NOT ANY RESIDUAL WATER ROUTES AT THE POND SYSTEMS

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ABSTRACT

Declining fishing returns from the world's oceans are stimulating interest in the production of fresh water fish and the building of the associated pond systems. Increasing temperatures are constantly reducing watercourse water volumes but also causing evaporation of diversion route residual water. Diversion routes should therefore be minimized and if possible avoided, not least to allow fish free passage throughout the ecotope and their ascent – also in residual water stretches – without fish ladders. The author has developed a method to fill and sustain the level of ponds - at least medium-sized ones – avoiding so-called residual water routes, whereby, for a state-of-the-art pond

- only evaporation losses from the pond surface must be accepted,
- diversion can be controlled according to air temperature/relative humidity
- should a fish disease occur, ponds can be de-coupled from the flowing water or from the stream or river system with maintenance of constant water levels.

Key words: Residual water, To fall dry, To divert the routes

INTRODUCTION

Declining fishing returns from the world's oceans are stimulating interest in the production of fresh water fish and the building of the associated pond systems. During the hot summer months, the residual water routes dry out and the fish in the puddles that remain die – the amount of water allocated to residual water routes is insufficient!

The falling mean annual water volumes within water courses, caused by climate change in eastern Austria, an area that held the world record for rainfall for decades with more than 600 mm within 2 hours – are already documented in the literature:

" … an increasing number of streams and channels are drying-up, in particular within the Vienna basin, i.e. the continual flow of water is being interrupted - oxygen-depleted water holes that also finally disappear are left behind in the deeper places.
... the entire eastern area of our country, as well as some areas in the south, have ... received too little rainfall. An inspection of archival data reveals the mean decade temperature in the Vienna region to have risen by around 1.4°C compared to the 1940s whereas rainfall has decreased considerably .... in comparison to that during the first half of the century. ...
It is high time … to consider the fact … that the blocking of a tributary during high summer for the purpose of generating power … leaves behind the slowly rotting corpses of fish elsewhere …"

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Water shortages, in many instances the result of the failure to prepare water budgets – connected with the reduced ecological und limnological carrying capacity of the watercourses – but also areas of fallow, non-commercially viable agricultural land create the temptation to reactivate abandoned ponds and to construct new ones. An example of an extreme diversion is the one from the section of the Mur between Mixnitz in the north and Laufnitzdorf in the south, for which no residual water volume was planned to begin with, rather its bed was planned to function solely for HQ-diversion and as an "absorptive trough" for insignificant feeders. The circumstances are similar for flowing water bodies with minimal water volume and diversions for ponds and pond chains. Measures of this type introduce ecological risks:

- Increased evaporation from larger water surface areas not only causes an elevated loss of ground and flowing water but also an increase in the absolute humidity level and as a consequence the creation of large areas of ground fog.
- The beds of flowing water bodies that are only fed with residual water behave as groundwater drainage and thus reduce groundwater levels. The original shore vegetation withers and dies, the banks of the residual water stretches erode, already at HQ_1 to HQ_5, the original stream/river bed gains – crum grano salis – wadi-like elements through the increasing emergence of dry grassland plants.

  On top of this, whether as a consequence of a lack of carrying power, any sediment remains in the residual water-carrying stretches, leading to the loss of the stream bed's character as the idealized "inclined level".

  A relatively minor level of intervention in a flow regime therefore leads to ecological consequences, in some cases with a high risk potential.

  Any planning of water supply management measures must therefore maintain a more or less intact flow regime, i.e. it must integrate water diversion and the re-introduction of allocated water.

THE DIMENSIONING OF ALLOCATED WATER (Q_A)

In Austria this must take into account:

The ecological functionality of a water body according to the valid version of § 4 Wasserrechtsgesetz (WRG) ("Water Protection Legislation") 1959

Increasingly, even channels with minimal water volumes are being harnessed for the allocation of ponds and allocations again approved from their minimal water volume (Q_A) – e.g. amounting to 0.25 l/s – 2.0 l/s, whereby in some cases the specified residual water (Q_R) in the original stretches of water amounts to only 0.5 l/s – 10 l/s.

As a consequence of these provisions, which are designed to maintain the ecological – and therefore also the limnological – functionality of a body of water – neither a limited nor a secure residual water (Q_R) can be technically guaranteed.

Provisions that from a water volume ≥ a l/s an allocation of ≤ b l/s, in Austria as a rule Q_{347}, can be diverted, whereby a > b, requires a testable

- limiting of the allocated water (Q_A), e.g. by means of a standardized pipe cross sectional area and a
- securing of the residual water that is required for ecological functionality (Q_R).

These can be guaranteed in a technical channel without dislodged sediment and with a fixed, non-modifiable bed, yet fail however with only minimal sediment transport when a more or less untreated bed, designed to guarantee the ascent of benthos and fish, is present. The ongoing suppression of even minimal quantities of dislodged sediment, in particular multilayered material, requires allocation or residual water volumes.

- An elevated (MQ) is to be ensured during the early part of the year / early summer in order to guarantee the volume of water that is necessary for the juvenile development of young salmon and for the spawning on the gravel of Cyprinidae.
- Periodic increases in water flow guarantee the removal of fine sediment particles, the inhibition of algal growth and the cleaning and structuring of the stream bed.

Whereby the following side-effects are to be taken into consideration:

- Diversion stretches with minimal residual water volume are *"removal stretches"* for predatory individuals, because the scope for fish to move and to escape is limited by a limited volume of water.
- The traversing of a stream bed with cables and lines in trenches causes ground infiltration losses, since the trenches function as drainage channels into the lower lying ground. A channel carrying residual water is therefore to be traversed exclusively by compression or drilling.
- Because he/she is locally based, an individual granted an allocation of water, is able to continually monitor the fulfillment of his/her allocation right and secure this – for instance through the removal of sediment from the diversion point (P_A).
  An official supervisory body or an authorized fishery can only test for the residual water volume needed to ensure ecological functionality – through testing based on random sampling – and remove the debris blocking the flow of residual water. As a result of this, an increased likelihood exists that a water allocation (Q_A), though not residual water, is ensured.
  An engineering office that was engaged to develop a diversion construction for a stream with minimal water volume that should guarantee both an exact quantification of the residual water (Q_R) and also an exact limiting of the water allocation (Q_A), the latter corresponding to a volume of 1 l/s, could not fulfill this assignment for technical-physical reasons and resigned.

Limitations to benefit fishing according to the valid version of § 15 Wasserrechtsgesetz (WRG) ("Water Protection Legislation") 1959

The VwGH ("higher administrative court") recognized, that the ecological functionality of a body of water is, in many instances intact, even if fish are unable to find a suitable habitat within it. A volume of water is however necessary that also permits the movement of fish through depressions and meanderings in the stream bed and as a consequence allow the fish to use the required hiding places and escape possibilities.

Ongoing observations shows that fish in diversion routes containing minimal water volumes easily fall victim to predators.

Consideration of temporary fluctuations in the water volume

Climatic and weather changes bring about regionally variable, though marked fluctuations in the amount of precipitation (h_N) and its distribution. The determination of the residual water volume requires a self-registering, continual measurement of the water volumes within water bodies, residual water stretches and diversion.

In the case that the registered water volume falls below the stipulated threshold level, the agreed allocation should – taking into consideration the altered circumstances – be reduced or completely suspended until the conditions underlying the original decision are again in place. It should be taken into account that:

- the residual water level may never fall below the stipulated level, i.e., the following must apply:

  $Q = Q_A + Q_R$

  $Q_A = Q - Q_R$

  whereby the symbols used mean:

  Q *Water volume, greater than or equal, above which a diversion was approved*

  Q_A *Dotation*

  Q_R officially allocated residual water

  whereby in Austria the following applies:

  $Q_R = Q_{347}$

- should the water volume however fall, the allocation (Q_A) is to be reduced:

  $Q - \Delta Q = [Q_A - \Delta Q\ ] + Q_{347}$

  not however Q_R

  $Q - \Delta Q = Q_A + [Q_{347} - \Delta Q\ ]$

  Whereby the symbols used mean:

  Q *Throughput*

  Q_A *Allocated water*

Should it be necessary to reduce the water allocation (Q_A) – in order to guarantee the stipulated amount of residual water (Q_R) - the officially determination allocated water (Q_A) is to be reduced in accordance with the altered natural circumstances, i.e., the commercial considerations and calculations of the pond operator are to take into account the fluctuations in (MQ). In the case of fundamental climatic and flow changes generally affecting all beneficiaries under water legislation, the owners of formal water rights cannot be favored at the expense of the remaining beneficiaries, the holders of informal water rights.

These circumstances were interpreted somewhat differently by U. Schälchli when, in the context of seasonal effects, he asserted:

> *"… The seasonal fluctuations in the base flow are taken into consideration through*
> - *a higher allocation flow for the high summer months (90 % HQ) – June/July*
> - *a lower allocation flow for the summer months (70 % HQ) – May/August/ September …"*

The acoustic effects of water volume

This constitutes an element of the *"ecological functionality"* as asserted by U. Schälchli:
"… to guarantee the usual acoustic background of a stream, a residual water flow rate of > 100 l/s is to be guaranteed …"

The minimal outflow depth

This constitutes an element of the *“ecological functionality“* in relation to the water depth that is to be always guaranteed within diversion routes as asserted by U. Schälchli:
“… in the draft of the revised water body protection legislation of the 24th January 199,1 a minimum outflow depth of 0.20m is required for fish-containing waters in the area of low water channels …“

Thus in diversion stretches – in order to ensure that water continuity is not broken - some areas with negative slopes are to be planned.

Water temperature

This constitutes an element of the *“ecological functionality“* as asserted by U. Schälchli:
“… when in winter, as a result of inflowing ground water, the water temperature in an extracted stretch is 4 or 5 °C over a period of weeks and months, whereas before the erection of the water catchment this fluctuated for example between 0 und 1°C, this can cause the larval development of water-inhabiting insects to proceed at around twice the rate, which can lead to the result that certain types of insects hatch too early, survive only for a short time due to the cold and snow on the banks and as a result are unable to reproduce, and/or that many facets of the development process in the extracted stretch no longer correspond to those in the upstream area, the return area and also in side streams. (Pechlaner, 1989) …“

Flow velocity

This constitutes an element of the *“ecological functionality“* as asserted by U. Schälchli:
“… if the rate of flow falls below 0.4 m/s, deposits of sand build up. With a flow rate under 0.2 m/s, a total re-structuring of the original running water ecosystem results from the deposition of silt and organic detritus and the mostly unavoidable changes in further physical environmental factors (temperature, oxygen content in stream sediment etc) (Jäger, 1985) …“

THE CIRCUMSTANCES IN AUSTRIA

Diversion applications in Austria are generally approved – with the exception of the federal region of upper Austria, which only permits diversion when the water volume is > 50 l/sec – because the view is taken that the water volume of a flowing body of water can, in all cases, irrespective of its size, be reduced by diversion when an application is submitted by an interested party. I have water rights decisions on my desk which approved the diversion of 0.5 – 1.0 l/sec with a water volume of 1.0 – 1.5 l/sec.

This excessive diversion causes the following theoretical water losses at the point at which pond diversion and residual water stretches meet:
- Evaporation losses as approximate site value (ca. 1.0 l/sec/ha pond surface)
- Infiltration losses from pond construction und pond banks
- Evaporation losses of residual water in the partially dried-up stream beds resulting from diversion and warmed by the suns rays.

The water losses caused by diversion are in fact significantly higher:
- In Austria the volume of water within a flowing body of water is assessed exclusively using the surface area of the catchment area and the precipitation data gathered by

measurement stations that are frequently located many kilometers away. The resultant conclusion is in many instances based on the use of annotated maps that have not been updated for several decades, with the result that replanted and felled areas of woodland, new roads and railway routes etc are not taken into consideration or are considered to the wrong extent.
The responsible hydrographical institute indeed notes in a footnote to each report it prepares that the data it has collected do not form the basis of an expert opinion. Despite this, they are indeed considered as binding by the responsible authorities.

- The difference ($Q - Q_{347}$) is, moreover, considered to be divertible water and approved as such.
- On top of this, water balances for flowing water bodies are only prepared in Austria in a few special cases, with the result that the theoretical water volume stemming from rainfall determined by the hydrographical institute is considered to be the *a priori* condition and diversions that have already been approved are neglected.

All of this causes, even for the return of the removed water – to begin with without infiltration and evaporation losses – the following solutions and balances:

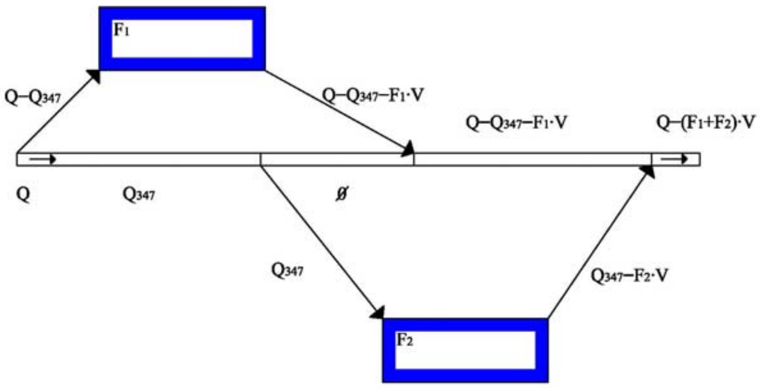


Fig. 1 The result of removals and returns without taking a water balance into consideration– Example 1
Should no partial stretches dry out - with the retention of the questionable Austrian legislation - the water volume is 2*(Q + Q347) instead of (Q).

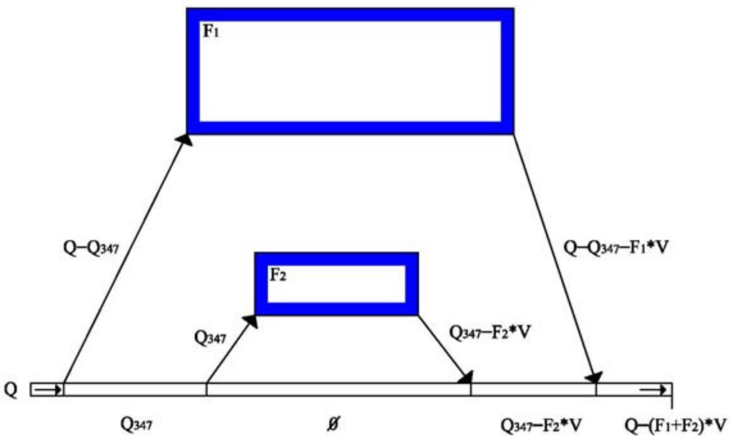


Fig. 2 The result of removals and returns without taking a water balance into consideration – Example 2
Should no partial stretches dry out - with the retention of the questionable Austrian legislation - the water volume is 2*(Q + Q347) instead of (Q).

Finally, the cross sectional areas of the water-diverting pipes are carefully calculated, though oversized, to counter the cross sectional relocation of the diversion by the movement of sediment, it is not however tested whether the necessary return (Q_E) is also ensured.

From this emerge the following requirements for diversion routes und residual water volumes:

- Diversion point (P_A) and return point (P_E) need only feature a small separation in the diversion construction (B_{AE}).
- The diversion point (P_A) is to be designed in such a manner that it cannot be relocated by sediment, i.e. a water depth of > 0.5 m is to be guaranteed in the diversion construction (B_{AE}).
- The diversion construction (B_{AE}) may not interrupt the ascent of fish and Benthos, i.e. ledges are to be limited to < 0.12 m and the floor of the diversion construction is to be covered with a coarse, porous substrate.

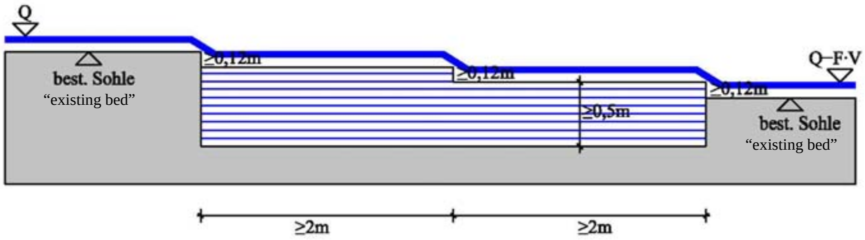
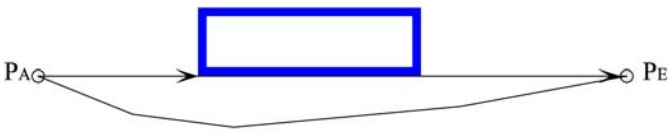


Fig. 3 The targeted elevations in the area of a diversion construction (B_{AR})

- The difference between (Q_A) and (Q_E) is to be continually recorded.

THE LENGTH AND REQUIRED WATER VOLUME OF DIVERSION ROUTES

Water law approvals are generally based on the concept that the water diversion occurs at a position that is higher than the site that will receive the allocation, so that this can receive the allocation down a gradient. The diversion again occurs down a gradient to the water body to receive the allocation. Depending on the topography, this results in diversion routes with a length up to > 0.5 km.



Whereby the symbols used mean:

P_A	*Diversion point*
P_E	*Point of reintroduction*

Fig. 4 Conventional allocation to a pond by diversion. The residual water stretch extends from (P_A) to (P_E)

(1) Evaporation and infiltration losses (V)
- in the pond, as a rule assumed to be
  [F * V] and/or [F * 1] (in l/s)

- in the diversion and return routes in the area of the pond surface (F) occur to the extent
  $Q_A – F * V$

Whereby the symbols used mean:

F	*Pond surface area or sum of pond surface areas (in ha)*

V — *Evaporation or infiltration losses (in l/s/ha), whereby in Austria the following applies: V = 1 l/s/ha*

(2) Water volume (Q) following the return of the reduced allocation water due to evaporation and infiltration losses corresponding to
$Q' = Q_R + [Q_A - F * V]$

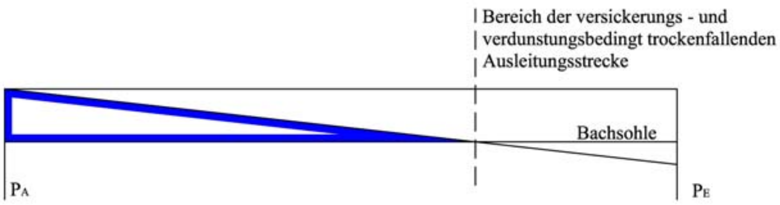
<u>*Whereby the symbols used mean:*</u>

Q' — *Water volume of the water body after the return of the remaining allocation*

As a rule, the residual water (Q_R) is determined on the basis of the assumption of an ideal and constant remaining channel cross-sectional area and it is presumed that the quantity is identical at the diversion point (P_A) and the return point (P_E). This is however not the case. Residual water (Q_R) can infiltrate within an existing stream bed or evaporate from a river / stream bed that has been warmed by the sun.

Based on the use of an outflow with a cross-sectional area in the form of an equilateral triangle, a reduction in the absolute water level of 50 % has the following effects:
- a reduction in the flow cross sectional area of ca. 75 %
- a reduction in the hydraulic radius of ca. 50 %

i.e. the evaporation and infiltration losses increase disproportionately, so that longer residual water stretches dry up frequently.



"Area of the diversion route dried-up due to infiltration and evaporation losses"

"Stream bed"

Fig. 5 Reduction of the residual water in the diversion route through infiltration and evaporation

- The reduced allocated water at the point of return (P_E) is roughly determined by:
  $Q_A - F * V = Q_E$
- The water volume (Q) of a flowing water body – despite all caveats in the expert reports from the hydrographical institution – are derived virtually exclusively from the latter. Hydrographic expert reports are prepared *ex post* on the basis of time series, with the result that trends in the development of rainfall amounts and distribution are strongly qualified.
  On top of this, both hydrographic institutions and local authorities neglect to consider water balances, with the result that interventions in the water volume, whether extraction and/or diversion, are not captured in the reports. As a consequence of this
  - the water volume (Q) of a flowing water body in expert hydrographical reports is – as a result of the system used – assumed to be too high and
  - the residual water (Q_R) – determined by evaporation and infiltration – is set too low, with the result that it is only guaranteed in a part of the diversion route.

THE GOAL

If one accepts, that despite the described, altered boundary conditions that interventions will be made in the water household of running water bodies for the benefit of the water rights of individuals, these interventions must occur in a controllable manner and must minimize the length of the affected water sections in order to guarantee the ecological and limnological functionality of the running water body.

THE MODIFIED SOLUTION

The goal stated in chapter (4) can be achieved by following the concept that is set-out below:

- Place diversion and return lines adjacent to one another

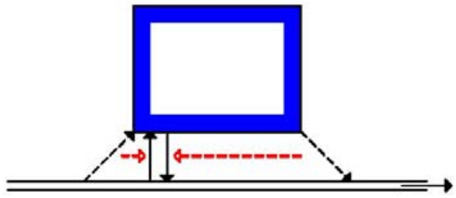


Fig. 6 Close juxtaposition of diversion (P_A) and return (P_E), in order to avoid the creation of stretches of residual water.

In this regard is required:

- a minimizing of the disturbances in the area of the diversion and return by
  - pre-positioning of a wooden rake.
  - the flow of the body of water in the diversion and return area over a dammed or non-dammed deck roller.
- a division of the diversion construction (B_{AE}) into a diversion and a return section
  - in the diversion section the water should *"flow"*, so that the characteristic speed (v) is lower than the speed of the surface (v_c), whereby the following is valid according to Froude:
    $F_r < 1$ and $v < 0.4$ m/s
  - in the return section the water should *"shoot"*, so that the characteristic speed (v) is greater than the speed of the surface (v_c) and the surface waves only extend in the direction of flow, whereby the following is valid according to Froude:
    $F_r > 1$ and $v > 0.4$ m/s,
    so that the returned water cannot enter the diversion again.

  This sequence of *"flowing"* and *"shooting"* is achieved through the use of a wedge-shaped or right angled narrowing of the diversion construction (B_{AE}), that subdivides the diversion and return area.

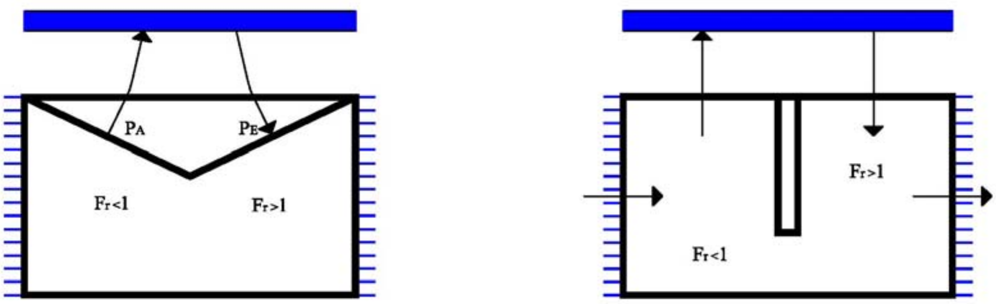
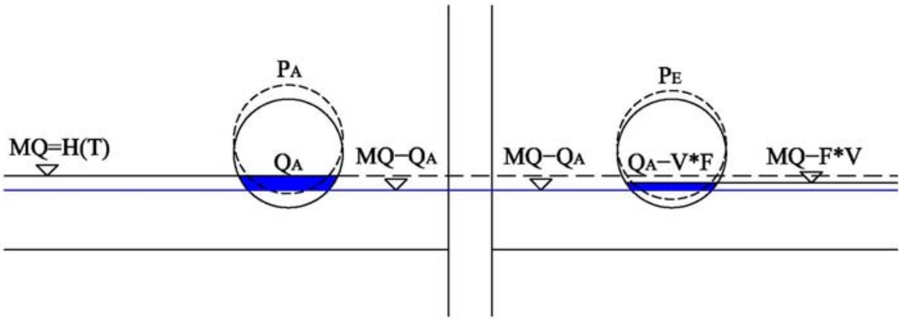


Fig. 7 Possible ways to achieve the direction of flow

- The pond water level must be identical to the absolute level of (MQ – Q_A) (allocation) in the diversion area.
  The diversion discharges into the nearest point in the pond.



<u>In this context the symbols used mean:</u>
H(T) Pond level and coupling level

Fig. 8 Elevation of P_A and P_E

- The level of the return position (P_E) corresponds to the absolute height. The return occurs from the deepest and furthest position of the pond, whereby the following applies:
  $Q_E = Q_A – F * V$

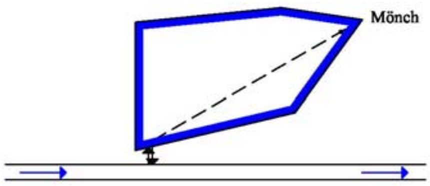


Fig. 9 The return line (LQ_E) is laid on the pond bed and ascends to P_E parallel to the bank

A system of communicating pipes results, whereby losses caused by friction in the return pipe are compensated for by solar-powered pumps that are activated by pressure on or the drying out of the diversion.

- The diversion and return construction must contain:
  - a water depth ≥ 0.5 m, to guarantee the ascent of fish and to obviate the relocation of the diversion and return by debris.
  - a length of ≥ 2 m per section in order to guarantee the ascent of fish.

- Depending on the size of the water body the diversion and return construction (B_{AE}) can be placed next to the channel.

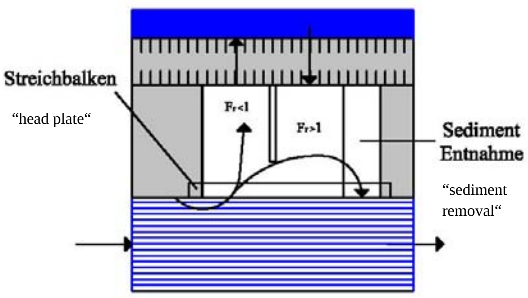


Fig.10 Next to this one for a broad channel and high (MQ)

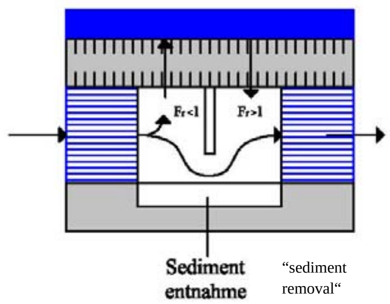


Fig.11 In this one for narrow channel and low (MQ)

- In the case of a suboptimal location of the pond – the (MQ) of the flowing wave lies, according to the land type and land use ca. 0.7 – 16 m under the adjacent natural level – the diversion and/or return of the allocation can be made possible by the use of solar-powered pumps.
- The described mode of operation allows the avoidance of any kind of residual water stretches (LQ_R).
  Evaporation and infiltration losses will only occur in the area of the diversion and return construction (B_{AE}).
- The return line occurs at the base of a monk, that also guarantees return with sediment in the pond through vertical stranded wire and from which also an underground pipe leads to the flowing wave via a mud retention reservoir.

The following additional economic and ecological advantages are moreover provided by this:

- Easement and/or line rights are only necessary for the draining line.
- The ecological and limnological functionality of the flowing water body must only be secured with respect to possible stresses and strains on the ponds as a result of (Q_E).
- Allocation can be documented and checked without problems with registering equipment.
- A temporary inactivity of the solar-powered pump systems during the winter months occurs in a time period during which the pond is not coupled.

CONCLUSION

Through the modification of a diversion construction, diversion and return, the residual water stretches that frequently dry out and lead to ecologically unjustifiable effects can be avoided with pond systems.
Only the evaporation and infiltration losses from the pond/chain of ponds will affect the original residual water stretch.

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