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Deliverable No. 99

Report on the first year of sampling lowland streams

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1 Introduction

Climate change will, amongst others, result in a increase in precipitation. This increase will be most significant in winter. Not only the overall precipitation will go up also the intensity of severe rain showers will increase in both winter and within dry summer periods. Consequently the discharge pattern in lowland streams will become more irregular with floods and dry periods. To study the effects of these expected disturbances in discharge we took a reverse example.

The stream Springendal is situated on the glacier hill ridge of Ootmarsum (province of Overijssel, The Netherlands). A few decades ago, the stream still was in a near natural condition. From the second half of the former century on, land use intensified in the infiltration areas of the upper catchment. This resulted in a disturbed hydrology and eutrophication. Especially, the disturbed hydrology impoverished the stream community and caused the stream to cut itself into the landscape causing a drying and acidification of the stream valley. Inundations with nutrient rich stream water caused nearby stream valley areas to become more eutrophic. This pre-restoration phase is comparable with the situation in about 50 years due to climate change.
In the late nineties several restoration measures were undertaken. These measures aimed to reduce both discharge dynamics and eutrophication. The post-restoration phase is taken as the current situation before climate change will have its impact.

To evaluated the effects of restoration, two approaches were initiated:

- Large scale measurements of hydrology and morphology took place over the whole stream length (large spatial scale of kilometres) in 1995 and 2004 (large time span of years).
- Small scale measurements of hydrology and morphology took place at six sections in the catchment (small spatial scale of metres) over three periods of four to five weeks (small time span of days).

2 Study area

2.1 Catchment and stream description

Geographic position
The lowland stream Springendal is situated on the east side of a glacial hill-ridge in the eastern part of the Netherlands (figuur 1). The Springendal catchment comprises about 485 ha, most of this area (346 ha) is assigned nature reserve ("Het Springendal"). The total length of the stream is 5.5 km, with a slope of 40 m (TNO 1999). The Springendal stream consists of two major upper courses, a northern and a southern one (Figure 1), both fed by in total 7 helocrene springs. After about 600 m these two upper courses join into the middle course. Along the upper and middle courses several spring-fed ponds, and some additional helocrene springs and seepage zones occur. After about 2 km from the source the stream enters an agricultural area and becomes channalised. The stream discharges into the lower course of the stream "Hollander graven", which somewhat further downstream enters the river Dinkel.
The upper part of the catchment is covered with oak-birch, beech-oak and pine forest (large parts owned by 'Staatsbosbeheer', a nature management organization). In the upper and middle course the stream community is still well developed. Cold-stenothermic species occur as well as representatives of rheophilic inhabitatnts of gravel, sand and detritus habitats.

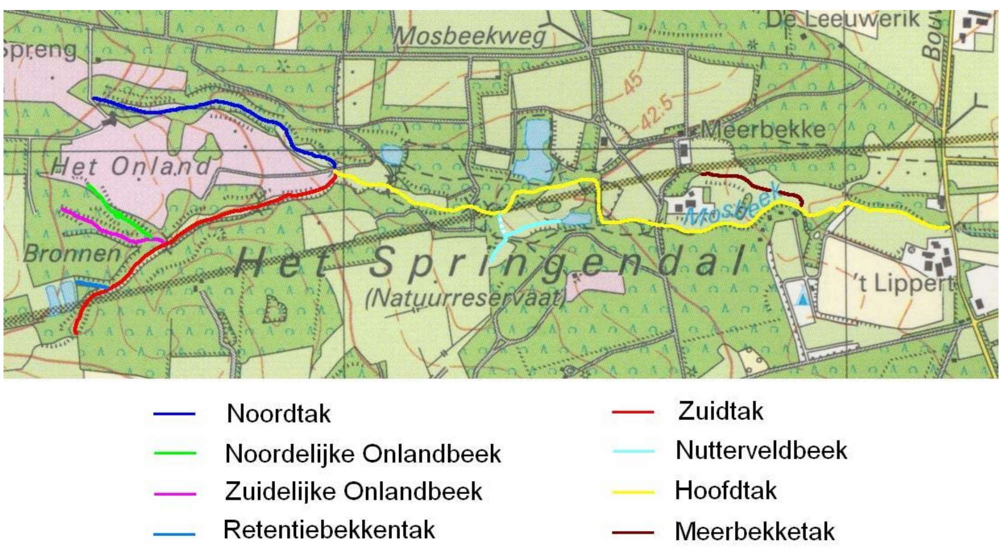


Fig. 1. Geographic position of the Springendal stream.

Geology
The last two ice ages shaped the valley and surroundings of the Springendal stream. During the Saalien (the last but one ice age) the glacier ice pushed the depositions, from tertiary origin, up into hill ridges. These tertiary depositions are marked by a

limited permeability for water. The tertiary hill ridges were then covered by a layer of fluvioglacial origin and by bottom moraine (Formation of Drente). The absence of plant cover during the Weichselien (last ice age), due to the cold climate, erosion further shaped the hill ridge landscape. Melt water transported sand and gravel and created a U-shaped glacial erosion valley. Later on, this valley was again partly filled with fluvioglacial depositions. Furthermore at the end of the Weichselien, wind transported also a lot of sand and the valley and hill ridges were covered by aeolic sand (Formation of Twente). During the warmer and wetter period of the Holocene, a precipitation surplus in combination with a limited bottom permeability, springs came into existence. These springs were situated close to the top of the hill ridge, there were the tertiary deposition reach the surface (TNO 1999).

Soil composition

The major soil type in the valley of the Springendal stream is podzol (a leached soil formed mainly in cool, humid climates). These soils are composed of fine with low to moderate loam content. In the sides of the hill ridge also coarse sandy soils with gravel occur. Loam/clay layers with gravel mainly occur in the south western part at 40 – 120 cm depth. In the rest of the catchment these loam-gravel layers occur much deeper under the surface. Close to the stream and in the north western part stream ' beekeerdgronden' (a sandy soil with a humic upper layer) and peaty stream valley soils occur.

Hydrology

The Springendal stream originates from helocrene springs on the steep sides of the hill ridge, there were groundwater reaches the surface due to the presence of impermeable loam layers (TNO 1999). The helocrene springs mainly feed two upper courses, a northern and a southern one. Both upper courses join after about 600 m. The northern course is fed by a near natural helocrene spring and a near natural forested area of the catchment. The southern upper course is fed partly by some helocrene springs and partly through a drainage system from an agricultural enclave. The infiltration area is situated on the top of the hill ridge. The northern upper course is fed from an area of about 63 ha, the southern from about 48 ha.

The sandy top-layer of the hill ridge functions as a rain water reservoir. This top-layer is situated above the impermeable loam/clay layers. In the south western part of the catchment these layers are situated quite close to the surface and are scattered, in the north western part these layers are situated somewhat more regular and deeper. This causes the discharge in the northern springs to be more constant throughout the year in comparison the southern one.

Land-use

The catchment of the Springendal stream is partly used as forest and partly as agricultural area. Until 1850–1900 the area was mainly covered with heather. Around the year 1900 large parts of the north western part were forested and about 50 years later also the wetter south western part was forested or turned into fields and grasslands (Jalink 1997). Nowadays the north western part still is forested and is designated as nature reserve. The infiltration area of the south western part still is used for agricultural purposes. The agricultural areas are heavily fertilized and drained. In 1997 one of these agricultural enclaves was turned into nature area.

Disturbance

The last decades the Springendal stream was threatened by increasing discharge fluctuations, drought, and nutrient enrichment. In the stream valley also acidification occurred. The causes are related. The major cause of these disturbances is due to the agricultural use of the upper part of the catchment, especially the southern upper course and the Nutterveld branch. Due to the drainage system rain water is directly transported towards the main course of the stream. This results in extreme discharge events, and in periods without rain duet o a less well filled groundwater reservoir, to low discharges or even drought events. Downstream canalization, widening and deepening of the profile caused the stream to incise upstream. These incisions lower the stream bottom and increase the streams draining capacity. This is an extra cause for an increase in discharge dynamics and drought events. Intensive fertilization of the agricultural land enriched the groundwater and surface water with nutrients. All these disturbances caused specific spring and rheophilic stream species to decrease or even to disappear (van Gerven et al. 1997).
The stream valley became dryer and the nutrient poor upper sandy soil acidified. The more organic and peaty soils mineralized and the inundation with nutrient rich water caused eutrophication, locally. Vulnerable stream valley vegetation types disappeared, especially those characteristic for wet and/or oligotrophic conditions

2.2 Major stream sections

Southern upper course

The total length of the southern upper course is about 720 m. This course mainly is forested, except for the most downstream 250 m where it passes a hayfield. Since 1998?, this field is not mowed anymore. Here, re-growth of *Alnus glutinosa* occurs. The uppermost helocrene spring is situated at about 65 m above sea level. Furthermore, the course is fed by a retention pond, the Onland branch and several adjacent springs and seepages areas. Before the construction of the retention pond, the hydrology of the southern upper course was disturbed with high discharge peaks and periods of very low flow. This hydrological condition caused the course to locally incise itself.

<u>Outlet branch retention pond</u>

In 1995 a retention pond was constructed west of the southern upper course to prevent nutrient rich drainage water from the upper most situated agricultural land to enter the stream. This drainage water was one of the major causes of a very instable hydrological condition. The outlet of the retention pond is to the southern upper course. The total length is about 90 m. In 1998 the drainage system from one of the agricultural enclaves was removed. Furthermore, the nutrient rich top soil layer was excavated from part of the enclave and shaped as a gully. There after, this wide gully started to carry a small network of temporary streams and spring or seepage areas.

Onland branch

The upper most part of the northern Onland branch is temporary, only transporting rain water during short wet periods. Though this branch originally emerged from a former helocrene spring area. Halfway it crosses a small man made pond. The temporary southern Onland branch emerges in two small erosion valleys of which only the northern one still provides water. Also these two branches originally emerged more upstream in a former pool and seepage area. Both are dry now. These two branches join in a more down stream situated seepage area. This area adds extra seepage water to the southern branch. The seepage area ends in a waterfall with a height of about 1 m. The southern Onland branch is about 225 m in length. The whole system of the Onland branches is shaded, except the uppermost, now dry, parts. Both northern and southern branch join some tents of meters before joining the southern upper course of the Springendal stream.

Northern upper course

The total length of the northern upper course is about 560 m. This courses mainly is forested, except for the most downstream 180 m where it passes a hayfield. Since, 1998? this field is not mowed anymore. When entering this hayfield a waterfall was present caused by a big tree root and some large stones. To prevent this waterfall the break whereby the stream would incise, a cascade was constructed in 1998. The uppermost helocrene spring is situated at about 52 m above sea level. The northern branch lacks side branches, but receives water from adjacent helocrene springs and seepage areas. At about 150 m before joining the southern upper course, a dry erosion valley in very wet periods can add extra water. In 1998 a culvert situated just before the joining with the southern upper course was replaced by a square culvert and a small cascade made from stones. This construction caused part (the last 50 m about) of the bottom of northern upper course to rise because of sand sedimentation.

Middle course

Where northern and southern course join the middle course starts. The middle course first crosses small haylands and forested areas. Until the border of the nature reserve its length is about 1600 m. Over the last 210 m it crosses a wooded bank and a fertilized agricultural grassland. Some helocrene springs, seepage areas and three major spring ponds, all man made by damming former helocrene springs, feed the middle course. Furthermore, two major side branches are present, the temporary Nutterveld branch and the small Meerbekke branch. The two major upstream situated spring ponds supply the largest amount of water to the middle course. The third, more swampy, spring pond only adds little to no water anymore. The temporary Nutterveld branch is flashy and causes the middle course to become more instable. Together with the instable southern upper course, before the construction of the retention pond, both branch caused the middle course locally to incise deep into the landscape.

Nutterveld branch

The Nutterveld branch emerges in the Nutterveld area, and was drained and channalized in 19..? Lateron, the channalized part was culverted. Nowadays, the water reaches the surface when entering the nature area. Because of these parctises the water runoff became temporary and flashy. To buffer the flashy floods, in 2004 the branch was diverted through a hayfield towards the swampy spring pond. This pond collects the water and releases it slowly again back to the middle course.

Meerbekke branch

The Meerbekke branch emerges as a helocrene spring near the former farmhouse Meerbekke. It transports only little amount of water. The whole branch is more or less ditched and situated in wet hayfield. When joining the middle course it is fed by a second helocrene spring.

Lower course

The lower course starts at the road crossing Uelserdijk and runs down to the junction with the stream Hollander Graven. The lower course is regulated and receives, just after the road crossing Uelserdijk waste water from a laundry. Several reservoir 9acting as sand collector) and weirs interrupt the course of the stream.

2.3 Restoration measures

Four major restoration measures were undertaken:

1. *Stabilizing the discharge regime and nutrient load;* by the construction of a reservoir upstream of the southern upper course and the change of land use in a part of the agricultural enclaves in 1998. The reservoir should buffer surface and subsurface runoff and reduce nutrient run off. Therefore, the drainage system of the agricultural enclave in the south western part of the catchment was connected with the reservoir. The reservoir itself consists of two parts, a collection reservoir and a retention reservoir. The first will be overgrown with helophytes to further reduce the nutrient load, the second functions as discharge buffer. The transformation of a small enclave of agricultural land (this former intense fertilized corn field became natural land in 1996) into natural land in the south western part of the catchment should add to both discharge peak buffering as well as nutrient load reduction. To optimize nature development in this area the drainage was removed and part of the upper soil (nutrient enriched) was extracted and transformed into a gully. Part of the area will be covered by natural forest and part is mowed yearly to further reduce nutrient loads and to develop a natural hayfield (Gerven et al. 1999). Shortly after the implementation of these measures in 1998, a few temporary springs and a temporary stream emerged in the newly developed upstream natural area.
   A second major measure in this category was buffering the Nutterveld branch discharge peaks by diverting the down stream part of this stream towards a shallow pond which discharges more down stream into the main course of the

Springendal stream. The pond will function like a helophyte filter and extract nutrients as well as a buffer to reduce discharge dynamics.

2. *Rising the incised stream bottom;* by adding clay (in 1997) a section of the southern upper course and rising the stream bottom with about 0.8-1 m. In another deeply incised section of the southern upper course, in 1997 tree stems were installed (no data available) and in 1999 submerged gravel dams were constructed to induce a slow but steady bottom rise by instream within dam sedimentation.
3. *Shading;* by stopping the yearly mowing regime (in 1998) in the grasslands along both the northern and southern upper course, so mainly elder (*Alnus glutinosa*) development can take its course. Shortly after, the southern upper course was invaded by young elder plants. Along the northern upper course the elder development is very slow.
4. *Remeandering* of a section of the middle course. This measure is foreseen in 2006.

2.4 Research hypotheses

I. A dynamic discharge pattern will result in a more dynamic substrate and/or stream bottom incision. Stream bottom incision results in an eroded bottom substrate which is either hard or instable. Both situations will result in an impoverishment of the stream macroinvertebrate community.

Test: the differences between more and less hydrological dynamic stream sections in the upper courses can be analyzed by comparing:

- √ the southern upper course until 1996, the pre-restoration phase
- √ the southern upper course after 1995, the post-restoration phase
- √ the northern upper course, the reference sites

Test: the differences between more and less hydrological dynamic stream sections in the middle course can be analyzed by comparing:

- √ the middle course after the junction of the Nutterveld branch before 2004, the pre-restoration phase
- √ the middle course after the junction of the Nutterveld branch after 2004, the post-restoration phase
- √ the middle course upstream of the Nutterveld branch junction, the references

II. Stream bottom rise will results in a more balanced process of erosion and sedimentation, a more stable stream substrate and a more diverse habitat mosaic that sustains a more diverse macroinvertebrate community.

Test: the differences between sections before (incised) versus after measures to rise the stream bottom were taken; clay test 1) and dam construction (test 2), respectively:

1. the southern upper course clay section before (until 1998) versus after filling (from 1998 on)
2. the southern upper course gravel dam section before (until 2000) versus after dam construction (from 2000 on)

III. Tree development along the stream ensures leaf and woody debris input, provides shade and reduces temperature fluctuations of the water, all processes contributing to a more diverse macroinvertebrate community.

Test: the differences between more and less shaded sections can be analyzed by comparing:

- √ the southern upper course in hayfield before 2000; the pre-shading phase
- √ the southern upper course in hayfield after 2000 (maybe even later as development of wooded bank goes on)
- √ the southern upper course in the forest

IV. Remeandering will result in a shallow stream with an asymmetric profile, reduced discharge dynamics and a more diverse macroinvertebrate community.

Test: the differences between the current versus the future remeandering section of the middle course:

- √ the middle course before and after 2006 (? if the restoration is finished) (not sampled yet)

3 Longitudinal morphology survey 1995 and 2004

3.1 Introduction

The hydromorphological processes of erosion and sedimentation, partly resulting in incision of lowland streams, are reflected in a number of hydrological, morphological and biological features in the stream by:

- √ longitudinal morphology of the stream bed (including the macro-substrate pattern)
- √ discharge pattern, current velocity and depth profile
- √ micro-substrate pattern and substrate dynamics
- √ vertical substrate composition
- √ distribution of macroinvertebrates

The macroinvertebrates express the conditions before and changes after a measure or event has occurred.

3.2 Material and methods

Sections surveyed

Before any restoration took place a morphology survey was done in June 1995. At that time, the main stream was surveyed from the culvert at the road crossing 'Blue road' until the springs of both the northern and southern upper course. The whole stream was on forehand divided in 30 m long sections, following the longitudinal course.

In 2004 this survey was repeated. At this time also the downstream part of the main stream from the culvert at the road crossing 'Blue road' until the culvert at the road crossing 'Uelserdijk', the spring of the northern upper course, as well as the southern Onland branch were included in the survey.

For a large part of the Springendal stream system the following parameters were surveyed:

- √ width and depth
- √ incision: height of both banks (until ground surface level)
- √ water level slope
- √ substrate pattern
- √ other structures: in the stream rooting trees, organic dams

Width and depth

For each 30 m section the maximum wet width and depth at each 5 m section was measured.

Incision

At each 10 m section the distance between water level and ground surface level was measured to calculate the true stream bottom depth.

For each 10 m section the difference between ground surface level and stream bottom was calculated by adding the stream depth to the difference between stream water level and ground surface level. In three sites, deep erosion pools behind dams disturbed the pattern. For these sites the average depth of the up- and downstream section was used as Figure. As for all section grond surface levels at both bnks were measured in the field. for the calculation of the incision the minimum value of both measurements, thus the lowest bank, was used.

Slope
Over the whole 30 m the water level slope was measured, using a water filled tube (diameter 2 cm). The upstream opening of the tube was kept submersed while the downstream end of the tube was lifted above the water level in the stream. The distance between tube and stream water level was measured.

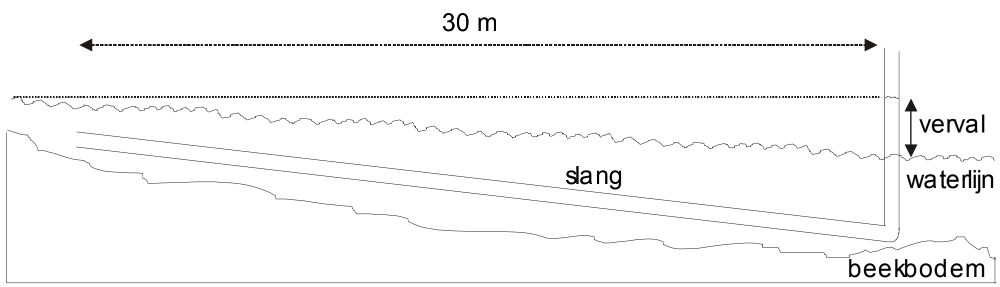


Figure 3.1 Wet slope measurement.

The culvert at the road crossing 'Blue road' was considered as a reference, as this is a stable point in the whole survey. The height of the culvert was extracted from a map (scale 1:25.000; 28F (2002)) and identified as being 36 m above sea level. The measured wet slope were all related to this point.

Substrate pattern
The following substrate categories were distinguished:
- √ fine detritus (small not with the bare eye recognizable organic material particles < 2 mm)
- √ coarse detritus (leave fragments, pieces of small twigs, pieces of decaying vegetation, and so on)
- √ leaves
- √ branches and tree roots
- √ gravel (including stones)
- √ sand
- √ living tree roots
- √ terrestrial vegetation hanging in the stream
- √ aquatic vegetation (in 2004 the species *Berula erecta* was separately noted)
- √ anthropogenic stones (including bricks, tiles, concrete stones and constructions, et cetera)
- √ others (including clay layers, peat layers and iron deposits)

The cover percentage of each of the substrate categories present was estimated. In case of a homogeneous longer section, estimates covered a section up to a maximum of 30 m.

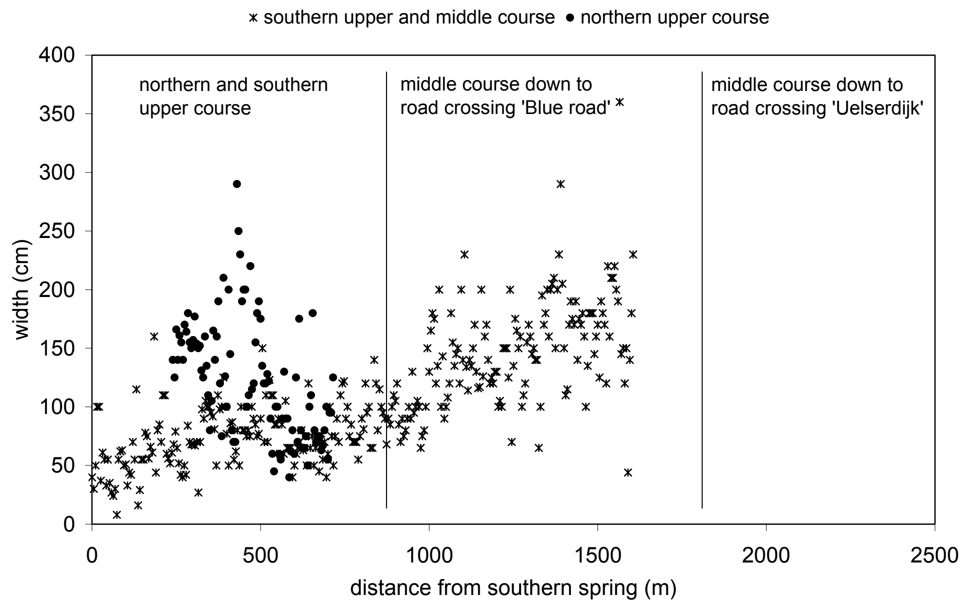
As for each section both cover percentage of the substrates as well as average width were known, the actual cover area per substrate was calculated.

Other structures
Over each 30 m section also the following structures were noted:
- √ the number of trees (partially) rooting in the stream
- √ the number of organic dams (defined as an obstruction that dams the whole width of the stream and interrupts the steam continuity).

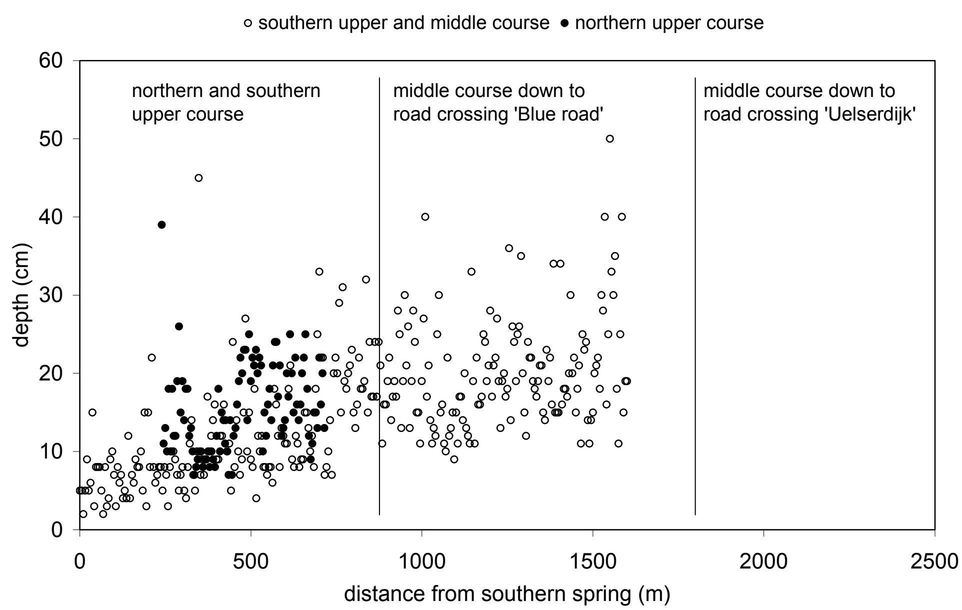
Accuracy
The accuracy of measurements under the field conditions is more or less influenced by factors like waves of the stream surface, geomorphology of the terrain (ground surface level), differences in longitudinal and transversal profile and ability of researchers to make cover estimations. Therefore, the following inaccuracies were accepted:
The wet water level slope registration the distance between water level in the stream and in the tube is measured. The water level in the stream fluctuates through waves. An inaccuracy of about 2 mm is accepted.
The ground level is a fixed line but depends on the geomorphology of the terrain. In general, we estimate an inaccuracy of about 5 cm.
Also the measurement of width and depth depends strongly on local conditions. An inaccuracy of about 5 cm is accepted.
The inaccuracy of substrate cover percentages depends on the heterogeneity of the substrate mosaic. Based on earlier experiences we estimated an inaccuracy of about 5%.

3.3 Results

Width and depth
As expected, the width and depth increased from the spring of the southern upper course down to the crossing with the road the Uelserdijk (Figure 3.2, 3.4 and 3.3, 3.5).
The width in the southern upper course varied between 30 and 150 cm, the depth between 3 and 23 cm. Three exceptions of wide sections occurred of which two measurements in the spring area, where the separation between stream and swampy surrounding is hard to tell. Notice the small width of the southern upper course just before the confluence with the northern one.



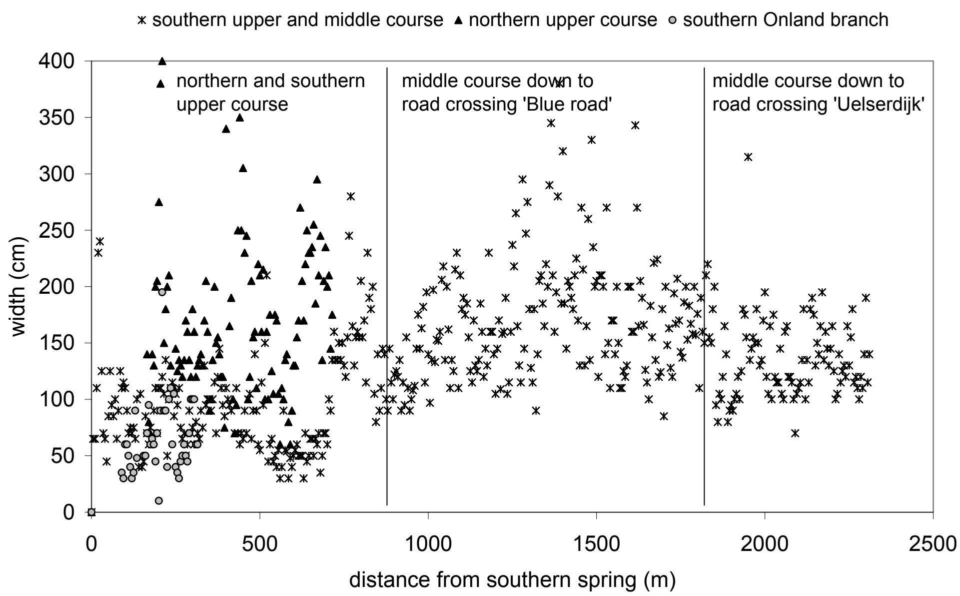
Figuur 3.2 Width of the Springendalse stream along its longitudinal course as recorded in 1995.



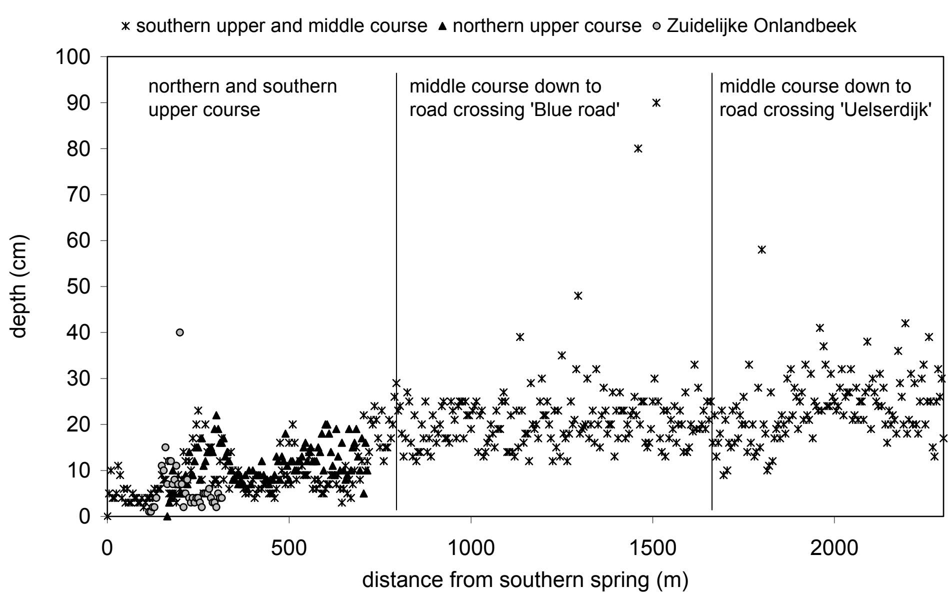
Figuur 3.3 Depth of the Springendalse stream along its longitudinal course as recorded in 1995.

Comparing 2004 with 1995, the southern upper course became narrower at this section (Figure 3.2 versus 3.4). Along the first 250 m downstream of the spring the southern upper course widened up to twice the width of 1995. This could have been caused by a fall down of steep banks which were formed before 1995, at the time the stream cut itself deep in the landscape. Steep banks in such a sandy area are more quite instable and collapse at periods of high floods. But also the filling with clay in part of this section added to the widening. There was also a deeper section present in

2004 at about 200 to 300 m downstream of the spring. Probably the clay filling caused a rise of the water level (deeper section). Further downstream a rise in bottom level is visible in 2004 (shallower section). This is due to the construction of gravel dams that led to this rise.
The width of the southern Onland branch varied between 10 and 110 cm, except for the swampy area which was not measured. The depth varied between 1 and 15 cm, with an exception of one measurement of 40 cm.



Figuur 3.4 Width of the Spingendalse stream along its longitudinal course as recorded in 2004.



Figuur 3.5 Depth of the Spingendalse stream along its longitudinal course as recorded in 2004.

The width of the northern upper course varied from 60 to 350 cm, with an exception of 400 cm in the spring area. The width did not change between 1995 and 2004, except for the most downstream 150 m where the width doubled. This is caused by the construction of a new culvert just upstream of the confluence with the southern upper course. The culvert caused the water and stream bottom level to rise.

The width of the middle course varies between 70 and 380 cm, the depth between 3 and 22 cm. In 1995 the confluence of southern and northern upper course was much more smooth in comparison with 2004. The middle course widened up to twice the width, just after the confluence. A comparable situation developed about 1200 m after the confluence in the middle course. Again the collapse of instable banks could have been the cause. Larger depths (>25 cm) disappeared in 2004 in comparison to 1995. The most downstream 300 m become shallower in 2004.
After the road crossing 'Blue road' the middle course only three times exceeds the 250 cm in width. The width of the more downstream part showed little variation. This is partly due to bank fixation by stones (artificial) and tree roots.

Incision
In Figure 3.6 the average distance between stream bottom and ground level per 30 m section of the southern upper course is illustrated for the years 1995 and 2004. In general, the stream bottom rose a little between 1995 and 2004. This did not account for the most downstream section where alder developed. At some section the stream cut itself in to more then 25 cm. This section also became more narrow (Figure 3.4). Furthermore, the bottom rise of about 65 cm due to the clay filling is visible in

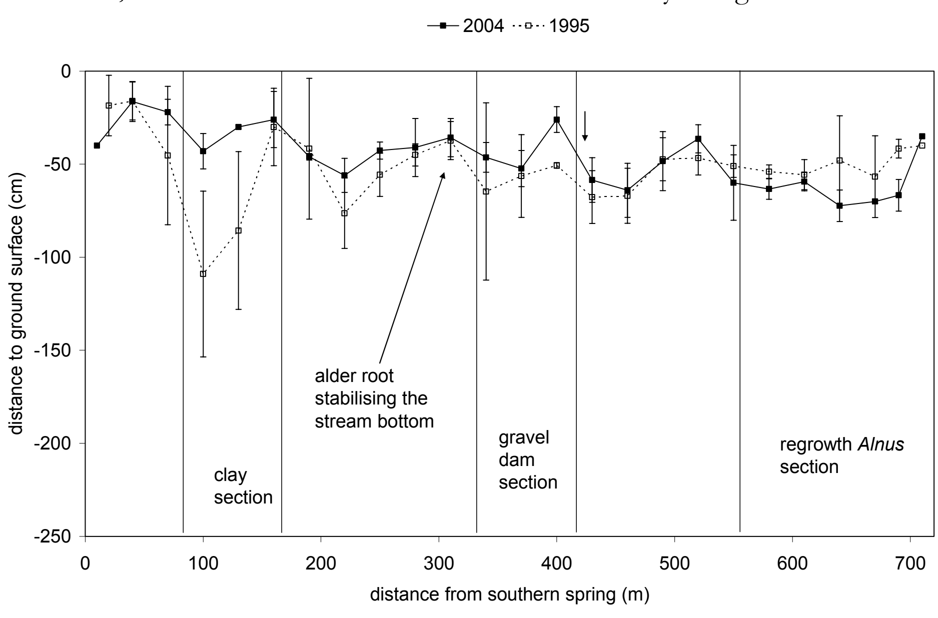


Figure 3.6 Average incision of the stream bottom of the southern upper course per 30 m. Error bars indicate the standard deviation. Data points without bars represent single measurements.

Figure 3.6. The bottom rise in the dam section is less clear because both this section and the upstream part, maybe also due to the dams, rose. About 300 m downstream

of the spring an old alder stabilized the stream bottom. This section did not change between 1995 and 2004. In Figure 3.7 the average distance between stream bottom and ground level per 30 m section of the southern Onland branch is illustrated for the years 1995 and 2004. This branch is not incised and showed little variation. The maximum incision is about 35 cm.

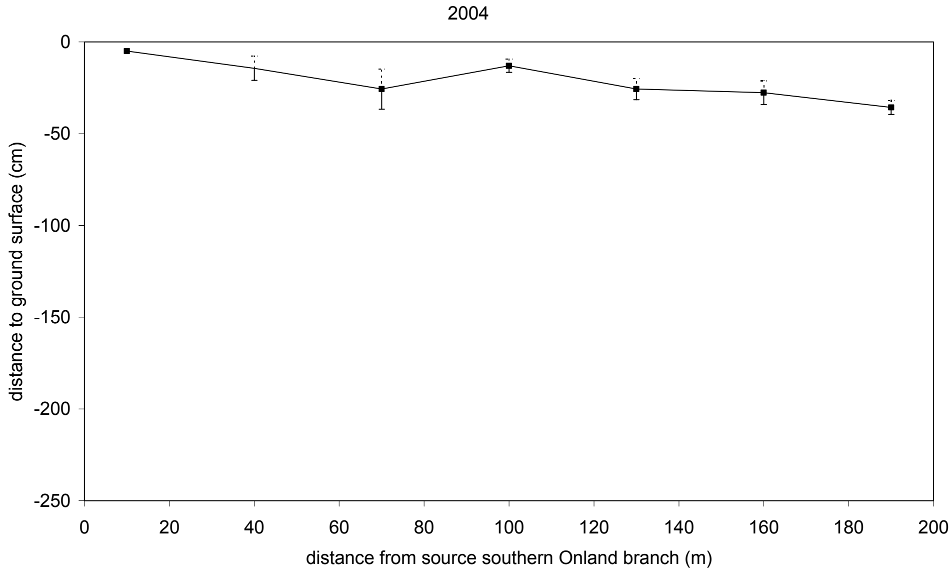


Figure 3.7 Average incision of the stream bottom of the southern Onland branch per 30 m. Error bars indicate the standard deviation. Data points without bars represent single measurements.

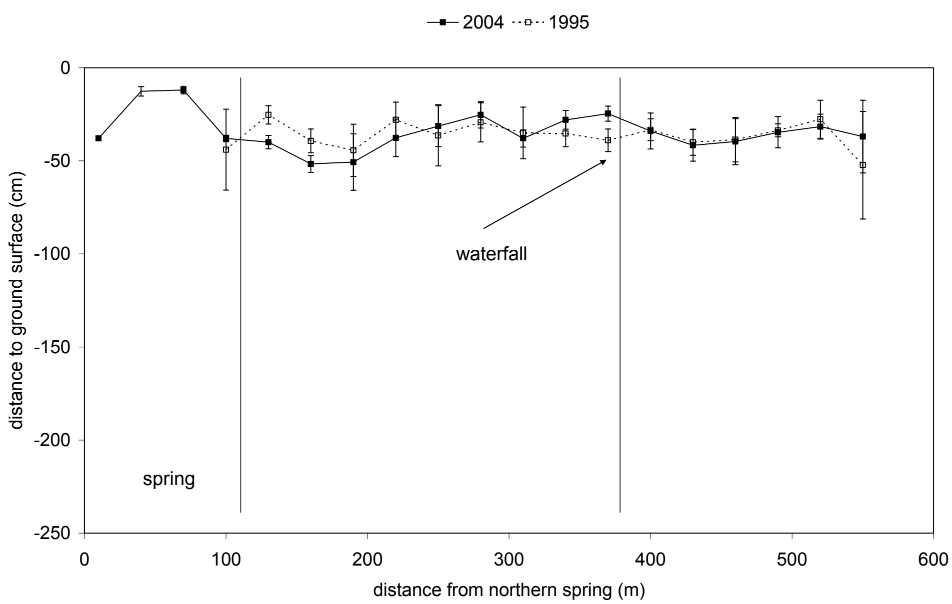


Figure 3.8 Average incision of the stream bottom of the northern upper course per 30 m. Error bars indicate the standard deviation. Data points without bars represent single measurements.

In Figure 3.8 the average distance between stream bottom and ground level per 30 m section of the northern upper course is illustrated for the years 1995 and 2004. Just downstream of the spring the northern upper course deepened over about 120 m. Just upstream of the waterfall, which was reconstructed in a cascade, the stream lifted. Also the section before the confluence with the southern upper course rose duet o the newly constructed culvert.
The average distance between stream bottom and ground level per 30 m section of the middle course is illustrated for the years 1995 and 2004 in Figure 3.9. The deepest incision occurred after the confluence with the Nutterveld branch, just downstream of an alder root that stabilized its upstream section. Also the culvert at the road crossing 'Blue road' acts as a stabilizer. Downstream of this culvert the stream bottom was situated deep in the landscape. Between 1995 and 2004, the middle course deepened itself, except for the upstream first 240 m. One section (at about 1320 m) rose. This section also widened. A bank collapse could have caused both processes or a natural dam could have been started to act as a material collector.

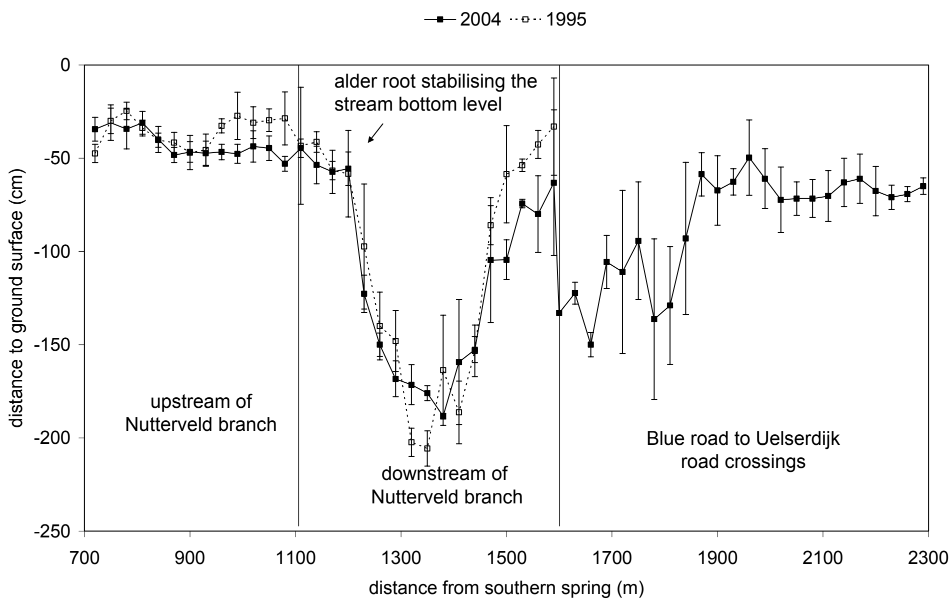


Figure 3.9 Average incision of the stream bottom of the middle course per 30 m. Error bars indicate the standard deviation. Data points without bars represent single measurements.

Wet slope

The wet slope of the southern upper course was 17.28 m over a distance of 720 m. The slope became more regular, thus the physical profile stabilized, when comparing 2004 with 1995 (Figure 3.10). Hydrological measures taken prevent extreme discharge peaks that in the past led to dam formation and dynamic erosion-sedimentation patterns. The slope changed slightly along the first 260 m downstream of the spring due to the clay filling. The alder, 300 m downstream of the spring stabilized the slope. Also about 500 m downstream the spring the slope changed due to a mass development of *Berula erecta* which drove up the water.

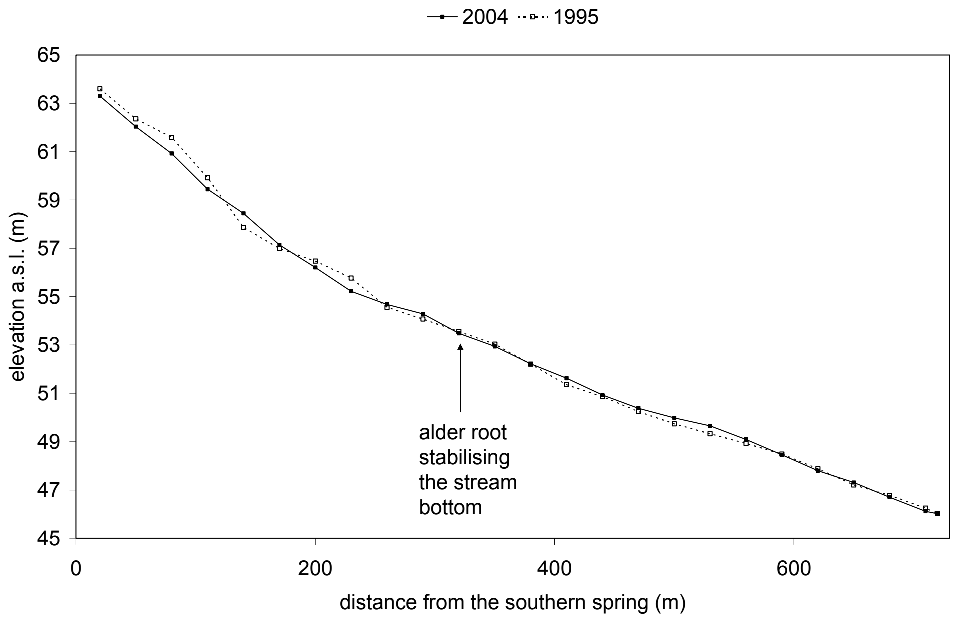


Figure 3.10 Slope of the southern upper course based on measurements over 30 m long sections.

The wet slope of the southern Onland branch was 6.15 m over a distance of 200 m. The waterfall at about 40 m downstream of the spring has a height difference of 1 m (Figure 3.11).

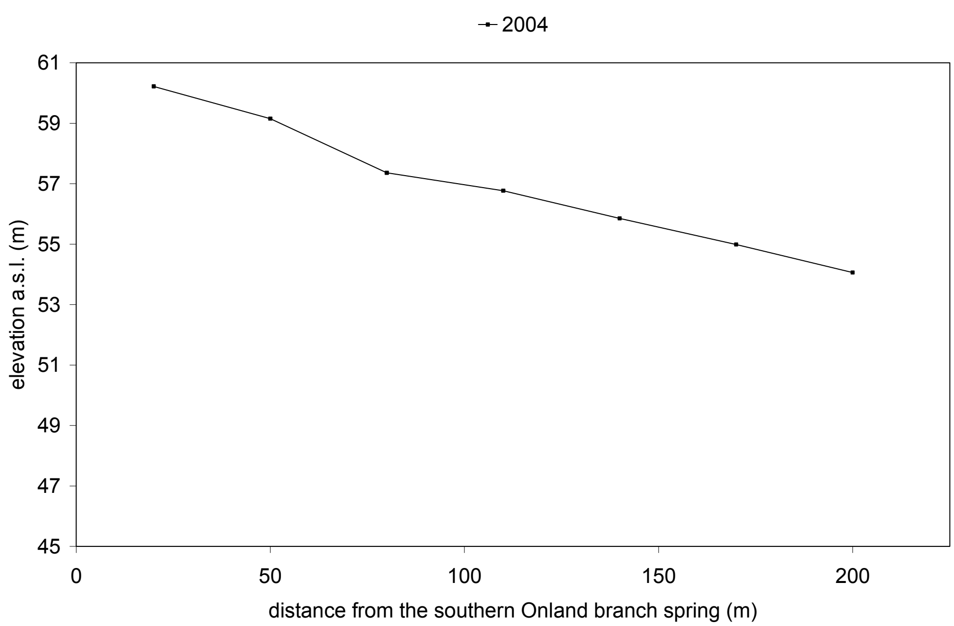


Figure 3.11 Slope of southern Onland branch course based on measurements over 30 m long sections.

The wet slope of the northern upper course was 9.30 m over a distance of 550 m. The somewhat deeper incision just downstream of the spring is illustrated in Figure

3.12. Only in the downstream section the slope slightly decreased due to again a mass development *Berula erecta*.

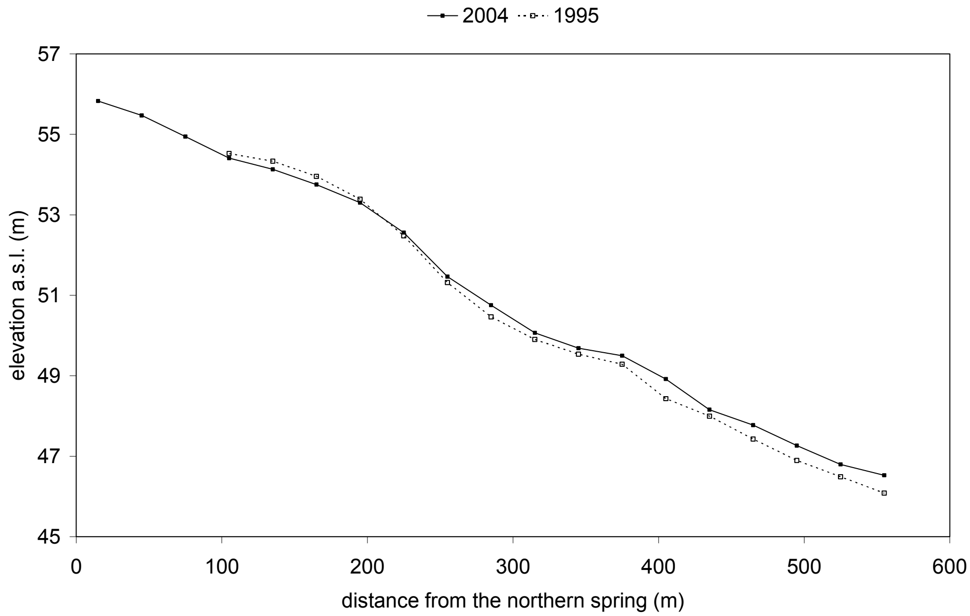


Figure 3.12 Slope of the northern upper course based on measurements over 30 m long sections.

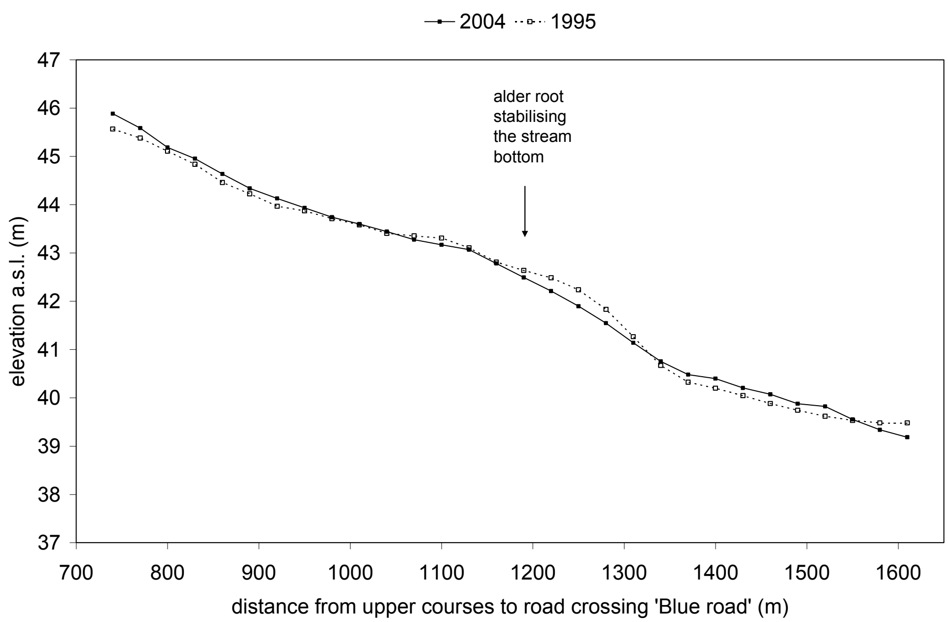


Figure 3.13 Slope of the middle course until the road crossing 'Blue road' based on measurements over 30 m long sections.

The wet slope of the middle course until the road crossing 'Uelserdijk' was 11.40 m over a distance of 1580 m. The slope slightly decreased due to again a mass development *Berula erecta* (Figure 3.13). From the confluence with the Nutterveld branch on, the wet slope showed the same pattern as described for the incision. Both approaches show a deepening of the stream after about 1200 m and a rise after about 1300 m. Deepening again occurred after 1440 m, though this is only visible in the wet slope after 1550 m.
Downstream of the road crossing 'Blue road' the middle course wet slope is smooth (Figure 3.14).

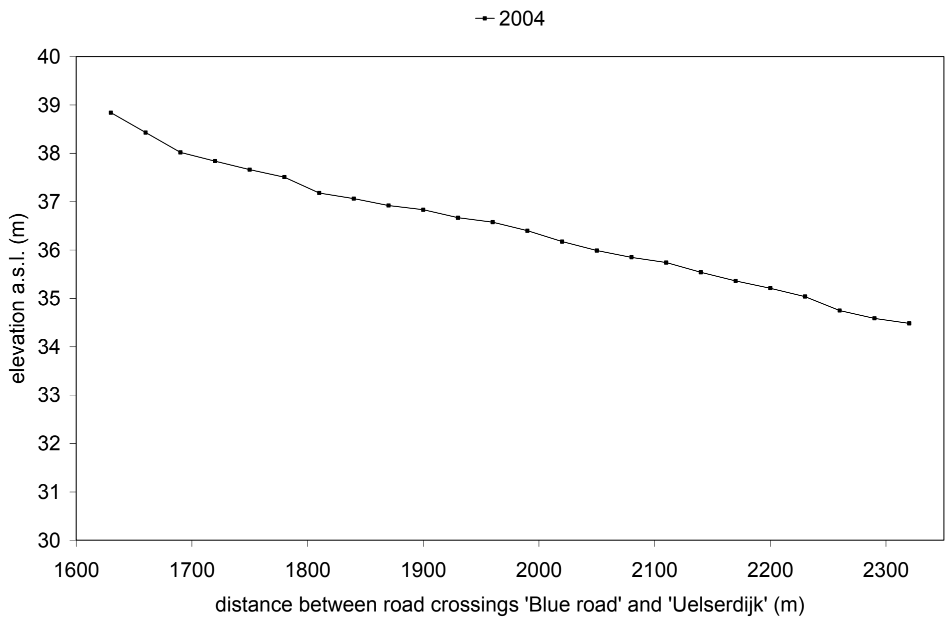


Figure 3.14 Slope of the middle course from the road crossing 'Blue road' to the road crossing 'Uelserdijk' based on measurements over 30 m long sections.

Substrate pattern
The mineral substrates in the southern upper course as well as the middle course mainly consisted of sand (Figure 3.15 and 3.17). Stones only occurred in the most downstream sections, as these were not natural added to stabilize the banks. Large stretches of the stream lack gravel beds. Organic substrates mainly occurred in the wooded areas and the first sections just downstream of the wooded areas (Figure 3.16 and 3.18). Coarse detritus is abundantly present downstream of the road crossing 'Blue road'. Fine detritus prevailed mainly in the southern upper course (early summer with low discharges) and indicates lower current velocities. The high amounts at about 1500 m indicates the presence of an organic dam. On the contrary, in the fast running, narrow downstream part of the middle course fine detritus is lacking almost completely as deposition zones are very scarce.
In 2004 the portion of gravel was reduced in comparison to 1995. Downstream of the confluence of southern and northern upper course this was due to the mass development of *Berula erecta*.

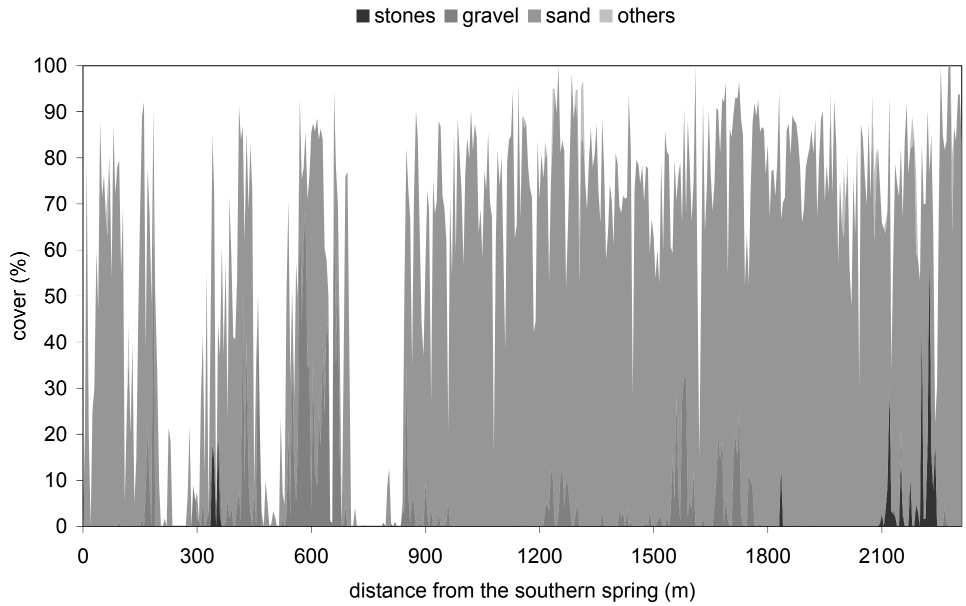


Figure 3.15 The distribution of mineral substrates along the southern upper course and middle course of the Springendal stream in 1995. Note that the most upstream 160 m and the most downstream 700 m were not recorded.

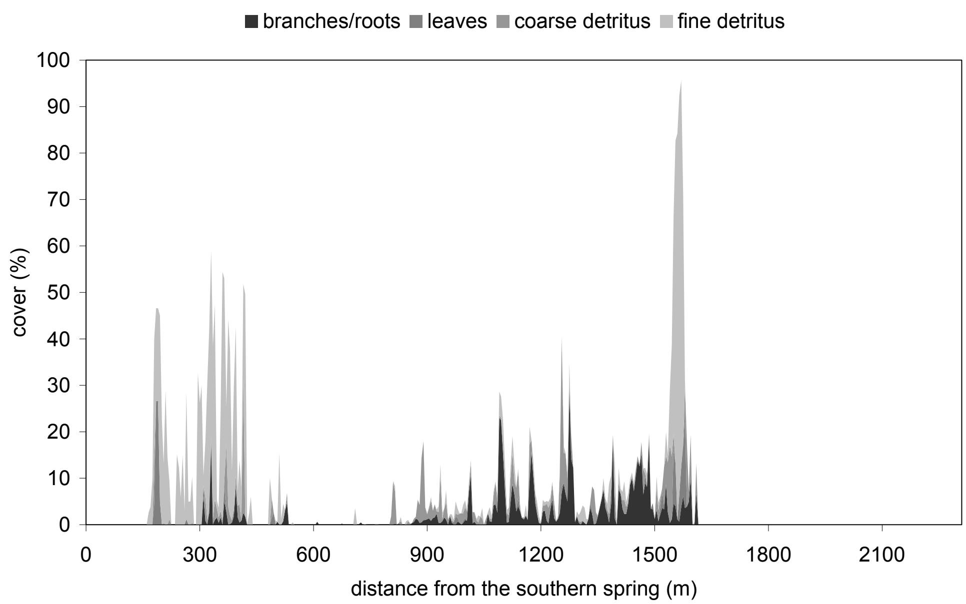


Figure 3.16 The distribution of organic substrates along the southern upper course and middle course of the Springendal stream in 1995. Note that the most upstream 160 m and the most downstream 700 m were not recorded.

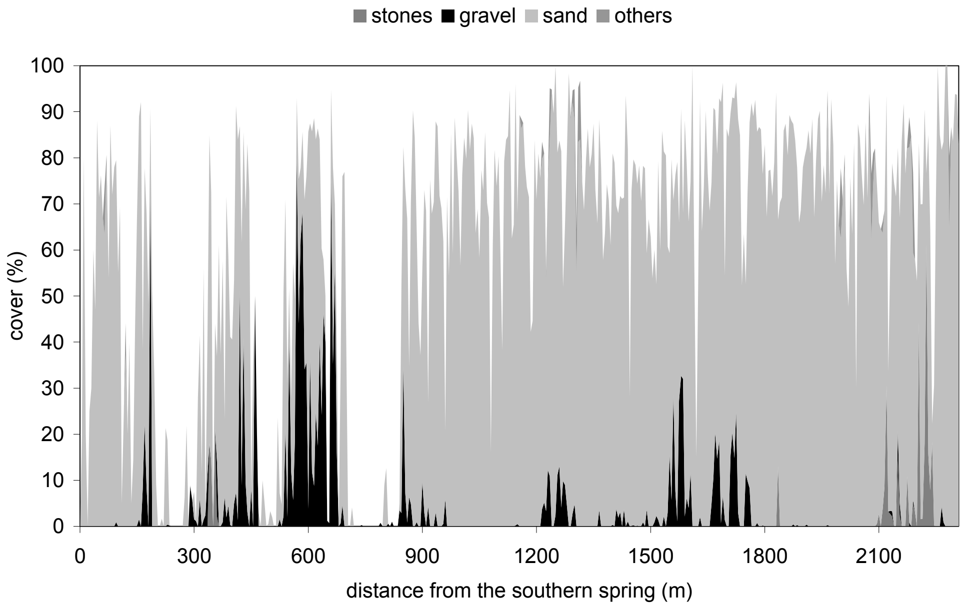


Figure 3.17 The distribution of mineral substrates along the southern upper course and middle course of the Springendal stream in 2004.

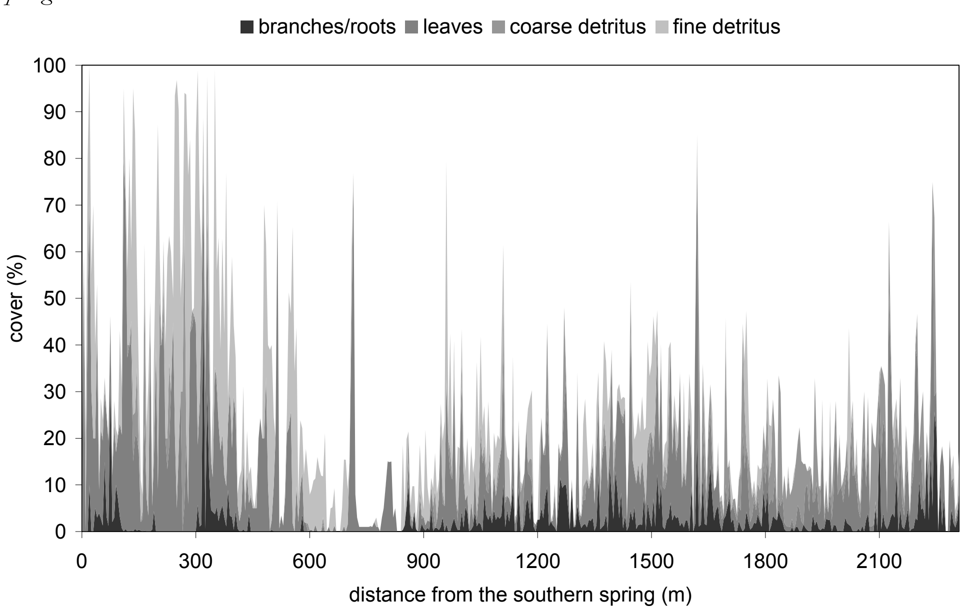


Figure 3.18 The distribution of organic substrates along the southern upper course and middle course of the Springendal stream in 2004.

The hydrological stability in the southern upper course caused an increased in organic substrates in 2004. Although, partly this difference can also be due to the fact that the surveys did not take place in the same season, namely in 1995 the survey was done in early summer and in 2004 in late autumn. Locally, clay and peat banks were found.
Seasonal differences between the surveys of 1995 and 2004 also caused differences in leave coverage. In early summer leaves were broken down while in late autumn leave fall is very high. Still, the more dynamic discharge pattern of 1995 will also have added to lower amounts of leaves.

The southern Onland branch is characterised as an organic stream (Figure 3.19). Mineral substrates more or less lack. Especially, coarse detritus prevailed.

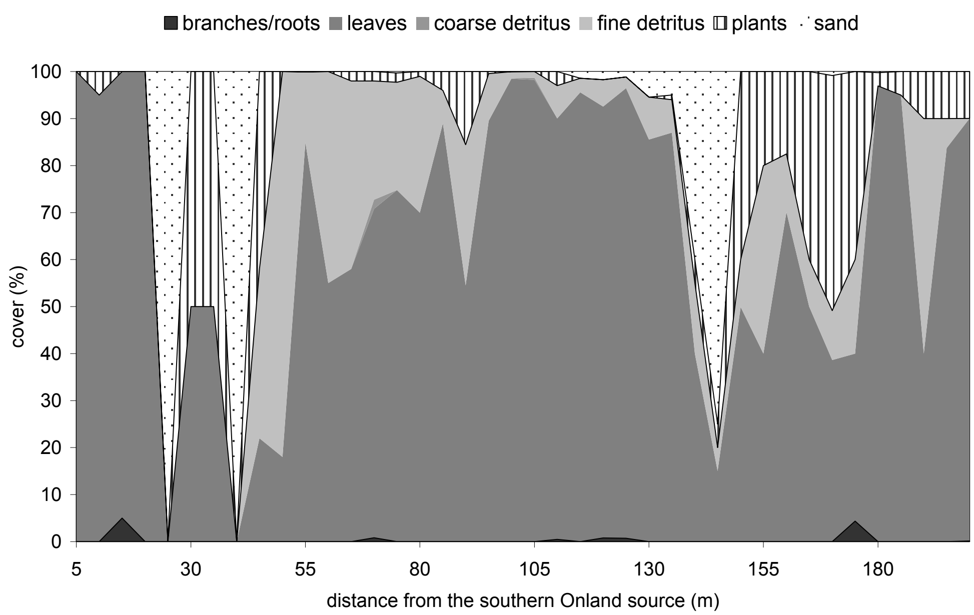


Figure 3.19 The distribution of substrates along the southern Onland branch of the Springendal stream in 2004.

Also in the northern upper course the proportion of gravel decreased between 1995 and 2004 (Figure 3.20, 3.22). Again the expansion of *Berula erecta* was one of the main causes, but also the seasonal difference between both surveys plays a role. The proportion of leaves and other organic substrates were much higher in the 2004 survey due to season (Figure 3.21, 3.23). The proportion of fine detritus was low and indicates higher current velocities. Note that in between *Berula erecta* vegetation patches fine detritus accumulates. This fraction though was not taken into account.

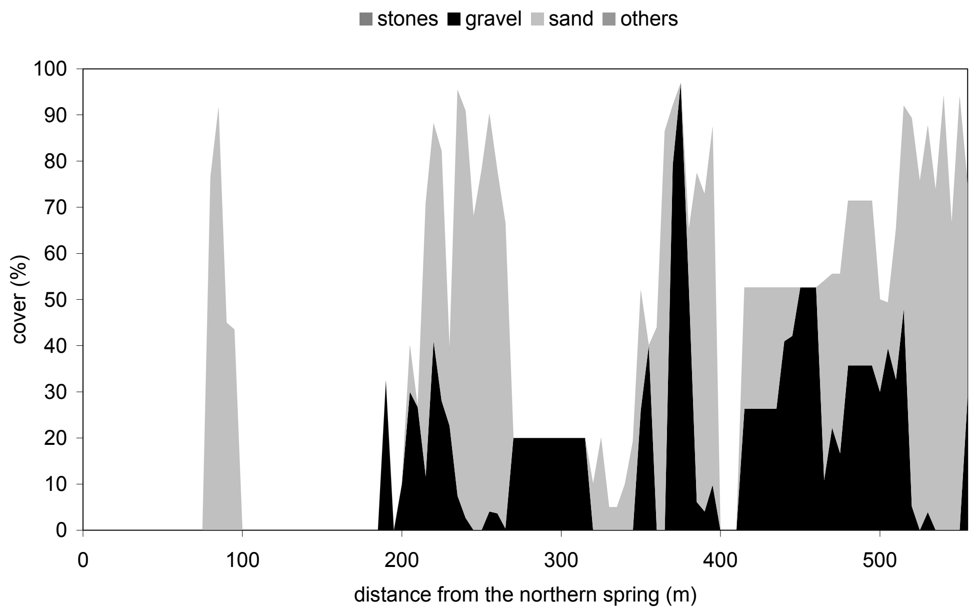


Figure 3.20 The distribution of mineral substrates along the northern upper course of the Springendal stream in 1995. Note that the most upstream 75 m were not recorded.

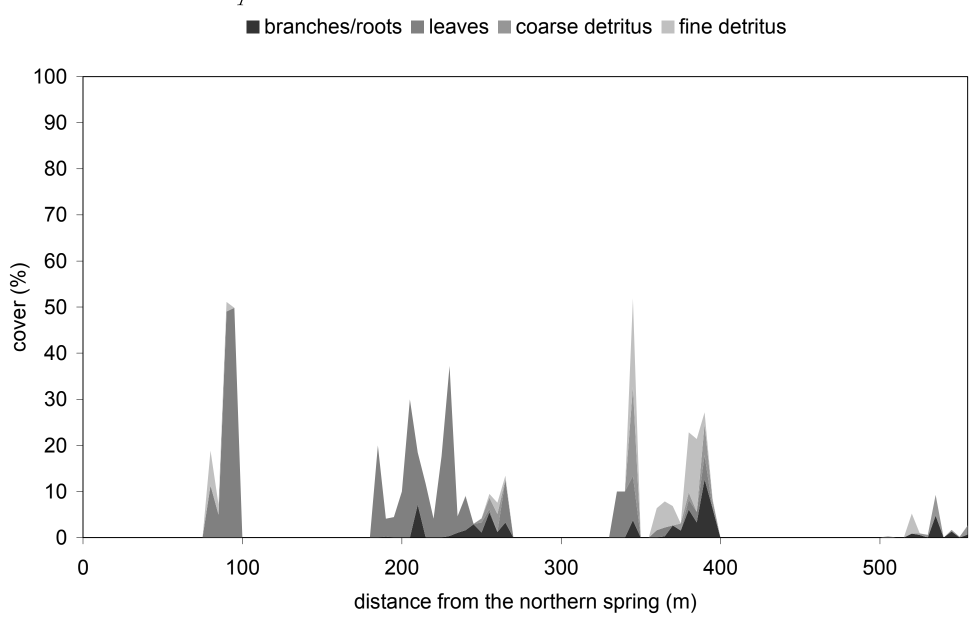


Figure 3.21 The distribution of organic substrates along the northern upper course of the Springendal stream in 1995. Note that the most upstream 75 m were not recorded.

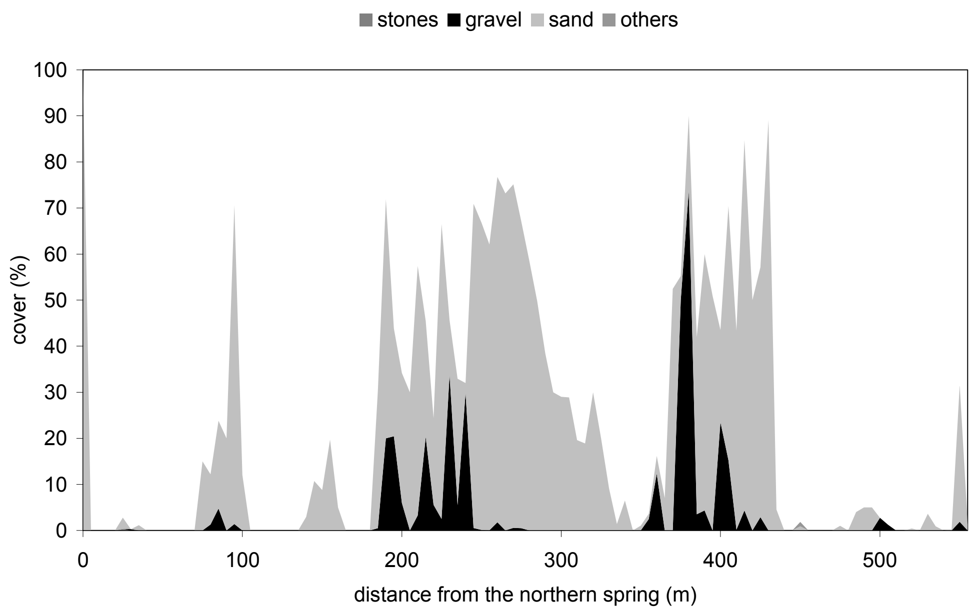


Figure 3.22 The distribution of mineral substrates along the northern upper course of the Springendal stream in 2004.

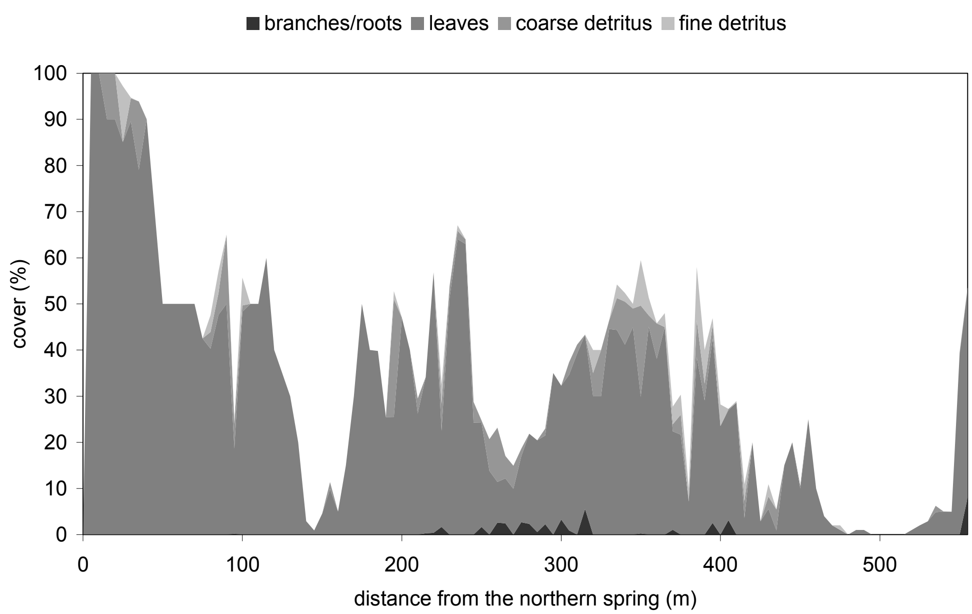


Figure 3.23 The distribution of organic substrates along the northern upper course of the Springendal stream in 2004.

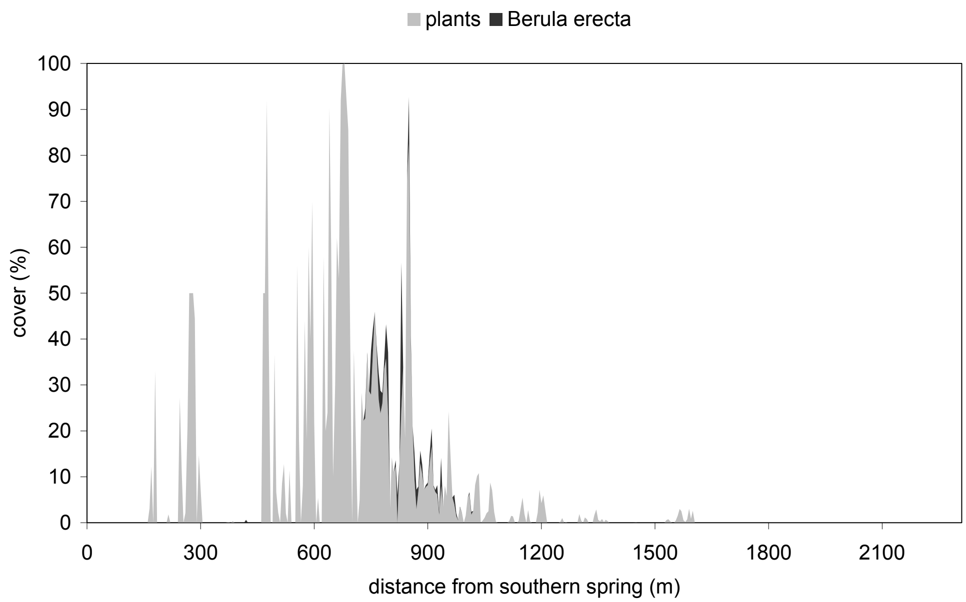


Figure 3.24 The distribution of Berula erecta along the southern upper course and middle course of the Springendal stream in 1995. Note that the most upstream 160 m and the most downstream 700 m were not recorded.

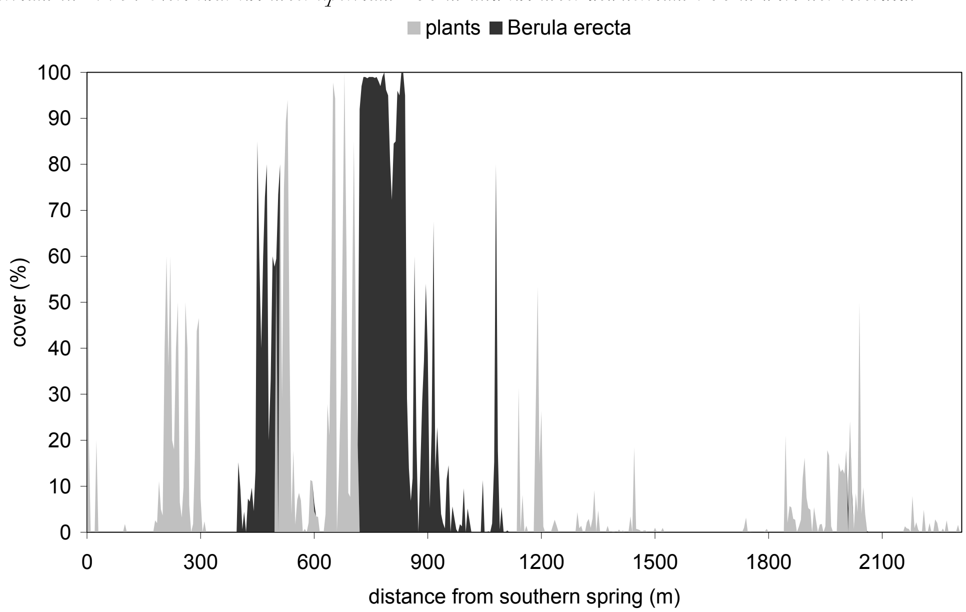


Figure 3.25 The distribution of Berula erecta along the southern upper course and middle course of the Springendal stream in 2004.

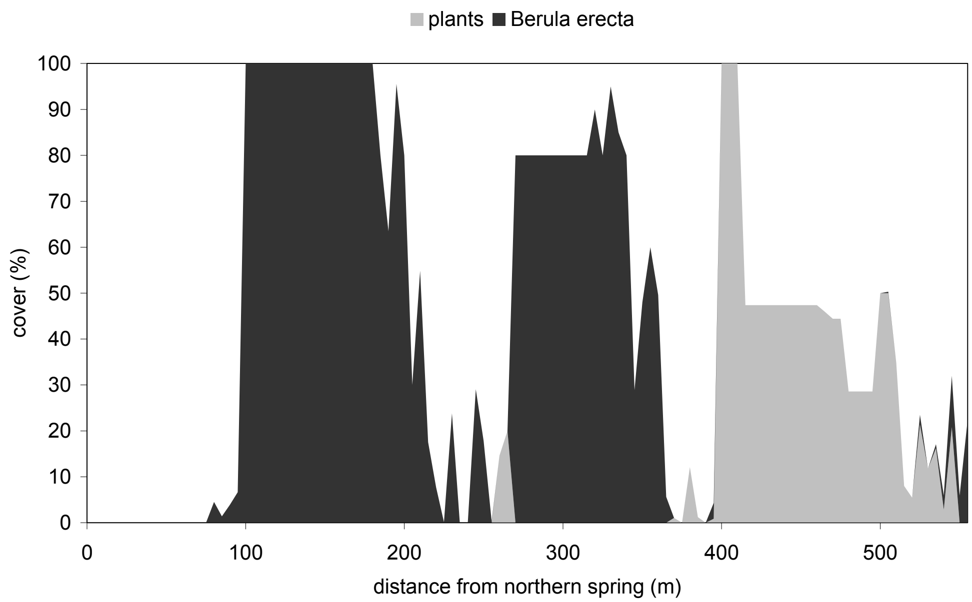


Figure 3.26 The distribution of Berula erecta along the northern upper course and middle course of the Springendal stream in 1995. Note that the most upstream 75 m were not recorded.

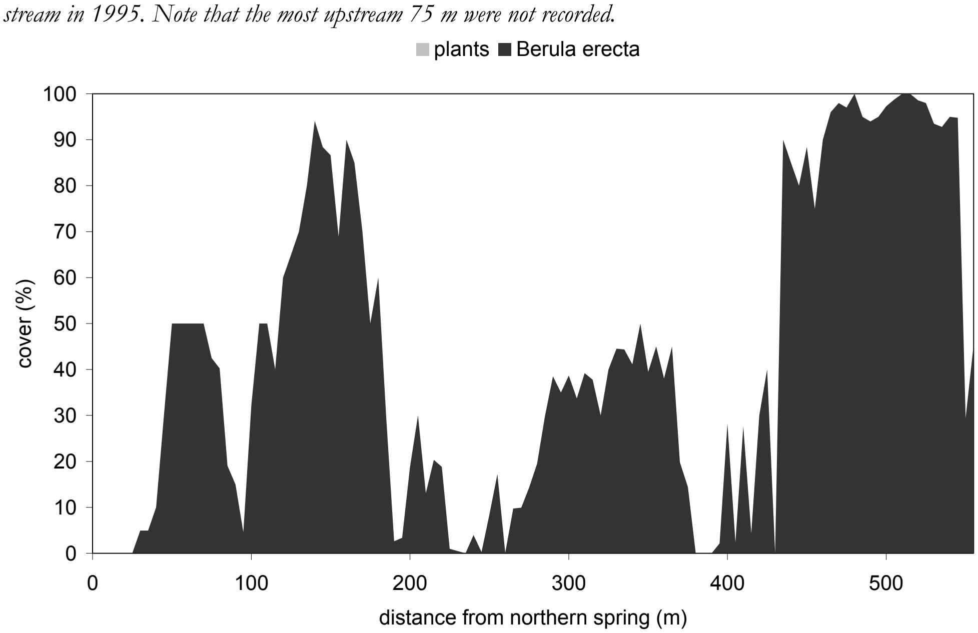


Figure 3.27 The distribution of Berula erecta along the northern upper course and middle course of the Springendal stream in 2004.

Vegetation

Vegetation coverage was estimated in two classes, either *Berula erecta* or other plants (mainly terrestrial plants reaching the water). There is a strong expansion visible of *Berula erecta* patches in unshaded stretches in 2004 compared to 1995 (Figure 3.24 and 3.25). This emergent water plant has small roots and can easily be washed out. The more stable discharge after 1995 probably offered the plant the possibility to expand. The offshoots of this species make local expansion even stronger. The northern upper coure is dominated by *Berula erecta* in 2004 (Figure 3.26, 3.27). There was a mass expansion in the downstream part due to the culvert reconstruction (Figure 3.27) that caused lower current velocities and a wider transversal profile.

Trees rooting in the stream

During the surveys also trees rooting in the stream were noted per 30 m section. Locally, there were clear differences between 1995 and 2004 in the southern and middle course (Figure 3.27). These differences are most probably caused by the definition of rooting trees, which was differently interpreted between the two surveys. Still, in general 1 to 5 trees root in the stream along a 30 m stretch. Only in the downstream part of the middle course the tree density was higher (up to 18 trees per 30 m). In this stretch the stream runs through a wooded bank causing a higher tree density close to the stream bank.

The stretch along the southern upper course, where alder could develop, the number of rooting trees (though very young) was up to 60 per 30 m. Along the northern upper course up to 7 rooting trees per 30 m section were found. The differences between 1995 and 2004 were due to differences between observers (Figure 3.28).

Along the southern Onland branch the number of rooting trees was only two.

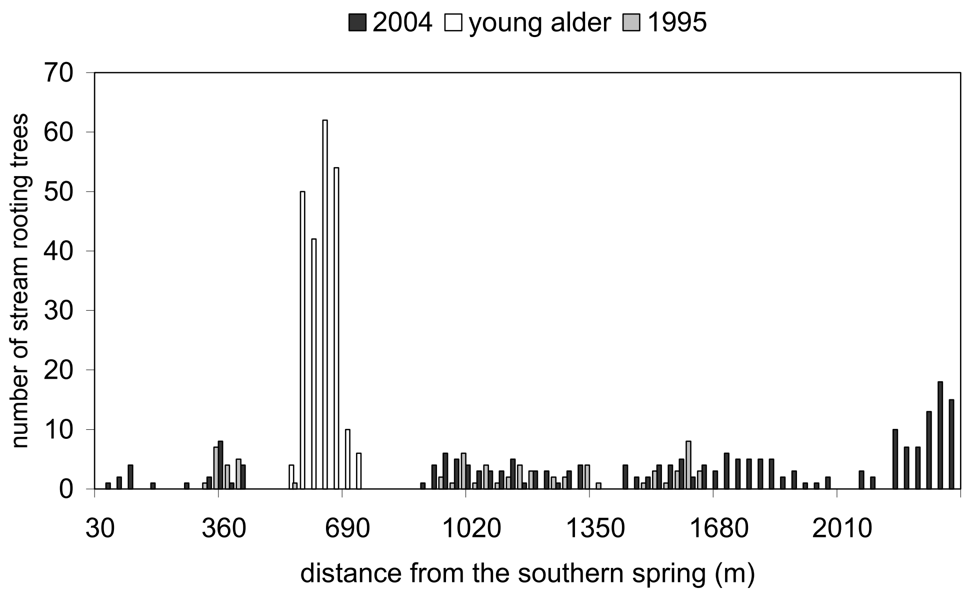


Figure 3.27 Number of in the stream rooting trees along the southern upper course and the middle course per 30 m section in 1995 and 2004.

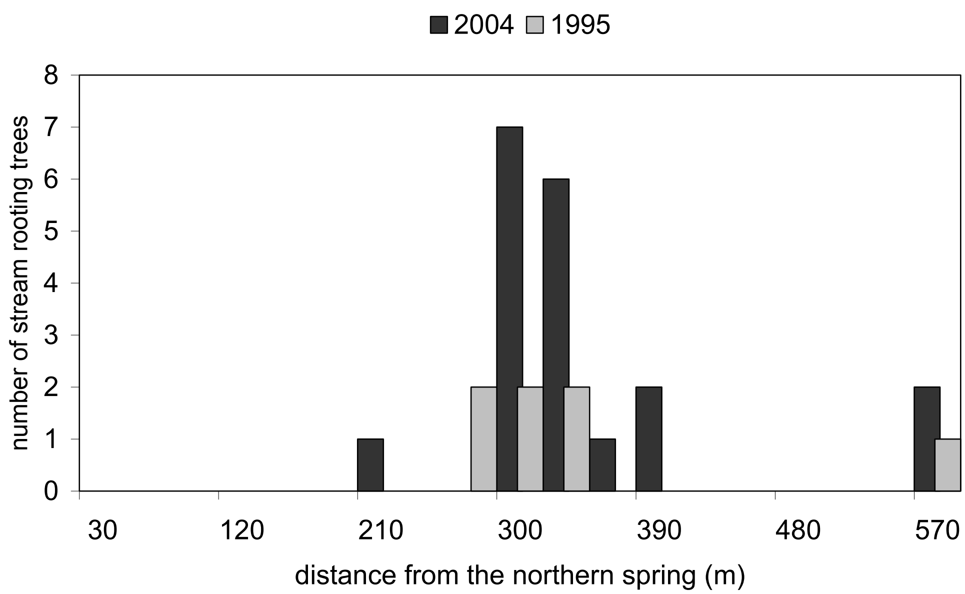


Figure 3.28 Number of in the stream rooting trees along the northern upper course course per 30 m section in 1995 and 2004.

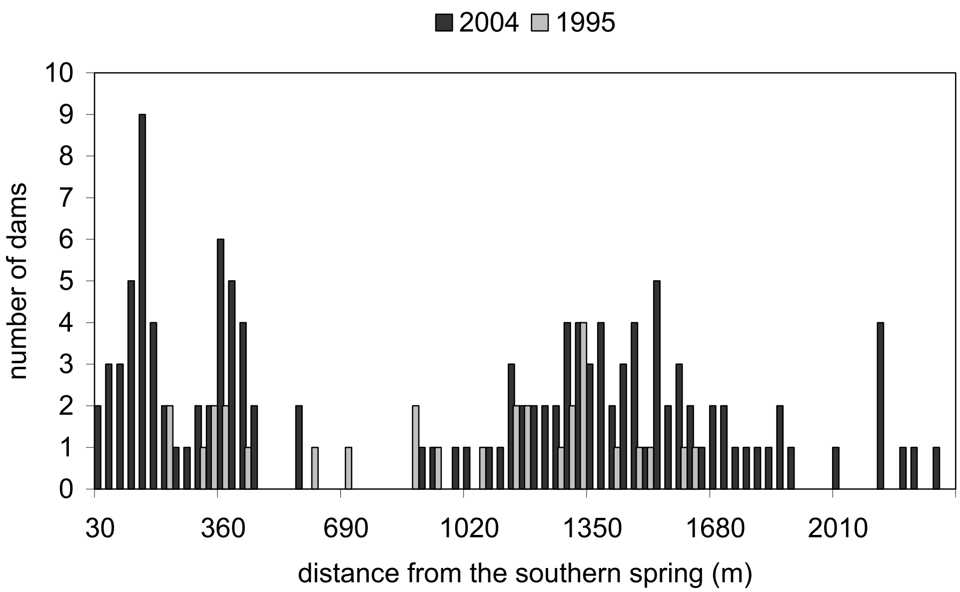


Figure 3.29 Number of organic dams along the southern upper course and the middle course per 30 m section in 1995 and 2004.

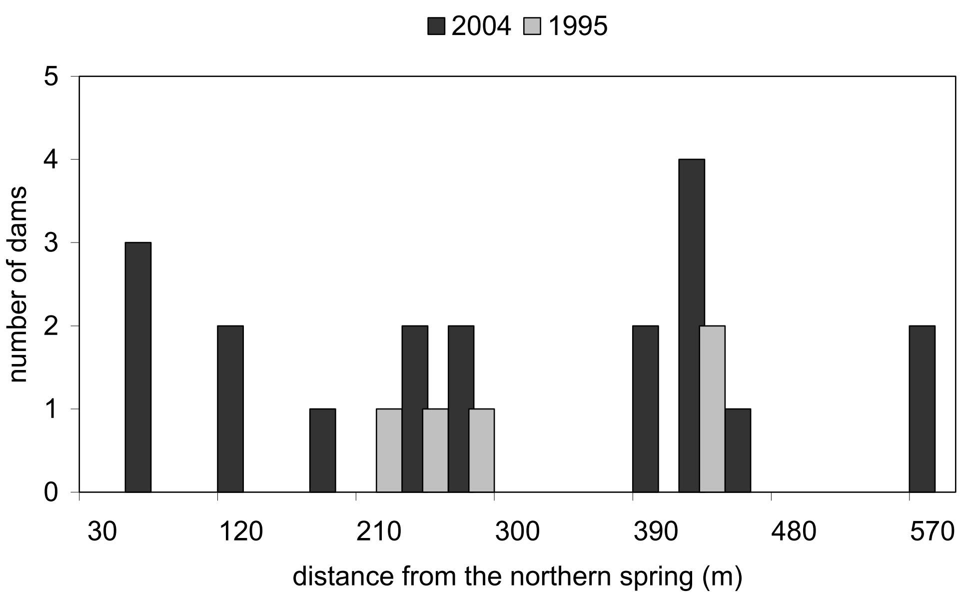


Figure 3.30 Number of organic dams along the northern upper course per 30 m section in 1995 and 2004.

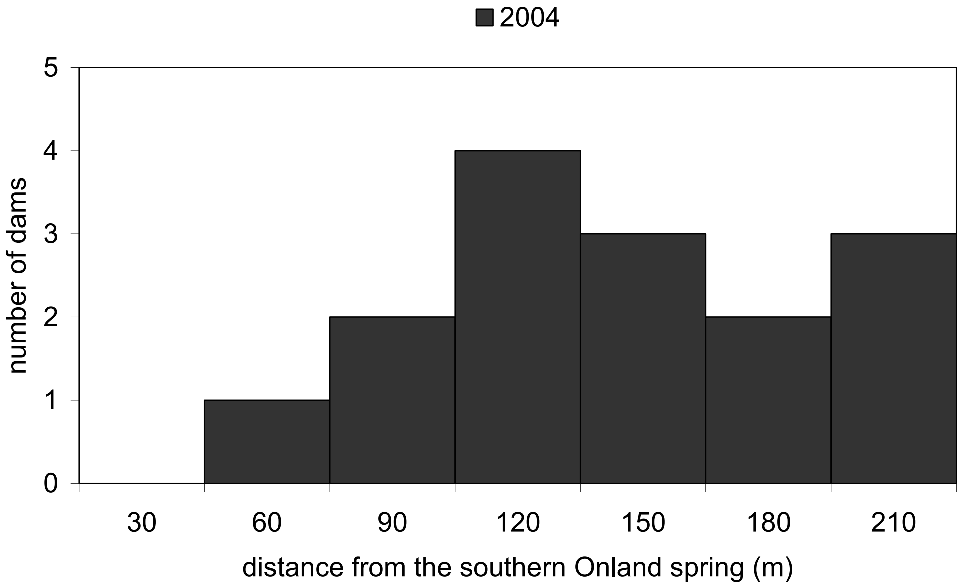


Figure 3.31 Number of organic dams along the Onland branch per 30 m section in 1995 and 2004.

Organic dams

The number of organic dams increased between 1995 and 2004 (Figure 3.29). This could be caused by a seasonal difference in survey date. Most of these dams were noted from forested areas and such dams are formed amongst others by leave accumulation. In 1995 a maximum of four dams was found, in 2004 one section had even nine dams. On average in 1995 each 30 m section had one dam while in 2004 two to three.

The northern upper course only had few dams in 1995 (Figure 3.30).

The southern Onland branch had on average two dams in each of its 30 m sections (Figure 3.31).

3.4 Conclusions

In between the years 1995 and 2004 several restoration measures were taken in the Springendal stream catchment to reduce discharge dynamics as well as to reduce eutrophication. Large scale changes in morphology in time were recorded.

The reduction of peak flows induced a process in the stream to reach a new morphological balance in length and depth profile. Incision, caused by floods before 1995 had created steep banks. In 2004 at several sections the stream had widened and the steep banks were collapsed. Still, locally the stream bottom showed incision whereby steep banks had formed. This could be due to broken dams or disappearance of tree roots. Old tree roots blocking the stream appeared to be of high importance in lowland streams. Such roots act as fixed points in the longitudinal profile and stabilize the morphological processes in the whole stream.

Construction like culverts, gravel dams or clay filling induced sedimentation processes whereby the stream bottom rose. Rising of the bottom in several section went parallel with widening of the stream.
Another important change that took place was the mass development of *Berula erecta*. This emergent water plant has small roots and is easily washed out. The more stable discharge after 1995 probably offered the plant the possibility to expand. The plant packets act as material collector (both organic and mineral) and lift the stream bottom as well as widen the bed. As *Berula erecta* is indicative for nutrient rich, carbonate rich, neutral to basic water, it indicate the slight enrichment of the stream.
On the one hand, discharge stabilisation caused a higher substrate diversity as more organic substrates settled and thus a gain of habitats. On the other hand, the plant development together with other stream bottom rise measures did gravel beds to be reduced, a loss of an important habitat.
The number of organic dams increased again due to discharge stabilisation. Organic dams cause a high variety substrates to develop and thus add to diversity. These dams mainly occur in wooded areas. Along with the importance of tree roots and leave input, dams are the third argument in favour of the presence of trees along lowland streams. Shading furthermore limits the development of *Berula erecta*.

4 Material transport, discharge and substrate pattern

4.1 Introduction

Substrate dynamics can either be measured indirectly by a cumulative collection of transported material or by a frequent mapping of the substrate pattern.
The substrate dynamics of a stream must go parallel with a transport, either suspended or moving, of material. A method to measure transport is through a cumulative collection of transported material. We devised two methods, one to collect moving sediment and one to collect suspended material. Moving sediment is the bottom material that is rolling or sliding over the stream bottom, while the suspended material floats/whirls in the water column. The cumulative collection of suspended and moving mineral and organic material together tells about the (in)stability of the stream, not per habitat but per whole stream stretch. In this way, various stream stretches with different discharge regimes can be compared and the amount of material transported will be related to discharge.
The second approach concerns the mapping of the habitats in the sections. Therefore, a grid is used.

4.2 Materials and methods

Discharge
Discharge was recorded continuously by using an automated water level registration equipment linked to measure weirs. The weir provided a fixed profile in the stream. In fact not the discharge but the water level was measured continuously, using data loggers. These data loggers were constructed within a metal pipe which is situated in the river bank (Figure 4.1). A transversal pipe ensured the horizontal connection with the water column of the stream. Water moved from the stream into this pipe. The data logger recorded the pressure of the water in the pipe.

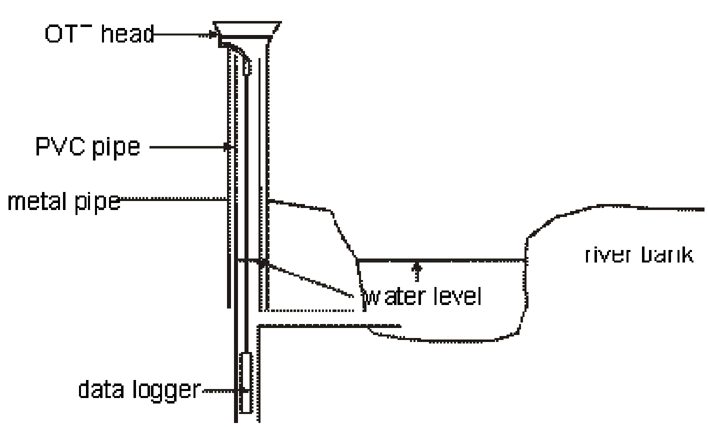


Figure 4.1. Continuous discharge measurement equipment.

The water level data were transformed in discharge data by using data collected from the transversal profile of the measuring weir.
Discharge was measured in six stream sections that differed in discharge pattern through either canalization or runoff.
downstream in the northern upper course
downstream in the southern upper course
upstream in the middle course (the so-called reference section)
downstream in the Nutterveld branch
downstream in the middle course after the culvert at the crossing of the road 'Blue road'.
in the middle section of the lower course

Mineral and organic matter collector (MOC) and sediment trap
The mineral and organic material collector (MOC) is devised according to the principle of extracting a small part of the stream water layer, including its suspended material, and leading it through an almost still reservoir that allows material to deposit (Figure 4.2). The bottom sediment collector is devised to collect the moving and rolling sand that is not suspended in the water layer (Figure 4.3).
Both collectors are emptied every 2 weeks

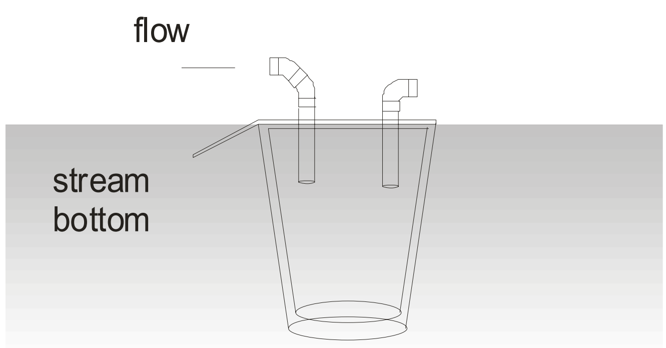


Figure 4.2. Scheme of the mineral and organic material collector.

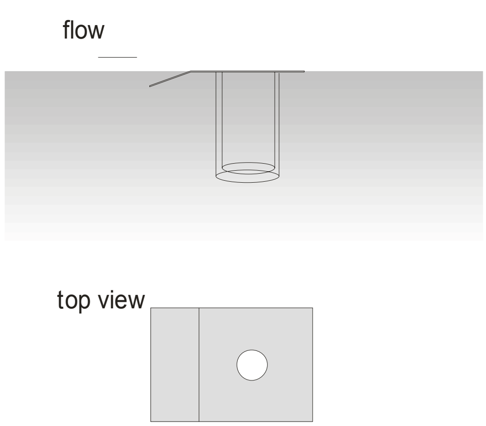


Figure 4.3 Scheme of the bottom sediment collector.

Sampling took place every week in three periods. Period one was from May 31st up to July 5th. Samples were collected with MOC (3 replicates) and sediment collector (3 replicates) while also substrate patterns were recorded at the sampling dates: 07-06-05, 14-06-05, 22-06-05, 28-06-05, and 05-07-05. Period two and three included the same methods and were from October 10th up to November 11th, and January 10th up to February 7th. Sampling dates were 17-10-2005, 24-10-2005, 31-10-2005, 8-11-2005, and 17-01-06, 24-01-06, 31-01-06, 07-02-06, , respectively.

Substrate pattern
To record the substrate pattern in the field, the potential substrate types are listed in Table 4.1.

Table 4.1 Substrate types.

substrate type	description
coarse gravel	> 6 mm
fine gravel	2 - 6 mm
sand	0.125 - 2 mm
clay and mineral silt	mineral not recognizable particles < 0.125 mm
fine detritus, organic silt	fine, not recognizable parts and organic material with particles < 2 mm
coarse detritus, branches, twigs, roots, leaves	coarse, recognisable organic material, particles > 2 mm
macrophytes	living plants

The substrate is recorded, by estimating the percentage cover per substrate over two stretches of 1.8 m per stretch. To do so, the substrate (habitat) mosaic of the stream bottom is mapped. Therefore, a grid is used (Figure 4.4). The grid was constructed of iron bars (diameter 0.5 cm) waved into a mat with cells of 15 by 15 cm. At each date of measurement per grid cell the most dominant substrate present is noted on a field form.

.This provides the opportunity to study the stability of the substrate present in each grid cell in a stretch (how often changes the substrate in time?) as well as the habitat diversity (how many different substrates are there and what is the surface area for each substrate?).

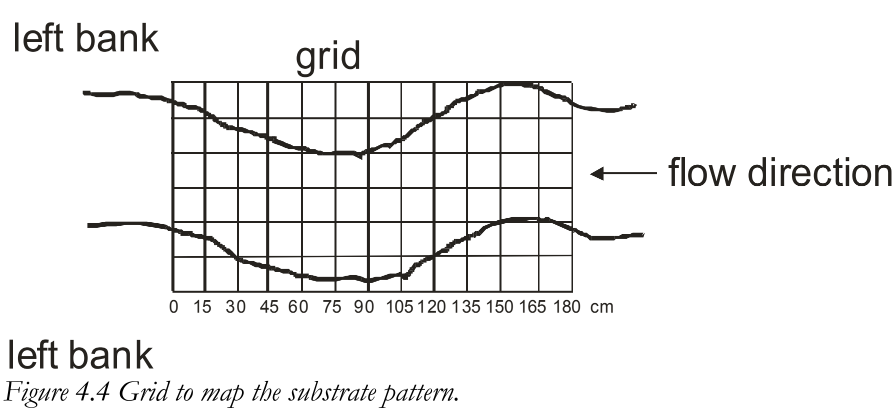


Figure 4.4 Grid to map the substrate pattern.

4.3 Results

Northern upper course

At the end of the first period of measurements, in June, an extreme flood occurred. This flood eroded part of the northern upper course and washed out a large part of the *Berula erecta* vegetation. Before this flood (Figure 4.5) more suspended organic material then mineral material was transported, although both quantities were quite low. The flood itself released a reasonable amount of suspended material. This extreme June flood changed the whole northern upper course. The course there after started to establish a new sedimentation-erosion balance. This process appeared visible in both the October and January measurements. In both periods a large amount of suspended material was transported while only minor dynamics in discharge occurred. This pattern is also shown in the data obtained from the sediment traps, the moving bottom material (Figure 4.6).
The substrate pattern changed quite drastically after the extreme June flood event. In one section (Figure 4.6) the flood washed the detritus and a large gravel bed appeared. In the second section the detritus was largely replaced by sand due to the extreme flood (Figure 4.7). In both other periods of measurement only gradual changes in substrate pattern occurred (Figures 4.7 and 4.8).

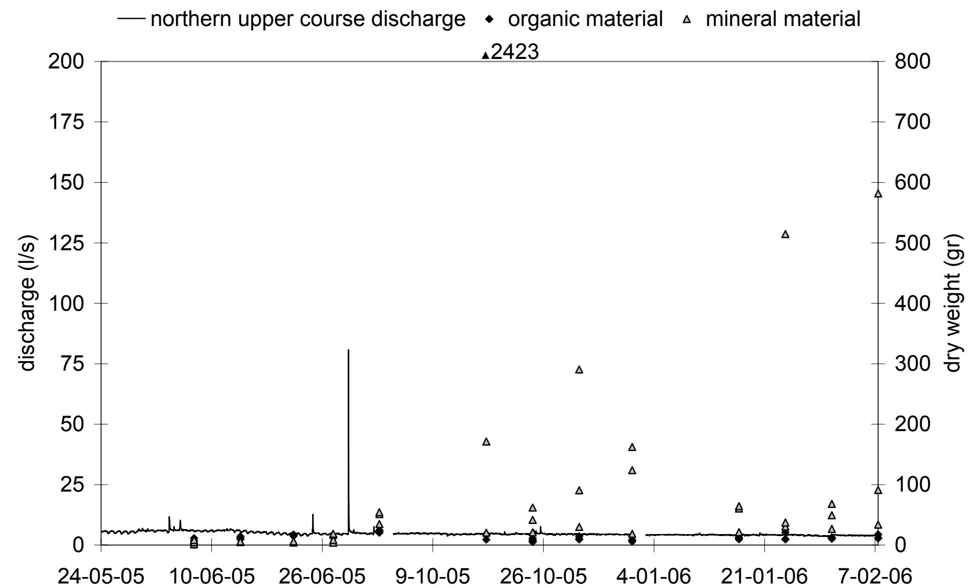


Figure 4.5 Continuous discharge pattern and material collected by means of the MOC's, during three periods of measurement (June 2005, October 2005 and January 2006).

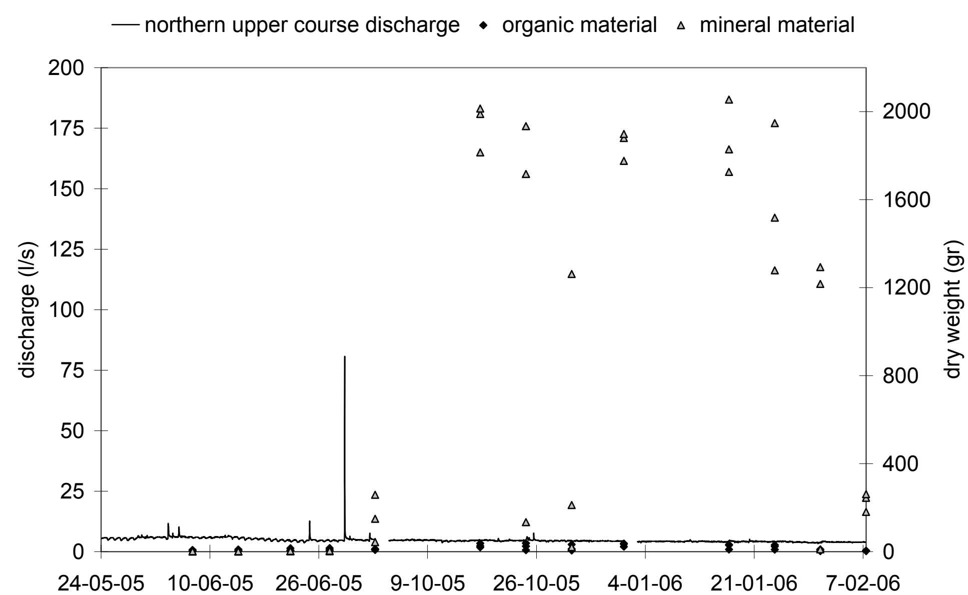


Figure 4.6 Continuous discharge pattern and sediment collected by means of the sediment traps, during three periods of measurement (June 2005, October 2005 and January 2006).

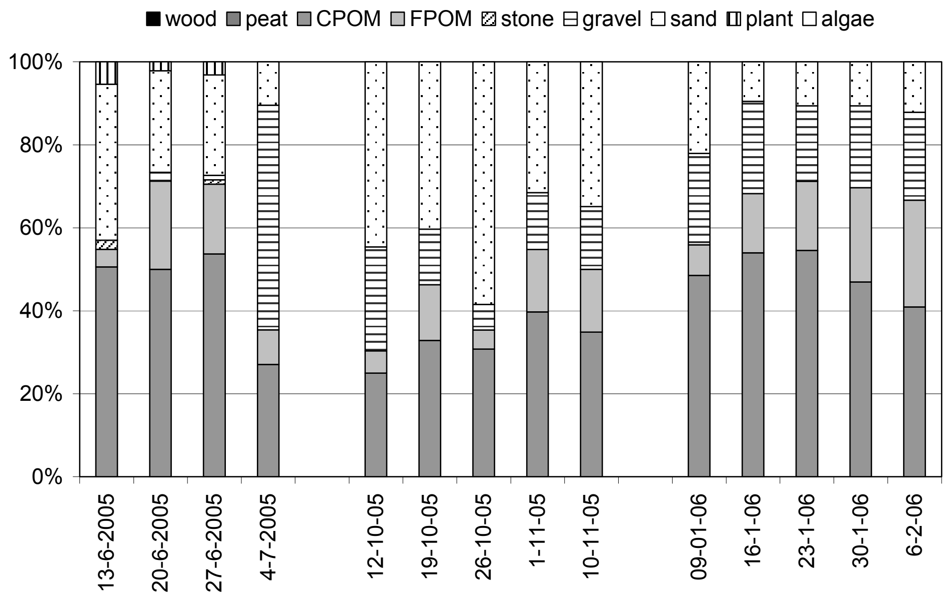


Figure 4.7 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

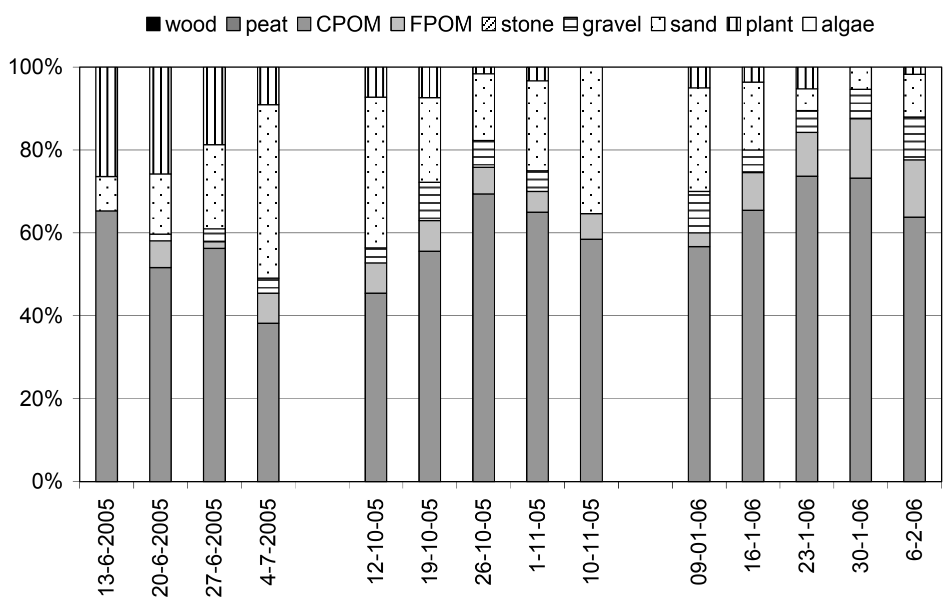


Figure 4.8 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

Southern upper course
At the end of the first period, in June, an extreme flood occurred in the whole catchment (Figure 4.9). The effect of this flood was not registered in the southern upper course. After two weeks several specimens of the endangered fish species *Lampetra planeri* were caught in the MOC's as well as the sediment traps. Therefore, we decided to remove the equipment and install it in another stream section. Before that the first measurements showed a direct response of suspended material transport after small discharge peaks.
In both the October and January measurements little transport took place, except for the second date of measurement in January. This movement was caused by a small discharge increase in the week before. The moving bottom sediment traps regularly were filled. Most probably sand is rolling or moving over de stream bottom in irregular waves or mini-dunes (Figure 4.10).
The substrate pattern did not change much during all three periods (Figure 4.11 and 4.12), except for gradual changes. Only in the October period, after a small discharge event, CPOM increased with about 15% in contrast to the same decrease in FPOM (Figure 4.11).

Middle course, reference section
The mineral and organic matter collectors in the middle course almost perfectly registered the different discharge events in terms of amount of suspended material collected. After both small and large floods in June the suspended material transport increased (Figure 4.13).
The sediment traps, on the contrary, collected reasonable amounts after the small June flood and large amounts after the large June flood (Figure 4.14). But during both the October and January period still large quantities of moving bottom material were collected. This is most probably also be due to the instability caused by the June flood?
Surprisingly, both substrate sections did not show much change during each of the three periods of measurement (Figure 4.15 and 4.16). This indicates little impact of floods on the substrate composition of these stream sections, but confirms the MOC measurements. Both sand and plants presence covers up the moving sand as recorded by the sediment traps. The sand either moves over the large sand area present or in between the plants packets growing in these sections, and in both cases is thus not noticed.

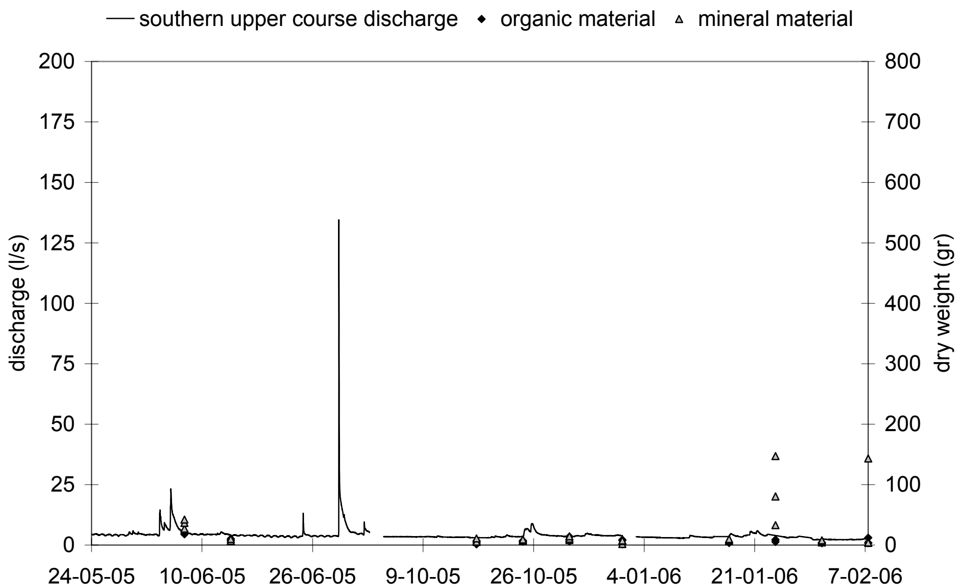


Figure 4.9 Continuous discharge pattern and material collected by means of the MOC's, during three periods of measurement (June 2005, October 2005 and January 2006).

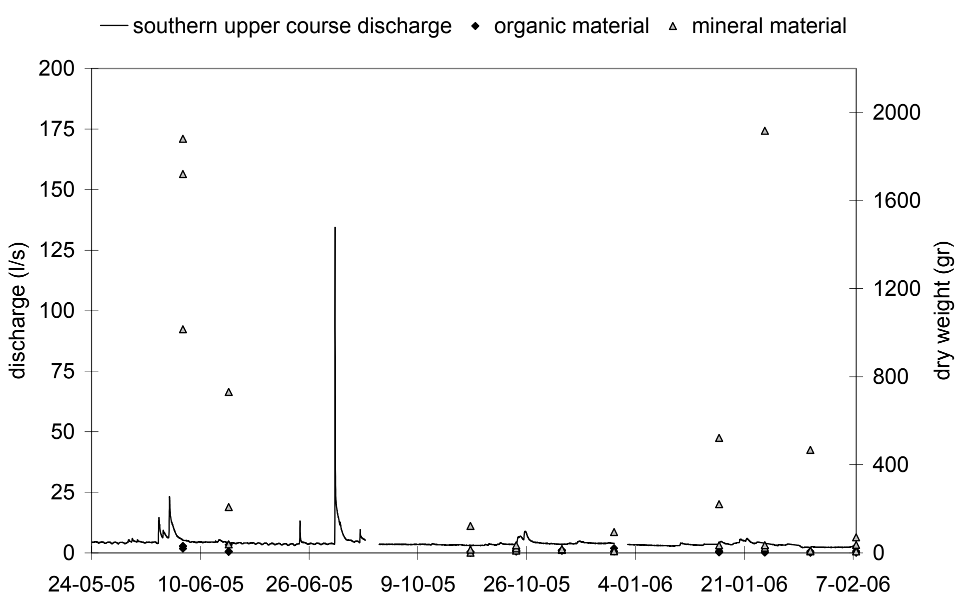


Figure 4.10 Continuous discharge pattern and sediment collected by means of the sediment traps, during three periods of measurement (June 2005, October 2005 and January 2006).

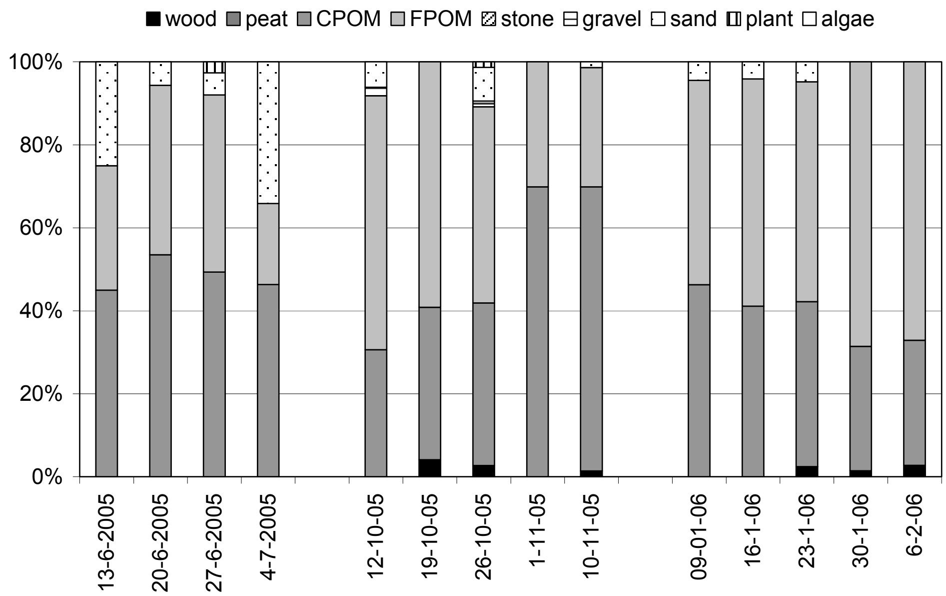


Figure 4.11 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

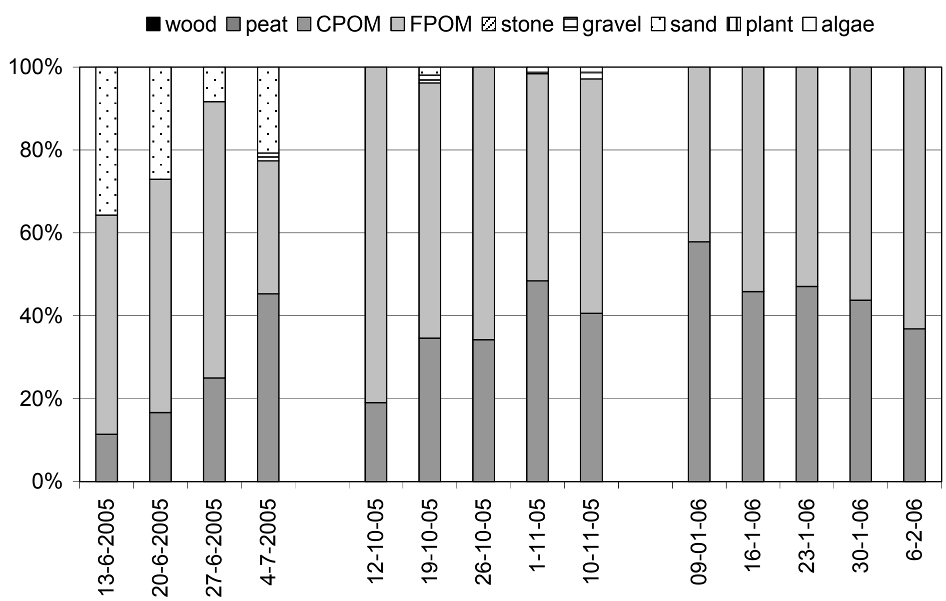


Figure 4.12 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

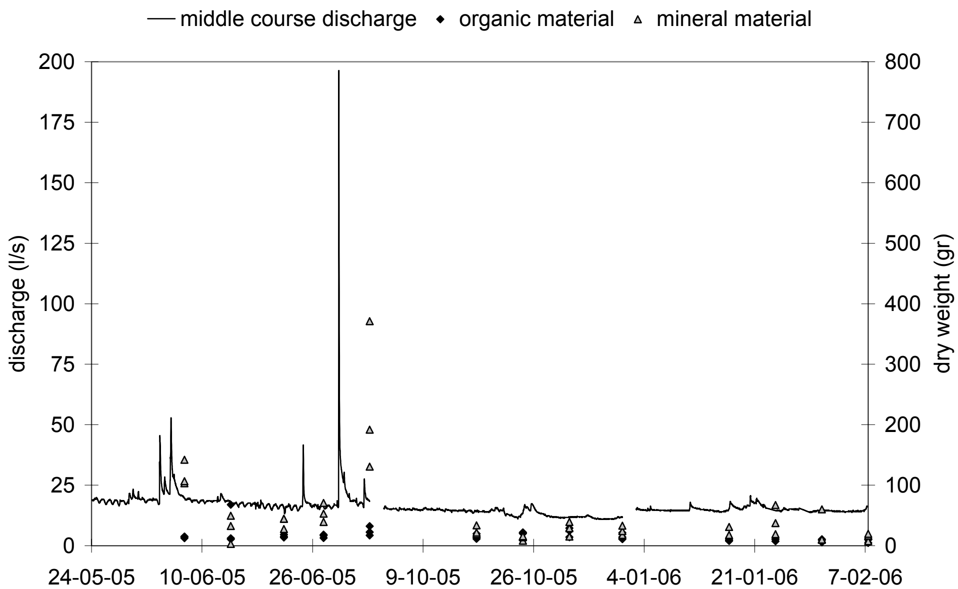


Figure 4.13 Continuous discharge pattern and material collected by means of the MOC's, during three periods of measurement (June 2005, October 2005 and January 2006).

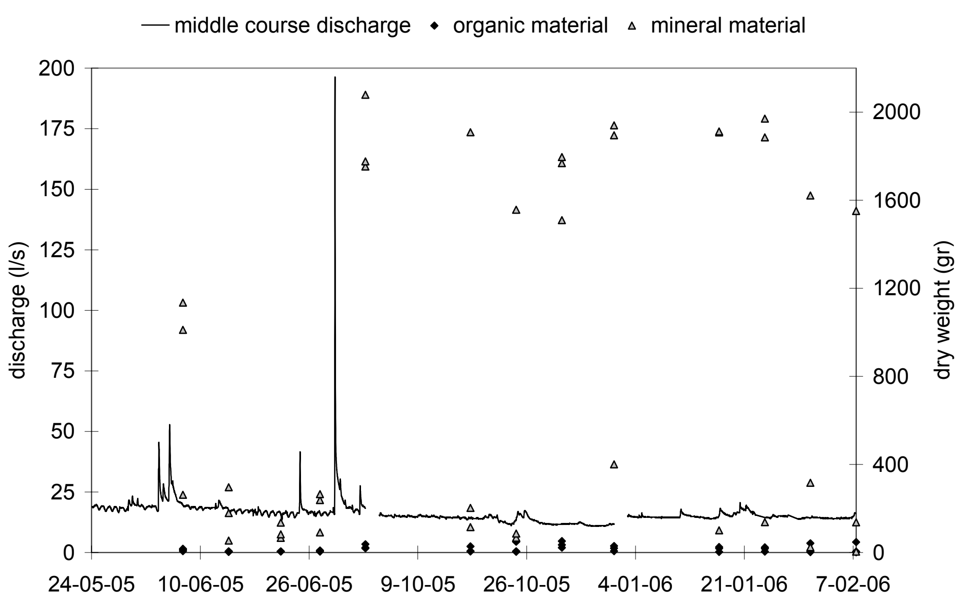


Figure 4.14 Continuous discharge pattern and sediment collected by means of the sediment traps, during three periods of measurement (June 2005, October 2005 and January 2006).

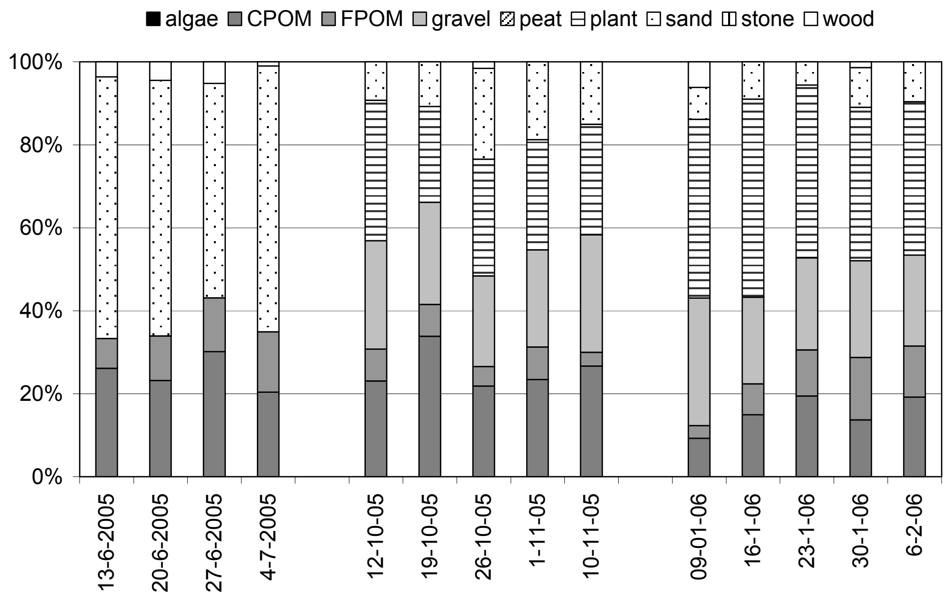


Figure 4.15 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

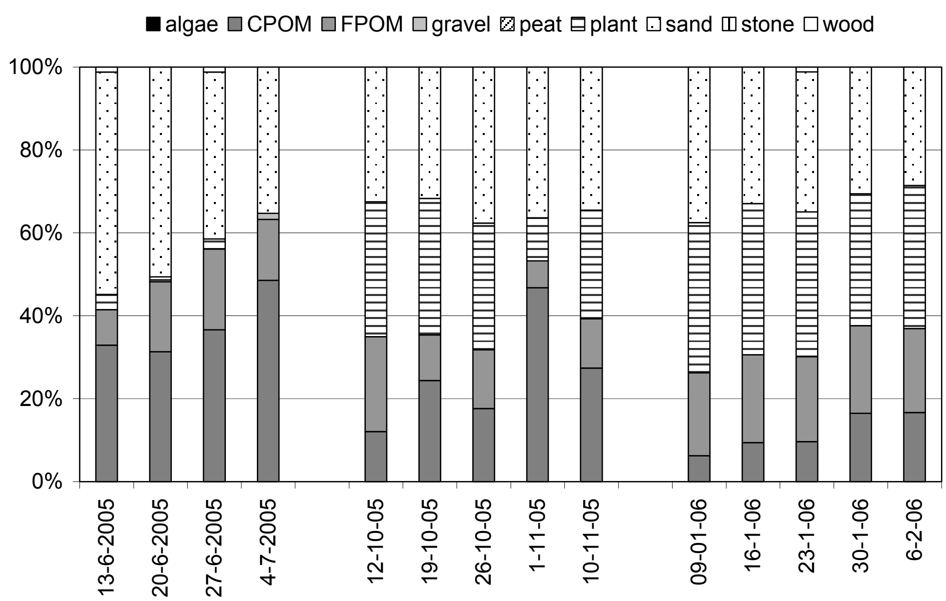


Figure 4.16 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

Nutterveld branch
The suspended material, both sand and organic, increases strongly when floods occur (Figure 4.17). The smaller floods of October and January did not show transport of suspended material. Also the moving bottom material responded to flood events (Figure 4.18).
The first, smaller June flood did not change the substrate pattern (Figure 4.19 and 4.20). The extreme June flood effect was not recorded. On the other hand, the mid-October and mid-January floods had clear effects on both substrate patterns. In both sections organic material was replaced or covered by sand.

Middle course, Blue road crossing
At middle course, Blue road crossing section both suspended and moving bottom material was recorded continuously (Figure 4.21 and 4.22). Floods did increase the material transport slightly. These observations indicate that this stream section is morphologically instable.
The substrate patterns remain about the same in both section during all periods (Figure 4.23 and 4.24). Dominant substrate is sand, most probably instable based on the transport data.

Lower course
The transport of suspended material in the lower course is small and only slightly responded to floods (Figure 4.25). The moving bottom transport showed to moments of increase, both related to higher discharge events (Figure 4.26). The substrate pattern remained quite constant per period, except for the last October measurement. In between the two last recordings the plants were removed by the water manager. This cleaning caused the substrate pattern to change (Figure 4.27 and 4.28).

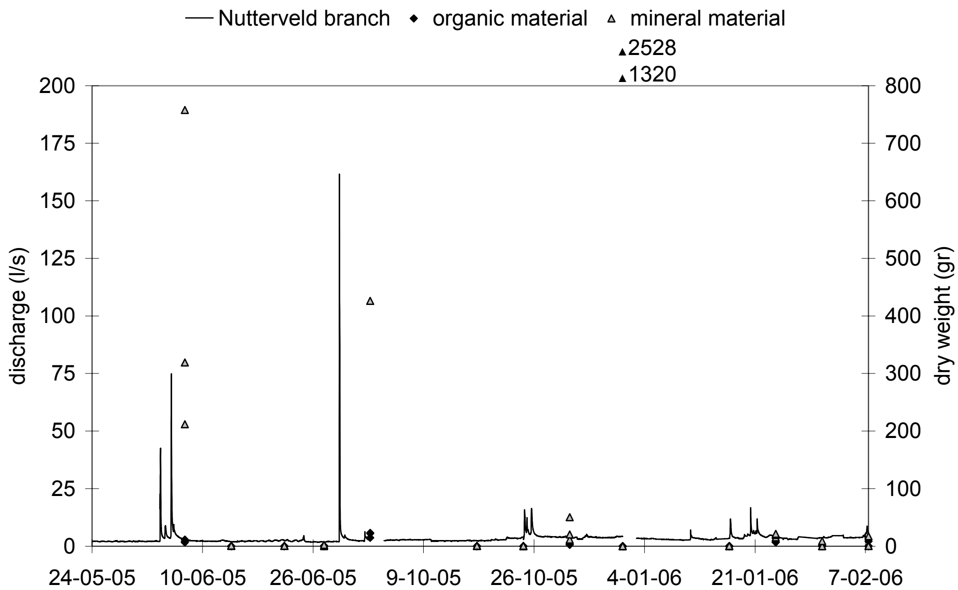


Figure 4.17 Continuous discharge pattern and material collected by means of the MOC's, during three periods of measurement (June 2005, October 2005 and January 2006).

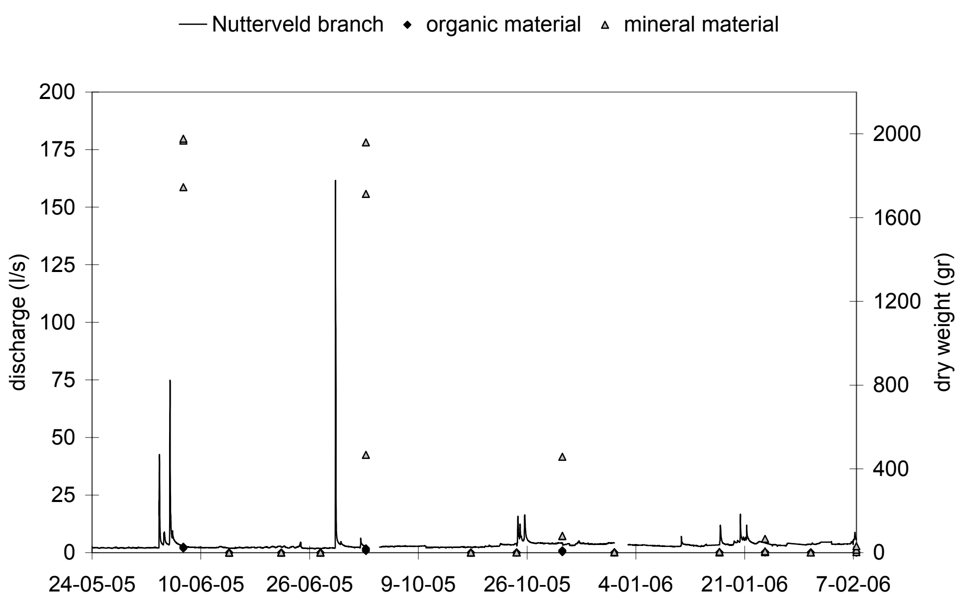


Figure 4.18 Continuous discharge pattern and sediment collected by means of the sediment traps, during three periods of measurement (June 2005, October 2005 and January 2006).

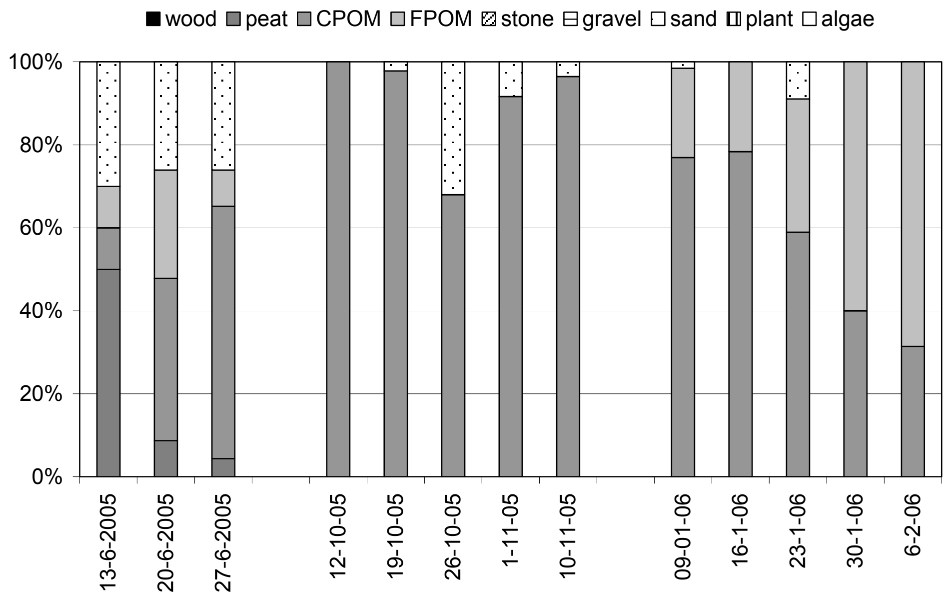


Figure 4.19 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

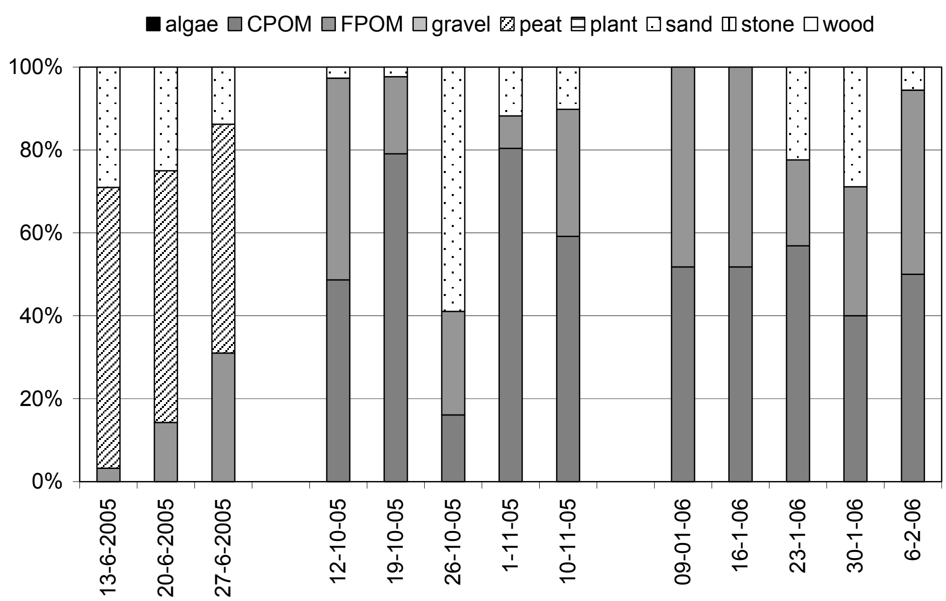


Figure 4.20 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

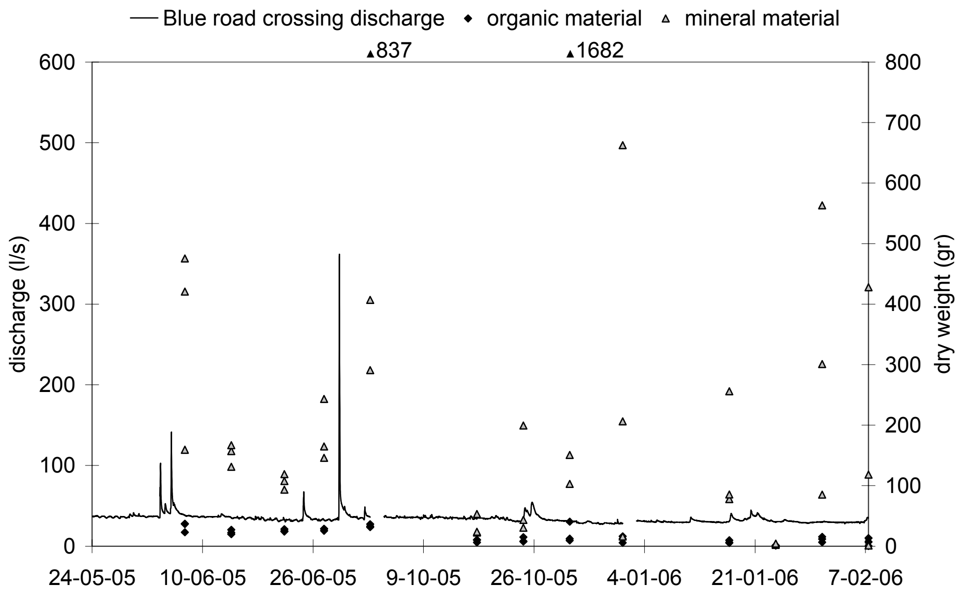


Figure 4.21 Continuous discharge pattern and material collected by means of the MOC's, during three periods of measurement (June 2005, October 2005 and January 2006).

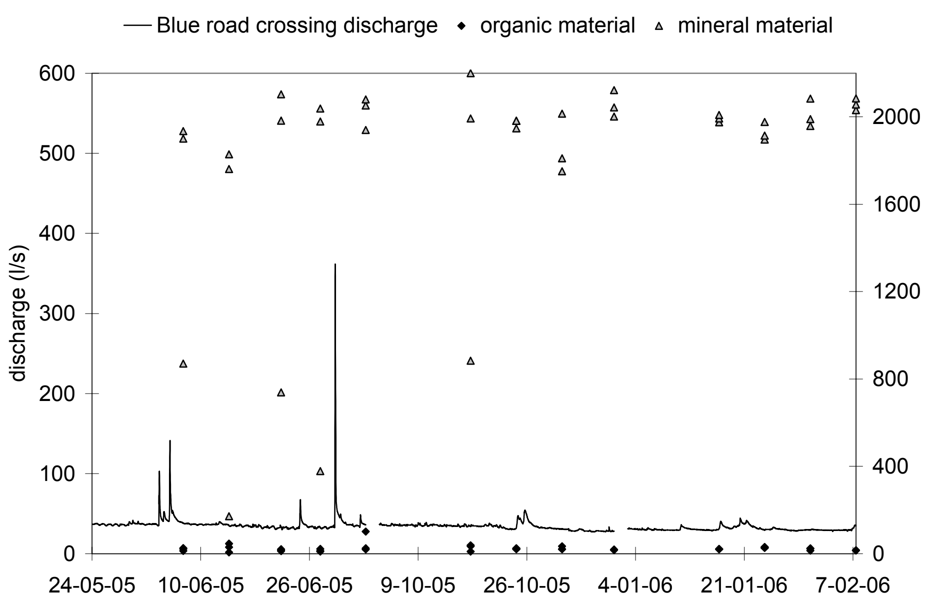


Figure 4.22 Continuous discharge pattern and sediment collected by means of the sediment traps, during three periods of measurement (June 2005, October 2005 and January 2006).

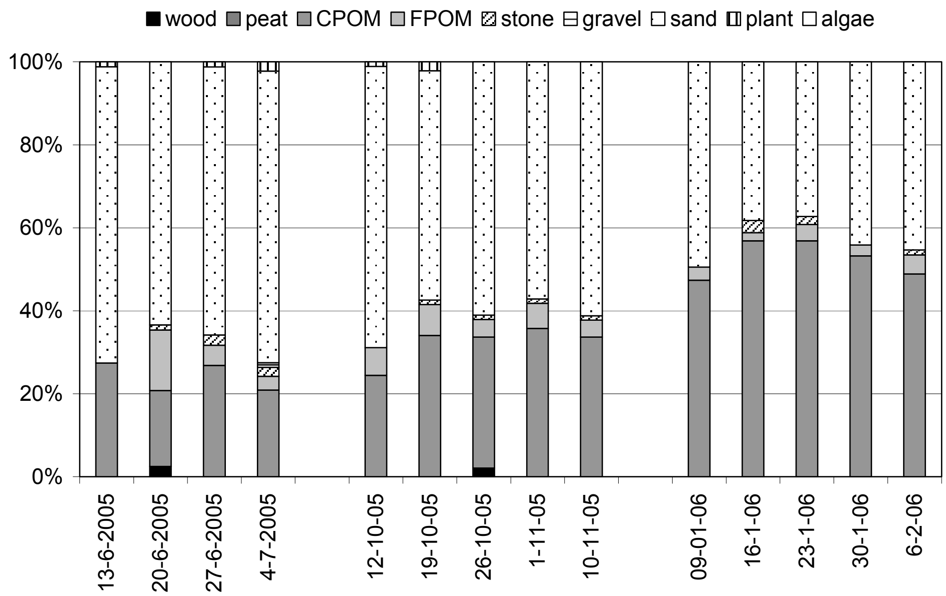


Figure 4.23 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

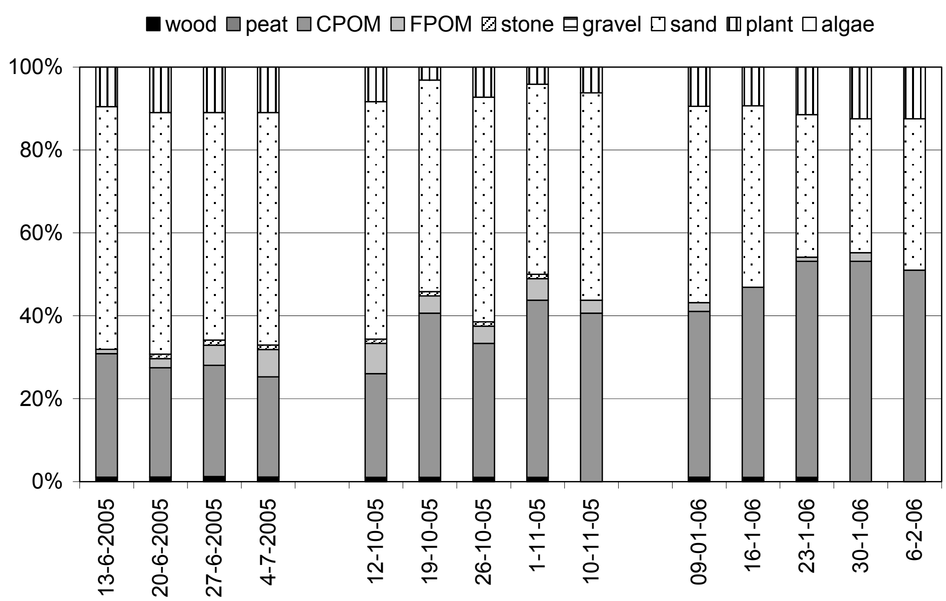


Figure 4.24 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

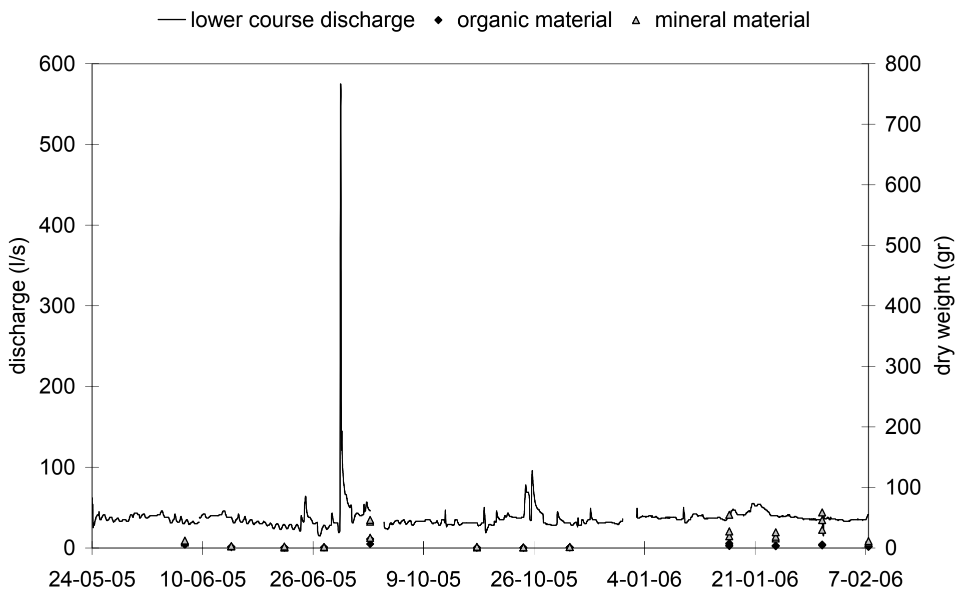


Figure 4.25 Continuous discharge pattern and material collected by means of the MOC's, during three periods of measurement (June 2005, October 2005 and January 2006).

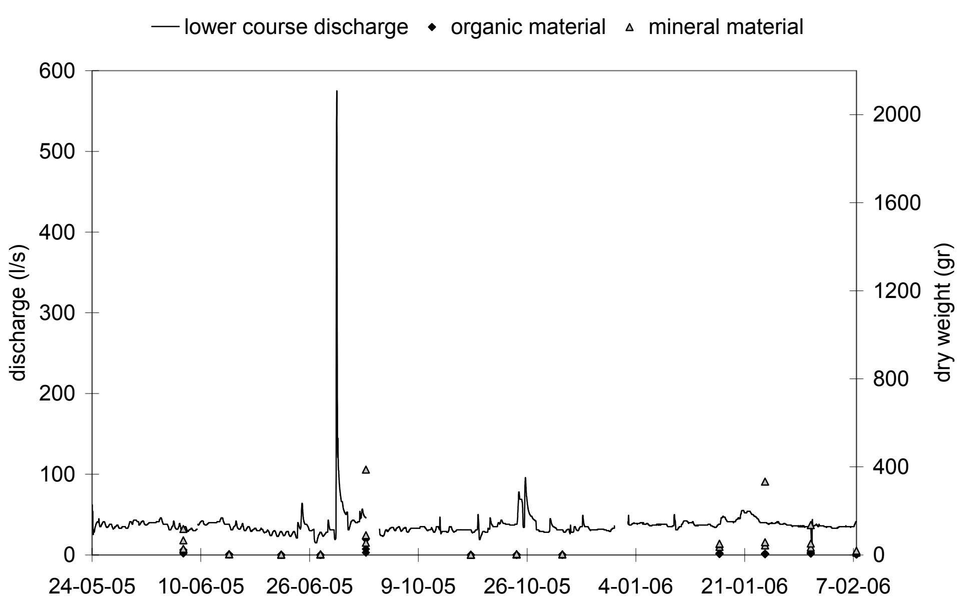


Figure 4.26 Continuous discharge pattern and sediment collected by means of the sediment traps, during three periods of measurement (June 2005, October 2005 and January 2006).

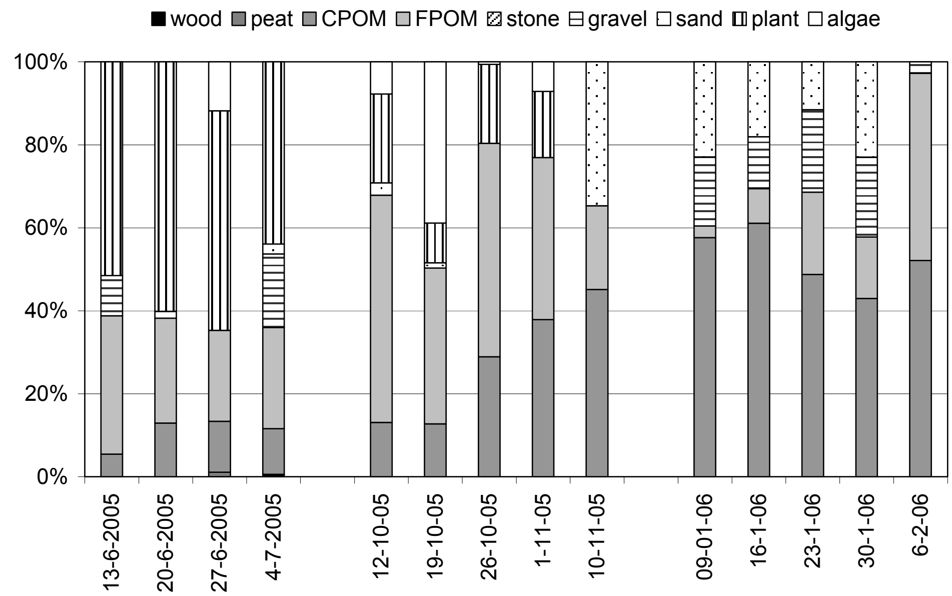


Figure 4.27 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

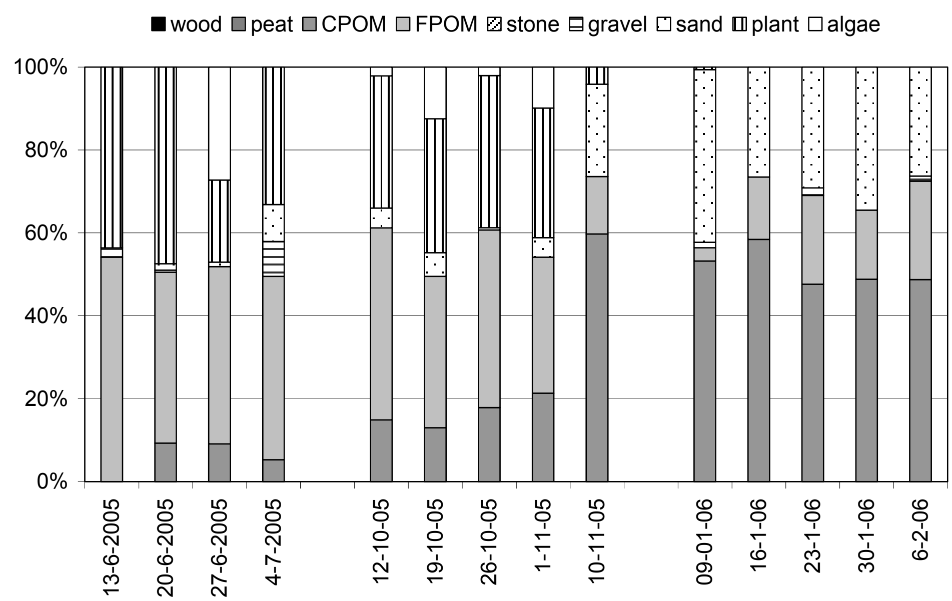


Figure 4.28 Relative substrate composition, during three periods of measurement (June 2005, October 2005 and January 2006).

4.4 Conclusions

From these small scale discharge-morphology measurements can be concluded that:

- in general, discharge increase goes along with suspended material transport as was best shown in the middle course and the Nutterveld branch;
- extreme floods can destabilise a stream for at least one year as was shown in the northern upper course;
- even a small increase in discharge can result in material transport as was shown in the middle course in October and the southern upper course in January;
- some stream sections most probably are continuously instable as was shown in the Blue road crossing;
- canalised and regulated streams do hardly transport suspended material as was shown in the lower course;
- bottom material transport is less related to changes in discharge and can occur continuous as was shown in the northern upper course, the middle course, and the Blue road crossing, or regular as was shown in the southern upper course, incidentally as was shown in the lower course, or discharge related as was shown in the Nutterveld branch;
- in general, substrate patterns do gradually change from week to week at all sites but these changes do not seem to be related to discharge. either substrates stabilize quickly after floods and should be monitored on a daily or hourly bases after a flood or sedimentation and erosion processes act mainly at those areas were the respective material is present e.g. sand areas change as sand is eroded during the flood and deposited afterwards but without hardly changing the surface area;
- an exception is that an extreme flood can drastically change the substrate pattern as was shown in the northern upper course in June.

5 Macro-invertebrates

5.1 Materials and Methods

Macroinvertebrate sampling

Macroinvertebrates were sampled with a micromacrofaunashovel (10 cm width, 10 cm high, 15 cm length, 0.5 mm mesh size) according to Tolkamp (1980). The shovel is made of stainless steel, on the top and the rear there are openings covered with nylon gauze. On the sides, adjustable wings are screwed, which decide the depth of the sample. This depth is fixed at 2 cm. The shovel is pushed into the substrate at an angle of 30-45^o and brought in a horizontal position when it reaches its 2 centimetres depth. At the same moment the shovel is pushed through the substrate over a distance of 15 cm, tilted backwards and lifted above the water surface. The sample is transferred into a bucket. Thus, an area of 15 cm^2 is sampled. All substrate-type/habitat samples were kept separate.
A multihabitat approach by sampling the dominant (occurrence > 5%) habitat types in proportion to their frequency of occurrence in the stream reach was also used. At most of the sites fine gravel, sand, fine detritus, coarse detritus and leaves were combined and sampled in such way. Taxa-poor substrates/habitats were sampled 2-3 times (area of 30-45 cm^2).
All samples were processed in the laboratory by rinsing the sample over two sieves (mesh size 1 and 0.25 mm), placing the residue in a white tray, and sorting the animals alive.

Taxonomic adjustment

A common problem in macroinvertebrate community samples is that many inconsistencies occur in the data after identification of the taxa. Many but not all specimens are identified to species level, others to higher taxonomic levels. Such inconsistencies can ultimately lead to pseudo replication and need to be resolved prior to analyses. Inconsistencies were resolved by removing the data from higher taxonomic groups when occurrence of higher groups was sparse, or by clustering species data to higher taxonomic groups when needed. More specifically, the methods described by Nijboer & Verdonschot (2000) were used. The original and new taxa lists are presented in Appendix 1.

Multivariate analysis methods

The ordination techniques DCA and DCCA (CANOCO 4.5 for Windows) were used. All options used in the runs are listed in Table 5.1.

Table 5.1 Options used in the DCA and DCCA analyses.

Analysis	Objective	Choice of method
General	Transformation	Log_2 (abundance+1)

	Environmental variables	Nominal variables, unless specified otherwise
	Rare species	Downweighting of rare species
DCA	Detrending	By segments or 2nd order polynomials
DCCA	Detrending	2nd order polynomials
	Scaling focus	Inter-sample distances
	Scaling type	Hill's scaling (L^a) / (1-L)
PCA & RDA	Scaling focus	Inter-sample distances
	Species scores	Do not post transform
	Sample centering	By samples
	Species centering	By species
Significance testing	Monte Carlo permutation test	-499 Permutations -Unrestricted permutations

5.2 Results

Analyses of macroinvertebrate communities and indicator species along a hydromorphological gradient in the middle course was performed. The macroinvertebrate communities were compared between natural, semi-natural and canalized stream sections in the middle course of the Springendal stream. A total of 51 samples were obtained between 1981 and 2006, of which 37 were from the natural stream section (1983-2006), 5 from the semi-natural section (1981-2006) and 9 from the canalized stream section (1979-2006). A total of 432 taxa occurred in the samples, of which 238 taxa and taxa-groups remained for analyses after taxonomic adjustment (Appendix 1).

The ordination techniques DCA and DCCA (CANOCO 4.5 for Windows) are used successively to compare the macroinvertebrate communities at the three hydromorphologically different stream sections. This analysis accounts for the previously described (4.4) effect of the pre- and post- phases of the Nutterveld branch restoration measure, which would also have affected the focal stream sections in this analysis. Subsequently, a macroinvertebrate community typology analysis (EKO), including indicator-species analysis, is carried out with the program Nodes (Verdonschot 1990).

Table 5.2 shows the results of the first DCA, which uses the detrending method 'by segments' and allows for determination of the gradient lengths. Gradient length of especially the first ordination axis approaches three (Table 5.2a), indicating an intermediate homogeneity in species composition between samples, at least along the first ordinal axis (Verdonschot & ter Braak 1994). This suggests that, possibly, both linear and unimodel detrending techniques could be justified for further analyses. However, the use of unimodel assumptions on species distributions should be preferred over linear assumptions in most biological systems (ter Braak & Verdonschot 1995) and it is therefore that we use unimodel techniques in subsequent analyses. Table 5.2 (b) shows the results of the DCA based on unimodel assumptions, the eigenvalues are similar to those in 5.2 (a).

Table 5.2 DCA results, detrended (a) by segments and (b) by second order polynomials

(a) Axes		1	2	3	4	Total inertia
Eigenvalues	:	0.458	0.165	0.097	0.068	2.469
Lengths of gradient	:	2.522	1.697	1.861	1.495	
Cumulative percentage variance of species data	:	18.6	25.3	29.2	31.9	
Sum of all eigenvalues						2.469

(b) Axes		1	2	3	4	Total inertia
Eigenvalues	:	0.458	0.193	0.142	0.090	2.469
Cumulative percentage variance of species data	:	18.6	26.4	32.1	35.8	
Sum of all eigenvalues						2.469

To investigate the relationships between the macroinvertebrate communities and the environmental variables including natural, semi-natural or canalized stream sections a DCCA was carried out (the hydro morphological gradient variable group is hereafter abbreviated as: 'the gradient variable group'). The eigenvalues of the first two ordinal axes were substantially higher than those of axis 3 and 4, which indicates that a substantial amount of the total variation explained by our environmental variables is comprised in the first two ordinal axes (Table 5.3). Together the first two axes explain 25.7 % of all species variation among samples, which is nearly as high as in the preliminary DCA (Table 5.3b).

Table 5.3 DCCA results (detrended by 2^{nd} order polynomials). Included were the gradient, year, pre- post Nutterveld restoration, sample location and season variable groups.

Axes		1	2	3	4	Total inertia
Eigenvalues	:	0.451	0.182	0.124	0.067	2.469
Species-environment correlations	:	0.993	0.979	0.986	0.940	
Cumulative percentage variance						
of species data	:	18.3	25.7	30.7	33.4	
of species-environment relation	:	28.0	39.3	47.1	51.2	
Sum of all eigenvalues						2.469
Sum of all canonical eigenvalues						1.610

The ordination diagram of this DCCA (Figure 5.1) shows, even with all variables included, that the gradient variable group has a substantial effect and mostly determines the first ordinal axis. The samples taken from the canalized stream section are clearly separated in the right side of the diagram, the samples from the natural and semi-natural stream sections are hardly separated at all. It can thus be concluded that the canalized stream section had a largely different macroinvertebrate community compared to the relatively similar natural and semi-natural stream sections. The second ordinal axis is mostly determined by the location variable group with a clear separation between samples from m1, m2, m4 and m6 together on the top left of the diagram and samples from m5 on the bottom left of the diagram (Fig. 5.1). Both ordinal axes significantly fit the species data (Monte Carlo permutation test; first axis: $f = 6.26$, $p = 0.02$; all axes: $f = 2.39$, $p = 0.02$).

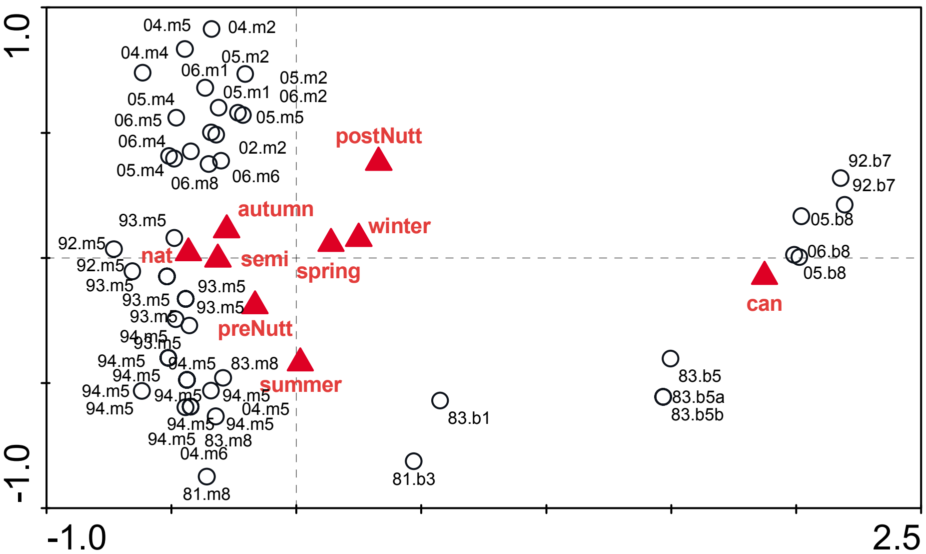


Figure 5.1 DCCA ordination diagram for the hydromorphological gradient analysis with the gradient, pre- post Nutterveld restoration, sample location, sample season and year variable groups included. The triangles represent the relative effects of the variables; the open circles represent each sample site. Sample sites are labelled by sample year and location. The variables sample location and year are included in the analysis, but illustratively suppressed in this diagram. The information on year and location can be obtained from the sample labels. The different hydromorphological gradients are indicated by: 'nat' for the natural stream section, 'semi' for the semi natural section and 'can' for canalized.

Indicator species analysis

The methods used for the indicator species analysis require that the sample sizes of the groups to be compared are not largely different (i.e. largely unequal sample sizes render problems with calculating fidelity and concentration). Therefore, for this analysis, the samples from location m5 were not used. M5 was the location that was largely separated along the second ordinal axes in the preceding DCCA (Figure 5.1). New sample sizes are now: natural stream section 11; semi-natural 7, canalized 9.

The analysis did not detect any highly indicative species for any of the three stream morphologies. However, we could identify several species with moderate or low indicative values, especially for the canalized stream section (Table 5.4). For all three stream morphologies, several, and mostly different highly abundant and frequently occurring species were detected (Table 5.4).

Table 5.4 Macroinvertebrate community typology analysis with Nodes. Species are listed when they 1) were of indicative value for one the different hydro morphologies, 2) had particularly high abundances, or 3) had frequent occurrence. Moderate indicative value stands for an EKO-indicator weight of 8, low indicative value for an indicator weight of 5 (Verdonschot 1990). The abundance is based on the numbers of individuals per sample and the occurrence is based on the number of samples a species occurs in.

natural stream section					
indicative value		**abundance**		**frequency**	
moderate	**low**	**dominant**	**abundant**	**very common**	**common**
	Dixa sp	Gammarus pulex	Dugesia gonocephala	Dugesia gonocephala	Dicranota sp
	Lebertia stigmatifera		Micropsectra sp	Elodes minuta	Pisidium sp
	Stylodrilus heringianus		Polypedilum sp	Eloeophila sp	Sperchon sp
	Zavrelimyia sp			Gammarus pulex	
				Micropsectra sp	
				Plectrocnemia sp	
				Polypedilum sp	
				Sericostoma personatum	
				Zavrelimyia sp	
semi-natural stream section					
indicative value		**abundance**		**frequency**	
moderate	**low**	**dominant**	**abundant**	**very common**	**common**
	Limnophila sp	Gammarus pulex	Dugesia gonocephala	Prodiamesa olivacea	Elodes minuta
	Tipulidae	Micropsectra sp			Ptychoptera sp

Table 5.4 continued

cannalized stream section					
indicative value		abundance		occurrence	
moderate	**low**	**dominant**	**abundant**	**very common**	**common**
Athripsodes aterrimus	Agabus sp	Micropsectra sp	Cricotopus sp	Apsectrotanypus sp	Asellus aquaticus
Clinotanypus nervosus	Asellus aquaticus	Tubificidae juvenile- with chaetae	Pisidium sp	Gammarus pulex	Ceratopogonidae
Glossiphonia complanata	Conchapelopia sp				Conchapelopia sp
Hygrobates sp	Cricotopus sp	Tubificidae juvenile- without chaetae			Erpobdella octoculata
Ilybius sp	Erpobdella octoculata				Hygrobates sp
Laccobius minutus	Graptodytes pictus				Micropsectra sp
Lebertia inaequalis	Helobdella stagnalis				Pisidium sp
Limnephilus lunatus	Orthocladius sp				Procladius sp
Microtendipes gr chloris	Physa fontinalis				Prodiamesa olivacea

Nepa cinerea	Pilaria sp	Pyrrhosoma nymphula
Paratendipes albimanus	Proasellus sp	Tabanidae
Phaenopsectra sp	Pyrrhosoma nymphula	Tubificidae juvenile- with chaetae
Polycelis sp	Tubificidae juvenile- without chaetae	Tubificidae juvenile- without chaetae
Procladius sp		
Radix sp		
Sphaerium sp		

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Appendix 1- Hydromorphological gradient analysis

taxon code	taxon code new	taxon name	taxon number	frequency	total abundance
TRICLADI		Tricladida	116	1	41.14
DUGESISP		Dugesia sp	120	2	174.25
DUGEGONO	DUGEGONO	Dugesia gonocephala	122	36	10907.88
DUGELUPO	DUGELUPO	Dugesia lugubris/polychroa	126	1	16.80
DUGELUGU	DUGELUPO	Dugesia lugubris	127	1	1.33
DUGEPOLY	DUGELUPO	Dugesia polychroa	130	1	16.80
POLISSPE	POLISSPE	Polycelis sp	136	3	37.78
POLIFELI	POLISSPE	Polycelis felina	138	1	19.05
POLINITE	POLISSPE	Polycelis nigra/tenuis	141	3	55.22
POLITENU	POLISSPE	Polycelis tenuis	144	4	41.56
NERITIAE	NERITIAE	Neritidae	184	1	26.67
LYMNAEAE		Lymnaeidae	323	1	0.46
RADIXSPE	RADIXSPE	Radix sp	336	1	2.00
RADIPEOV	RADIXSPE	Radix peregra/ovata	341	2	112.27
RADIPERE	RADIXSPE	Radix peregra	344	3	568.00
RADIOVAT	RADIXSPE	Radix ovata	348	2	8.67
STAGPALU	STAGPALU	Stagnicola palustris	354	1	35.20
GALBTRUN	GALBTRUN	Galba truncatula	361	1	9.52
PHYSFONT	PHYSFONT	Physa fontinalis	378	7	224.02
GYRAALBU	GYRAALBU	Gyraulus albus	429	3	13.87
PLBICARI	PLBICARI	Planorbis carinatus	445	3	62.19
HIPPCOMP	HIPPCOMP	Hippeutis complanatus	449	2	6.00
PLBACORN	PLBACORN	Planorbarius corneus	462	1	13.33
ZONINITI	ZONINITI	Zonitoides nitidum	488	0	0.00
PISIDNAE		Pisidiinae	529	1	13.33
PISIDISP	PISIDISP	Pisidium sp	531	25	2441.88
PISICASE	PISIDISP	Pisidium casertanum	534	14	389.22
PISIHENS	PISIDISP	Pisidium henslowanum	542	1	2.67
PISIHIBE	PISIDISP	Pisidium hibernicum	545	1	13.33
PISIMILI	PISIDISP	Pisidium milium	546	1	2.00
PISINITI	PISIDISP	Pisidium nitidum	549	4	441.14
PISIOBOB	PISIDISP	Pisidium obtusale obtusale	556	3	15.57
PISIPERS	PISIDISP	Pisidium personatum	557	14	355.36
PISIPULC	PISIDISP	Pisidium pulchellum	561	1	19.05
PISISUBT	PISIDISP	Pisidium subtruncatum	562	2	182.95
PISISUPI	PISIDISP	Pisidium supinum	565	2	57.62
SPUMSPEC	SPUMSPEC	Sphaerium sp	573	5	276.90
SPUMCORN	SPUMSPEC	Sphaerium corneum	575	3	173.90
GLSIPHAE		Glossiphoniidae	708	1	1.37
THERTESS	THERTESS	Theromyzon tessulatum	711	2	3.33
GLSICOMP	GLSICOMP	Glossiphonia complanata	716	5	105.13
HECLMARG	HECLMARG	Hemiclepsis marginata	729	1	2.00
HEBDSTAG	HEBDSTAG	Helobdella stagnalis	741	6	12.00

ALBOHETE	ALBOHETE	Alboglossiphonia heteroclita	746	1	1.60
ERPOBDAE		Erpobdellidae	796	2	18.67
ERPOBDSP		Erpobdella sp	798	1	2.00
ERPOOCTO	ERPOOCTO	Erpobdella octoculata	801	18	245.29
ERPOTEST	ERPOTEST	Erpobdella testacea	804	2	4.00
ERPONIGR	ERPONIGR	Erpobdella nigricollis	809	3	16.86
OLCHAETA		Oligochaeta	825	2	27.12
NAIDIDAE		Naididae	865	1	0.46
CHTEDIAS	CHTEDIAS	Chaetogaster diastrophus	871	1	6.86
NAISSPEC		Nais sp	876	1	72.80
NAISELIN	NAISELIN	Nais elinguis	883	1	28.57
NAISCOVA	NAISCOVA	Nais communis/variabilis	890	1	13.33
NAISCOMM	NAISCOMM	Nais communis	891	4	81.37
NAISVARI	NAISVARI	Nais variabilis	892	6	131.75
STLALACU	STLALACU	Stylaria lacustris	895	1	14.40
SPECJOSI	SPECJOSI	Specaria josinae	917	2	40.76
OPHISERP	OPHISERP	Ophidonais serpentina	924	3	112.10
SLAVAPPE	SLAVAPPE	Slavina appendiculata	927	5	292.29
VEJDCOMA	VEJDCOMA	Vejdovskiella comata	930	0	0.00
PIGUBLAN	PIGUBLAN	Piguetiella blanci	941	1	19.05
PRNEAMPH	PRNEAMPH	Pristinella amphibiotica	973	2	31.77
PRNEJENK	PRNEJENK	Pristinella jenkinae	975	3	51.11
TUFICIAE		Tubificidae	979	2	26.67
TUFICJZH	TUFICJZH	Tubificidae juveniel zonder haarsetae	981	15	3058.97
TUFICJMH	TUFICJMH	Tubificidae juveniel met haarsetae	983	34	1274.09
TUFEIGNO	TUFICJMH	Tubifex ignotus	989	2	40.10
TUFETUBI	TUFICJMH	Tubifex tubifex	994	22	1715.15
LIDRCLAP	TUFICJZH	Limnodrilus claparedeianus	999	3	411.81
LIDRHOFF	TUFICJZH	Limnodrilus hoffmeisteri	1001	9	3519.14
LIDRPROF	TUFICJZH	Limnodrilus profundicola	1003	1	76.19
LIDRUDEK	TUFICJZH	Limnodrilus udekemianus	1004	6	160.83
POTHHAMM	TUFICJMH	Potamothrix hammoniensis	1020	1	4.00
POTHHEUS	TUFICJMH	Potamothrix heuscheri	1021	1	9.52
POTHBEDO	TUFICJMH	Potamothrix bedoti	1026	1	9.52
AUDRJAPO	TUFICJMH	Aulodrilus japonicus	1046	4	1437.52
AUDRPIGU	TUFICJZH	Aulodrilus pigueti	1048	1	2.00
AUDRPLUR	TUFICJMH	Aulodrilus pluriseta (zie opmerking)	1049	6	2273.07
RHDRCOCC	TUFICJMH	Rhyacodrilus coccineus	1056	3	20.00
RHDRSUBT		Rhyacodrilus subterraneus	1059	0	0.00
ENCHYTAE	ENCHYTAE	Enchytraeidae	1099	19	501.65
LUCULIAE	LUCULIAE	Lumbriculidae	1142	28	952.34
STLOHERI	STLOHERI	Stylodrilus heringianus	1147	16	248.90
LUCUVARI	LUCUVARI	Lumbriculus variegatus	1151	11	299.61
LUMBRIAE	LUMBRIAE	Lumbricidae	1156	6	19.88
EISETETR	EISETETR	Eiseniella tetraedra	1159	7	62.20
HYMADESP	HYMADESP	Hydrodroma despiciens	1370	2	8.00
SPCHONSP	SPCHONSP	Sperchon sp	1382	3	69.41
SPCHONS5	SPCHONSP	Sperchon sp nymf	1383	7	53.03
SPCHGLAN	SPCHONSP	Sperchon glandulosus	1392	14	500.80
SPCHSETI	SPCHONSP	Sperchon setiger	1398	9	96.97

SPCHSQUA	SPCHONSP	Sperchon squamosus	1399	5	35.47
SPCHTHIE	SPCHONSP	Sperchon thienemanni	1400	11	333.83
LEBERTSP		Lebertia sp	1412	0	0.00
LEBERTS5		Lebertia sp nymf	1414	2	32.38
LEBELINE	LEBELINE	Lebertia lineata	1424	16	110.10
LEBEINAE	LEBEINAE	Lebertia inaequalis	1433	6	69.54
LEBESTIG	LEBESTIG	Lebertia stigmatifera	1438	6	64.54
LISIKOEN	LISIKOEN	Limnesia koenikei	1485	2	1.60
LISIMACU	LISIMACU	Limnesia maculata	1487	1	9.52
HYTESSPE	HYTESSPE	Hygrobates sp	1497	3	68.80
HYTESSP5	HYTESSPE	Hygrobates sp nymf	1498	2	27.05
HYTELOPA	HYTESSPE	Hygrobates longipalpis	1506	2	94.00
HYTENIGR	HYTESSPE	Hygrobates nigromaculatus	1511	5	252.27
ATRANODI	ATRANODI	Atractides nodipalpis	1531	2	7.47
WETTPODA	WETTPODA	Wettina podagrica	1702	4	37.05
TIPHTORR	TIPHTORR	Tiphys torris	1736	1	0.80
LJANBIPA	LJANBIPA	Ljania bipapillata	1811	3	23.05
MIOPSIS5		Mideopsis sp nymf	1841	1	1.33
MIOPCRAS	MIOPCRAS	Mideopsis crassipes	1843	2	52.80
MIOPORBI	MIOPORBI	Mideopsis orbicularis	1844	3	216.08
ARRECRAS	ARRECRAS	Arrenurus crassicaudatus	1901	1	0.80
ARRECYLI	ARRECYLI	Arrenurus cylindratus	1908	2	3.60
ARREGLOB	ARREGLOB	Arrenurus globator	1920	2	1.60
ARRELEUC	ARRELEUC	Arrenurus leuckarti	1941	0	0.00
ARREMEDI	ARREMEDI	Arrenurus mediorotundatus	1945	1	9.52
ARREMUEL	ARREMUEL	Arrenurus muelleri	1950	2	21.52
ARREOCTA	ARREOCTA	Arrenurus octagonus	1957	2	2.40
ORIBATID	ORIBATID	Oribatida	2027	7	122.22
ASELLIAE		Asellidae	2169	2	27.33
ASELAQUA	ASELAQUA	Asellus aquaticus	2172	12	1006.72
PROASESP	PROASESP	Proasellus sp	2177	3	5.60
PROAMERI	PROASESP	Proasellus meridianus	2185	4	52.50
GAMMARSP	GAMMPULE	Gammarus sp	2290	36	122547.89
GAMMPULE	GAMMPULE	Gammarus pulex	2298	48	46595.79
CRANPSEU	CRANPSEU	Crangonyx pseudogracilis	2323	3	31.52
COLLEMBO		Collembola	2418	3	64.44
CALOPTSP	CALOPTSP	Calopteryx sp	2466	1	9.52
CALOSPLE	CALOPTSP	Calopteryx splendens	2468	1	2.00
CONAGRAE		Coenagrionidae	2498	2	4.00
ISCHELEG	ISCHELEG	Ischnura elegans	2506	1	1.60
PYRRNYMP	PYRRNYMP	Pyrrhosoma nymphula	2512	8	36.46
BAETIDAE		Baetidae	2683	1	11.43
BAETISSP	BAETISSP	Baetis sp	2684	4	124.15
BAETRHOD	BAETRHOD	Baetis rhodani	2696	6	719.03
CLOEDIPT	CLOEDIPT	Cloeon dipterum	2727	3	158.13
LEPPARSP	LEPPARSP	Leptophlebia (Paraleptophlebia) sp	2822	2	1.60
CAENHORA	CAENHORA	Caenis horaria	2874	2	58.48
CAENLUCT	CAENLUCT	Caenis luctuosa	2881	1	9.52
PLECOPTE		Plecoptera	2905	1	0.91
NEMOURAE		Nemouridae	2920	1	2.00

AMNEMUSP	AMNEMUSP	Amphinemura sp	2921	27	7853.88
AMNESTAN	AMNEMUSP	Amphinemura standfussi	2923	4	335.47
AMNESULC	AMNEMUSP	Amphinemura sulcicollis	2924	1	77.78
NERASPEC	NERACINE	Nemoura sp	2925	3	42.25
NERACINE	NERACINE	Nemoura cinerea	2928	12	156.08
NEMUPICT	NEMUPICT	Nemurella pictetii	2937	6	124.46
CORIXIA5		Corixidae nymf	3027	1	2.40
SIGAFALL	SIGAFALL	Sigara falleni	3211	1	1.60
SIGASTRI	SIGASTRI	Sigara striata	3255	2	6.40
SIGASEMI	SIGASEMI	Sigara semistriata	3273	1	0.80
NEPACINE	NEPACINE	Nepa cinerea	3320	5	14.59
PLEAMINU	PLEAMINU	Plea minutissima	3336	1	0.80
NOTONESP	NOTONESP	Notonecta sp	3345	1	0.80
HYMESTAG	HYMESTAG	Hydrometra stagnorum	3396	1	0.80
MIVELIS5	MIVELIS5	Microvelia sp nymf	3415	0	0.00
VELIASPE	VELICAPR	Velia sp	3430	1	26.67
VELIASP5	VELICAPR	Velia sp nymf	3431	2	77.78
VELICAPR	VELICAPR	Velia caprai	3434	12	97.60
VELICAP5		Velia caprai nymf	3437	0	0.00
GERRLACU	GERRLACU	Gerris lacustris	3462	2	1.60
SIALISSP		Sialis sp	3493	9	92.34
SIALFULI	SIALFULI	Sialis fuliginosa	3495	11	86.46
SIALLUTA	SIALLUTA	Sialis lutaria	3496	11	235.49
OSMYFULV	OSMYFULV	Osmylus fulvicephalus	3504	2	7.47
COLEOPTE		Coleoptera	3512	1	13.33
HALIPLSP		Haliplus sp	3545	1	2.00
HALILAMI	HALILAMI	Haliplus laminatus	3570	2	6.40
HALIHEYD	HALIHEYD	Haliplus heydeni	3607	1	6.40
HALIFLUV	HALIFLUV	Haliplus fluviatilis	3618	2	2.80
LAPHHYAL	LAPHHYAL	Laccophilus hyalinus	3648	1	0.80
HYDPONA6		Hydroporinae larve	3661	1	1.60
HYPODISC	HYPODISC	Hydroporus discretus	3725	1	1.33
HYPOMENA	HYPOMENA	Hydroporus melanarius	3738	2	1.60
HYPOMEMN	HYPOMEMN	Hydroporus memnonius	3740	2	2.51
HYPOPALU	HYPOPALU	Hydroporus palustris	3750	3	3.91
HYPOPLAN	HYPOPLAN	Hydroporus planus	3755	1	1.60
GRTOPICT	GRTOPICT	Graptodytes pictus	3809	4	11.60
NEBRDEPR	NEBRDEPR	Nebrioporus depressus	3880	2	5.60
PLTAMAC6	PLTAMAC6	Platambus maculatus larve	3921	3	13.33
RHANTUSP	RHANTUSP	Rhantus sp	3922	2	1.60
AGABUSS6	AGABUSSp	Agabus sp larve	3970	3	8.80
AGABBIPU	AGABUSSp	Agabus bipustulatus	3980	1	0.91
AGABDIDY	AGABUSSp	Agabus didymus	3993	3	3.60
AGABPALU	AGABUSSp	Agabus paludosus	4038	4	4.46
ILYBIUSP	ILYBIUSP	Ilybius sp	4046	3	2.40
ILYBIUS6	ILYBIUSP	Ilybius sp larve	4047	2	1.60
ILYBFUL6	ILYBIUSP	Ilybius fuliginosus larve	4060	1	9.33
GYRISUBS	GYRISUBS	Gyrinus substriatus	4168	1	22.00
POLYPHAG		Polyphaga	4184	1	1.33
POLYPHA6		Polyphaga larve	4185	1	11.11

HYENBRIT	HYENBRIT	Hydraena britteni	4194	2	13.79
HYENTEST	HYENTEST	Hydraena testacea	4212	1	1.33
HERUBREV	HERUBREV	Helophorus brevipalpis	4347	1	0.46
HERUAEAQ	HERUAEAQ	Helophorus aequalis/aquaticus	4392	1	0.80
HERUAEQU	HERUAEAQ	Helophorus aequalis	4393	1	1.37
HERUFLOB	HERUFLOB	Helophorus flavipes/obscurus	4404	3	2.40
HERUOBSC	HERUFLOB	Helophorus obscurus	4418	1	1.37
HYUSFUSC	HYUSFUSC	Hydrobius fuscipes	4483	3	7.31
HYUSFUS6	HYUSFUSC	Hydrobius fuscipes larve	4484	2	12.71
ANACAESP		Anacaena sp	4490	0	0.00
ANACGLOB	ANACGLOB	Anacaena globulus	4500	8	123.50
ANACLUTE	ANACLUTE	Anacaena lutescens (zie opmerking)	4502	1	0.80
LABICOLO	LABICOLO	Laccobius colon	4523	2	4.80
LABIMINU	LABIMINU	Laccobius minutus	4528	4	15.12
LABISTRI	LABISTRI	Laccobius striatulus	4536	1	0.80
HERELIVI	HERELIVI	Helochares lividus	4552	2	2.69
ENOCAFFI	ENOCAFFI	Enochrus affinis	4572	1	9.52
DRYOPSS6	DRYOPSS6	Dryops sp larve	4660	1	13.33
ELMIMISP	ELMIAENE	Elmis sp	4710	1	14.81
ELMIMIS6	ELMIAENE	Elmis sp larve	4713	6	53.24
ELMIAENE	ELMIAENE	Elmis aenea	4715	4	19.11
OULITUBE	OULITUBE	Oulimnius tuberculatus	4740	2	3.60
LIUSSPEC	LIUSVOLC	Limnius sp	4763	1	1.37
LIUSSPE6	LIUSVOLC	Limnius sp larve	4764	2	23.33
LIUSVOLC	LIUSVOLC	Limnius volckmari	4773	1	8.33
SCIRTIA6	SCIRTIA6	Scirtidae larve	4781	3	18.09
ELODESSP	ELODMINU	Elodes sp	4792	7	816.97
ELODESS6	ELODMINU	Elodes sp larve	4793	9	334.56
ELODMINU	ELODMINU	Elodes minuta	4796	17	6065.33
ELODMIN6	ELODMINU	Elodes minuta larve	4797	7	799.73
CYPHONSP	CYPHONSP	Cyphon sp	4814	1	3.20
DIPTERA		Diptera	5126	1	22.22
LIMONIAE		Limoniidae	5151	4	17.83
CHTRICSP	CHTRICSP	Cheilotrichia sp	5160	1	11.11
ORMOSISP	ORMOSISP	Ormosia sp	5230	1	0.91
RHYPHOSP	RHYPHOSP	Rhypholophus sp	5253	2	26.67
MOLOPHSP	MOLOPHSP	Molophilus sp	5352	2	7.83
LIMNONAE	LIMNONAE	Limnophilinae	5385	3	16.80
ELOEOPSP	ELOEOPSP	Eloeophila sp	5401	35	1378.46
EPIPHRSP	EPIPHRSP	Epiphragma sp	5423	2	1.60
LILASPEC	LILASPEC	Limnophila sp	5471	5	27.91
NEMYIASP	NEMYIASP	Neolimnomyia sp	5483	3	87.03
NEMYNESG	NEMYIASP	Neolimnomyia (Neolimnomyia) sp	5496	11	108.46
PHLIDOSP	PHLIDOSP	Phylidorea sp	5518	2	1.69
PILARISP	PILARISP	Pilaria sp	5543	6	49.85
PSLIMNSP	PSLIMNSP	Pseudolimnophila sp	5553	3	22.91
HEUSSPEC	HEUSSPEC	Helius sp	5587	3	14.67
LIPSOTSP	LIPSOTSP	Lipsothrix sp	5614	0	0.00
DITASPEC	DITASPEC	Dicranota sp	5706	23	703.71
DITABIMA	DITASPEC	Dicranota bimaculata	5711	5	12.00

PEDICISP	PEDICISP	Pedicia sp	5722	5	204.06
PEDIRIVO	PEDICISP	Pedicia rivosa	5735	1	13.33
TIPULIAE	TIPULIAE	Tipulidae	5759	7	20.53
TIPULASP	TIPULIAE	Tipula sp	5868	1	6.00
TIPUMAXI	TIPULIAE	Tipula maxima	5880	2	12.94
TIPUPRUI	TIPULIAE	Tipula pruinosa	6029	1	22.22
PSYCHDAE		Psychodidae	6033	1	6.67
PECOMASP	PECOMASP	Pericoma sp	6051	3	177.78
TESCOPSP	TESCOPSP	Telmatoscopus sp	6178	3	104.44
PTYCHOSP	PTYCHOSP	Ptychoptera sp	6190	8	20.17
PTYCLACU	PTYCHOSP	Ptychoptera lacustris	6198	13	491.09
PTYCSCUT	PTYCHOSP	Ptychoptera scutellaris	6207	6	155.56
DIXIDAE		Dixidae	6405	1	1.78
DIXASPEC	DIXASPEC	Dixa sp	6407	6	28.23
DIXAGMAC	DIXASPEC	Dixa gr maculata	6416	4	59.80
DIXASUBM	DIXASPEC	Dixa submaculata	6421	5	17.53
DIXELLSP	DIXELLSP	Dixella sp	6422	1	18.67
CEPOGOAE	CEPOGOAE	Ceratopogonidae	6442	25	562.93
CEPOGOA4	CEPOGOAE	Ceratopogonidae pop	6445	1	13.33
CHIRODAE		Chironomidae	6735	3	51.11
CHIRONAE		Chironominae	6738	6	208.89
CHIROINI		Chironomini	6740	2	69.87
CHIRONSP		Chironomus sp	6750	7	120.71
CRCHIRSP	CRCHIRSP	Cryptochironomus sp	6916	2	26.25
DEMIVULN	DEMIVULN	Demicryptochironomus vulneratus	6952	3	12.86
DITELOBI	DITELOBI	Dicrotendipes lobiger	6960	2	1.60
DITENOTA	DITENOTA	Dicrotendipes notatus	6970	1	9.52
GLTOTESP	GLTOTESP	Glyptotendipes sp	7005	2	1.60
MITEGCHL	MITEGCHL	Microtendipes gr chloris	7118	5	199.37
PADOPESP	PADOPESP	Paracladopelma sp	7189	2	133.33
PADONIGR	PADOPESP	Paracladopelma nigritula	7192	14	486.73
PADOLAMA	PADOPESP	Paracladopelma laminata agg	7197	1	28.57
PATEALMA	PATEALMA	Paratendipes albimanus	7210	5	637.56
PHAENOSP	PHAENOSP	Phaenopsectra sp	7224	4	25.33
POPEDISP	POPEDISP	Polypedilum sp	7235	31	1737.94
POPEDIS4	POPEDISP	Polypedilum sp pop	7236	1	13.33
POPEUNCI	POPEDISP	Polypedilum uncinatum	7250	0	0.00
POPEPEDE	POPEDISP	Polypedilum pedestre	7275	4	58.52
POPESCAL	POPEDISP	Polypedilum scalaenum	7288	35	11727.79
POPENUBE	POPEDISP	Polypedilum nubeculosum	7293	1	38.10
TATARINI		Tanytarsini	7386	3	16.86
CLADOTSP	CLADOTSP	Cladotanytarsus sp	7389	1	714.29
PATANYSP	PATANYSP	Paratanytarsus sp	7440	2	661.94
PATADISA	PATANYSP	Paratanytarsus dissimilis agg	7455	1	676.19
RHTANYSP	RHTANYSP	Rheotanytarsus sp	7474	1	9.52
MIPSECSP	MIPSECSP	Micropsectra sp	7516	29	8528.20
MIPSBIDE	MIPSECSP	Micropsectra bidentata	7522	2	19.50
MIPSJUNC	MIPSECSP	Micropsectra junci	7524	1	0.46
MIPSFUSC	MIPSECSP	Micropsectra fusca	7528	4	26.19
MIPSGNOT	MIPSECSP	Micropsectra gr notescens	7545	17	14578.90

MIPSNOT4	MIPSECSP	Micropsectra notescens pop	7547	1	6.67
MIPSAPC4	MIPSECSP	Micropsectra apposita/contracta pop	7552	1	9.52
MIPSGATR	MIPSECSP	Micropsectra gr atrofasciata	7553	1	13.33
MIPSATR4	MIPSECSP	Micropsectra atrofasciata pop	7555	1	19.05
TATARSSP	TATARSSP	Tanytarsus sp	7560	5	332.88
DIAMINSI	DIAMINSI	Diamesa insignipes	7686	1	13.33
POTTLONG	POTTLONG	Potthastia longimanus	7693	1	2.00
ORCLANAE		Orthocladiinae	7704	13	254.80
ORCLANA4		Orthocladiinae pop	7705	1	28.57
BRILMODE	BRILMODE	Brillia modesta	7723	33	8422.10
BRILMOD4	BRILMODE	Brillia modesta pop	7724	4	220.00
CHCLADSP	CHCLADSP	Chaetocladius sp	7761	2	1.60
CHCLADS4	CHCLADSP	Chaetocladius sp pop	7763	1	9.52
CHCLGPIG	CHCLADSP	Chaetocladius gr piger	7774	1	9.52
CHCLDENT	CHCLADSP	Chaetocladius dentiforceps	7780	1	13.33
CONEURSP	CONEURSP	Corynoneura sp	7795	1	2.74
CORYANTC	CONEURSP	Corynoneura cf antennalis	7805	3	53.33
CONELOAG	CONEURSP	Corynoneura lobata agg	7811	1	0.46
CORYLOBC	CONEURSP	Corynoneura cf lobata	7812	1	0.46
DICLCULT	DICLCULT	Diplocladius cultriger	7822	2	12.91
EUKIEFSP		Eukiefferiella sp	7830	4	197.79
EUKICLAR	EUKICLAR	Eukiefferiella claripennis	7834	10	799.73
EUKIGGRA	EUKIGGRA	Eukiefferiella gr gracei	7843	1	2.00
EUKIBREA	EUKIBREA	Eukiefferiella brevicalcar agg	7845	14	1653.49
EUKIBREV	EUKIBREA	Eukiefferiella brevicalcar	7846	5	104.44
EUKIBRE4	EUKIBREA	Eukiefferiella brevicalcar pop	7847	7	166.11
HETAAPIC	HETAAPIC	Heterotanytarsus apicalis	7897	2	26.67
HETRMARC	HETRMARC	Heterotrissocladius marcidus	7902	17	813.90
LIESSPEC	LIESSPEC	Limnophyes sp	7914	7	49.59
MEOCHYGA	MEOCHYGA	Metriocnemus hygropetricus agg	7971	1	1.78
NANOCLSP	NANOCLSP	Nanocladius sp	7993	1	9.52
NANORECT	NANOCLSP	Nanocladius rectinervis	8001	2	49.62
PADICONA	PADICONA	Paracladius conversus agg	8016	1	4.80
PAOCSTYL	PAOCSTYL	Parametriocnemus stylatus	8039	7	238.91
RHCRICSP	RHCRICSP	Rheocricotopus sp	8190	3	45.71
RHCRGFUS	RHCRICSP	Rheocricotopus gr fuscipes	8194	5	13.60
RHCRFUSC	RHCRICSP	Rheocricotopus fuscipes	8199	14	561.06
SYNOSEMI	SYNOSEMI	Synorthocladius semivirens	8238	1	9.52
THELFLAA	THELFLAA	Thienemanniella flaviforceps agg	8257	1	152.38
TVETDISA	TVETDISA	Tvetenia discoloripes agg	8282	1	76.19
CRICOTSP	CRICOTSP	Cricotopus sp	8300	7	45.12
CRICOTS4	CRICOTSP	Cricotopus sp pop	8304	1	9.52
CRICCRSG	CRICOTSP	Cricotopus (Cricotopus) sp	8306	1	352.38
CRICBICI	CRICOTSP	Cricotopus bicinctus	8308	1	19.05
CRICVIER	CRICOTSP	Cricotopus vierriensis	8312	1	1885.71
CRICGSYL	CRICOTSP	Cricotopus gr sylvestris	8385	1	9.52
ORCLADSP	ORCLADSP	Orthocladius sp	8412	1	2.00
ORCLADS4	ORCLADSP	Orthocladius sp pop	8413	2	13.11
ORCLORSG	ORCLADSP	Orthocladius (Orthocladius) sp	8432	3	170.70
ORCLFRIG	ORCLADSP	Orthocladius frigidus	8436	1	40.00

ODMEFULV	ODMEFULV	Odontomesa fulva	8485	2	68.67
ODMEFUL4	ODMEFULV	Odontomesa fulva pop	8486	1	19.05
PRODOLIV	PRODOLIV	Prodiamesa olivacea	8490	40	1758.74
PRODRUFO	PRODRUFO	Prodiamesa rufovittata	8494	0	0.00
TAPODNAE		Tanypodinae	8501	13	238.11
CLTANERV	CLTANERV	Clinotanypus nervosus	8521	4	138.70
PSTAVARI	PSTAVARI	Psectrotanypus varius	8531	1	2.40
APSEMALO	APSEMALO	Apsectrotanypus sp/Macropelopia sp	8533	9	46.50
APSETRIF	APSEMALO	Apsectrotanypus trifascipennis	8540	19	855.60
MALOPISP	APSEMALO	Macropelopia sp	8543	16	308.13
NATARSSP	NATARSSP	Natarsia sp	8555	4	83.81
PENTAINI		Pentaneurini	8560	5	69.01
KRENOPSP	KRENOPSP	Krenopelopia sp	8582	3	28.19
ZAMYIASP	ZAMYIASP	Zavrelimyia sp	8645	24	402.96
CONCGCOA	CONCGCOA	Conchapelopia sp/Arctopelopia sp/Rheopelopia sp/Thienemannimyia sp	8657	7	320.00
CONCHASP	CONCGCOA	Conchapelopia sp	8668	12	557.96
PRDIUSSP	PRDIUSSP	Procladius sp	8690	9	676.46
SIMULIAE	SIMULIAE	Simuliidae	8734	11	1746.67
SIMULISP	SIMULIAE	Simulium sp	8736	13	10327.41
SIMUANIP	SIMULIAE	Simulium angustipes	8772	1	13.33
SIMULATI	SIMULIAE	Simulium latipes	8778	2	26.67
SIMUCOST	SIMULIAE	Simulium costatum	8792	0	0.00
SIMUMORS	SIMULIAE	Simulium morsitans	8825	2	6.40
SIMUIOTR	SIMULIAE	Simulium intermedium/ornatum/trifasciatum	8836	6	86.06
SIMUIOT4	SIMULIAE	Simulium intermedium/ornatum/trifasciatum pop	8839	1	160.00
SIMUTRIF	SIMULIAE	Simulium trifasciatum	8842	14	3484.44
SIMUINOR	SIMULIAE	Simulium intermedium/ornatum	8848	10	1188.76
SIMUINTE	SIMULIAE	Simulium intermedium	8852	1	20.00
SIMUORNA	SIMULIAE	Simulium ornatum	8855	3	52.62
NEMATOCE		Nematocera	8878	2	24.44
TABANIAE	TABANIAE	Tabanidae	8913	3	10.78
CHSOPSSP	TABANIAE	Chrysops sp	8917	3	22.28
CHSOCAET	TABANIAE	Chrysops caecutiens	8922	2	8.67
HYBODIST	TABANIAE	Hybomitra distinguenda	8997	1	2.00
TABANUSP	TABANIAE	Tabanus sp	9020	3	3.20
TABABOVI	TABANIAE	Tabanus bovinus	9026	1	14.22
EMPIDIAE	EMPIDIAE	Empididae	9252	5	27.77
HEMERNAE		Hemerodromiinae	9265	1	12.80
CHFEIFSP	CHFEIFSP	Chelifera sp	9271	3	29.26
HEMEROSP	HEMEROSP	Hemerodromia sp	9283	0	0.00
NEOASCSP	NEOASCSP	Neoascia sp	9714	1	13.33
BRACHYCE		Brachycera	9765	3	64.44
EPDRIDAE	EPDRIDAE	Ephydridae	9935	1	0.80
SCTOPHAE	SCTOPHAE	Scatophagidae	10286	2	2.40
TRICHOPT		Trichoptera	10322	5	51.57
BEEASPEC		Beraea sp	10326	1	2.00
BEEAMAUR	BEEAMAUR	Beraea maurus	10328	1	2.00
BEEAPULL	BEEAPULL	Beraea pullata	10330	2	148.67

BEEOMINU	BEEOMINU	Bereodes minutus	10337	2	183.33
AGAPETSP	AGAPFUSC	Agapetus sp	10341	1	0.46
AGAPFUSC	AGAPFUSC	Agapetus fuscipes	10343	1	69.49
HYPSYCSP	HYPSANGU	Hydropsyche sp	10352	4	95.33
HYPSANGU	HYPSANGU	Hydropsyche angustipennis	10357	7	94.31
LECERIAE	LECERIAE	Leptoceridae	10432	2	14.67
ADICEOSP	ADICREDU	Adicella sp	10435	1	0.80
ADICREDU	ADICREDU	Adicella reducta	10437	8	162.09
ATHRATER	ATHRATER	Athripsodes aterrimus	10444	5	421.20
MYSTACSP		Mystacides sp	10460	1	17.33
MYSTAZUR	MYSTAZUR	Mystacides azurea	10463	1	2.67
MYSTLONG	MYSTLONG	Mystacides longicornis	10465	1	9.52
MYSTNIGR	MYSTNIGR	Mystacides nigra	10467	1	0.80
LIMNEPAE		Limnephilidae	10530	23	912.35
GLPHPELL	GLPHPELL	Glyphotaelius pellucidus	10556	7	397.47
LILUSSPE		Limnephilus sp	10557	1	19.05
LILUEXTR	LILUEXTR	Limnephilus extricatus	10574	3	2.40
LILULUNA	LILULUNA	Limnephilus lunatus	10582	5	39.77
LILURHOM	LILURHOM	Limnephilus rhombicus	10588	3	9.87
ANABNERV	ANABNERV	Anabolia nervosa	10599	2	325.81
CHPTERSP	CHPTVILL	Chaetopteryx sp	10605	3	37.78
CHPTVILL	CHPTVILL	Chaetopteryx villosa	10608	10	137.45
POLAROTU	POLAROTU	Potamophylax rotundipennis	10625	2	7.47
HALESUSP	HALESUSP	Halesus sp	10627	3	14.40
HALEDIRA	HALESUSP	Halesus digitatus/radiatus	10629	1	8.00
HALERADI	HALESUSP	Halesus radiatus	10632	3	92.00
STPHYLSP	STPHYLSP	Stenophylax sp	10639	1	0.80
MONAANGU	MONAANGU	Molanna angustata	10674	3	56.57
POTROPAE	POTROPAE	Polycentropodidae	10731	6	60.00
PLTRCNSP	PLTRCNSP	Plectrocnemia sp	10749	6	220.64
PLTRCOSP	PLTRCNSP	Plectrocnemia conspersa	10752	27	430.15
PSMYIIAE		Psychomyiidae	10761	1	26.67
LYPESPEC	LYPESPEC	Lype sp	10762	6	66.51
LYPEREDU	LYPESPEC	Lype reducta	10765	18	251.08
TINOASSI	TINOASSI	Tinodes assimilis	10771	0	0.00
SETOMAAE	SETOPERS	Sericostomatidae	10800	7	430.31
SETOMASP	SETOPERS	Sericostoma sp	10801	9	1279.78
SETOPERS	SETOPERS	Sericostoma personatum	10803	22	504.76
SILONIGR	SILONIGR	Silo nigricornis	10823	1	0.46
LEPIDOPT	LEPIDOPT	Lepidoptera	10840	2	17.78
CATACLSP	LEPIDOPT	Cataclysta sp	10855	1	0.80