the river reach Litzauer Schleife is a coniferous forest. Downstream from Landsberg to the confluence of Lech with Danube, the land cover changes, and more and more land is used for agriculture and industry.

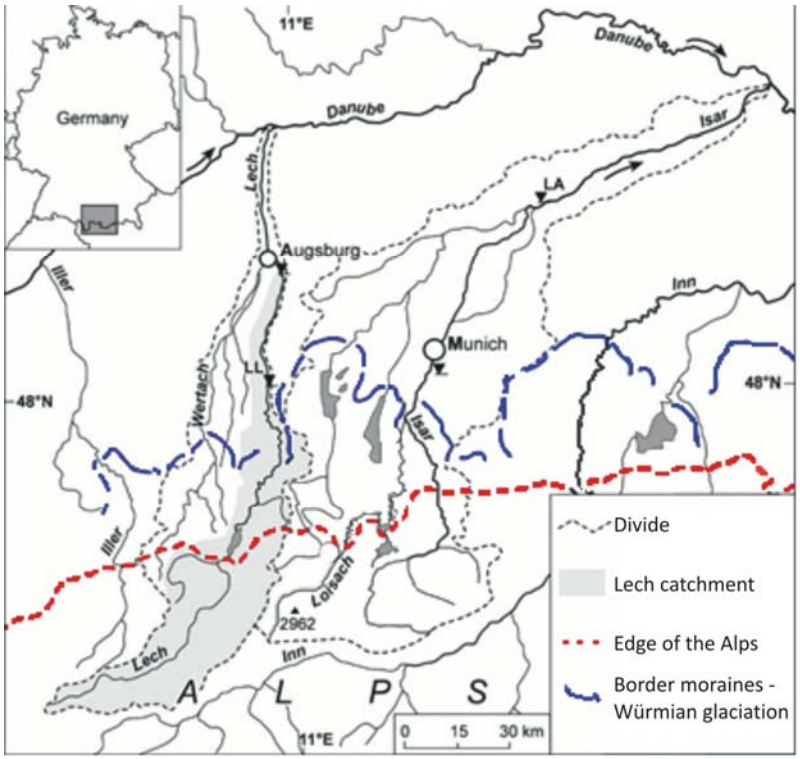

Figure 3. Geological situation in the river Lech catchment

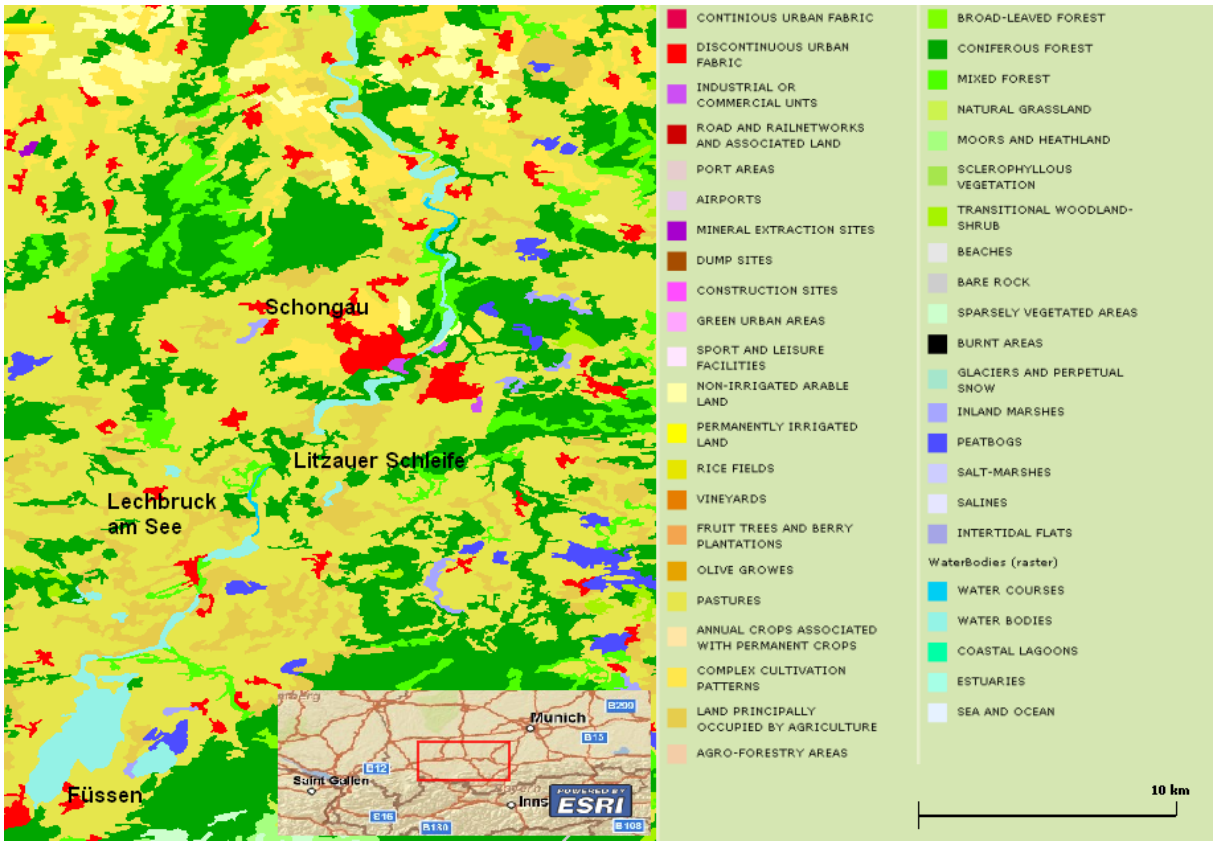

Figure 4. CORINE 2000 land cover situation in the region of the case study reach Litzauer Schleife

1.3 Climate

The climatic situation in the catchment area of Lech show the typical features of an alpine influenced climate with foehn and lee side effects on the one side and special geographical features stemming from different altitudes.

Precipitation

There is a large variation in precipitation within the Lech catchment. The average annual precipitation height in the Alpine part is about 1800 to 2500 mm, in the areas on the edge of the Alps about 1400 mm and in the northern lower part of the catchment (at the confluence with the Danube) only 700 mm.

Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Winter (Nov-Apr)	Summer (May-Oct)	Year
61	49	63	59	56	66	113	141	154	110	101	72	354	691	1045

Table 1. Average precipitation heights for the city Landsberg (587 a.s.l.), in mm.

It can be seen from **Table 1** that the average annual precipitation in the case study area of Litzauer Schleife for the period of 1931 to 1960 comprise 1045 mm and is slightly above the average value for Bayern – 900 mm.

Temperature

The temperature conditions are predetermined to a large extent by the altitudes and landscape structure. In the Alpine part of the Lech catchment the annual average temperature does not exceed the freezing point, whereas in the areas of the Alpine foothills it already comprises about 6.5°C and raises up to 8.0°C in the northern part of the catchment.

Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year
2.8	-1.2	-1.8	-0.2	2.8	5.9	11.3	14.3	16.1	15.7	12.4	7.2	7.1

Table 2. Average monthly air temperature near the city Landsberg (community Kaufering, 585 a.s.l., series 1968-1980), in °C.

Near Landsberg, around 20-30 days per year show a maximum temperature above 25°C, whereas nearly 110-120 days have their minimum temperature and about 30-40 days their maximum temperatures below the freezing point.

1.4 Hydrology

The mean annual course of Lech's runoff is dominated by the Alpine part of the catchment. It is characterised by snow accumulation during winter and snowmelt runoff in spring and early summer, leading to a snowmelt-related runoff regime. Because high totals of precipitation are accumulated in the upper part of the basin during winter, severe winter floods are rare on Lech.

The Bavarian part of Lech is fully developed for hydropower production. Consequentially, the hydrological situation in the Lech basin below Füssen is shifted to a considerable degree from a natural situation. An important Lech's hydropower chain component – the head reservoir Forggensee with an active storage of 135×10^6 m^3, in operation since 1954 – provides the flow regulation on the annual basis. Although the Alpine character of Lech's runoff is not completely altered now, the annual distribution of monthly discharges is shifted to insure the needs of hydropower production, recreation and provide flood protection. The distribution of monthly discharges before and after construction of the head hydropower station Roßhaupten is shown in **Figure 5**. It can be seen that the regulated average discharges of May and June are reduced and those of December to April are considerably increased in comparison to the natural flow situation.

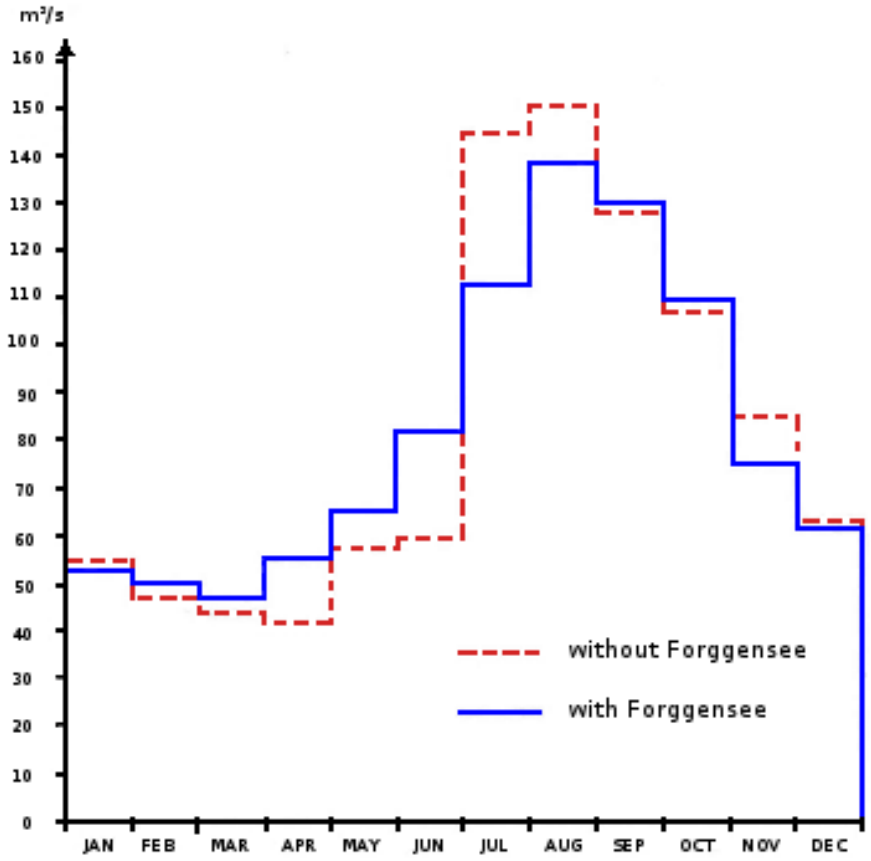

Figure 5. Average monthly discharges of Lech by Landsberg before and after construction of the head reservoir Forggensee, 1901-1953 and 1954-1980 time series.

One of the operational rules applied to Forggensee foresees that the water surface elevation in the period from 15th of June to 30th of September is not allowed to fall below 781.0 m a.s.l due to recreational needs. This constraint results in a relatively small volume of 15.4×10^6 m^3 that can be used for flood protection, thus the influence of Forggensee on high water discharges can be seen only for events up to 10 year probability (see **Table 3**).

Flood probability	1	2	5	10	20	50	100
Q without Forggensee, m^3/s	550	660	800	900	1050	1250	1400
Q with Forggensee, m^3/s	370	410	550	800	1050	1250	1400

Table 3. Flood discharges at Landsberg before and after construction of the head reservoir Forggensee.

Another operational rule regulates minimum flow discharges due to downstream sanitary requirements. It requires releasing 75 m^3/s or the total inflow to the reservoir on a mean daily basis, whichever is smallest [**Harboe (1976)**]. It should be noted here, that this restriction does not hinder the energy producer to perform hydropeaking flow regulation with discharges varying from 10 to 150-160 m^3/s during a day.

The nearest reference gauge for Litzauer Schleife is the discharge measuring gauge below the hydropower station Urspring at river kilometre 143 thus situating about 6 km upstream to the study reach. Unfortunately the flow rates from this gauge cannot be taken directly for the case study, as the operation of the hydropower station Dessau at km 140 and inflow of the Illach at km 139.8 deform the

hydrograph. The nearest flood prediction gauge Lechbruck lies at river kilometre 147.1 and accounts for the discharge/water surface elevation series from the year 1951.

1.5 Bed-load and suspended matter transport

The *bed-load transport* of Bavarian Lech in the 20th century undergoes continuous changes, determined by river correction measures and construction of weirs and hydropower stations. The estimated annual bed-load yield of Lech at Füssen in 1950 comprises about 140 000 m^3/year [**Bayer. Landesamt für Wasserwirtschaft (1984)**]. Later this number was corrected to 110 000 m^3/year. Since 1966 the bed-load volume is reduced to a maximum of 70 000 m^3/year due to gravel removal at Weißhaus near the Austrian-German border. Additionally, since 1954 measures are taken to detain and remove the incoming bed-load at the inflow area of the head reservoir, thus keeping Forggensee free from sedimentation.

The bed-load volume at Landsberg in the years 1922-1927 comprised about 78 000 m^3/year. Since 1867 up to 1937 numerous river correction works between Landsberg and Augsburg aimed on land reclamation and flood protection were undertaken. These measures together with the construction of the Lech hydropower chain tremendously altered the bed-load regime of the river. Its high transport capacity now can only be saturated through the gravel entrainment from the own bed deposits. This results in high bed erosion rates with the corresponding deepening of the river bed.

Suspended matter measurements are performed on Lech at Füssen since 1924. The average annual volume comprises about 230 000 m^3/year for the period from 1924 to 1979. Nearly 60% of this volume is detained in Forggensee. Extreme values of 46 000 and 720 000 m^3/year suspended matter were registered in 1960 and 1970 correspondingly. For the period 1954-1979, the suspended matter related to the sedimentation of Forggensee comprised about 5.5x10^6 m^3. According to [**Bayer. Landesamt für Wasserwirtschaft (1984)**], sedimentation due suspended matter has not yet shown any adverse effects on the hydropower chain operation (status 1984).

1.6 River quality

The river quality data review for the Litzauer Schleife is based on the on-line materials and maps of the Bavarian Environment Agency (http://www.lfu.bayern.de/index.htm), in particular, on the WFD inventory of 2004 and subsequent status appraise dated 2009. Additional information concerning composition and abundance of fish and macrozoobenthos fauna is taken from the detailed study about hydropeaking effects for Litzauer Schleife of Schnell [**SCHNELL (2005)**].

WFD river topology

Due to its unique morphological characteristics and essential distinction to the upstream and downstream reaches, Litzauer Schleife is a standalone river unit according to the Bavarian water bodies' classification. The length of the water body is 6.1 km and it belongs to a *Type 4 – Large Rivers of the Alpine Foreland* (German: *Große Flüsse des Alpenvorlandes*) [**LAWA (2003)**]. To this type belong rivers of the Alpine Foreland at altitudes from 200 to 800 m a.s.l., where *Large Rivers* are those with a catchment area of 1000 to 10 000 km^2. Litzauer Schleife has the status of a not significantly modified water body (see Appendix 1).

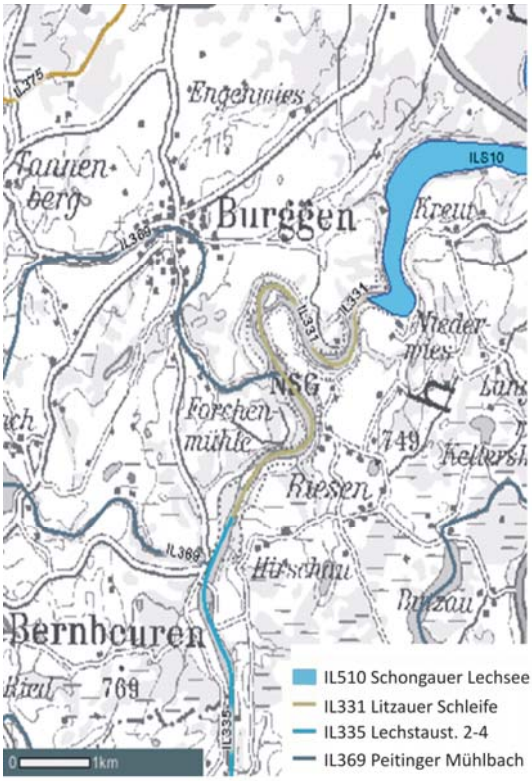

Figure 6. Litzauer Schleife and adjacent water body units

Upstream from Litzauer Schleife a river unit of about 14 km in length is defined – *Lechstaustufen 2-4.* Although of the same topological type as Litzauer Schleife, it has the status of a heavily modified water body. The downstream reach unit *Schongauer Lechsee* with a 210.1 ha water surface area is represented by a storage reservoir of the hydropower station Dornau and is also classified as a heavily modified water body.

WFD river quality

According to the profile of Litzauer Schleife acquired during the WFD inventory in 2004, the following ecological units are expected to reach a good ecological status:

- *Trophy*
- *Saprobic index*
- *Pollutants – chemical and ecological status*

For the category *hydromorphology* however the achievement of a good ecological status is unlikely [**Kartendienst Gewässerbewirtschaftung Bayern**] (see also Appendix 1. River unit profile Litzauer Schleife).

In 2009 the status of Litzauer Schleife for the following components comprised:

- Chemical quality: good
- Ecological quality: moderate
  with components:
  - Macrophytes and phytoplankton: very good
  - Macrozoobenthos – module saprobic index: good
  - Macrozoobenthos – module general degradation: good
  - Fish fauna: moderate
  - Specific pollutants: good

The colour legend for the status assessment of quality components is defined as follows:

Composition and abundance of invertebrate fauna

According to the WFD inventory with the PERLODES system [**Kartendienst Gewässerbewirtschaftung Bayern**], the reach Litzauer Schleife has following characteristics:

Macrozoobenthos – module saprobic index: good

Macrozoobenthos – module general degradation: good

The study of Schnell [**SCHNELL (2005)**] shows a general tendency towards a reduction of macrozoobenthos abundance and species richness for the Litzauer Schleife in comparison to the reference reach not affected by hydropeaking. This trend is especially pronounced in a fluctuation zone, i.e. the area which is not permanently wetted during the hydropeaking event. The lowest macrozoobenthos biomass was found in this area. Only some specialists accustomed to such conditions can survive in this zone, what is reflected also in the general species poorness in this region. Additionally, a reduction of macrozoobenthos biomass in the deep channel was found that can be related to relatively high flow velocities resulting in mobilisation of bottom sediments and thus very unfavourable conditions for benthos species. Moreover, such hydraulic conditions result in the disappearance of algae which stays in close relation with macrozoobenthos abundance and species richness.

Composition and abundance of fish fauna

The case study reach Litzauer Schleife belongs to the grayling (Thymallus thymallus) fish region according to the German ecological classification of flowing waters. This region belongs to the Hyporhithral and is characterised by relative high flow velocities and oxygen content, more aquatic plants as in the trout region, water temperatures up to 15° C, and sediments consisting of medium or large gravel. The indicator fish species for this region are brook lamprey [Lampetra planeri], chub [Leuciscus cephalus], dart [Leuciscus leuciscus] and Atlantic salmon [Salmo salar].

According to the fish catch results of 2003 [**SCHNELL (2005)**], eight fish species were found in the Litzauer Schleife: grayling, Danube salmon, brown trout, bullhead, European eel, rainbow trout, chub and pike.

Five of them have the following status in the red book list of endangered species or in the FFH species as listed in the table:

Fish species	Endangerment status Red List	FFH Status
Grayling	Lc	Yes
Danube salmon	En	Yes
brown trout	Lc	-
bullhead	Lc	Yes
European eel*	Cr	-

*not typical for the grayling region

Legend (IUCN Red List of Threatened Species, Version 3.1):

lc = least concern,

en = endangered,

cr = critically endangered.

In general, according to the study of Schnell [**SCHNELL (2005)**], the river reach fish fauna:

- shows a low species diversity (Simpson index = 0.51) with tendency to an increasing monotony;

- shows a shift in community composition with a strong dominance of two species (grayling and bullhead) (Community Dominance Index = 85.9 %). A shift in the age structure of the indicator species reflects the unacceptable conditions during hydropeaking events, especially for the young fish stadiums;
- potential fish species like barbel, dart, ide and smaller species like spirlin, common minnow and stone loach, that could be expected in the reach due its high structural quality, could not be found in Litzauer Schleife. All these species were present in Lech before the construction of the hydropower chain [**Bayer. Landesamt für Wasserwirtschaft (1984)**:].

The total estimated fish biomass is much less than its potential having in mind the high structural quality of the Litzauer Schleife. Some reasons for this:

- additional pressure from external and internal predators (birds and mammals) due hydropeaking effects (continual drying and flooding).
- negative effects of hydropeaking on spawning and young fish.

According to the integral biological parameter "Fish" estimated according to the WFD related monitoring method fiBS [**Kartendienst Gewässerbewirtschaftung Bayern**], the Litzauer Schleife has a status of moderate.

River continuity

River continuity of Lech in the case study area is completely disturbed, as the hydropower stations and weirs on Lech, except one, do not have fish passes or similar constructions (see **Table 4**). Additionally, the missing bed-load inflow due to detainment in the head storage reservoir results in a deep bed erosion of the downstream river reaches and consequentially the degradation and disappearance of spawning grounds for fish.

2. Plans and management programs

2.1 Existing management plans and application rules

A number of management plans apply directly to the Litzauer Schleife reach. Thus, it:

- has been declared to the Bavarian state conservation area "Lechabschnitt Hirschauer Steilhalde - Litzauer Schleife" according to BNatSchG in 1986;
- constitutes a part of the NATURA 2000 Special Protection Area (SPA) "Mittleres Lechtal" (Code 8031-471, see **Figure 7** where the borders of the SPA within Litzauer Schleife are shown)
- and a part of the NATURA 2000 Site of Community Importance (SCI) "Lech zwischen Hirschau und Landsberg mit Auen und Leiten" (Code 8131-371, see **Figure 8** where the borders of the SCI within Litzauer Schleife are shown)

Indirectly, the situation in the reach will depend on the following management programs:

- Bavarian strategic management concept for the biological connectivity (German: Strategisches Gesamtkonzept Durchgängigkeit Bayern).
- The program aimed on restoration of gravel spawning grounds (German: Die Restaurierung von Kieslaichplätzen).

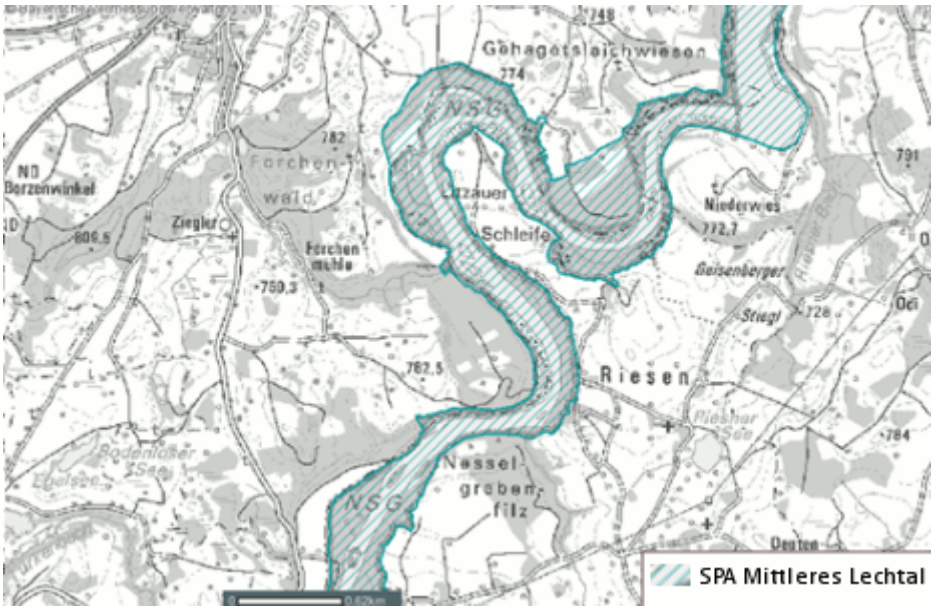

Figure 7. The borders of SPA "Mittleres Lechtal" in the area of Litzauer Schleife

Figure 8. The borders of the SCI "Lech zwischen Hirschau und Landsberg mit Auen und Leiten" in the area of Litzauer Schleife (coincide with the borders of the conservation area).

2.2 Monitoring programs

Since 2007 the Litzauer Schleife is a point of an operative WFD monitoring (monitoring point N 3010). The biological components "Fish", "Macrophytes and Phytobenthos" and "Macrozoobenthos" are monitored here. The next upstream from Litzauer Schleife monitoring point on Lech is situated immediately below the hydropower station Dessau (river kilometre 140.0) and is also an operative monitoring station with components "Macrophytes and Phytobenthos" and "Macrozoobenthos". The next downriver station is situated below the Landsberg at a river kilometre 84.6 and is used only for monitoring of the "Fish" biological component.

3. Water uses

3.1 Hydropower exploitation

Hydropower production is the major water use of the river Lech that is almost completely regulated in its German section. The case study reach Litzauer Schleife situates in the domain of the E.ON

Wasserkraft Company, which owns twenty-two run-of-river plants and one storage power station on the Lech from Füssen to Augsburg (see **Figure 9**). This hydropower chain generates about 1,162 GWh of electricity per year on the back of an aggregate output of 258 MW. The hydropower stations on Lech below the city of Augsburg belong to two other companies – LEW (Lechwerke AG) and RMD (Rhein-Main-Donau AG) and have a total of 70 MW installed capacity. In **Table 4** the major characteristics of hydropower plants and weirs on the Middle and Lower Lech from Füssen to Rain are given. It can be seen that only one plant – HP Kinsau built in 1992 – is equipped with a fish pass, thus the longitudinal connectivity of Lech is completely broken up having a tremendous effect on the river ecosystem.

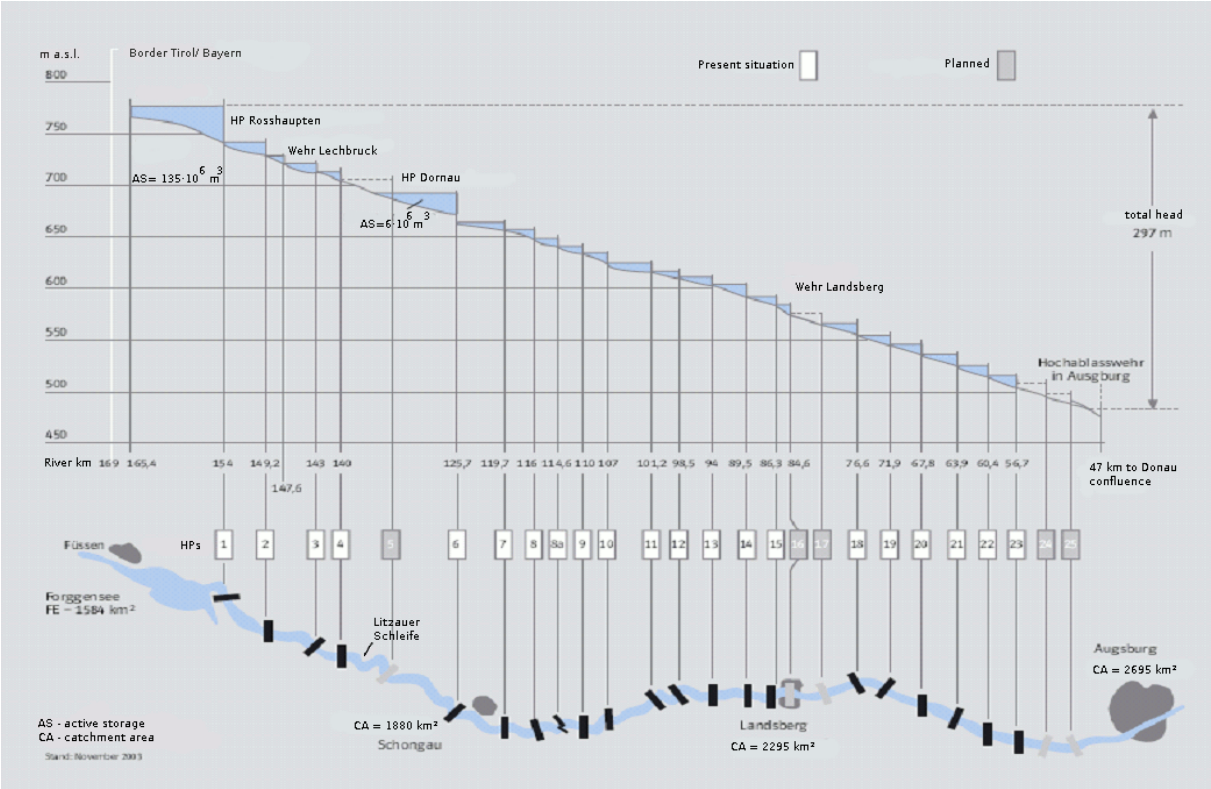

Figure 9. E.ON hydropower chain on Lech between Füssen and Augsburg

HP Station/ Weir	Name	River km	Type	Reservoir level m a.s.l.	Fish pass	Head m	Installed capacity MW	Owner
HP	Füssen-Horn	164.5	run-of-river	786.6		6.1	5.0	AÜW
HP 1	Roßhaupten	154.0	storage HP	780.5		35.4	45.5	E.ON
HP 2	Prem	149.3	run-of-river	745.6		15.2	19.2	E.ON
HP	Lechbruck	147.1	channel HP	730.0		-		AÜW
HP 3	Urspring	143.0	run-of-river	722.0		8.2	10.1	E.ON
HP 4	Dessau	140.0	run-of-river	713.0		8.5	10.3	E.ON
HP 5*	Litzauer Schleife	133.5	planned	-		-		-
HP 6	Dornau	125.7	run-of-river	694.0		19.0	16.6	E.ON
HP 7	Finsterau	119.7	run-of-river	667.0		8.0	7.7	E.ON
HP 8	Sperber	116.0	run-of-river	659.0		7.5	7.2	E.ON
Weir	Kinsau Weir	114.4	weir					
HP 8a	Kinsau HP	114.6			yes	6.5	1.1	
HP 9	Apfeldorf	110.0	run-of-river	642.0		7.0	7.2	E.ON
HP 10	Epfach	107.0	run-of-river	635.0		9.0	8.3	E.ON

HP 11	Lechblick	101.2	run-of-river	626.0		8.0	8.1	E.ON
HP 12	Lechmühlen	98.5	run-of-river	618.0		9.0	7.9	E.ON
HP 13	Dornstetten	94.0	run-of-river	613.0		8.0	8.2	E.ON
HP 14	Pitzling	89.5	run-of-river	601.0		8.0	7.9	E.ON
HP 15	Landsberg	86.3	run-of-river	593.0		8.0	7.8	E.ON
Weir	Karolinenwehr	84.6	weir	584.0		-		-
HP 16*	Landsberg	84.6	planned	-		-		-
HP 17*	Landsberg	80.6	planned	-		-		-
HP	Mülbach							
HP 18	Kaufering	76.6	run-of-river	569.5		13.3	16.7	E.ON
HP 19	Schwabstadl	71.9	run-of-river	555.9		9.6	12.0	E.ON
HP 20	Scheuring	68.2	run-of-river	546.0		10.0	12.2	E.ON
HP 21	Prittriching	63.7	run-of-river	536.1		9.9	12.1	E.ON
HP 22	Unterbergen	60.4	run-of-river	526.2		9.9	12.2	E.ON
HP 23	Merching	56.7	run-of-river	516.3		8.3	12.0	E.ON
Weir	Augsburg	-	weir	-		-		-
HP 24*	Kissing	53.8	planned	-		-		-
HP 25*	Augsburg-Siebenbrunn	50.6	planned	-		-		-
HP 26*		47.8	planned					
Weir	Augsburg-Hochzoll	47.0	weir	486.0		5.7		-
HP	Eisenbahnerwehr-Augsburg	45.6	run-of-river	476.8		6.0	3.2	LUWA Energie GmbH
Weir	Wolfzahnauwehr-Augsburg	40.7	weir	-		5.7		-
Weir	Gersthoferwehr-Augsburg	37.3	weir	457.0		4.0		LEW
HP	Gersthofen	3 (Lech Channel)	channel HP	456.0		9.5	10.0	LEW
HP	Langweid am Lech	9 (Lech Channel)	channel HP	446.0		7.2	7.1	LEW
HP	Meitingen	14 (Lech Channel)	channel HP	438.0		12.5	11.8	LEW
HP	Ellgau	17.1	run-of-river	426.0		8.3	10.0	RMD
HP	Oberpeiching	11.5	run-of-river	416.0		8.4	12.3	RMD
HP	Rain	6.1	run-of-river	408.0		8.1	11.2	RMD
HP	Feldheim	1.3	run-of-river	400.0		6.8	8.5	RMD

Table 4. Characteristics of hydropower stations and weirs on Lech from Füssen to Rain.

The pilot case study reach Litzauer Schleife represents the last quasi natural river section within the E.ON hydropower chain. The construction of HP 5 at river kilometre 133.5 was given up due to the declaration of the reach as a conservation area in 1986. Although not impounded and unregulated, the reach cannot be referenced as intact or free flowing: its hydrological regime is completely altered due to the hydropeaking operation of the chain. Additionally, the river continuity interruption results in the cut off of natural sediment inflow and respective degradation of the gravel bed.

The E.ON hydropower production scheme on Lech operates as following. The head reservoir Forggensee with the storage station Roßhaupten at river kilometre 154.0 provides an annual / daily flow regulation [**BAWAG (1988)**]. Its operation is determined by hydropower production optimisation as well as recreation and flood protection restrictions (see also 1.4). The stations below Roßhaupten are all run-off-river plants with small daily regulation reservoirs. The end storage plant HP Merching at river kilometre 56.7 performs and contra daily regulation to smoothen the hydropeaking discharges of

Lech below Augsburg. The missing HP 5 in Litzauer Schleife hampers the optimal energy production of the chain as its not impounded reach delays the flow wave on the way downstream.

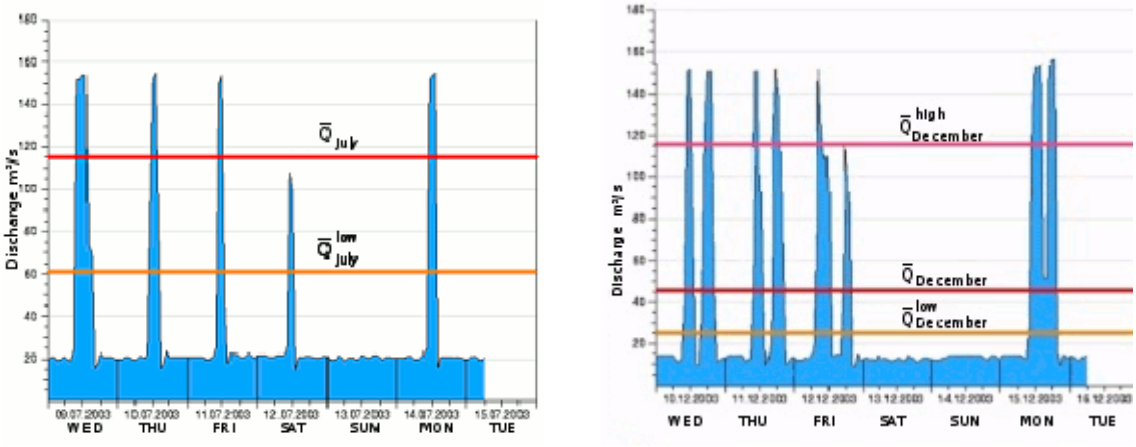

Figure 10. The typical summer und winter discharge situations during hydropeaking operation on Lech in 2003 [Schnell (2005)]

The upstream station to the Litzauer Schleife is HP 4 Dessau built in 1967 at river kilometre 140.0. The downstream station HP 6 Dornau built in 1960 situates at river kilometre 125.7. The stations account for an installed capacity of 10.3 and 16.6 MW respectively. Like most of the Lech plants, both of them have no fish pass or similar construction.

The typical discharge regulation situation in year 2003 for study reach is shown in **Figure 10**. It can be seen, that the base flow discharges in summer and winter are restricted to 20 m^3/s and 10 m^3/s respectively. The maximum hydropeaking flows exceed 150 m^3/s, both in winter and summer. In winter, two discharge peaks per day are usual.

3.2 Farming

The wetlands and scarps of Lech by Litzauer Schleife constitute a part of the NATURA 2000 Site of Community Importance (SCI) “Lech zwischen Hirschau und Landsberg mit Auen und Leiten“. Among other aims, the very vulnerable and species-reach nitrogen-poor swards and anthropogenic heathlands have to be protected and conserved. One of the approaches to maintain them is to reactivate traditional nomadic shepherds what experience nowadays a real revival. The so called “Lechtal Lamb” finds a great success on the market.

3.3 Factory

Among industry, an UPM factory Schongau as the one of world wide largest paper recycling factories is of mention. The historical timber rafting has receded in importance since the beginning of the 20th century and disappeared completely in 1935.

3.4 Waste discharges

Waste water treatment stations in the close proximity to Litzauer Schleife study reach together with chemical water quality (status: good) are shown in **Figure 11**. The relevant stations upstream from Litzauer Schleife have following capacities (inhabitants number):

LECHBRUCK ALT (Lech)	7000
AV LECHBRUCK-BERNBEUREN (Lech)	11000
BURGGEN (Peitinger Mühlb.)	2000

Figure 11. Waste water treatment plants in the area of the case study and chemical quality of flowing waters (status: good).

3.5 Drinking water

There are no drinking water supply points within the Litzauer Schleife reach itself. In the close proximity to the river on the right looking downstream there are two drinking water protection areas: Steingaden with an area of around 52 000 m^2 and Peiting M with an area of 720 000 m^2 (see **Figure 12**).

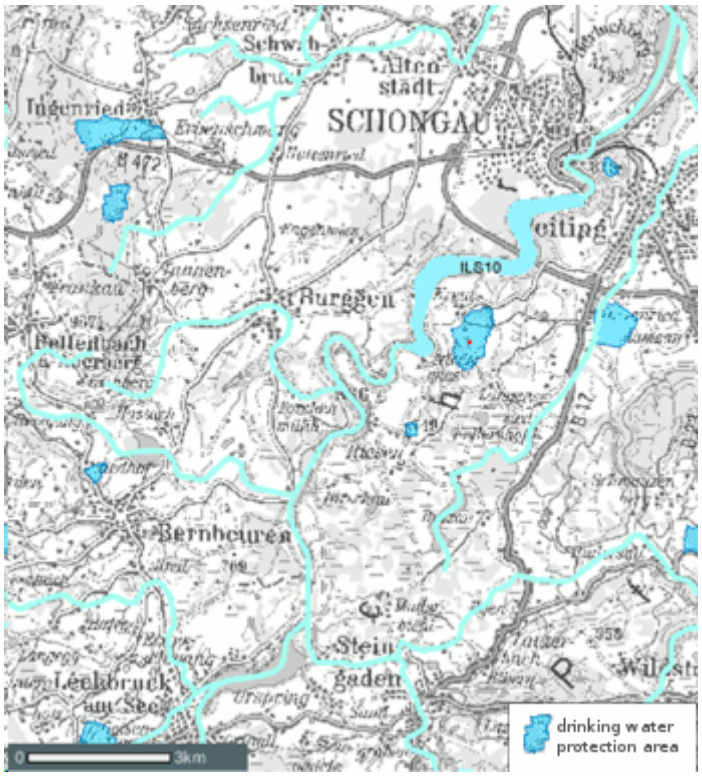

Figure 12. Location of drinking water protection areas in the case study area.

3.6 Touristic fruition

Besides the number of touristic attractive cities such as Schongau, Landsberg and Augsburg, the landscapes along the river with well developed bike paths and nature conservation areas are favoured by tourists. Kayak is also very popular on Lech. Due to the restrictions of a nature conservation area, the gravel banks and islands are off limit for tourists. Rafting is allowed only when shallow water zones are avoided.

3.7 Fishing

Up to the 19th century as the main source of food supply for much of the population, fishing has lost its importance almost completely. As the main reason for this, Lech (and Danube) regulation for hydropower and flood protection, but also timber rafting and water pollution in general can be named. At present in some areas fishing is prohibited to ensure the conservation of the remaining species.

4. Restoration and mitigation actions

4.1 Mitigation of hydropeaking effects

In respect to the Water Framework Directive obligations there is an urgent need to reconsider the discharge situation in the Litzauer Schleife.

Alternative hydro peaking schemes aimed on reduction of negative effects on flora and fauna by means of

- increasing the basic discharge,
- reduction of maximum (peak) discharges and
- optimisation of daily discharge variation

should be developed and assessed. Despite its urgency, definite measures aimed on an improvement of the hydromorphological situation are not in the management catalogue for Litzauer Schleife.

4.2 Restoration of river connectivity

The large problem of Bavarian Lech is the interruption of habitat connectivity. In the study of [**BNGF (2009)**] an assessment of migration barriers and suggestions on improvement of habitat connectivity is done for all major tributaries of Danube. In present, only the one Lech hydropower station – HP Kinsau - has a fully functioning fish passage. For another two stations Merching and Kaufering the plans of fish passages already exist. To improve the situation in particular for Lech this study suggests the following measures:

- Installation of technical fish passages on at least 15 HP stations.
- Reconnection of Lech tributaries accounting for the strongly varying water levels as a result hydropeaking.

4.3 Restoration of spawning grounds

The long tradition of hydropower use of Lech resulted in complete interruption of not only ecological river connectivity but also of a natural sediment transport regime of the river. All incoming bed load from Alps is dumped in the Forggensee resulting in erosion of a river bed in downstream river reaches. Litzauer Schleife as a one of the last free flowing Lech reaches is affected as well in this respect. Considerable areas of uncovered tertiary “Flinz” can be observed nowadays within the reach.

The loss of gravel has a negative effect on fish resulting primarily in degradation or complete disappearance of spawning grounds. Mitigation measures aimed on reconstruction of spawning grounds are initiated by the [**Landesfischereiverband Bayern E.V**. (2007)]. Unfortunately these newly installed spawning grounds usually get eroded again after 3 to 5 years and cannot help to solve this problem sustainably.

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Appendix

Appendix 1. River unit profile Litzauer Schleife

(source: Bavarian Environment Agency, status from 22.12.2009)

Flusswasserkörper (FWK) Code	Bezeichnung
IL331	Litzauer Schleife

Beschreibung des Flusswasserkörpers

Einstufung Flusswasserkörper	Nicht erheblich veränderter Wasserkörper
Länge Fließgewässer gesamt [km]	6,1
- Länge Gewässer 1. Ordnung [km]	6,1
- Länge Gewässer 2. Ordnung [km]	-
- Länge Gewässer 3. Ordnung [km]	-
Größe unmittelbares Einzugsgebiet des FWK [km²]	7
Biozönotischer Gewässertyp	Typ 4: Große Flüsse des Alpenvorlandes
Fischfaunistisches Vorranggewässer	ja
Fischgewässer (gemäß Bayer. Fischgewässerqualitätsverordnung)	teilweise
EU-Badestelle(n)	nein
Entnahme von Wasser für den menschlichen Gebrauch	nein

Gebiete, in denen der Flusswasserkörper vollständig oder anteilig liegt

Flussgebietseinheit	Donau
Planungsraum	IL: Iller-Lech
Planungseinheit	IL_PE02: Mittlerer und Oberer Lech / Wertach
Regierung	Oberbayern
Gemeinde/Stadt (Länge Gewässer 3. Ordnung mit Unterhaltungslast bei der jeweiligen Kommune in km)	Peiting (-), Steingaden (-)
Amtsbezirk Wasserwirtschaftsamt	Weilheim

Zusammenhang mit NATURA 2000

NATURA 2000-Gebiet(e) mit funktionalem Zusammenhang zum Flusswasserkörper		
Gebietsnummer	**Bezeichnung**	**FFH/SPA**
8031-471	Mittleres Lechtal	SPA

8131-371	Lech zwischen Hirschau und Landsberg mit Auen und Leiten	FFH

Ergebnisse der Bestandsaufnahme

(Einschätzung der Zielerreichung im Rahmen der Bestandsaufnahme 2004)

Trophie	Zielerreichung zu erwarten
Saprobie	Zielerreichung zu erwarten
Hydromorphologie	Zielerreichung unwahrscheinlich
Schadstoffe - ökolog. Zustand	Zielerreichung zu erwarten
Schadstoffe - chem. Zustand	Zielerreichung zu erwarten

Zustand des Flusswasserkörpers

(Bewertung für den 1. Bewirtschaftungsplan: Datenstand Mitte 2009)

Chemischer Zustand	Gut
Ökologischer Zustand	Mäßig
Zuverlässigkeit der Bewertung zum ökolog. Zustand	Hoch
Ergebnisse zu Qualitätskomponenten des ökologischen Zustands	
Phytoplankton	Nicht relevant
Makrophyten & Phytobenthos	Sehr gut
Makrozoobenthos - Modul Saprobie	Gut
Makrozoobenthos - Modul Allgemeine Degradation	Gut
Fischfauna	Mäßig
Schadstoffe	Gut

Umweltzielerreichung für den Flusswasserkörper

Guter chemischer Zustand	erreicht
Guter ökologischer Zustand	voraussichtlich bis 2015 erreicht

Maßnahmen (gemäß Maßnahmenprogramm)

Code (lt. LAWA)	**Geplante Maßnahme**
Belastung: Punktquellen	
	keine
Belastung: Diffuse Quellen	
	keine
Belastung: Wasserentnahmen	
	keine
Belastung: Abflussregulierungen und morphologische Veränderungen	

* Maßnahme mit Synergien für Ziele des/r NATURA 2000-Gebiets/e

** Maßnahme gemäß Managementplan zur Zielerreichung des/r NATURA 2000-

Gebiets/e		
64	Maßnahmen zur Reduzierung von nutzungsbedingten Abflussspitzen	*
72	Maßnahmen zur Habitatverbesserung im Gewässer durch Laufveränderung, Ufer- oder Sohlgestaltung inkl. begleitender Maßnahmen	*
78	Maßnahmen zur Reduzierung der Belastungen infolge von Geschiebeentnahmen	*
Belastung: Andere anthropogene Auswirkungen		
	keine	
Konzeptionelle Maßnahmen		
501	Mögliche Maßnahmen zur Durchgängigkeit: siehe "Strategisches Durchgängigkeitskonzept Bayern"	
501	Abstimmung mit Managementplänen zu Natura 2000-Gebieten	