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Report on the restoration success of lowland streams following re-meandering projects

Piet Verdonschot

Introduction

Lowland streams are characterised by a gentle slope of the terrain (zero to five per mill) and a sandy soil. They occur in the flat lowland areas of the Western European plain. Lowland streams are fed by rainwater; they often lack a well-defined source. Thus, their discharge shows a smoothed relation with the amount and frequency of precipitation in the various seasons.
Lowland streams occur in the eastern and southern part of the Netherlands. Their current velocity varies from 5-30 cm s^{-1} in summer and early autumn and from 30-60 cm s^{-1} in late autumn to spring. Often the rainwater fed upper courses dry up in summer, though sometimes they are fed by a helocrene spring and then show a more constant discharge pattern (Verdonschot, 1990).
After a long time-period of adapting lowland streams and their catchment to agricultural, domestic, drinking water and industrial needs, one became aware of the damages of these alterations. In the Netherlands, only about 4% of the streams still have a natural hydro-morphology. The last ten years, the ecological importance of streams became more and more apparent.
Nowadays, stream restoration is one of the answers to the lowland stream deterioration. In order to make the proper choices in stream restoration; one firstly has to understand the complex spatial and temporal interactions between physical, chemical and biological components. The success of restoration depends on steering the appropriate key factor(s). Which factor this is, differs for each stream and each site.
To provide a more detailed idea of the status of the ecological effects of lowland stream restoration projects a pragmatic approach is to analyse current project. This means learning by doing!. The examples analysed examples represent an average overview of stream restoration in The Netherlands. They make clear what can be expected looking more in detail at the positive and negative aspects from an ecological point of view.

Example 1: Re-meandering of the stream "Vloedgraaf"

Study area

The stream "Vloedgraaf" is a channelised middle to lower course of a lowland stream. The water quality is moderate due to input of sewer and effluent of a purification plant. The water does not meet the standard for phosphate, nitrogen, ammonia, copper, zinc, lindane, and sulphate. The bottom is polluted by PAK's and PCB's. Before restoration the channel was straight, and fixed by stones and concrete. The streams hydrology showed extreme discharge peaks due to runoff from paved areas.

Measures

Originally, the stream "Vloedgraaf" was reconstructed to optimise discharge capacity but in such a way that it meets landscape ecological and stream ecological demands. The channelised stream was reconstructed in 1992-1993 by:

- digging a meandering longitudinal profile (over a length of 1140 m),
- constructing a transversal profile with a varying bottom width between 3 and 7 m and a double profile in order to create swampy, inundated areas (over a width of about 75 m) whereby locally the surrounding grounds were lowered,
- digging of pools and oxbow lakes, and
- planting of trees at some stretches.

Current condition

Five years after reconstruction the first monitoring results became available (Maris, Peters & Kurstjens, 1998). The physical-chemical water quality was not improved. This could be expected because this problem was not tackled during restoration. The macro-invertebrate assemblages neither showed an improvement despite the increase in variation in current velocities and substrates, e.g. the construction of gravel beds (Figure 1). Part of the new or deposited substrates were polluted by organic wastes. This was especially true for the new pools and oxbows. Both were heavily polluted and did not support the intended communities. Only the riparian zone, which was extensively grazed by horses, showed an increase in diversity.

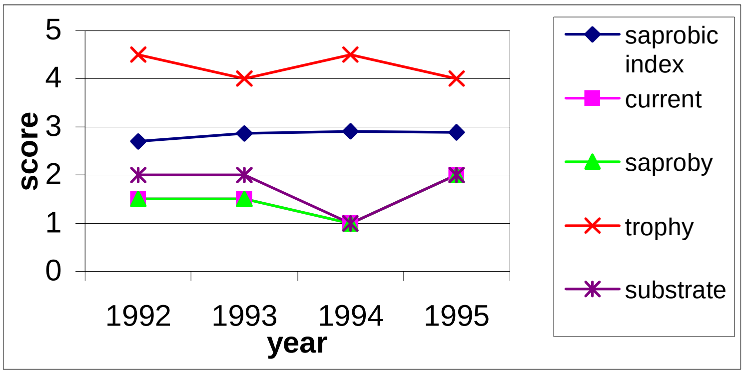

Figure 1. Quality scores based on macro-invertebrates over the years 1992 – 1995.

Conclusions

The stream "Vloedgraaf" restoration project showed that ecological development can be combined with other functions of streams. But when this restoration is not done from an integrated ecological approach of the catchment and the relevant key factors, the results are disappointing. Not tackling the water quality nor taking measures to reach a more natural hydrology resulted in a maybe visually changed streambed but with ecologically very small improvements.

Example 2: Water retention in the stream "Gasterense diep"

Study area

The stream "Gasterense diep" is a middle course of a half-natural, unshaded lowland stream. The water quality is good. The stream drains a natural area and a extensively used agricultural area. Before restoration the channel was slightly meandering, the water was shallow and the substrates were diverse.

Measures

Firstly, in 1993 a sewer discharge was removed. Secondly, in 1997 the stream "Gasterense diep" was reconstructed to heighten the groundwater levels in the near surroundings of the stream channel. The objective was to restore the former wet riparian areas parallel to the stream and to improve the conditions for groundwater dependent vegetation. The measures consisted of constructing six submersed weirs into the stream channel. The expectation was that the weirs would catch sand that is transported by the stream. After a few years sand deposition in the stretch upstream from a weir has filled up the stream until the level of the weir. Furthermore, no submersed vegetation will be removed from the stream anymore.

Current condition

Five years after sewer discharge removal and two years after construction of the weirs the monitoring results became available (Duursema, 1999). This evaluation focussed on the instream effects. The number of target species of macro-invertebrates increased after removal of the sewer discharge (Figure 2). But the in-stream effect of the weirs tends to be negative. The number of target species dropped.

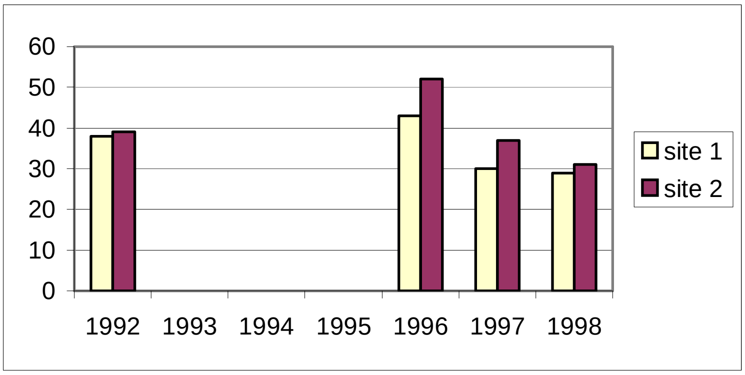

Figure 2. Number of target species since 1992.

Conclusions
Removal of organic pollution on the stream "Gasterense diep" showed a positive effect on the number of rare and valuable macro-invertebrate species. The construction of weirs, on the other hand, showed a negative effect. By constructing weirs the current velocity dropped and the substrate diversity decreased. The bottom became covered by silt. Again stream restoration by only looking at certain components of the whole stream ecosystem restricted the results.

Example 3: Wetland construction along the stream "Midden Regge"

Study area
The stream "Midden Regge" is a channelised lowland stream. The stream receives discharges of several purification plants and sewer systems. The water quality is moderate. The sewer system discharges also cause fluctuations in stream discharge during rainy periods. The stream bottom is polluted, comparable to the stream "Vloedgraaf"

Measures
To improve natural values in the stream valley of the "Midden Regge" the following measures were taken in 1988 and 1989:

- construction of a gradient between land and water to give freedom to erosion and deposition processes in a riparian zone of 2 to 6 m,
- removal of the top soil layer of 20 cm in this riparian zone which is contaminated and enriched,
- increase of stream bottom width and depth, and
- decrease of maintenance frequency.
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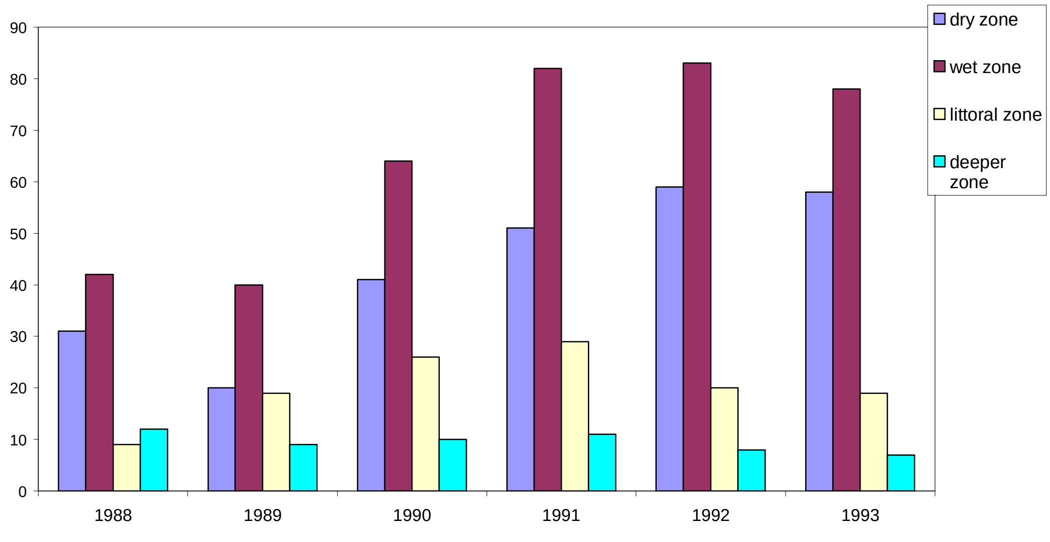
Current condition
The condition of the stream "Midden Regge" was reported in 1994, six years after measures were executed (Zonderwijk, 1994). As most measures were directed to the development of the riparian



zone, the evaluation is mainly focussed to this area. Figure 3 shows the number of plant species within the major riparian habitats.

Figure 3. Average number of plant species in different habitats in the riparian zone of the stream “Midden Regge”.

After implementation of the measures, the number of species increased until 1992. But in 1993 number of species decreased again and this decrease pointed towards an increase in eutrophication of the soil. The latter is due to sand and silt deposition in the riparian zone. The author concludes that only hydrological isolated habitats can be sustainable. The same conclusions accounted for fishes and amphibians. The increase in profile width and depth lead to a decrease in current and an increase in alga development and oxygen depletion.

Conclusions
Re-construction of the riparian zone of the “Midden Regge” initially led to improvement of the natural values in the terrestrial, amphibian and aquatic habitats. But this was only true for the first few years after construction. The last year showed again deterioration of the vegetation patterns due to deposition of contaminated and enriched silt. Profile changes also had a negative effect on the stream community.

Example 4: Remeandering of the Geeser stream (summary of WP 2Deliverable 232)

Research questions
The aim of this research is to gain insight into the processes and factors that lead to successful restoration.

1. Specific research questions to this end were:
2. What is the abiotic situation after remeandering?
3. Do changes in abiotic factors influence the indicator species to be expected in the stream?
4. Which species disappeared because of implementation of the restoration measures?
5. Which species have returned?
6. After how long and at what time did species return?

What is the abiotic situation after remeandering?
Hydrology
Before remeandering the stream was deeply incised, the bank was high and the water deep. As a result of the incision there was also little difference in height between the different parts of the stream and the stream was characterised by its short length and limited slope. Using profile measurements from before and after remeandering it can be concluded that in its altered condition the stream is longer, with a greater slope, less pronounced incision and a shallower water body. A notable structure that features strongly in all measurements is the fish ladder, which is installed just before the canal. This fish ladder is characterised by its significant height and fall, with very deep water and high banks directly after the ladder. In all patterns measured the fish ladder produces outliers that influence the average pattern.
The water level fluctuated from a few centimetres in April 2007 to nearly one metre during heavy rainfall in January 2007. It can clearly be seen that the water level follows the precipitation pattern. The flow rate was 0.10 m/s on average in 2006, compared with 0.02 m/s in 2005 and 0.06 m/s in 2004. It appears that the new watercourse flows in some locations, but data are limited.

Nutrients
The reference values (GES) of the WFD reference type R5 for the nutrients total nitrogen and total phosphorus are 4 mg N/l and 0.14 mg P/l. These values, in particular for total phosphorus, were

frequently exceeded in the restored Geeser Stream. It was also noticeable that rainfall in winter and in some months of the summer appeared to be linked to increases in nitrogen and phosphorus concentrations. Conversely, during dry periods nutrient concentrations were lower, which points to the influence of ground water seeping in. Oxygen concentrations were very variable but never fell below the limit of 2 mg/l, which is lethal for most fish and macroinvertebrates. Concentrations of other ions also varied greatly, without there being any clearly visible differences between the periods before and after remeandering.

Do the changes in abiotic factors influence the indicator species to be expected in the stream?
The new profile leads to altered flow conditions. It is expected that typical lowland stream species will be able to benefit from the increased slope and the changed hydromorphology, with the associated increase in flow rate and decrease in depth. However, the remeandering process and the changing weather conditions in 2006 and 2007 led to major fluctuations in abiotic conditions. As a result, species that are resistant to disturbances have so far predominated in the stream after remeandering. Furthermore, the concentrations of nutrients in the stream have hardly changed and the diatom community has thus also not showed a clear reaction to the remeandering. Nutrient-rich water from the agricultural land has not yet been entirely diverted, so that the water in the stream is too high in nutrients. As it is an upper-course system, the target values are a total phosphorus norm of 0.14/0.12 mg P/l and a total nitrogen norm of 4 mg N/l (those of the natural references R5/R4) for which it can be expected that typical lowland stream flora and fauna will develop.

Which species disappeared due to implementation of the restoration measure?
Fifty-one taxa (25%) disappeared following remeandering, mainly mites, bivalves, leeches, freshwater shrimps, alder flies, dragonflies and worms. It was noticeable that there were a large number of taxa that could not fly, such as snails, worms, mites and leeches. In addition, the habitat of many taxa was linked to nutrient-rich, vegetation-rich, still or regulated waters, as for example in the case of the beetles Anacaena limbata, Graptodytes pictus and Helochares punctatus, the true bugs Hebrus ruficeps, Ranatra linearis and the alder fly Sialis lutaria. These taxa were typical inhabitants of the Geeser Stream before remeandering was implemented.

Which species have returned?
The majority of the taxa (60 %) returned in 2007. In addition, 36 new taxa appeared. The new taxa that arrived after remeandering mainly use flight for locomotion (true bugs, chironomids), but some non-flying worms and snails also appeared. Some of these were typical colonists that are resistant to disturbances or that can survive in semi-permanent waters, for example the beetles Hygrotus impressopunctatus and Hydroglyphus geminus, and the true bugs of the genus Sigara. Some flow indicator species also appeared, such as blackfly Simulium, and the fairly rare beetle Berosus signaticollis. This last-mentioned species could indicate that the new, remeandering, stream offers habitat for stream organisms that were previously not present.
There was no increase in the number of rheophilic species following remeandering but there was a strong increase in 2007 in the number of indicators for drought, both for shorter as well as for longer periods of drought. The presence of many drought indicators points to the colonisation process still being in progress. This conclusion is also based on the diatom community of the Geeser Stream, which up to 2008 was still in an unstable condition.

After how long and at what time did species return?
In 2006 the number of macroinvertebrate taxa and their abundances were very low. The majority of taxa only returned in 2007. The expected arrival of typical lowland stream species and indicator species has not occurred so far. This can be explained by changing weather conditions and unchanged concentrations of nutrients. Some parts of the remeandering plan were also carried out differently in the end, so that the stream that finally resulted did not flow and dried out in many places. Finally, one cannot rule out dispersal problems for the lowland stream species that were expected and it is possible that barriers for the species still play a major role in the colonisation of the meandering stream. However, these species will only have a chance of dispersal if the abiotic conditions meet the Good Ecological Status norms.

Conclusions and the future

There are various indications from the diatom and macrofauna communities that the colonisation process in the restored Geeser Stream is still in progress. Monitoring of the process of remeandering over a long period will probably give a different and more complete picture of the effects of a large-scale remeandering project than the results after just two years described in this report.

It is possible that in future years there will be more changes that will influence the restoration of the Geeser Stream. In this context one can think of the diversion of the nutrient-rich water from agricultural land or the removal or restructuring of the fish ladder which would make it possible to increase the fall of the mid-course and lower course. It will also be interesting to see whether the extremes of weather of the last few years, which appear to have had a considerable influence on the stream's hydrological conditions, will increase or decrease in frequency.

General conclusions

Some general conclusions follow from the examples above, which more in general account for a high number of restoration projects included in the inquiries:

1. Often a combination of measures is necessary to really improve the stream ecosystem. Measures which focus on different components of the whole system as well as measures which tackle most stressing conditions.
2. Sometimes not the hierarchical most important measure was taken. In the example of the stream “Vloedgraaf” it becomes clear that even if the morphology of a stream is improved, the ecological stream quality does not improve if hydrology and/or water quality is insufficient. A similar experience can be concluded for the stream “Midden Regge”.
3. The relation between catchment and stream is often not included. In the example of the stream “Gasterense diep” as well as in the “Midden Regge” one focussed on the stream floodplain and forgot to think about the stream itself.
4. Only a small stream reach is restored. In the stream “Vloedgraaf” restoration was only focussed on about 1 kilometre of the stream without accounting for the upstream region and its characteristics.
5. Catchment hydrology and weather conditions as well as dispersal can affect colonisation and development processes after remeandering as was shown in the Geeser stream.