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Report

Water balance calculations for the case study regions in Austria, Hungary and Romania

Acknowledgement

The authors greatfully acknowledge the following local authorities and institutions making the following data available for the use within the daNUbs project:

Amt der Niederösterreichischen Landesregierung:

- Orographic base map Ybbs
- Digital Elevation Model Ybbs
- Digital river network and catchment boundaries Ybbs
- Hydrogeological map Ybbs
- Ybbs river discharges
- Climatological data Ybbs

Amt der Burgenländischen Landesregierung:

- Digital Elevation Model Wulka
- Digital river network and catchment boundaries Wulka
- Hydrogeological map Wulka
- Wulka river discharges
- Climatological data Wulka (e.g. rainfall, temperature)

Geologische Bundesanstalt:

- Additional hydrogeological maps Wulka and Ybbs

Universität für Bodenkultur
Institut für Vermessung, Fernerkundung und Landinformation:

- Landuse maps Wulka and Ybbs produced for the daNUbs project

Bundesamt für Wasserwirtschaft
Institut für Kulturtechnik und Bodenwasserhaushalt (BAW):

- Soil maps Wulka and Ybbs produced within the daNUbs project

1 Introduction

Workpackage 1 is a detailed analysis of the nutrient balances of the case study regions in different climatic and hydrologic conditions.

The objective of the investigations is the improvement of the knowledge about different key processes that lead to regional nutrient turnover. The MONERIS model, which should be applied to the whole Danube basin, is used in the case study regions and possible differences due to the downscaling process will be demonstrated.

The basis for the nutrient balances are the **water balance calculations** in the case study regions which are presented in this report. The estimation of the water balances had a special focus on the description of the runoff components surface runoff, lateral flow and base flow. The following methods were used:

DIFGA 2000 ... is a baseflow separation technique

SWAT 2000 ... is a conceptual continuous model based on physical equations

MONERIS ... is a GIS-based model based on empirical equations for large river basins using extensive statistical information

6 regions, which are located in Austria (Ybbs, Wulka), Hungary (Zala, Lonyai), Romania (Neajlov) and Bulgaria (Lesnovska) were chosen according to the following criteria. The regions had to be different in climatic and hydrological conditions. Moreover, the data availability had to be as high as possible in addition to a minimum of effort in assessment.

For the Lonyai catchment (Hungary) the necessary data could not be provided by the local authorities for calculation of the detailed water balance. Thus, the investigations with SWAT and DIFGA were not continued in this catchment. Only the MONERIS approach will be applied for nutrient balance calculations. The results for the Bulgarian catchment were not implemented in this report as there was no contribution from the Bulgarian partner.

The remaining 4 case study regions differ-partly considerably-in the catchment size, the hydrological conditions, climate and the landuse. The catchments represent a wide spectrum of climate conditions reaching from alpine and pannonian to transitional temperate continental conditions.

The following report is structured in a description of the investigated catchments, a explanation of the input data and the methods used. A detailed presentation of the results is given and followed by a summary.

2 Description of the case study regions

2.1 Case study regions in AUSTRIA

Two Austrian case study regions of the Danube basin have been selected for detailed investigation of the water and nutrient balances. The selection was addressed forwards representing different conditions in the Danube basin with regard to precipitation, specific surface water runoff, slope, soil types etc. Other important selection criteria were data availability, for instance high-quality, long-term data sets from groundwater and surface water monitoring as well as some understanding of the groundwater situation.

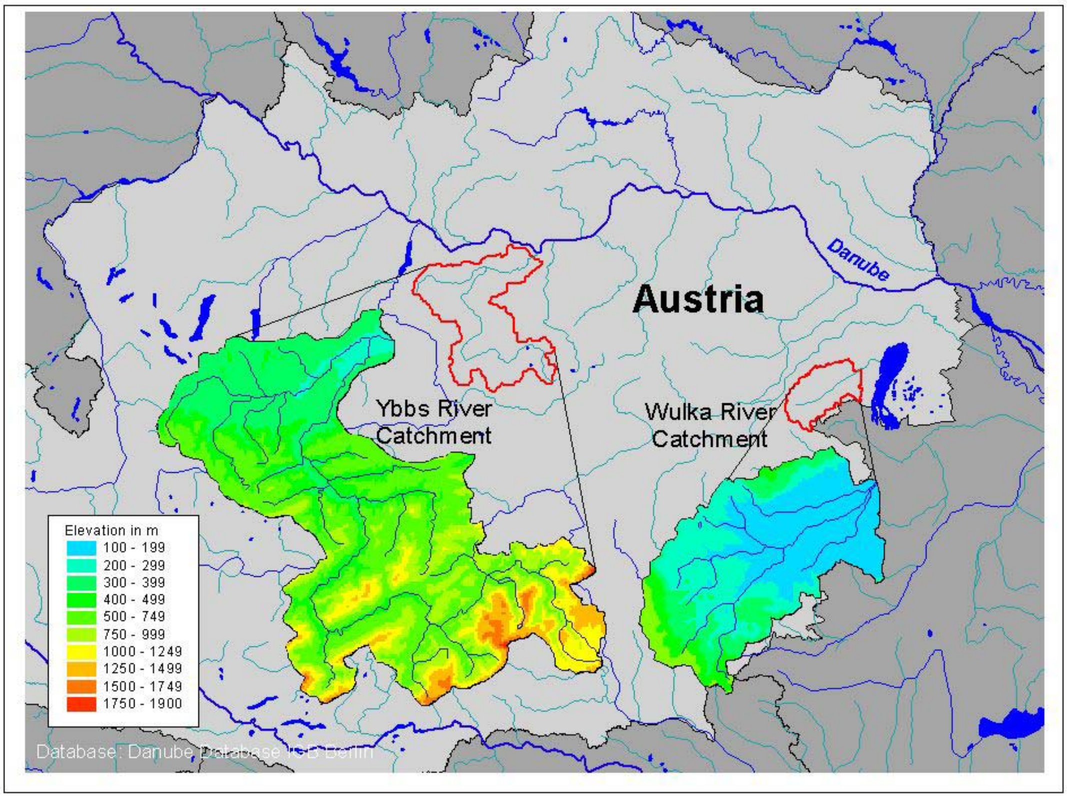


Fig. 2-1: Location of the Austrian case study regions

The Ybbs River catchment belongs to the northern limestone pre-Alps (Figure 2-1). It is characterised by wet climatic conditions with an annual precipitation of 1380 mm.

The Wulka River catchment is situated in the eastern part of Austria upstream of Lake Neusiedl (Figure 2-1). The landscape is hilly. The climate is of a dry pannonian type with an annual precipitation of 700 mm.

2.1.1 General processes

To understand the processes in the catchment better graphical models of the catchment including storages and fluxes were developed.

The upper Ybbs catchment is a mountainous region with big slopes and rocky underground. Depending from the rock-properties of the underground two different flow paths (bounderies of possibilities) of water are possible:

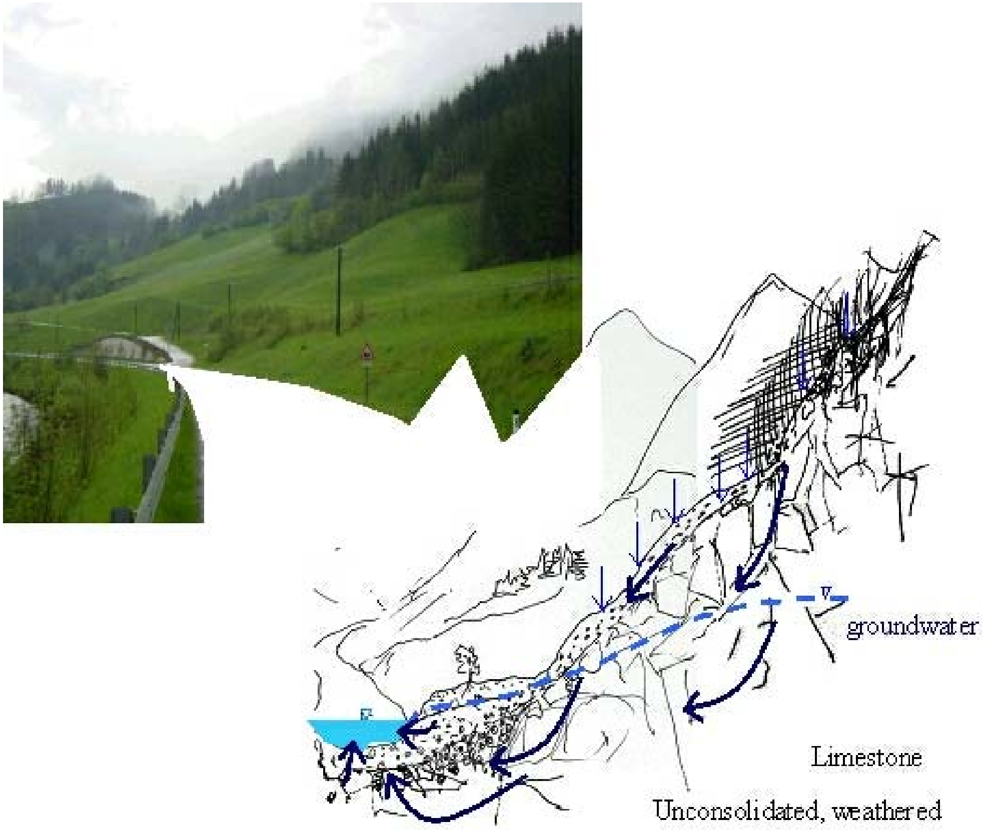


Fig. 2-2: graphical model 1of the upper Ybbs catchment, unconsolidated rock

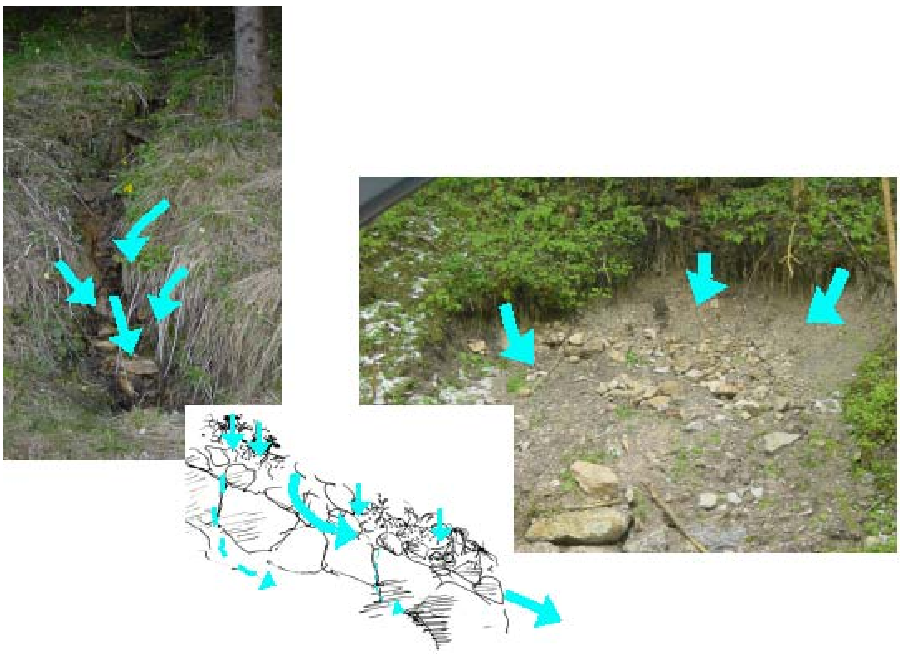


Fig. 2-3: possible lateral flow paths when rock is consolidated dolomit

In the first case. illustrated in Figure 2-2, the underground exists of weathered rock. In the unconsolidated limestone there are several ways, caverns and other karst phenomena, where groundwater is present, water movement is possible.
In the case of consolidated dolomite because of missing deep permeable layers, mainly surface and shallow subsurface flow paths are possible, as seen in Figure 2-3. No deep aquifer can be found.
In some cases this phenomena can be observed, as illustrated in Figure 2-4, where water leaks out from shallow subsurface layer, caused by the missing possibility to seep to deeper layers.

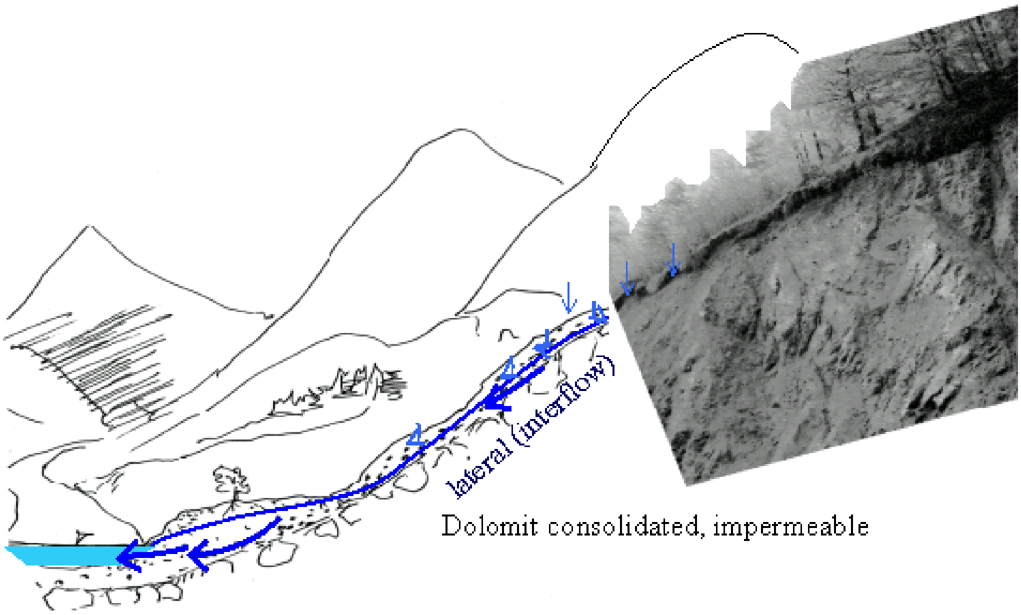


Fig. 2-4: graphical model 2 of the upper Ybbs catchment, consolidated rock

Only in the valleys are some fluvial sediments were porous ground water is possible. The imagination of flowpaths is similar to the lower Ybbs catchment or the Wulka basin, illustrated in Figure 2-5.

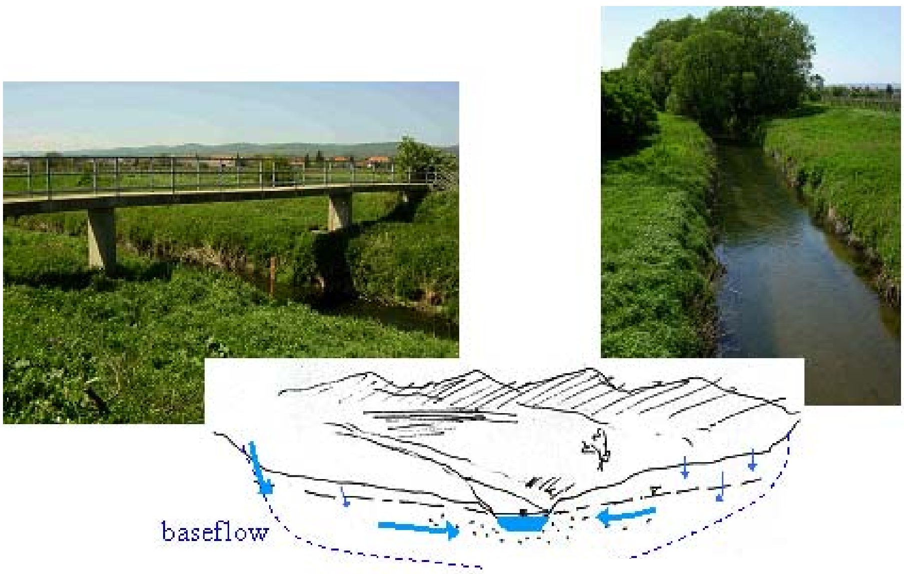


Fig. 2-5: graphical model of the Wulka and lower Ybbs catchment

2.1.2 The Ybbs river catchment - AUSTRIA

The Ybbs river is a tributary of the Danube river. The last gauging station before entering the Danube is Greimpersdorf, the outlet of the investigated Ybbs catchment. The main characteristics of the Ybbs river catchment are listed in Table 2-1.

Name of the river		Ybbs
catchment area	km^2	1117
average precipitation	mm/a	1377
average terrain slope	%	31
average runoff depth	mm/a	923
average river discharge	m^3/s	32.7
population density	inh/km^2	68
landuse characteristic		arable land, forest, pasture
main hydrogeological characteristic		consolidated rock, sediment

Tab. 2-1: Main characteristics of the Ybbs catchment

In the following subchapters the most important properties of the catchment will be discussed and displayed in detail.

2.1.2.1 Elevation characteristics and station location

The elevations in the Ybbs catchment range from 250 m to 1900 m above sea level (Figure 2-6). The catchments has an average slope of 31%. The part downstream (the northern third territory, with elevation < 500m) is more flat or hilly, while the more upstream part (southern two-third of the catchment area, elevations > 500m) is characterised by narrow valleys and steep slopes.
The climate and precipitation information are available over the whole catchment.

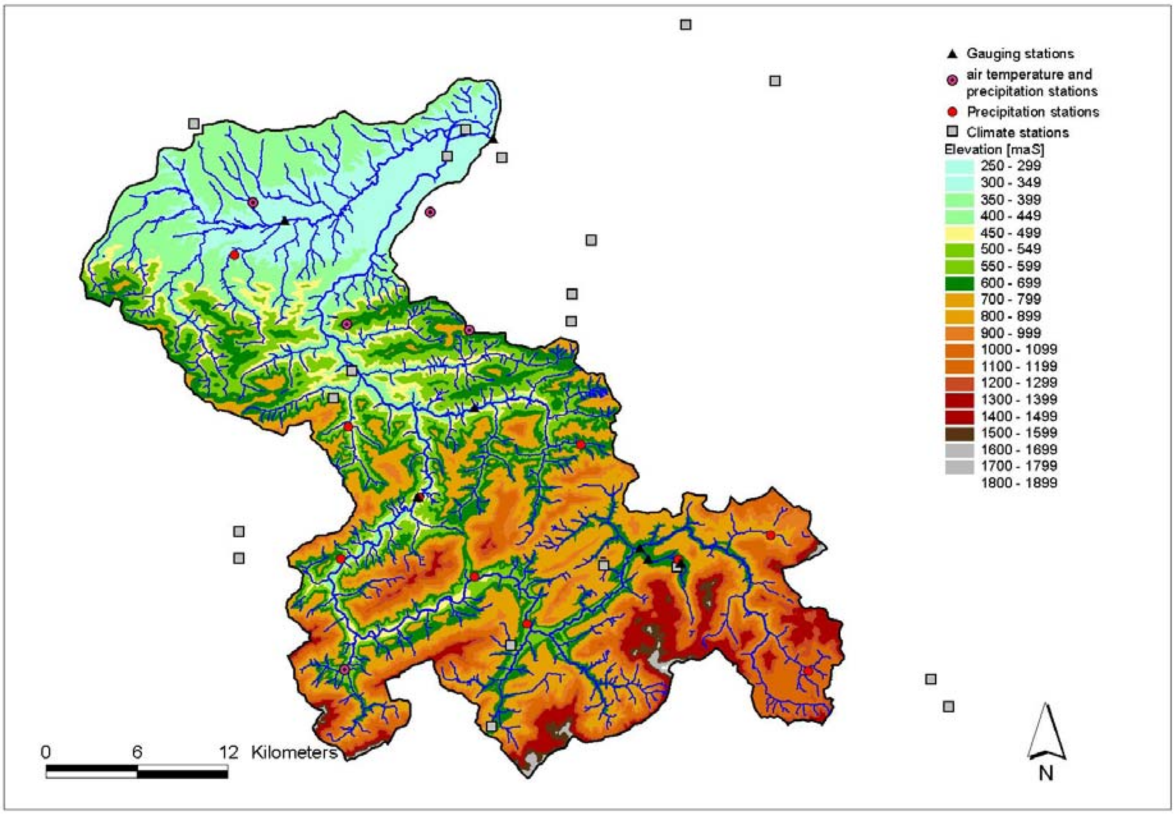


Fig. 2-6: Elevations and location of the precipitation stations, climate stations and gauging stations in the Ybbs catchment

2.1.2.2 Landuse characteristics

As digital map a landsat-grid created in the frame of this project (Figure2-7) with a grid resolution of 30 m based on orthofotos was used.

The following table (Table 2-2) characterises the dominant landuse in the Ybbs catchment. Thus, the main part of the catchment is covered by forest (52%), following grassland or pasture (32%) and arable areas (12%). Also the settlement areas (3%) have to be considered (Figure 2-8).

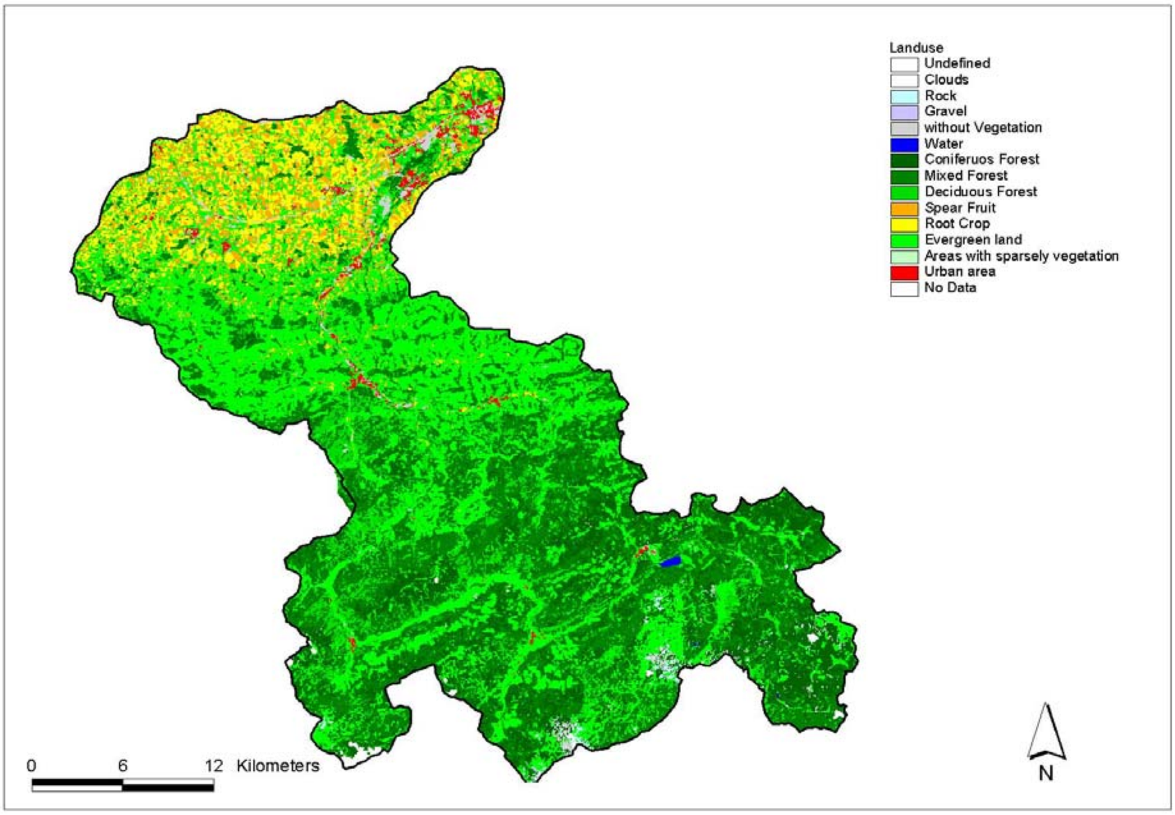


Fig. 2-7: Landuse distribution of the Ybbs catchment

Landuse class	Fraction [%]	Sum [%]
Grassland and pasture	**32,3**	**32**
Mixed forest	**31,3**	**52**
Coniferous forest	**11,9**	
Deciduous forest	**8,9**	
Root crop	**7,3**	**12**
Spear fruit	**4,7**	
Without vegetation	**1,6**	**3**
Urban areas	**1,1**	
Rock	**0,3**	**<1**
Water areas	**0,1**	**<1**

Table 2-2: Landuse distribution in the Ybbs catchment, listed in order of magnitude

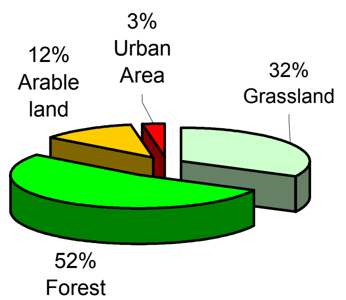


Fig. 2-8: Fraction of the landuse formations

2.1.2.3 Soil characteristics

The FAO soil map with a grid resolution of 250 m was used for soil information (Figure 2-9).

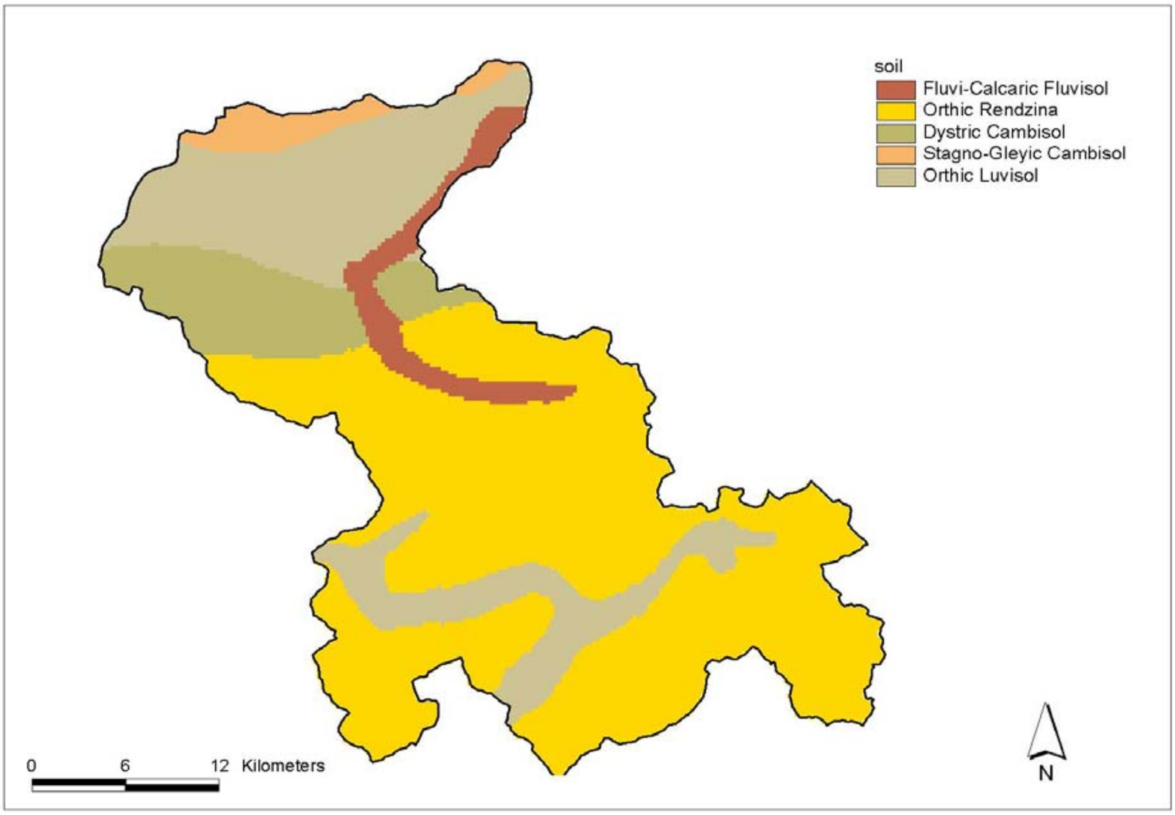


Fig. 2-9: Soil distribution in the Ybbs catchment (FAO-soil map)

The Rendzina (58%) is the dominating soil type, but to find in the upper part of the catchment only. The Ortic Luvisol dominates as the second large soil type (25%) the part downstream. In between the catchment is dominated by Dystic Cambisols (9%) and Fluvisoils (5%). A Gleyic Cambisol (3%) is situated at the north border of the catchment (Figure 2-9).

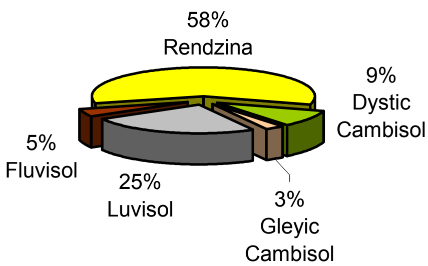


Fig. 2-10: Fraction of the total catchment area covered by each soil type

On the basis of the geological map (see Chapter 2.1.2.4) a more detailed soil map was generated by the Institute for Land and Water Management (Petzenkirchen, Austria) (Figure 2-11). In regard to the water balance calculations this map was used for the calibration of the SWAT model.

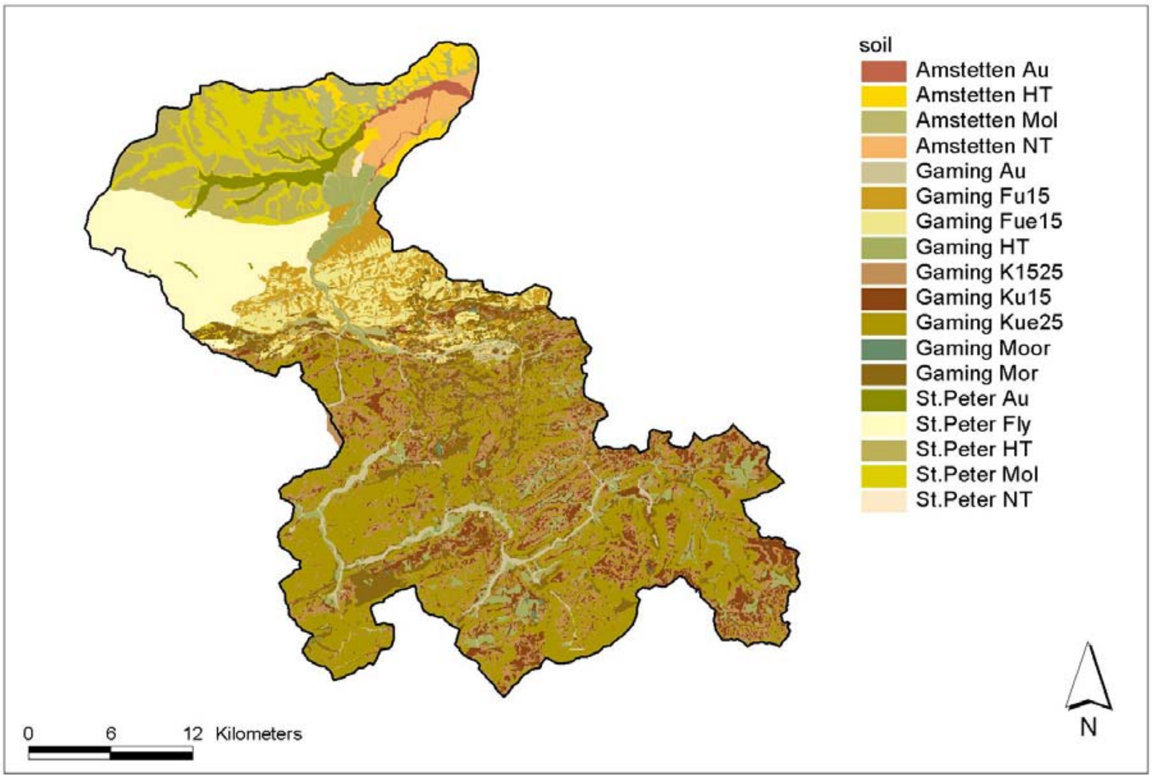


Fig. 2-11: Soil distribution in the Ybbs catchment on basis of the geological map

The dominating soil type is Gaming Kue25 (26%), which can be compared in the location to the Rendzina (Figure 2-10, Figure 2-12). The second largest soil type is Gaming K1525, which can be found in the same area than the dominant soil type. All following soil types have a fraction smaller then 10% of the total catchment area. But compared to the Fao-soil map, similarities were noticed in the soil location (Dystic Cambisol & St.Peter Fly; Orthic Luvisol &St. Peter HT; Fluvi-Calcaric Fluvisol & Amstetten NT/Amstetten Mol).
The fractions of the soil types at the total catchment area are diplayed in Fig. 2-12.

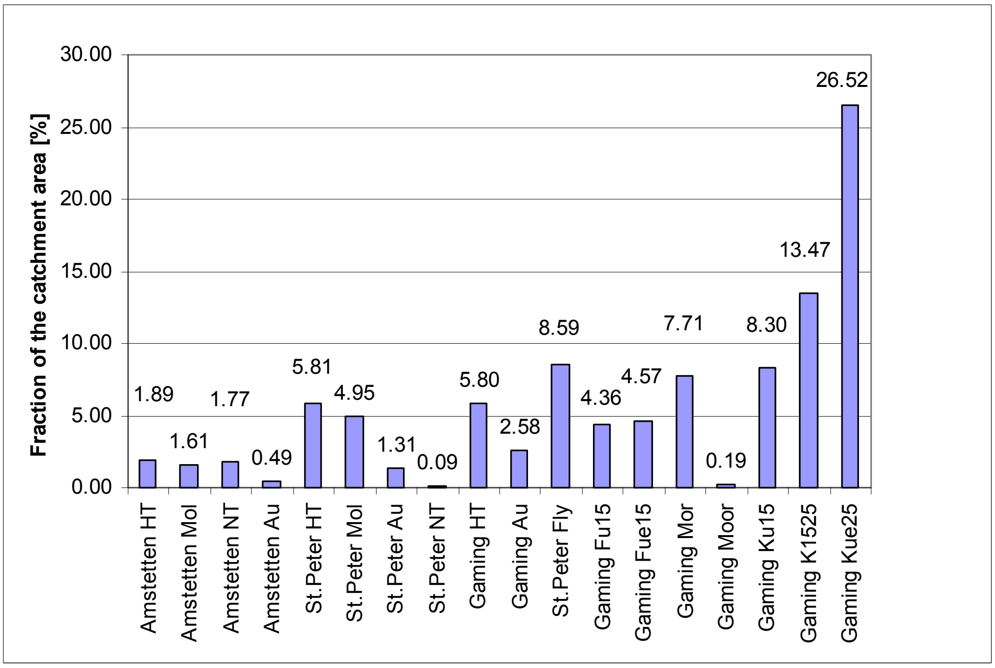


Fig. 2-12: Fraction of the total catchment area covered by the soil type

2.1.2.4 Geological characteristics

Hydrogeologically, the Ybbs catchment consists of two dominating parts, consolidated rock ($^2/_3$) and unconsolidated sediments and gravels ($^1/_3$).

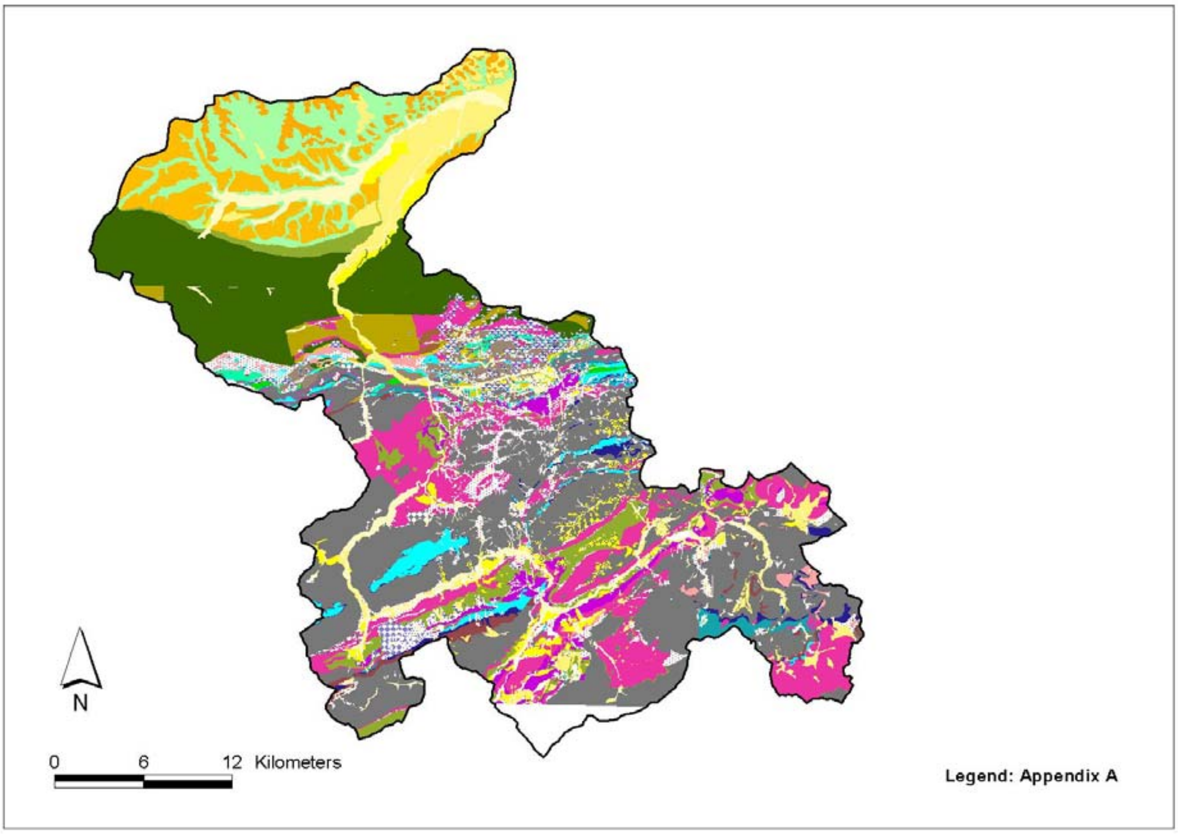


Fig. 2-13: Geological formations in the Ybbs catchment (Use of geological basics with the Authorisation by the Geological Survey of Austria - ©GBA-2002-Zl.29/1/02)

As Figure 2-12 and 2-13 showing, the part downstream is dominated by mostly unconsolidated sediments and gravels (yellow colour), partially covered by loam (orange colour). More upstream, there is a band mainly consists of schist's (green colour). It builds the zone of change from the unconsolidated to the consolidated material. Moving more upstream, the geological formations are dominated by rocks, mainly alternating between dolomite (grey) and limestone (cyan), in parts also loamy marl (violet), schist's and sandstones (brown).
Due to the geological conditions most of the groundwater monitoring stations are located in the downstream part of the Ybbs river catchment.

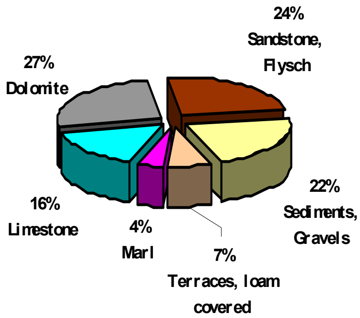


Fig. 2-14: Fraction of the geological formation in the Ybbs catchment

2.1.2.5 Partition into subcatchments

Due to the location of the main river gauging stations the Ybbs river catchment consists of 5 subcatchments (Figure 2-15). In regard to the water balance calculation, this partition was used to define the subcatchments for the SWAT 2000 model, the DIFGA model and the MONERIS model too.

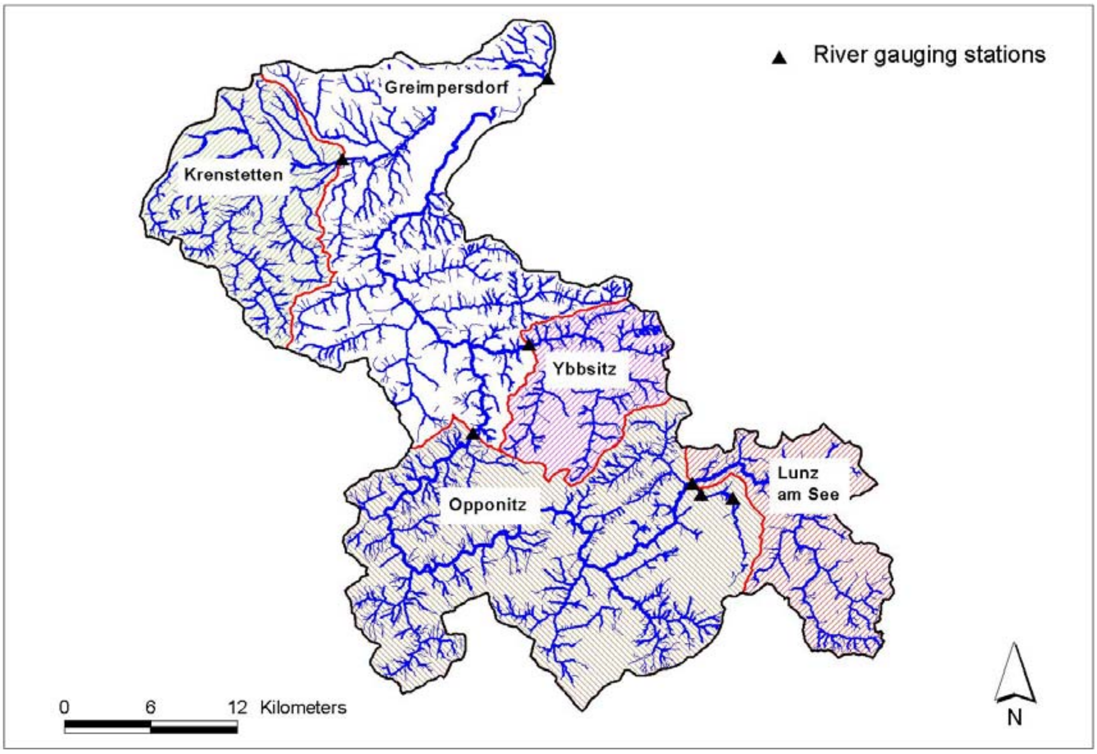


Fig. 2-15: Subcatchments and the location of the gauging stations in the Ybbs catchment

Near the most upstream gauging station „Lunz am See“, there are two more river gauging stations. They characterise the lake “Lunzer See” (see Figure 2-15), where the flow into and the flow out of the lake are measured. In regard to the definition of subcatchments, these gauging stations have not been considered. In the SWAT 2000 model, the measurements of the gauging station downstream the lake (outflow) have been used to define (simulate) the daily outflow of the lake.

Due to the large extend of the Ybbs river catchment the subcatchments differ in both the main characterisations and the climatic conditions (Table 2-3).

Subcatchment	Lunz a.S.	Opponitz	Ybbsitz	Krenstetten
Watershed area (brutto) [km^2]	**118**	**505**	**98**	**151**
Dominant landuse form	Forest (76%)	Forest (65%)	Forest (48%)	Evergreen land (41%)
Dominant soil type	Rendzina (93%)	Rendzina (80%)	Rendzina (93%)	Luvisol (46%)
Dominant geological formation	Dolomite (45%)	Dolomite (44%)	Dolomite (43%)	Sandstone, Flysch (65%)
Average annual precipitation [mm] Period 1994-1997	**1682**	**1572**	**1367**	**983**
Area-weighted average Elevation [maS]	**1045**	**914**	**700**	**440**

Tab. 2-3: Main characterisation of the subcatchments

This comparison does not consider the main outlet Greimpersdorf because it was characterised in the chapters before.
As Table 2-3 shows the average annual precipitation amount decreases with the average elevation. The average annual precipitation was interpolated with ArcView using the IDW-Method (Inverse Distance Weighted Interpolation) for the 12 nearest precipitation stations. That means, that the points closer to the processing cell were weighted greater than those are farther away.
The change in the landuse form, the soil type and the geological formation of the subcatchments is significant with the location in the Ybbs catchment. The upstream subcatchments have the same dominant types of landuse, soil and geology, but with a little change in the distribution of the other classes. Especially in the subcatchments Lunz am See, Opponitz and Ybbsitz due to the soil type and the geology there are no areas with arable use. The morphology and the weather conditions of this area explain the presence of mainly forest and pasture too.
The main change in the characteristics occurs at the subcatchment Krenstetten and downstream the subcatchments Opponitz and Ybbsitz, before the main outlet of the watershed.

2.1.3 The Wulka river catchment - AUSTRIA

The Wulka river is a tributary of the Lake Neusiedler See. To delimit the catchment, the gauging station Schützen was set to the main outlet of the watershed.
The main characteristics of the Wulka river catchment are listed in Table 2-4.

Name of the river		Wulka
catchment area	km^2	384
average precipitation	mm/a	709
average terrain slope	%	8
average runoff depth	mm/a	101
average river discharge	m^3/s	1.23
population density	inh/km^2	143
landuse characteristic		arable land
main hydrogeological characteristic		sediment

Tab. 2-4: Main characteristics of the Wulka catchment

In the following subchapters the most important properties of the catchment will be discussed and displayed in detail.

2.1.3.1 Elevation characteristics and station location

The elevations in the Wulka catchment range from 125 m to 750 m above sea level (Figure 2-16). The catchment has an average slope of 8%. The Mountains of the Rosaliengebirge in the South-West and of the Leithagebirge in the North are the only regions with a higher elevation and steeper slope. The main part of the catchment is dominated by a flat, partially hilly landscape.
The climate stations are situated without exception at the northern catchment border. Precipitation data are available over the whole catchment.

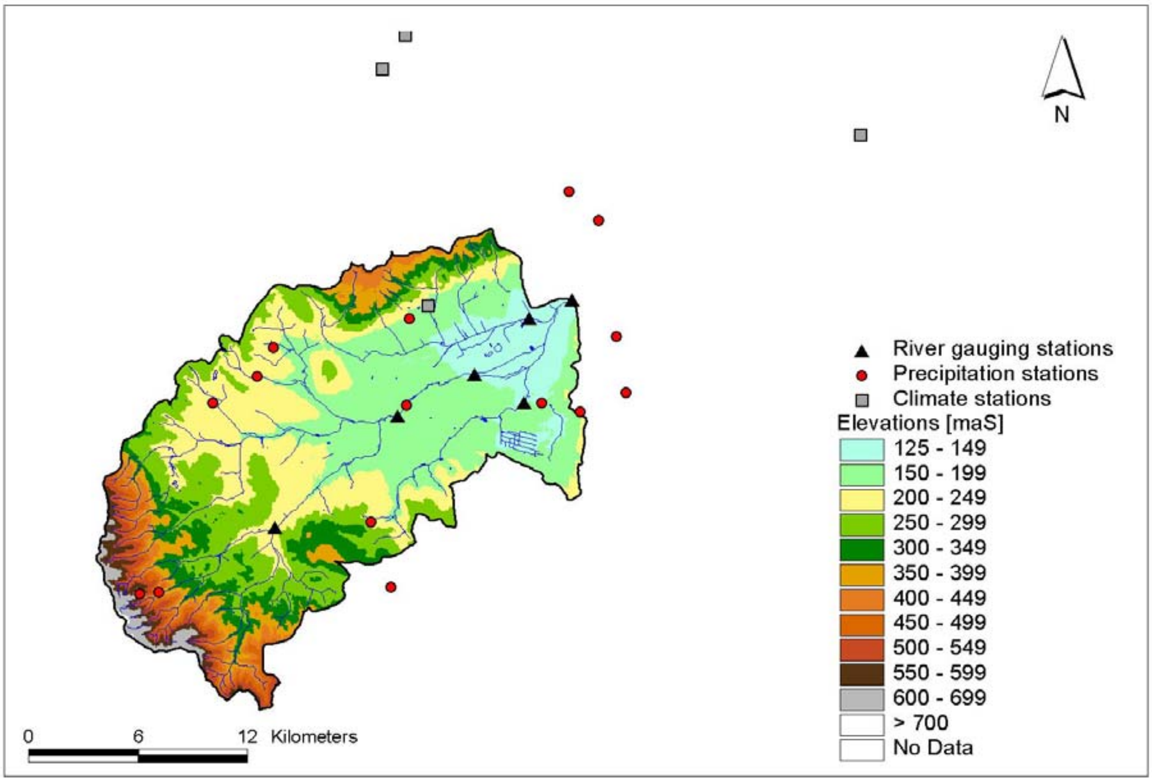


Fig. 2-16: Elevations and location of the climate, precipitation and gauging stations

2.1.3.2 *Landuse characteristics*

As digital map a landsat-grid was created within the project (Figure 2-17) also with a grid resolution of 30 m based on orthofotos was used.
The following table (Table 2-5) characterises the dominant landuse in the Wulka catchment. In opposite to the Ybbs catchment the main part of the catchment is covered by arable areas (54%), following forested areas (28%) and grassland or pasture (12%). Also the settlement areas (6%) have to be considered (Figure 2-18).

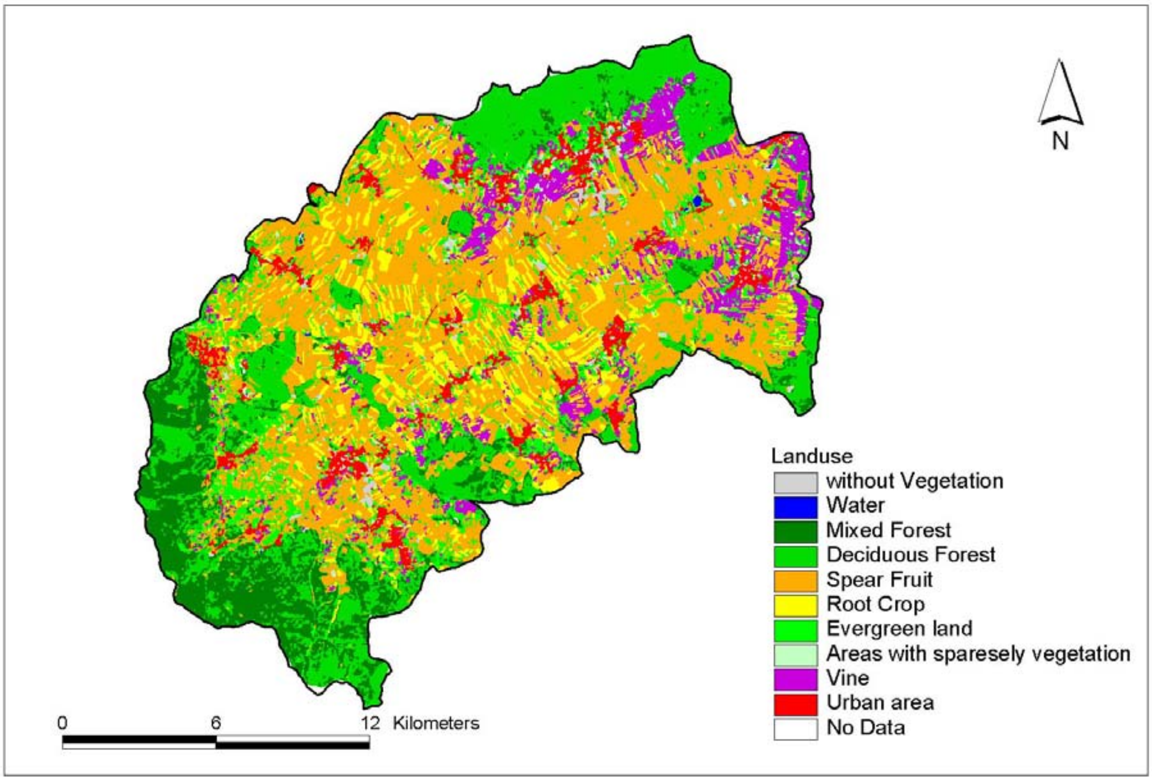


Fig. 2-17: Landuse distribution in the Wulka catchment

Landuse class	Fraction [%]	Sum [%]
Grassland and pasture	11,7	12
Mixed forest	11,0	28
Deciduos forest	16,5	
Root crop	8,9	54
Spear fruit	36,9	
Vine	8,0	
Without vegetation	1,1	6
Urban areas	4,9	
Water areas	0,1	<1

Tab. 2-5: Landuse distribution in the Wulka catchment, listed in size

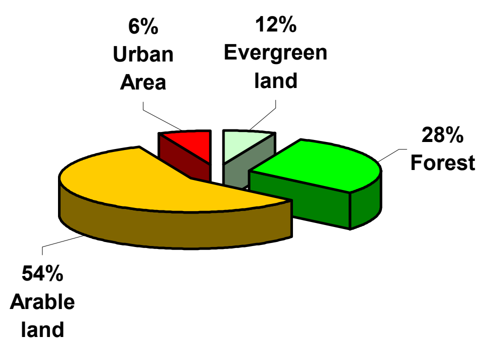


Fig. 2-18: Fraction of the landuse formation

2.1.3.3 Soil characteristics

In the Wulka catchment also the FAO-soil map with a grid-resolution of 250m was used for soil information (Figure 2-19).

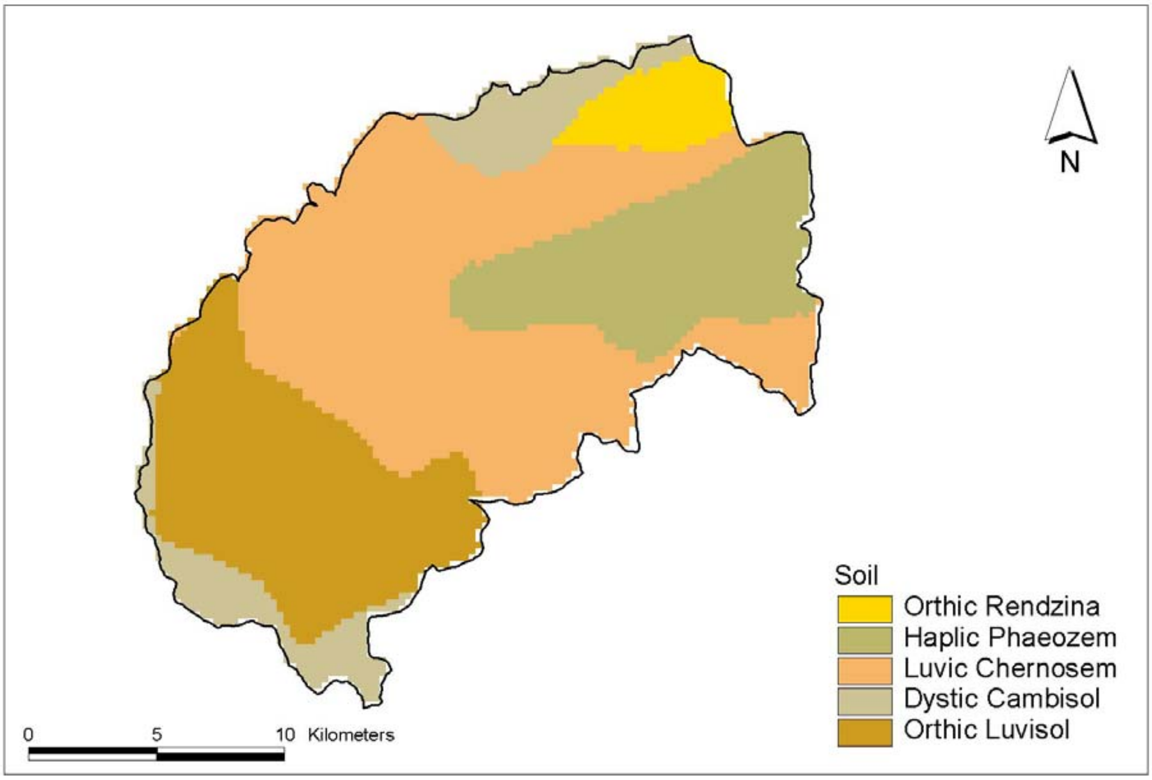


Fig. 2-19: Soil distribution in the Wulka catchment (Fao-soil map)

The Wulka catchment has two soil types, which are different from the Ybbs catchment. The Chernosem and the Phaeozem are typical for the North-east and South-east region of Austria. The Chernosem is the dominating soil type (42%), following the Luvisol (25%) and the Phaeozem (18%). The location of the Dystic Cambisol (10%) is joined to the location of the mountains of the Rosaliengebirge and the Leithagebirge. The Rendzina (5%) isn´t of a big importance in this catchment (Figure 2-20).

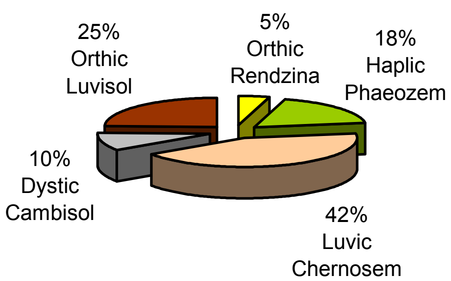


Fig. 2-20: Fraction of the total catchment area covered by each soil type

2.1.3.4 Geological characteristics

Data from the Geological Survey of Austria

Due to the process of digitalisation the availability of detailed digital maps was limited for the Wulka catchment. As much information as available from Figure 2-21, the geological formations in the Wulka catchment are dominated by sediments (48%) near the rivers and marl (37%). In the northern part, where the Mountains of the Leithagebirge are situated, mainly granite (4%), gneiss (2%) and also limestone (4%) and sandstone (3%) is to be find (Figure 2-22). Due to the limitation of the map extend the listed fractions can vary. As known from other reports, also the south-western region of the Rosaliengebirge is dominated by crystalline and metamorphic formations.

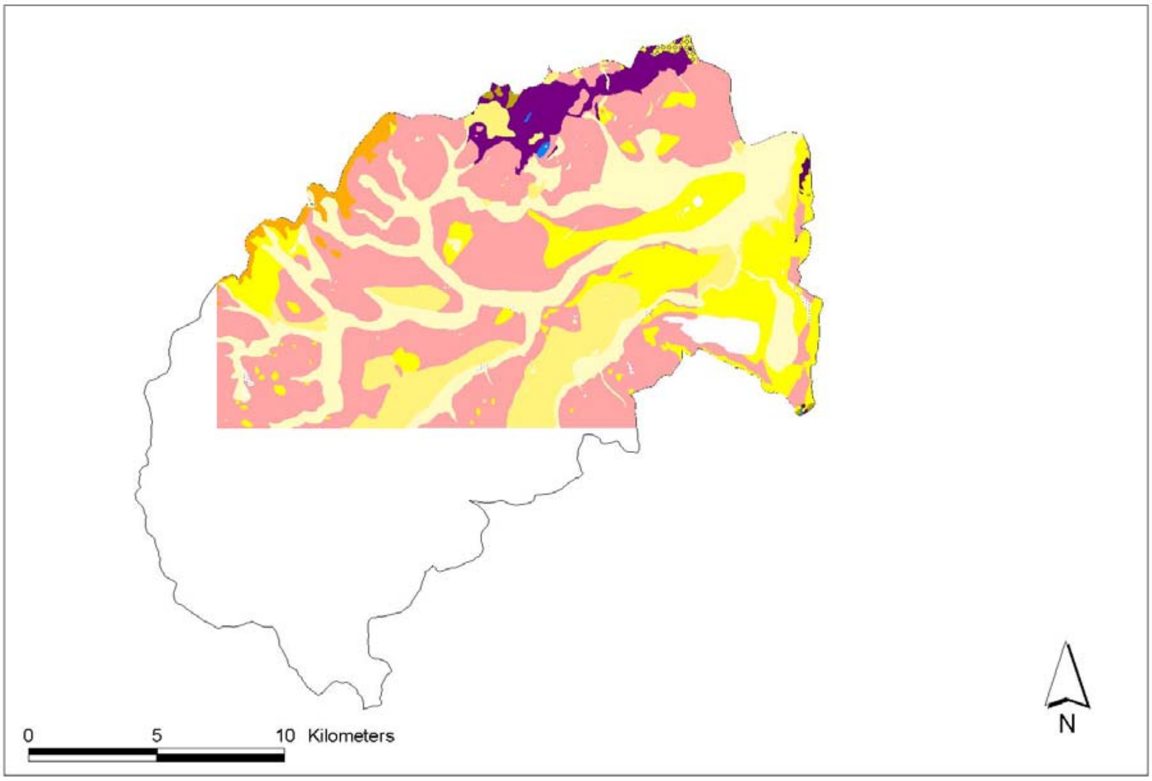


Fig. 2-21: Geological formations in the Wulka catchment (Use of geological basics with the Authorisation by the Geological Survey of Austria - ©GBA-2002-Zl.29/1/02)

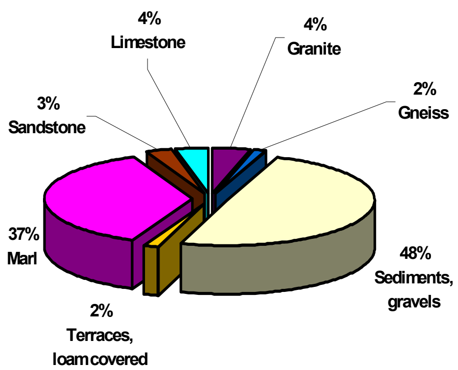


Fig. 2-22: Fraction of the geological formation in the Wulka catchment

Data from the local authorities of the Wulka catchment

As second, digital geological maps from the government of the County Burgenland were obtained. Due to the generalisation of this geological map (Figure 2-23) the informations from here have been used only for basic information.

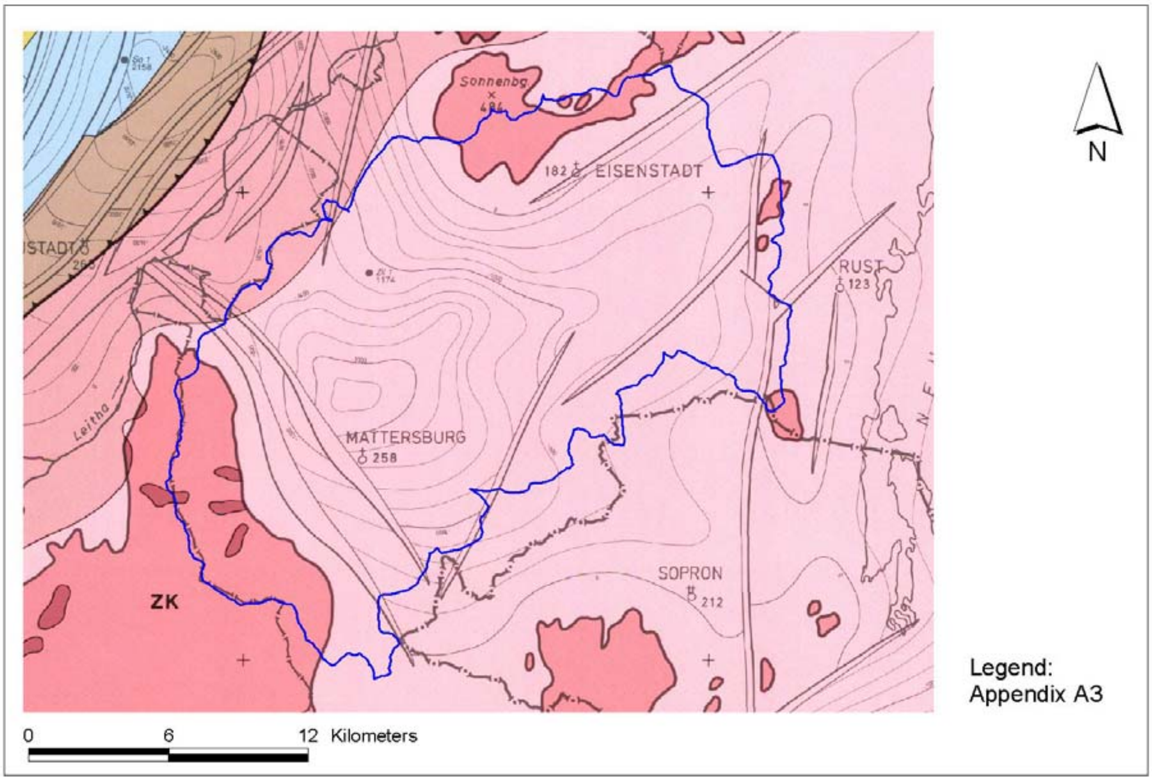


Fig. 2-23: Geological formations in the Wulka catchment (Clip) with the catchment boundaries

2.1.3.5 Partition into subcatchments

Due to the location of the main river gauging stations the Wulka river catchment consists of 6 subcatchments (Figure 2-24). In regard to the water balance calculation, this partition, except of the subbasin Trausdorf, was used to define the subcatchments for the SWAT 2000 model, the DIFGA model and the MONERIS model too.

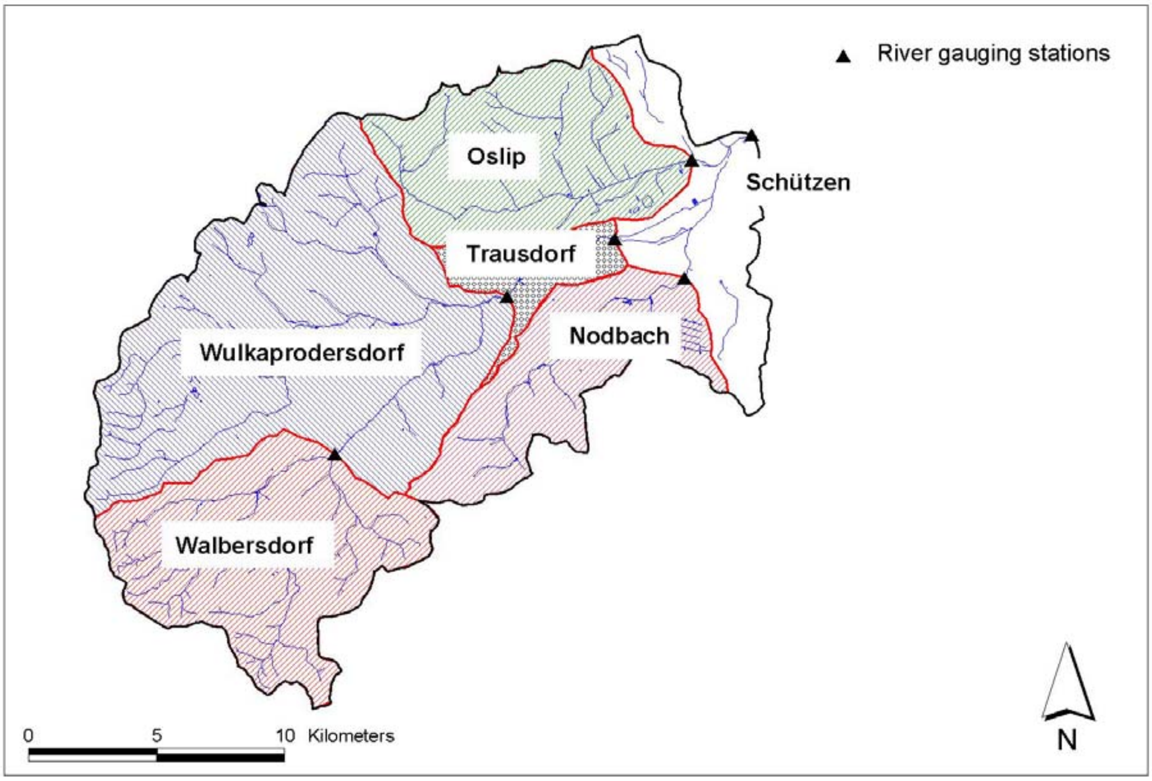


Fig. 2-24: Subcatchments and the location of the river gauging stations in the Wulka catchment

The subcatchments are characterised under different points of view in Table 2-6.

Subcatchment	Walbersdorf	Wulka-prodersdorf	Trausdorf	Oslip	Nodbach
Watershed area [km²]	**76**	**218**	**233**	**64**	**47**
Dominant landuse	**Forest (50%)**	**Spear Fruit (37%)**	**Spear Fruit (38%)**	**Spear Fruit (31%)**	**Spear Fruit (45%)**
Dominant soil	**Luvisol (76%)**	**Chernosem (44%)**	**Chernosem (43%)**	**Chernosem (44%)**	**Chernosem (65%)**
Dominant geological formation	*	**Marl (52%)***	**Marl (51%)***	**Sediments (39%)**	**Sediments (61%)***
Average annual precipitation [mm] Period 1993-1997	**789**	**735**	**729**	**667**	**656**
Area-weighted average Elevation [maS]	**387**	**304**	**295**	**226**	**203**

Tab. 2-6: Main characteristics of the subcatchments

As Table 2-6 shows the average annual precipitation amount decreases also with the average elevation. The average annual precipitation was interpolated with ArcView using the IDW-Method (see chapter 2.1.2.5) for the 12 nearest precipitation stations.
The change in the landuse form, the soil type and the geological formation of the subcatchments is not as significant as in the Ybbs catchment. The most upstream subcatchment Walbersdorf differs in the dominating landuse and soil type from the other subcatchments. Walbersdorf is dominated by a forested landscape, while the other subcatchments are dominated by arable land. This is also correlated to the dominant soil type. In the subcatchments Wulkaprodersdorf and Trausdorf, a second soil type (Luvisol) has nearly the same fraction then the dominant one.
Geologically, the *-signed subcatchments could not be or incomplete characterised. The reason therefore is the aerial extend of the geological map (see chapter 2.1.3.4). Accordingly the upstream part of the catchment is dominated by marl, while the subcatchments downstream near the outlet of the watershed are dominated by sediments and gravels.
Of a mayor importance are also the point sources in the Wulka catchment. In the subcatchments Trausdorf and Oslip, there are important inlets from waste water treatment plant with an amount of nearly 30% (gauging station Schützen) of the total river discharge.

2.2 Case study region in HUNGARY

2.2.1 The ZALA river catchment - HUNGARY

The primary purpose of the water balance calculations was the survey and evaluation of the hydrological processes and the determination of the different flow components contributing to the river discharge. The main reason of the selection of pilot catchments was the demand of widescale examinations including watersheds with different environmental conditions in the Danube basin such as meteorology, hydrogeology, morphology, soil and landuse types. The aspect of the selection were the existence and availability of the data, information and specific knowledge for the selected estimation methods of the water balance. Therefore the catchment of Zala river has been selected for the detailed examinations as case study region in Hungary. Another aspect was that the main focus of the Danube Project, i.e. the estimation, evaluation and management of the non-point nutrient emissions into the surface waters and the prediction of the effects of the management practices in the watershed on the water quality is a current problem in this region, since Zala river is the main influent of the Lake Balaton, which is suffering of quality problem related to nutrient inputs. Main characteristics of the watershed are summarized in the Table 2-7.

River name	**Zala**	
Outlet name	**Zalaapáti**	
	Unit	**Value**
Catchment area	**km^2**	**1528.54**
Average precipitation	**mm**	**656**
Average catchment slope	**%**	**3.15**
Population density	**Inh/km^2**	**82**
Average river discharge	**m^3/s**	**4.32**
Average runoff	**mm/a**	**89**
Landuse characteristic	**arable land, forest**	
Soil physical characteristic	**loam, sandy loam**	
Geological characteristic	**loess and glacial sediment**	

Tab. 2-7: Main characteristics of the Zala catchment (for the period 1997-2001)

2.2.1.1 Topography and hydrography

The Zala river catchment is located in the western hilly part of Hungary (Figure 2-25). The studied part of the watershed has an area of 1528 km^2, which is about 60 % of the total catchment area. The region has an elevation range between 100 and 300 m over Sea level, and it is a hilly area with moderate slopes (the average value is about 3.2 %, see Figure 2-26). The river length is about 100 km upstream Zalaapáti. The average channel slope is about 0.2 %. Additionally to the outlet station (Zalaapáti) there are 3 other monitoring stations (Zalalövő, Zalaegerszeg, Zalabér), where daily discharge time series are available. The average discharge value for the period 1997-2001 at the outlet is 4.3 m^3/s, that means 89 mm/a runoff volume. The river has more tributary channels, but there aren't any significant lakes, ponds or wetlands.

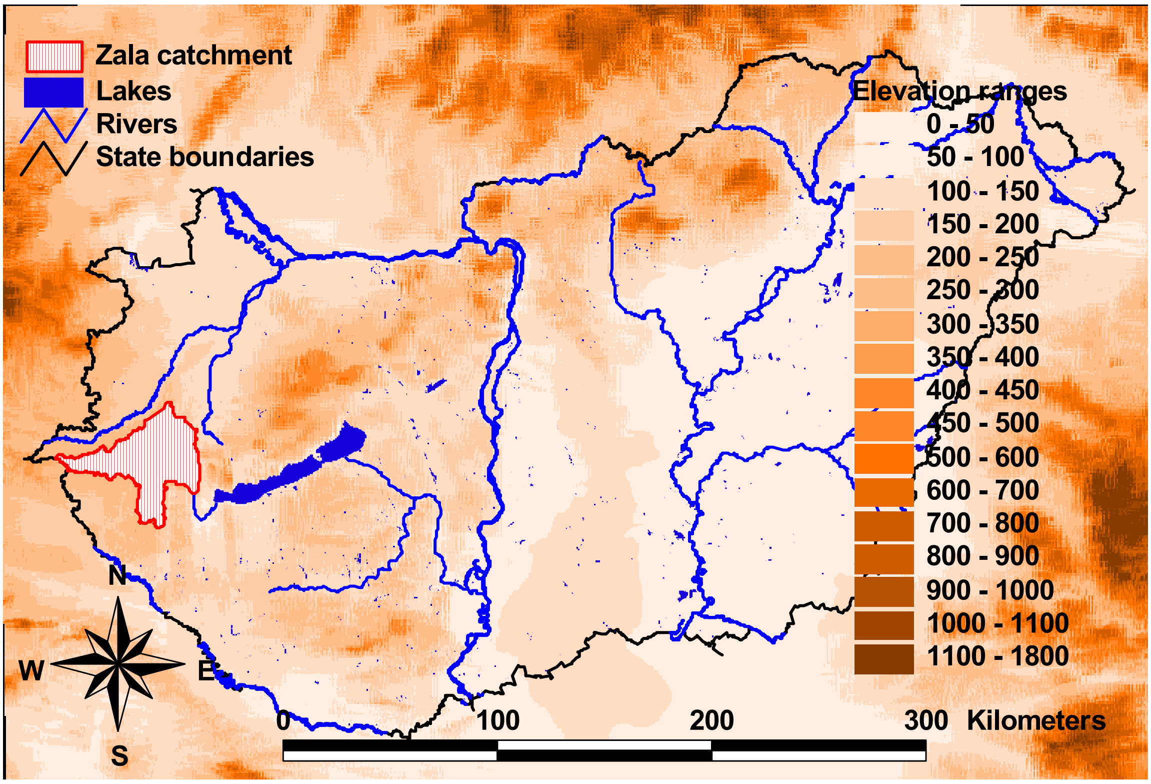


Fig. 2-25: Location of Zala catchment

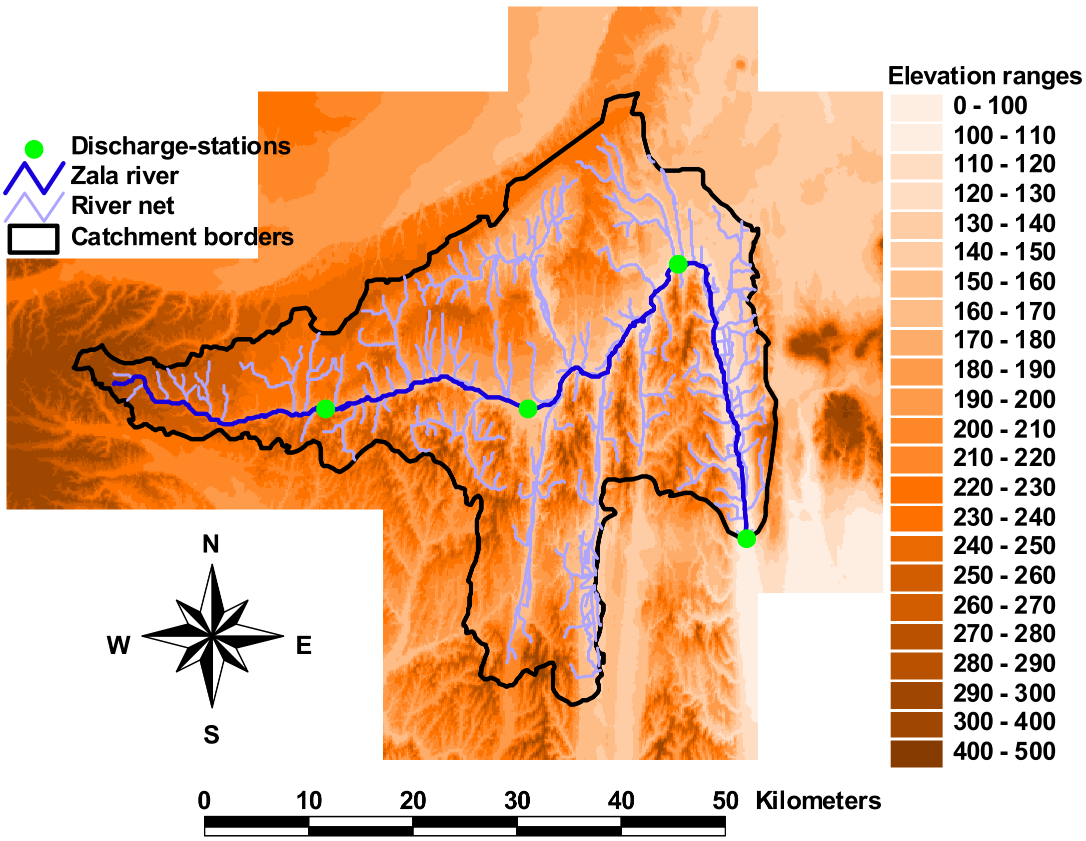


Fig. 2-26: Elevations, water courses and the location of discharge monitoring stations

2.2.1.2 Precipitation

The long-term (1961-1990 average) precipitation value of the region is about 740 mm/a and the evapotranspiration is about 600 mm/a. For the period 1997-2001 the average precipitation volume is 656 mm. It is the result of the interpolation of summarized monthly data of different meterological stations in or closed surroundings of the watershed (Figure 2-27).

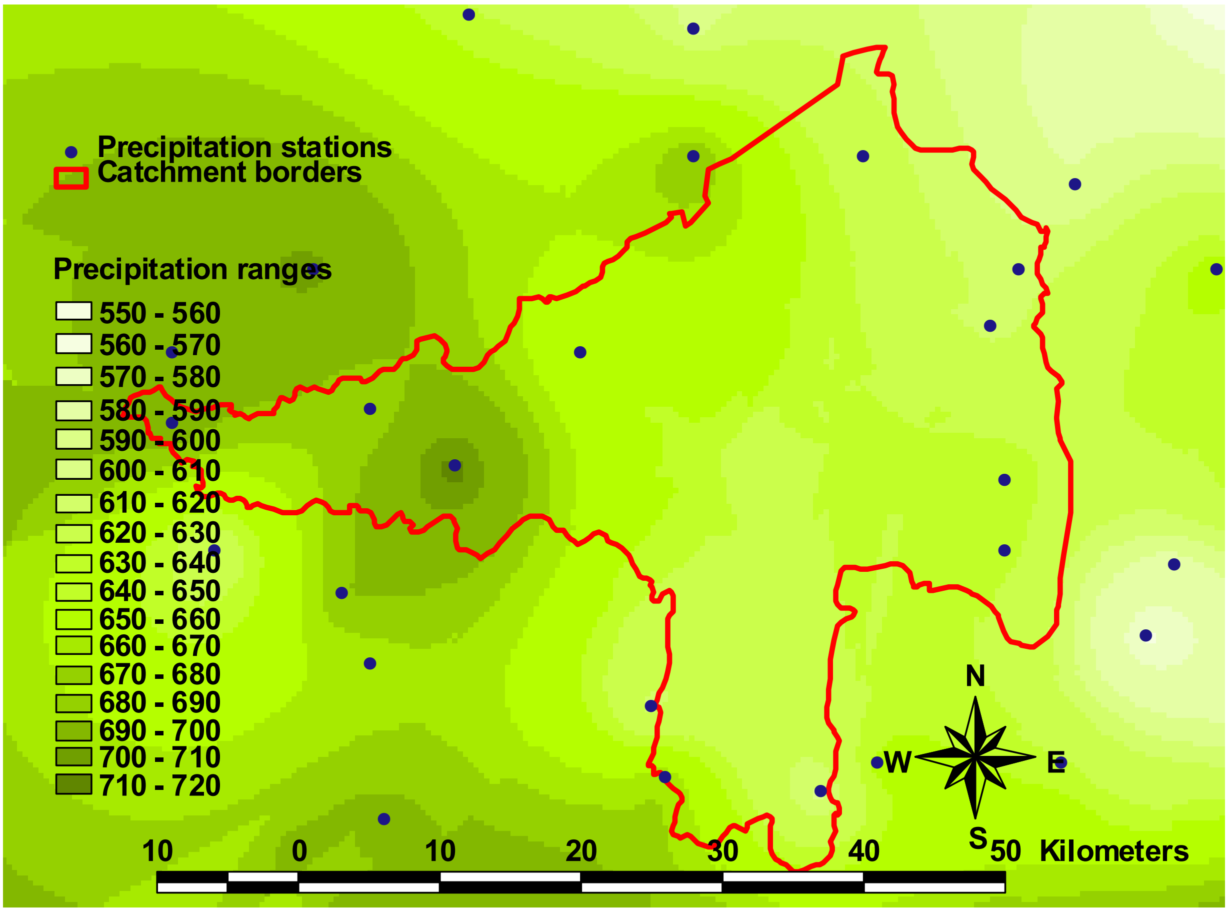
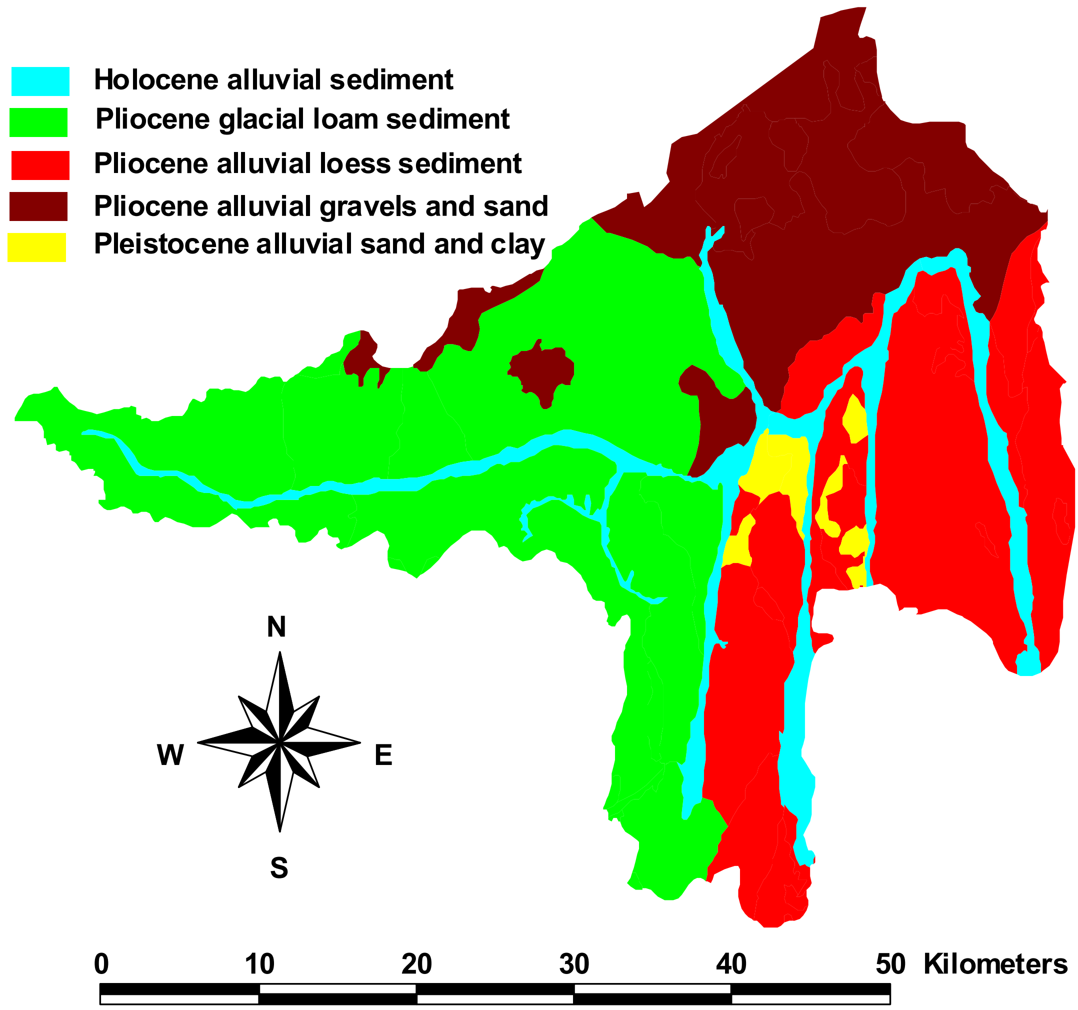


Fig. 2-27: Precipitation conditions of Zala catchment (for the period 1997-2001)

2.2.1.3 Geology

Three main geological types of soil (Pliocene Age) can be detected in the cover layer: the glacial loam sediments and two alluvial sediments such as sandy gravels and the loess-sediment (Figure 2-28). These rocks have been encroached on clayey-sandy mass from the Pleistocene Age.

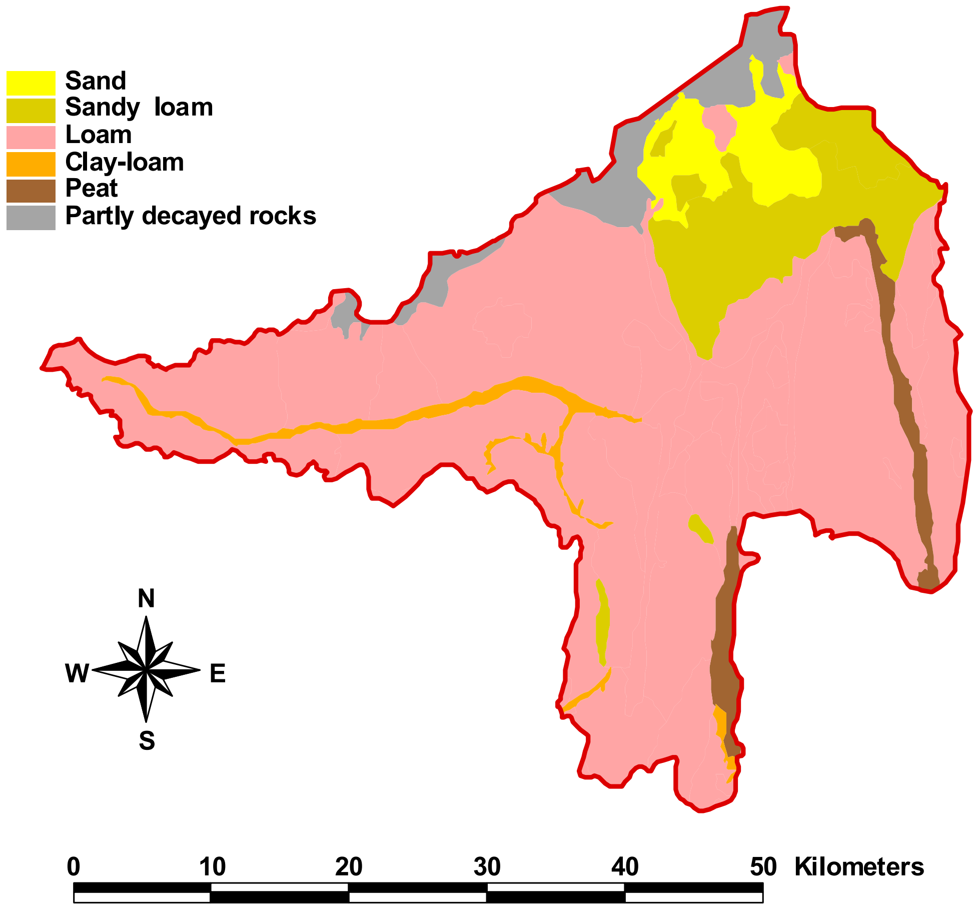


Geological types	Fraction
Pleistocene sand and clay	2.03
Pliocene alluvial gravels and sand	22.90
Pliocene alluvial loess sediment	25.63
Pliocene glacial loam sediment	38.70
Holocene alluvial sediment	10.74

Fig. 2-28: Geological characteristics of the Zala catchment

2.2.1.4 Soil

The dominant physical soil type is the loam soil (Figure 2-29). It has poor or moderate hydraulic conductivity. In small regions the loam soil or rather the loess sediment have been decayed, and the sand of Pleistocene Age having good hydraulic conductivity is on the surface.



Physical soil types	Fraction
Sand	4.47
Sandy loam	11.38
Loam	73.20
Clay-loam	2.52
Peat	3.26
Partly decayed rock	5.17

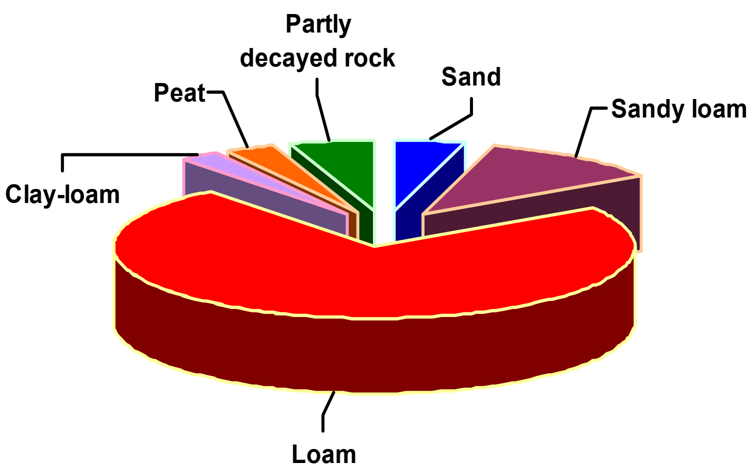
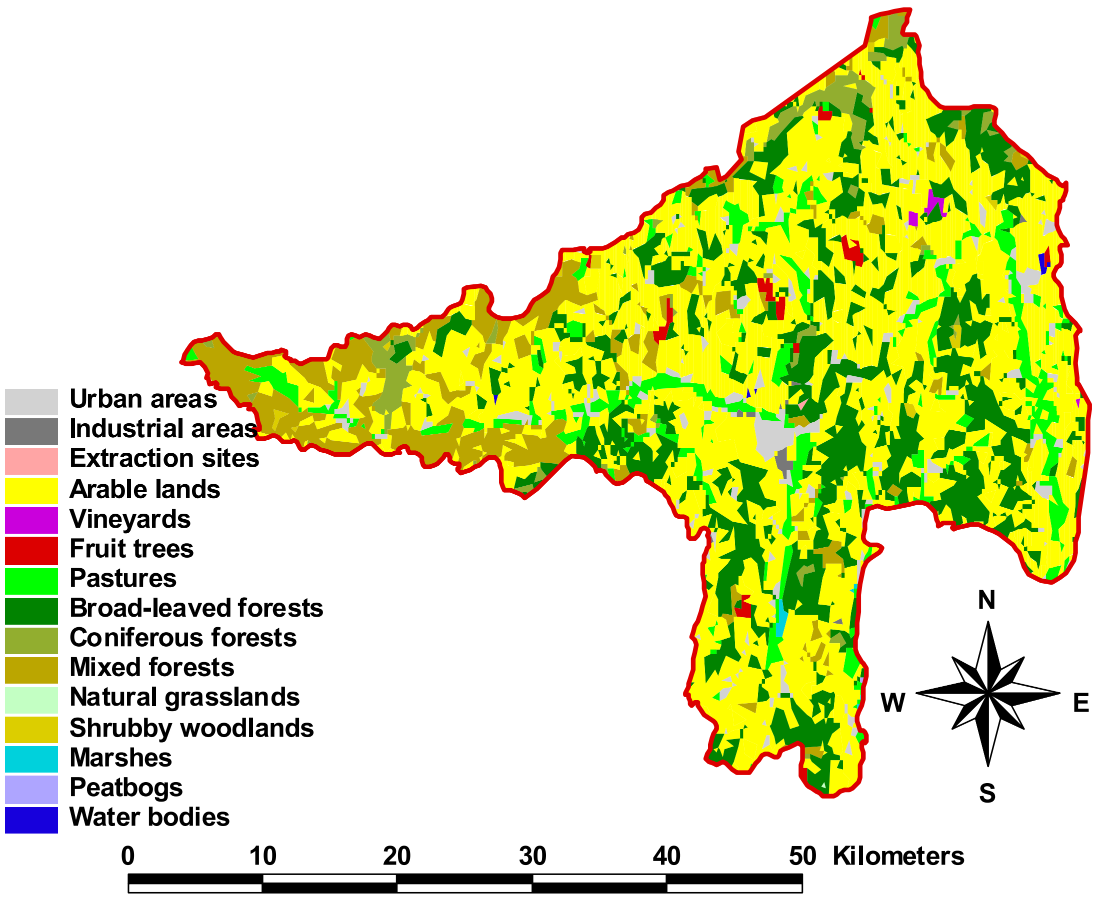


Fig. 2-29: Physical soil types of the Zala catchment

2.2.1.5 Landuse

The majority of the watershed is agricultural area, in particular arable land, which is 54 % of the catchment area. Forests are relatively important, since they cover approximately one third of the area. Details are shown in Figure 2-30.



Landuse class	Fraction	Sum
Urban areas	3.67	
Industrial areas	0.20	3.90
Extraction sites	0.03	
Arable lands	53.56	
Vineyards	0.15	
Fruit trees	0.67	61.74
Pastures	7.36	
Broad-leaved forests	21.19	
Coniferous forests	2.82	34.15
Mixed forests	10.14	
Marshes	0.12	
Peatbogs	0.03	0.21
Water bodies	0.06	

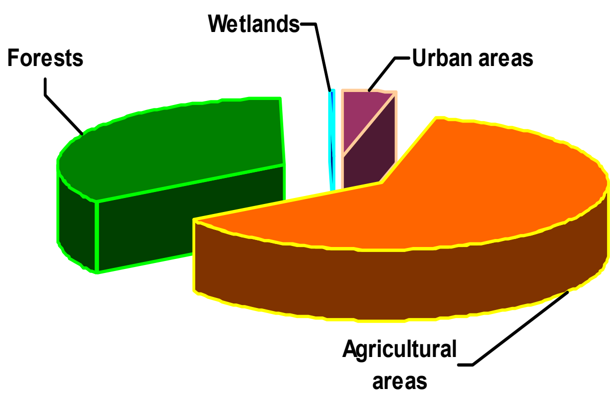


Fig. 2-30: Landuse characteristics of the Zala catchment

2.2.1.6 Population and public water services

The total population of the catchment is about 125.000 inhabitants, out of this 60.000 inhabitants live in Zalaegerszeg (the biggest city of the region). On the other hand the majority of the settlements have a population less than 1000 people. The average population density in the region is 82 inh./km^2. The gap in public water services is significant, since 95 % of the population is supplied through drinking water pipeline system, while only 50 % of the population is connected to the sewerage system and wastewater treatment plant. The total volume of the treated wastewater allowed to enter the river system is about 4.600.000 m^3/a, which means 0.15 m^3/s water discharge.

2.3 *Case study region in ROMANIA*

2.3.1 The NEAJLOV river catchment - ROMANIA

2.3.1.1 General description

Neajlov catchment is a sub-basin of Arges River catchment, an important tributary of the Danube River. Its location is in the southern part of Romania, between $43^0$56’00”N -$44^0$49’12”N latitude and $24^0$14’30”E-$26^0$15’36”E longitude. From the four main types of the agricultural landscapes, which could be found in Romania (mountainous, hilly, sylvo-steppe and steppe landscapes), the selected catchment is representative for sylvo-steppe landscape. The relief is characteristic for Getic piedmont – a plain with low slope, covered by loess, with compacting micro-depressions and large parallel valleys oriented to NW→ SE. The altitude is gradually decreasing from north (300 m) to south (about 60 m) (Figure 2-31).

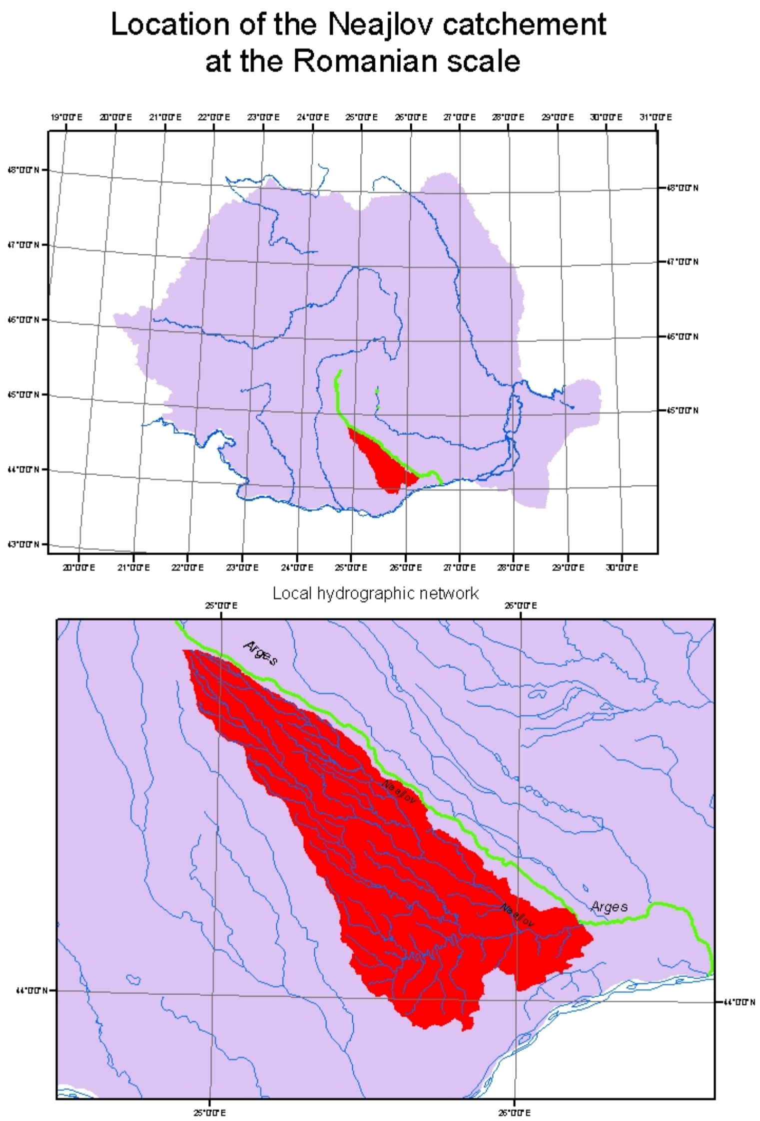


Fig. 2-31: Location of the Neajlov catchment at the Romanian scale

Parent material is loess, loess-like deposits and alluvial deposits. Predominant soil classes are: luvisols (61%), chernozems (9.5%), cambisols (7.8%), vertisols (6.2%), phaeozems (5%) and fluvisols (4%), as presented in Figure 2-35. General state of soil is moderate, but degradation processes, mainly compactation, destruction of structure and loss of nutrients and organic matter in the upper horizon of soil, affect some areas.

The climate is temperate-continental, with transition influences from sub-Mediterranean to draughty eastern climate. Mean annual temperature is between 10°C (in northern part) and 11°C (in southern part) and multi-annual precipitation is 400-600 mm. Annual mean thermal amplitude is of 25-26°C, global radiation is 127 kcal/cm^2 and relative air humidity is about 74%. The mean annual evapotranspiration is between 400 – 500 mm, with potential of about 1040 mm.

The catchment has an area of 3720 km^2 and contains 45 sub-basins, with surfaces between 10 and 664 km^2. The hydrographic network has a density of 0.3 km/km^2 and includes three main tributary rivers, Dimbovnic, Glavacioc and Cilnistea.

The low surface runoff (below 2 l/s/km^2) and non-uniform distribution of hydrographic network led to building of many ponds for agro-industrial purposes. Gradinari and Facau lakes are the most important reservoirs for irrigation, aquaculture and regulation. Deep groundwater is an important water resource for population and economic agents in the catchment (Figure 2-36). The chemical plant ARPECHIM and farms in the region (SUINTEST Oarja – pig farm, ALBOTA – cow farm) are important users and polluters. The Dimbovnic river recieves the most important waste water discharges, with a high content in nutrients and chemical compounds. Neajlov receives about 35 l/s from the municipal wastewater treatment plant of Gaiesti, after a biological treatment. Another treatment plant with mechanic and biological level is located in Videle and discharges in Glavacioc.

The geomorphologic features, hydrological characteristics, vegetation diversity and human interventions in the last 50 years explain the actual ecosystem composition in the catchment. The region is dominated by agro-systems, which represent 78.5% from total surface. In the category of semi-natural ecological systems secondary forests (10.4%) and pastures (4.3%) are dominant. Human-made systems cover 5.5% from the total surface area of the catchment (Figure 2-37).

The current ecological structure of the catchment supports a large variety of functions: flood water detention, groundwater recharge and discharge, sediment and nutrient retention, nutrient export, carbon retention and export, food web support and production of renewable resources and ecosystem maintenance. However, these functions are performed differently by the current ecological systems and in particular by the wetlands.

Rural settlements are prevalent in the region, and population density is lower than 70 inh/km^2. With a rate of birth of 11.5/1000 inh. and a rate of death of 17.2/1000 inh., the natural increase can only be negative (-0.57%). Almost 75% of rural population is dependent on small or subsistence agricultural farms. From the employed people (9.2%), most part belongs to the industrial sector (43.9%), especially the extractive (73.7%) and processing industry (20.6%).

The predominant economic activity in the catchment is agriculture, determined by the high percentage of arable land (~62.6%), followed by extractive industry and trade. Regarding the agricultural sector, it has to be underlined that since late 1989 this sector has been changed dramatically from large state and collective farms, relatively well equipped for agro-technical works and irrigation, to the current state consisting in small (2-3 ha) or family subsistence farms which lack the appropriate equipment and other facilities (e.g. fertilizers, pesticides, irrigation).

2.3.1.2 Hydrographical network

The Neajlov river has 187,5 km length and a catchment area of 3720 km^2. It is the tributary of the Arges river (length – 339.6 km and catchment area – 12521 km^2) (Figure 2-32).

The Neajlov spring is located near Pitesti city, at 322m altitude. The slope of the river is relatively high (1.5 m/km), which leeds to a rapid evacuation of waters in the high water level periods. Before the confluence of Neajlov with Arges the longitudinal slope values are decreasing to 0.25 m/km fact which has conducted to the formation of the Comana Lake at the Neajlov outlet.

The hydrographic network was extracted from hydrologic maps with 1: 50 000 scale. The Neajlov catchment is comprising 45 catchments. Main rivers of the Neajlov catchment are: Calnistea, Dambovnic, Glavacioc and Neajlovel.

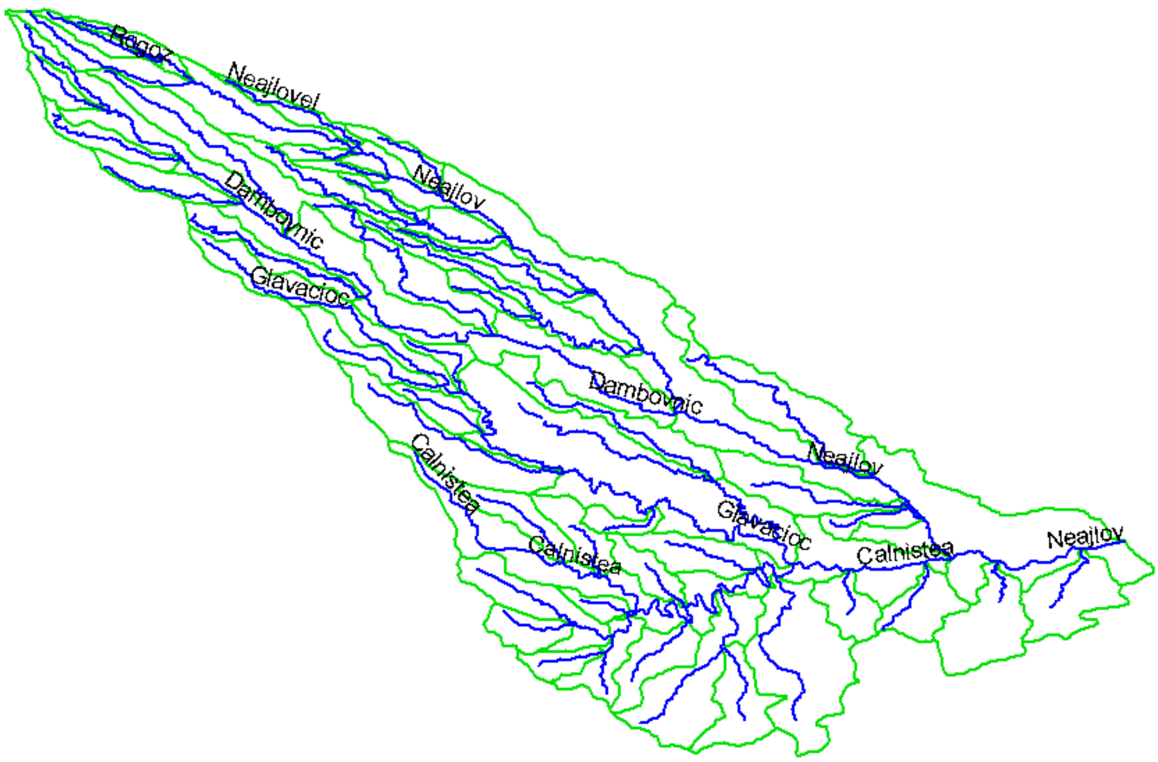


Fig. 2-32: Neajlov River - hydrographic network

2.3.1.3 The Digital Elevation Model

The DEM (Figure 2-33) was developed based on 1: 100 000 topographic maps that comprised 16 maps, covering an area of about 21 000 km^2. The maps were scanned and after that the images were rasterized, corrected and vectorized. In the final step the maps were geographically referenced. The used projection was UTM / WGS 84, Zone 35. The elevation curves were digitized on a 5 m step.

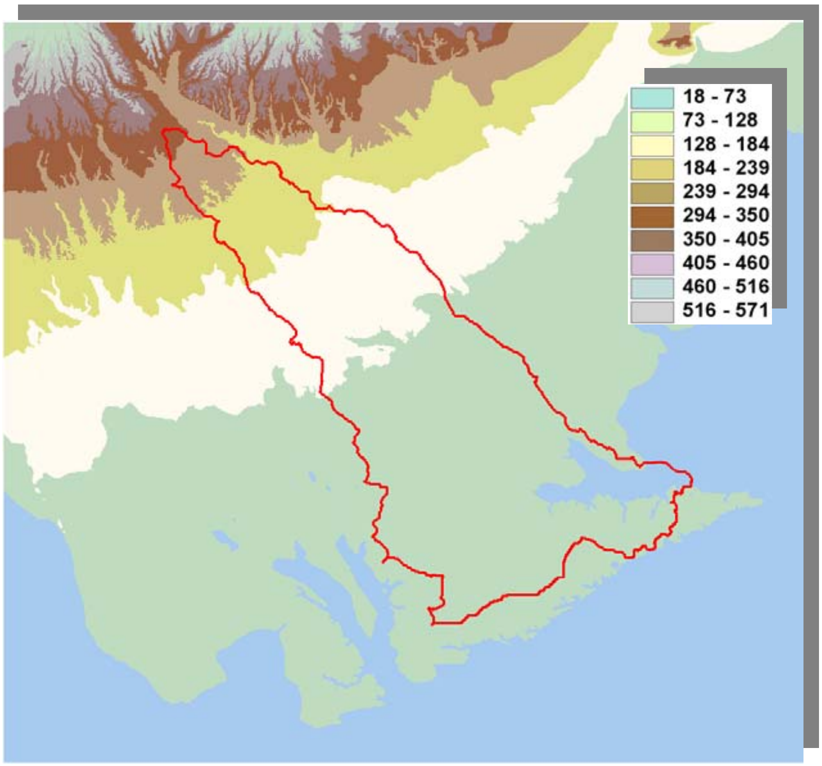


Fig. 2-33: Neajlov DEM

2.3.1.4 Soil types

The Soil Model was developed based on 1: 200 000 topographic maps that comprised 7 maps, covering an area of about 20 000 km^2. The maps were scanned and after that the soils polygons were on-screen digitized. For the definition of soil types and characteristics it was used the Romanian Soil Classification. For visualisation purposes it was made a translation between that classification and the FAO / UNESCO classification in order to insure the compatibility of soil models with the rest of the teams involved in the project (Figure 2-34).

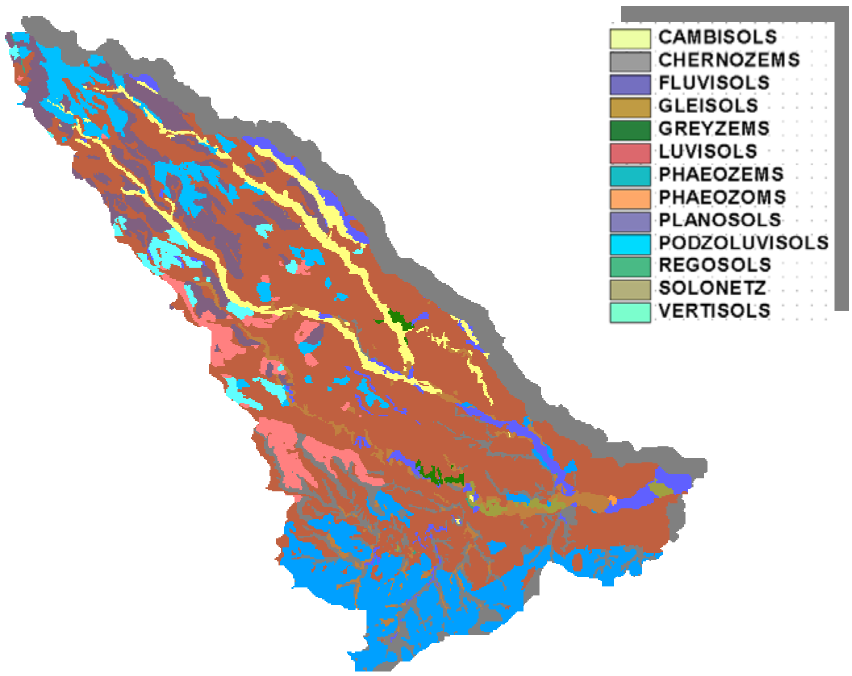


Fig. 1-34: Soil types in the Neajlov catchement

In accordance with the FAO soil classification the dominant classes at the entire basin spatial scale are: luvisols (61%), chernozems (9.5%), cambisols (7.8%), vertisols (6.2%), phaeozems (5%) and fluvisols (4%).

2.3.1.5 Land use

For definition of the Land Use types it was used the CORINE Landcover Database. For SWAT modeling purposes it was made a translation between the specific CORINE data / codes and the SWAT codes (Table 2-8). This translation was made with some errors due to the fact that the CORINE codes are not perfectly corresponding with the SWAT land use classes. The land cover is dominated by different types of agricultural land followed by the anthropic structures (Figures 2-35, 2-36).

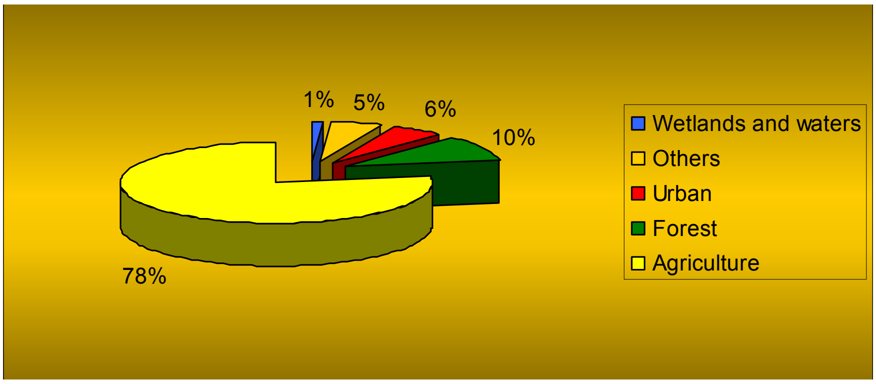


Fig. 2-35: Dominating land use types in the Neajlov catchment

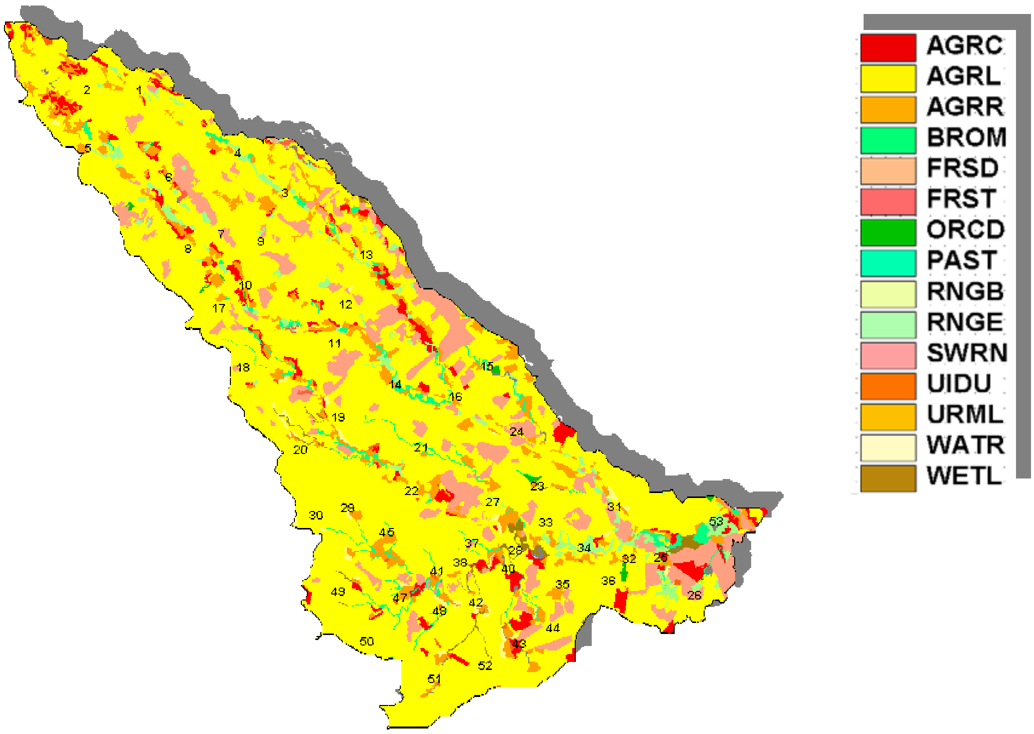


Fig. 2-36: Land use types spatial distribution in the Neajlov catchement

Due to the lack of data the Land Use Model was made after the CORRINE Database, which was developed as a Land Cover Database.

CORINE code	CORINE name	SWAT Code	SWAT Name	Area (%)
0	-	AGRL	Agricultural Land-Generic	0.07
112	Discontinuous urban fabric	URML	Residential-Med/Low Density	5.35
121	Industrial or commercial units	UIDU	Industrial	0.24
131	Mineral extraction sites	UIDU	Industrial	0.01
211	Non-irrigated arrable land	AGRL	Agricultural Land-Generic	70.88
221	Vineyards	RNGB	Range-Brush	0.70
222	Fruit trees and berry plantations	ORCD	Orchard	0.18
231	Pastures	PAST	Pasture	1.72
241	Annual crops associated with permanent crops	AGRR	Agricultural Land-Row Crops	1.41
242	Complex cultivation patterns	AGRC	Agricultural Land-Close-grown	3.45
243	Land principally occupied by agriculture, with significant areas of natural vegetation	AGRL	Agricultural Land-Generic	1.82
311	Broad - leaved forest	FRSD	Forest-Deciduous	10.26
321	Natural grasslans	RNGE	Range-Grasses	2.54
322	Moors and heatland	BROM	Smooth Bromegrass	0.00
324	Transitional woodland - shrub	FRST	Forest-Mixed	0.15
331	Beaches, dunes, sands	SWRN	Southwestern US (Arid) Range	0.12
411	Inland marshes	WETL	Wetlands-Mixed	0.54
512	Water bodies	WATR	Water	0.55

Tab. 2-8: Correlation between CORINE and SWAT codes for land use

3 Estimation methods for the water balance calculations

3.1 The SWAT 2000 model

3.1.1 Introduction and model description

For the estimation of the detailed water balances on the regional scale a model was used, which is able to simulate the hydrologic cycle on the basin level. That includes the influence of the landuse in regard to e.g. evapotranspiration, interception and surface runoff, the influence of the soil in regard to water storage capacity and hydraulic conductivity, the influence of the shallow groundwater in regard to base flow conditions and the anthropogenic influence like wwtp (waste water treatment plants), water transfer (e.g. for water supply or irrigation) or management activities like tillage operations. Additionally the model is able to simulate nutrient and pesticide routing and transformation into and inside the river.

SWAT is a distributed parameter, continuous time model, which was developed to help water resources managers assess water supplies and non-point source pollution on catchments and large river catchments (Rosenthal, 1995). SWAT incorporates features of several USDA - ARS models and is a direct outgrowth of the SWRRB 1 model (Simulator for Water Resources in Rural Basins) (Arnold et al., 1990). Specific models that contributed significantly to the development of SWAT were CREAMS 2 (Chemicals, Runoff, and Erosion from Agricultural Management Systems) (Knisel, 1980), GLEAMS 3 (Groundwater Loading Effects on Agricultural Management Systems) (Leonard et al., 1987), and EPIC 4 (Erosion-Productivity Impact Calculator) (Williams et al., 1984).

The SWAT 2000 model is available as freeware and provides an ArcView-Interface for pre- and post processing. It allows the user easily to incorporate digital maps and to process the results as maps, tables or text files.

The SWAT 2000 Model allows a number of different physical processes to be simulated in a catchment. For modelling purposes, a catchment may be partitioned into a number of subcatchments. The use of subcatchments in a simulation is particularly beneficial when different areas of the catchment are dominated by land uses or soils dissimilar enough in properties to impact hydrology.

The input information for each subcatchment is grouped or organized into certain categories (see chapter 3.1.2). The simulation of the hydrology of a catchment can be separated into two major divisions: the land phase and the water phase. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each subcatchment. The second division is the water or routing phase of the hydrologic cycle, which can be defined as the movement of water, sediments, etc. through the channel network of the catchment to the outlet.

A Digital Elevation Model (DEM) will be used to compute and delineate a river network. For the computation of the hydrographic network the SWAT model uses a catchment discretization scheme cells algorithm. Depending on the DEM accuracy and grid cell size there could be differences between real and computed hydrographic network. Especially for regions with a lower slope there is the possibility to use a digitised river network (ArcView-Shape-format) to identify the exact location.

A landuse and a soil distribution will be used to generate Hydrologic Response Units (HRU´s), which can be spatially varied on the subbasin level.

Within the catchments delineation there is necessary to link the soil layer, land use layer and climatic data to the SWAT database. If there are some lacks in the climatic

data it has to be build a “weather generator” which has the capability to simulate the climatic parameter behaviour for the missing data. It has to be mentioned, that for larger catchments it is recommended to use multiple climatic stations in order to reflect the heterogeneity of climatic factors over the catchment area. Setting up the SWAT model run is needed to choose the algorithm that will be used for evapotranspiration computation, routing method, period of simulation, results printout frequency etc.
The water balance will be calculated for the chosen time step (daily, monthly, yearly) for every HRU.
It will be printed out time step dependent for every HRU and every subbasin (as average of all HRU belonging to a subbasin), summarized as annual values for every HRU and subbasin, and as average annual values for the whole basin.

3.1.2 Model structure

The model provides several input files, where river-, basin-, or HRU-specific data are stored and can be edited:

- Soil input file (.sol)*
- Subbasin input file (.sub)*
- HRU input file (.hru)*
- Reach input file (.rte)*
- Groundwater input file (.gw)*
- Management input file (.mgt)*
- Pond/Wetland input file (.pnd)
- Weather generator input file (.wgn)
- Water use input file (.wus)
- Stream Chemical input file (.chm)

For the Austrian case study regions, the *-signed files were edited during the calibration process.

3.1.3 Definition of the runoff components

In the SWAT 2000 model, three runoff components will be used to be compared with results from DIFGA and MONERIS:

- Surface Runoff (**SURQ**): amount of water, which can not infiltrate into the soil due to the occurance of saturated conditions in the top soil layer, impervious areas or closed seeded landcover types; it flows directly to the river
- Lateral Flow (**LATQ**): fast saturated water movement, which is caused in the soil profile by underlying less conductive layers, preferential flow (macropores) or the occurance of saturated conditions in soils with a higher slope exposition; it contributes to the groundwater flow
- Base Flow (**GWQ**): saturated water movement in the shallow aquifer caused by differences in the potential head; occurs under the bottom layer of the soil

3.2 The Moneris model

3.2.1 Introduction and model description

The model **MONERIS (MO**delling **N**utrient **E**missions in **RI**ver **S**ystems) (Behrendt et al, 1999) was developed and applied to estimate the nutrient inputs into river basins of Germany by point sources and various diffuse pathways. The model is based on data of river flow and water quality as well as a geographical information system (GIS), which includes digital maps and extensive statistical information.

Whereas point emissions from waste water treatment plants and industrial sources are directly discharged into the rivers, diffuse emissions into surface waters are caused by the sum of different pathways, which are realised by separate flow components (see Figure 3-1). This separation of the components of diffuse sources is necessary, because nutrient concentrations and relevant processes for the pathways are mostly very different.

Consequently seven pathways are considered:
- point sources
- atmospheric deposition
- erosion
- surface runoff
- groundwater
- tile drainage
- paved urban areas

Along the pathway from the source of the emission into the river substances are governed by manifold processes of transformation, retention and loss. Knowledge of these processes of transformation and retention is necessary to quantify and to predict nutrient emissions into the rivers in relation to their sources. Since current knowledge of the processes and the up to now limited database especially for river basins of medium and large size, the description of the processes can not be done by detailed dynamic models.

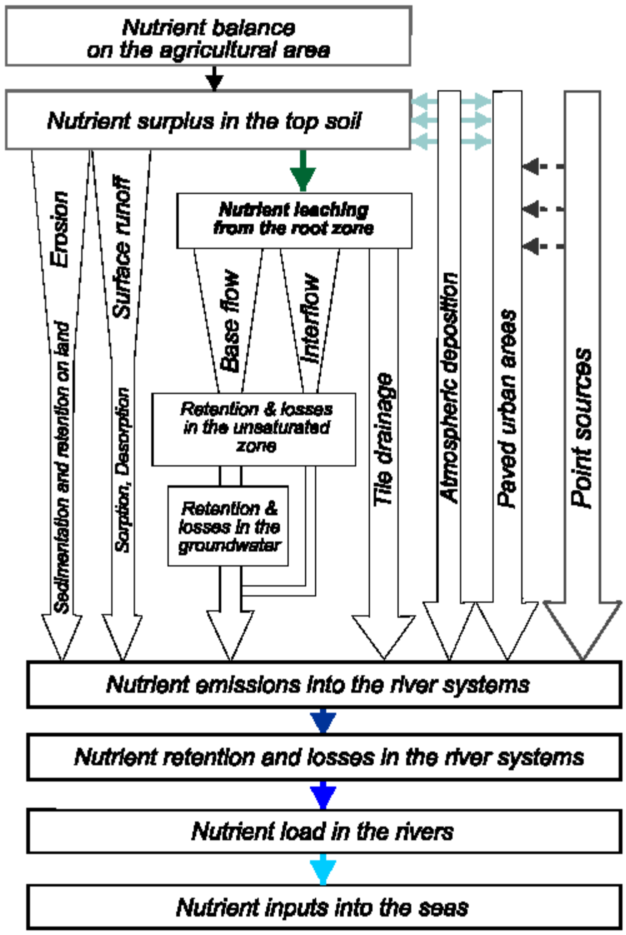


Fig. 3-1: Pathways and processes within MONERIS

Therefore, MONERIS estimates the different pathways with already existing and new conceptual approaches, which are developed especially for the modelling in the medium and large spatial scale. Topics of the model development were:

- to develop a GIS-supported method for regional differentiated estimation of diffuse and point emissions for river basins of a size of more than 500 km²,

- to establish a submodel for regionally differentiated estimation of nutrient discharges from waste water treatment plants by a countrywide detailed inventory of these waste water treatment plants,
- to establish a submodel for inputs of nutrients and suspended solids caused by erosion, which can be applied to all investigated river basins. This model is based on the modified uniform soil loss equation but considers only those areas, which are relevant for a input into the river system. The submodel was validated with observed loads of suspended solids and particulate phosphorus for river basins,
- to develop a submodel which allows the estimation of groundwater concentrations of nitrogen from the nitrogen surplus in agricultural areas by means of a retention function. This retention function is dependent on the hydrogeological conditions, the rate of groundwater recharge and the nitrogen surplus itself. The retention model includes first raw estimates of the residence time of water within the unsaturated zone and aquifer of the river basins,
- to develop a GIS-supported submodel for regionally differentiated estimation of the agricultural areas modified by tile drainage. The submodel is based on soil types and a classification of soil water conditions and is validated by overlaying digitised maps of tile drained areas with a soil map,
- to establish a submodel for different pathways of nutrient emissions within urban areas considering the regional differences in the sewer systems and the development of storage volume especially for combined sewer systems and
- to establish a submodel for nutrient retention and losses in surface waters, which can be applied for all river basins. This model is based on the dependency of the nutrient retention on the hydraulic load or the specific runoff in the river system. The model allows the estimation of the nutrient loads from the nutrient inputs in a river basins.

Therefore, a direct comparison of calculated and observed nutrient loads is possible for river basins upstream of a monitoring station.

3.2.2 Definition of the runoff terms

In the Moneris model, the following components are considered in the Water balance calculation:

- Groundwater flow ($\mathbf{Q_{GW}}$): Difference between the total measured river discharge and the other estimated runoff components (Groundwater + Interflow)
- Overland flow ($\mathbf{Q_{RO}}$): Surface runoff occurs on agricultural or open areas (no forested areas)
- Direct precipitation ($\mathbf{Q_{AD}}$): Balance between the precipitation fallen on water bodies and the evaporation from these water bodies
- Tile Drainage ($\mathbf{Q_{DR}}$): Runoff from drained areas, Function of the soil type
- Point sources ($\mathbf{Q_{PS}}$): Amount of water inlets from WWTP´s
- Urban Areas ($\mathbf{Q_{URB}}$): Runoff from sealed areas, which are connected to sewer systems, but not connected to WWTP´s; runoff from areas are not connected to a sewer system; runoff from combined sewer overflows and separate sewer systems

3.2.3 Formulas used in the MONERIS calculation of water balance and definition of the runoff components

The water balance in the Moneris model will be calculated as follows:

$$\mathbf{Q} = \mathbf{Q}_{\mathbf{GW}} + \mathbf{Q}_{\mathbf{DR}} + \mathbf{Q}_{\mathbf{RO}} + \mathbf{Q}_{\mathbf{URB}} + \mathbf{Q}_{\mathbf{AD}} + \mathbf{Q}_{\mathbf{PS}} \qquad \text{(Eq.3-1)}$$

where
- Q - average measured runoff [m³/s],
- Q_{GW} - base flow and natural interflow [m³/s],
- Q_{DR} - tile drainage flow [m³/s],
- Q_{RO} - surface runoff from non-paved areas [m³/s],
- Q_{URB} - runoff from urban areas [m³/s] and
- Q_{AD} – direct flow, i.e result of the balance between direct precipitation on the freshwater surfaces and the evaporation from these surfaces [m³/s]
- Q_{PS} – discharge from points sources [m³/s].

The baseflow QGW will be calculated as a difference between the measured river discharge Q and all the other calculated runoff components are mentioned above.

Calculation of the direct flow:

$$\mathbf{Q}_{\mathbf{AD}} = \frac{\mathbf{N}_{\mathbf{j}} - \mathbf{V}}{86{,}4 * 365} * \mathbf{A}_{\mathbf{W}} \qquad \text{(Eq.3-2)}$$

$$\mathbf{Aw} = \mathbf{A}_{\mathbf{WSEE}} + \mathbf{A}_{\mathbf{WFGW}} = \mathbf{A}_{\mathbf{WCLC}} + 0{,}001.\mathbf{A}_{\mathbf{EZG}}^{1{,}185} \qquad \text{(Eq.3-3)}$$

where
- N_J - average annual precipitation [mm/a],
- V – evapotranspiration [mm/a]
- A_W - total water surface area [km²],
- A_{WSEE} - water surface area from land use map [km²],
- A_{WFGW} - surface area of flowing waters [km²],
- A_{WCLC} - water surface area from CORINE-Landcover [km²] and
- A_{EZG} - catchment area [km²].

Calculation of the Surface runoff:

$$\mathbf{Q}_{\mathbf{RO}} = \mathbf{q}_{\mathbf{RO}} * (\mathbf{A}_{\mathbf{LN}} + \mathbf{A}_{\mathbf{OF}}) * 1000 \qquad \text{(Eq:3-4)}$$

where
- Q_{RO} - surface runoff from non-paved areas [m³/a],
- A_{LN} - agricultural area [km²] and
- A_{OF} -open area (mountainous areas and areas with natural vegetation) [km²].

$$\mathbf{q}_{\mathbf{RO}} = \mathbf{q}_{\mathbf{G}} * 2 * 10^{-6} * (\mathbf{N}_{\mathbf{J}} - 500)^{1{,}65} \qquad \text{(Eq:3-5)}$$

where q_{RO} - specific surface runoff [mm]

$$\mathbf{q}_{\mathbf{G}} = 0{,}86 * \mathbf{N}_{\mathbf{J}} - 111{,}6 * \frac{\mathbf{N}_{\mathbf{SO}}}{\mathbf{N}_{\mathbf{WI}}} - 241{,}4 \qquad \text{(Eq:3-6)}$$

where q_G - average yearly specific runoff [mm/ a)],
N_{SO} - average precipitation in the summer half year [mm/a]
N_{WI} - average precipitation in the winter half year [mm/a]

In the Austrian case study $\mathbf{q_G}$ is calculated as average from the daily hydrological run-off data, excluding the contribution of point sources.

Calculation of the Runoff from drained areas:

$$\mathbf{Q_{DR}} = \frac{\mathbf{q_{DR}} . \mathbf{A_{DR}}}{86{,}4 * 365} \quad \text{(Eq:3-7)}$$

$$\mathbf{q_{DR}} = 0{,}5 * \mathbf{N_{WI}} + 0{,}1 * \mathbf{N_{SO}} \quad \text{(Eq:3-8)}$$

where q_{DR} - specific drain water flow [mm/a)],
N_{WI} - average precipitation in the winter half year [mm/a] and
N_{SO} - average precipitation in the summer half year [mm/a].

$$\mathbf{A_{DR}} = (\mathbf{A_{MO}} * 0{,}1059) + (\mathbf{A_{AU}} * 0{,}1158) + (\mathbf{A_{STL}} * 0{,}5045) + (\mathbf{A_{GW}} * 0{,}0902) \quad \text{(Eq:3-9)}$$

where A_{DR} - drained area [km²],
A_{MO} - area of peat soil [km²],
A_{AU} - area of flood plain soil [km²],
A_{STL} - area of wet loamy soil [km²] and
A_{GWS} - area of wet sandy soil [km²].

Runoff from urban areas:

$$\mathbf{Q_{URB}} = \mathbf{Q_{URBSS}} + \mathbf{Q_{URBM}} + \mathbf{Q_{URBS}} + \mathbf{Q_{URBNS}} \quad \text{(Eq:3-10)}$$

where Q_{URBSS} – water discharge from separate sewer systems, [m³/s]
Q_{URBM} - storm water runoff from combined sewer system [m³/s]
Q_{URBS} – water discharge from areas connected only to sewerage system [m³/s]
Q_{URBNS} – water discharge from areas without sewerage system, [m³/s]

$$\mathbf{Q_{URBSS}} = \mathbf{q_{URBV}} . \mathbf{A_{URBSS}} \quad \text{(Eq:3-11)}$$

where A_{URBSS} – the area connected to separate sewer system, [km²]

$$\mathbf{q_{URBV}} = \mathbf{a_{URBV}} * \mathbf{N_J} \quad \text{(Eq:3-12)}$$

with q_{URBV} - specific surface runoff from impervious urban areas [mm/a]
N_J - annual precipitation [l/(m²· a)].

$$\mathbf{a_{URBV}} = 0{,}15 + 0{,}75 \frac{\mathbf{A_{URBV}}}{\mathbf{A_{URB}}} \quad \text{(Eq:3-13)}$$

where $\mathbf{a_{URBV}}$ - share of precipitation realized as surface runoff from impervious urban areas.

$$\mathbf{A_{URBV}} = \mathbf{u}_1 * (\mathbf{u}_2 * \mathbf{E_{Dichte}})^{\mathbf{u}_3 - \mathbf{u}_4 * \log(\mathbf{u}_2 * \mathbf{E_{Dichte}})} * \mathbf{A_{URB}} \quad \text{(Eq:3-14)}$$

where A_{URBV} - impervious urban area [km²],

A_{URB} - total urban area [km²],
E_{DICHTE} - population density [E/km²] and
u_1–u_4 - model coefficients.

$$\mathbf{Q_{URBM}} = \left[\mathbf{q_{URBV}} * \mathbf{A_{URBVM}} + \mathbf{Z_{NT}} * (\mathbf{E_{KA}} * \mathbf{q_E} + \mathbf{a_{GEW}} * \mathbf{q_{GEW}} * 100 * 86{,}4 * \mathbf{A_{URB}})\right] * \mathbf{RE}$$ (Eq:3-15)

A_{URBVM} - impervious urban area connected to combined sewer system [km²],
Z_{NT} - effective number of storm water days,
E_{KA} - number of inhabitants connected to combined sewer system,
Q_E - daily wastewater output per inhabitant [l/(E· d)],
Q_{GEW} - industrial-commercial wastewater [m³/s],
a_{GEW} - proportion of total urban area in commercial use and
q_{GEW} - specific runoff from commercial areas [l/(ha· s)].
RE - discharge rate of combined sewer overflows [%],

$$RE = \frac{\dfrac{4000 + 25 * q_R}{0{,}551 + q_R}}{V_S + \dfrac{36{,}8 + 13{,}5 * q_R}{0{,}5 + q_R}} - 6 + \frac{N_J - 800}{40}$$ (Eq:3-15)

where q_R - rainfall runoff rate [l/(ha· s)],
V_S - storage volume [m³] and
N_J - annual precipitation [l/(m²· a)].

$$\mathbf{Q_{URBS}} = \mathbf{q_{URBV}} * \mathbf{A_{URBS}}$$ (Eq:3-16)

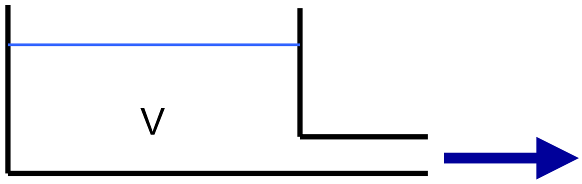
where A_{URBS} – the area connected only to sewer system, [km²]

$$\mathbf{Q_{URBNS}} = \mathbf{q_{URBV}} * \mathbf{A_{URBNS}}$$ (Eq:3-17)

where A_{URBNS} – the area without any sewer system, [km²]

3.3 Baseflow separation techniques

The main idea of these techniques is, that the runoff in rainless periods must derive from groundwater.
The most simple model is a linear model with one groundwater-storage:



$$Q = k \cdot V$$

Fig. 3-2: linear storage

This linear relationship between the storage volume V and the outflow Q results in an exponental form of Q (t). To recession limps in rainless periods $Q(t) = Q_0.e^{-kt}$ is fitted as shown in Figure 3-3.

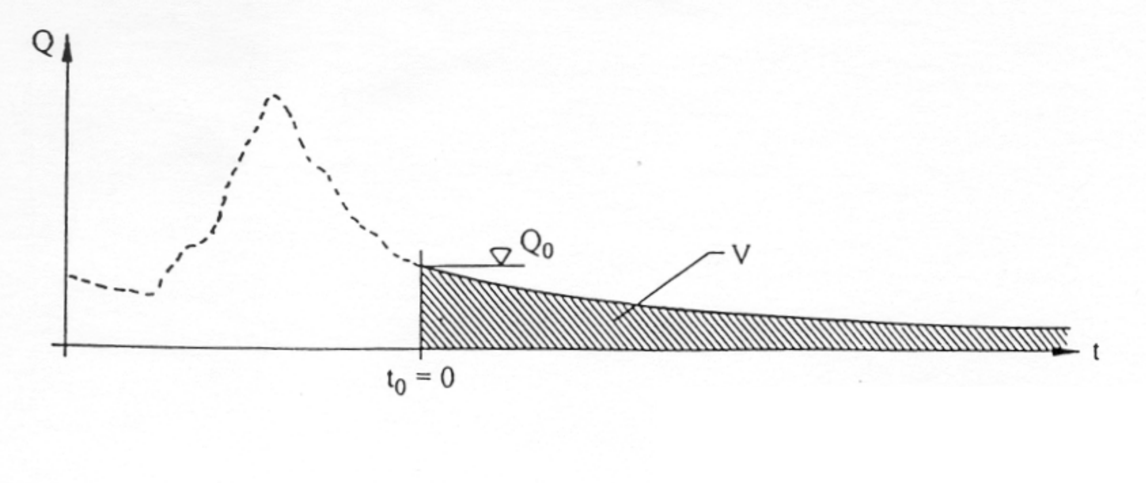


Fig. 3-3: linear baseflow recession (Gutknecht 2000)

$Q\ (t) = Q_0.e^{-kt}$ with Q_0 = baseflow at t=0, t = time, k = constant, storage volume is V.
In the project separations with a simple single linear storage model were done by manual calculation and by an automated separation technique (software package: Base Flow Filter Program, (Arnold 1995)).

The used software package Difga2000 (Schwarze 2001) has two linear storages for groundwater, it works with a lithofacies-concept to separate the runoff in three components. It tries to find recession-parameters „CG“ (in days, “CG”=1/”k”)) for the two groundwater-storages depending on hydrogeological and morphologic characteristics of the catchment.

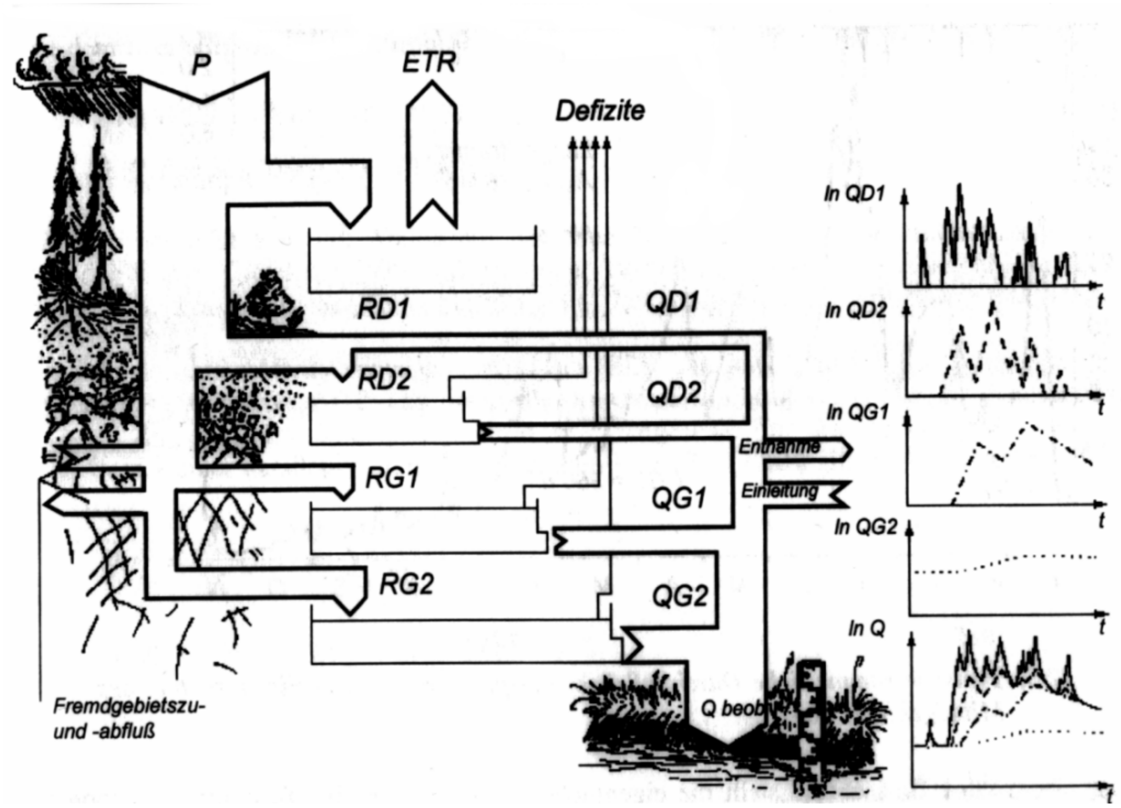


Fig. 3-4: composition of flow and storages in difga2000 (Schwarze 1991)

Baseflow separation with Difga2000 computes three runoff components (QG2) slow groundwater runoff, (QG1) fast groundwater runoff and (QD=Qd1+QD2) direct runoff:

Q(t) = QD(t) + QG1(t) + QG2(t)

runoff formation GW2 (slow): $\mathrm{RG2_i} = CG2_i \cdot \Delta QG2_i \cdot \frac{86{,}4}{A_E}$

runoff formation GW2 (fast): $\mathrm{RG1_i} = CG1_i \cdot \Delta QG1_i \cdot \frac{86{,}4}{A_E}$

direct : RD(t) = QD(t) = Q(t) – QG2(t) – QG1(t)

$CG2_i$ = Recession-constant for the slow groundwater-storage

$\Delta QG2_i$ = rise

A_E = catchment area

Pi – RG2i – RG1i – RDi – RESTi >= 0 water-balance for 1 month, evapotranspiration ETR: ETR = P - RG2 – RG1 – RD must be bigger or equal 0.

Q…. outflow from the storages
R …. filling of the storages
G1… fast groundwater
G2… slow groundwater
D… direct runoff
ETR… evapotranspiration

Detailed description and formulas can be found in (Schwarze 2001)

3.3.1 Definitions of the runoff components

Difga computes three runoff components (QG2) slow groundwater runoff, (QG1) fast groundwater runoff and (QD) direct runoff.

Slow Groundwater (**QG2**): slow, saturated, subsurface runoff component. The storage parameter CG2 is equal several months. This means the time for „volume exchange“ (not the age of the slow groundwater). This parameter is equal with the formation of groundwater (Schwarze 2001).

Fast Groundwater (**QG1**): fast, saturated, subsurface runoff component. The storage parameter CG1 is several days.

Direct flow (**QD**) is the surface or subsurface flow in the unsaturated zone. It is the fastest component of runoff in Difga.

4 Description of the input data

4.1 Case study regions - AUSTRIA

4.1.1 Climatic data

The climatic data are the main input of the SWAT 2000 model. They represent the driving force of the water and energy cycle and should be applied with attention.
The following data were used to generate the climatic conditions:

Ybbs basin	Wulka basin
Precipitation (15/1971-2001)*	Precipitation (15/1971-2001)*
Air Temperature (14/1946-2001)*	Temperature (7/1989-2001)*
Solar Radiation (5/1990-2000)*	Solar Radiation (1/1990-2000)*
Relative Humidity (5/1990-2000)*	Relative Humidity (1/1990-2000)*
Wind Speed (5/1990-2000)*	Pot. Evapotranspiration (1/1961-2000)*
Snow cover (8/1970-2001)	Snow cover (15/1970-2001)*

Table 4-1: Overview about the climatic stations, (number/the time series available)

In Table 4-1 the first Number inside the rows describes the number of stations, the second the largest interval of data are available. The *-signed data dedicate, that not all the stations covering the listed interval, Interruptions are included.

Precipitation

The SWAT 2000 model incorporates daily precipitation values. If there is a lag of data in the period of simulation, the model is able to generate daily values based on statistics, which have to be entered into the weather generator.
For every subbasin, the nearest precipitation station will be located and the daily values will be applied as measured. Precipitation correction or interpolation will not be considered. A possibility to enter a precipitation-laps-factor (changes in precipitation due to changes in elevation) is given in the (.sub)-file.

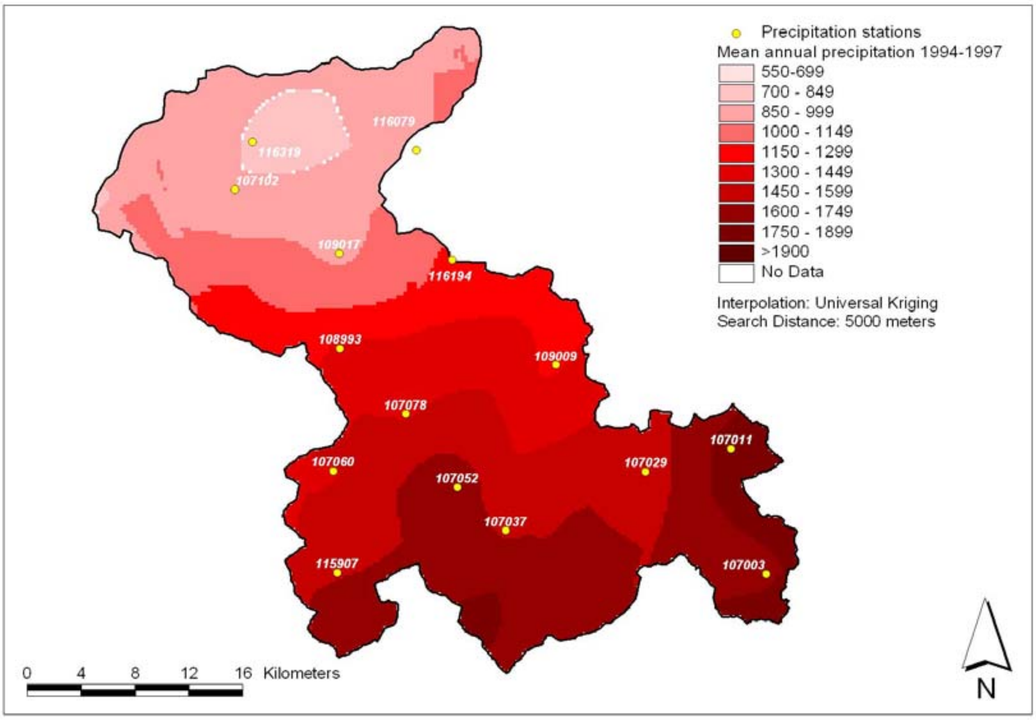


Fig. 4-1: Distribution of the average annual precipitation (1994-1997) for the Ybbs catchment

Figure 4-1 gives an imagination of the precipitation distribution in the Ybbs catchment. The Figure is based in the average annual precipitation values for the Period 1994-1997. It´s to be seen, that the precipitation amount rises with moving to the south, means with rising elevations.
Figure 4-2 shows the precipitation distribution for the Wulka catchment.

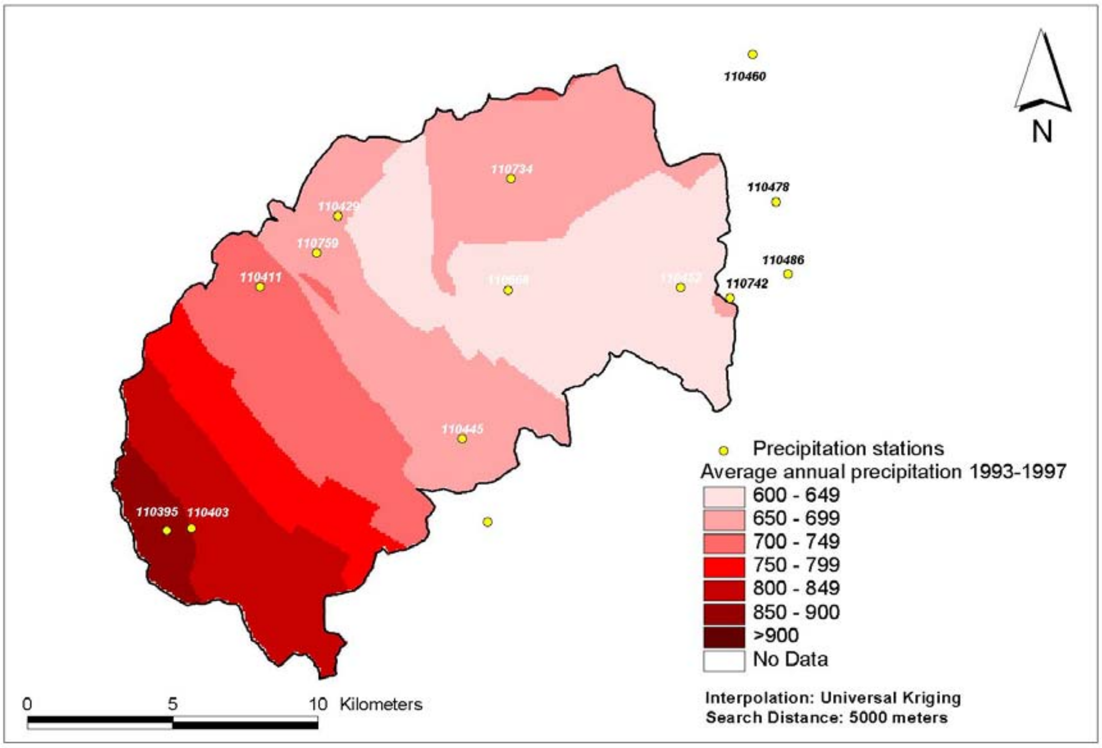


Fig. 4-2: Distribution of the average annual precipitation (1993-1997) for the Wulka catchment

The average annual precipitation ranges from 600m in the eastern part of the catchment to 750mm in the western part. In the upper parts of the Rosaliengebirge up to 900m precipitation are registrated.

Temperature
The SWAT 2000 model incorporates daily maximum and minimum temperature values. If there is a lag of data in the period of simulation, the model is able to generate daily values based on statistics, which have to be entered into the weather generator.

Solar Radiation, Relative Humidity, Wind Speed
The SWAT 2000 model incorporates daily values of these measurements. If there is a lag of data in the period of simulation, the model is able to generate daily values based on statistics, which have to be entered into the weather generator.
The data will be used to calculate potential Evapotranspiration.

Potential Evapotranspiration
The SWAT 2000 model incorporates daily values of potential Evapotranspiration, if measurements are available. Otherwise, it will be calculated out of the described data. In the Wulka basin, daily values of the PET (Potential Evapotranspiration) estimated with the Penman-Monteith-Method were used.

4.1.2 Hydrologic data

The hydrologic data were used to estimate and assess the model performance of the SWAT 2000 model. Therefore, the following data were available:

Ybbs basin	Wulka basin
River discharge (5/1971-1997)*	River discharge (6/1971-1997)* River water level (6/1976-2001)**

Tab. 4-2: Number of hydrologic stations and the time series available

In Table 4-2 the first Number inside the rows describes the number of stations, the second one is the largest interval of data are available. The *-signed data dedicate, that not all the stations are covering the listed interval.
The Figures 2-xx and 2-16 giving an overview about the location of the hydrologic stations in the Ybbs catchment and the Wulka catchment.
All the stations provide daily measured values. For the Wulka catchment, also hourly measured river discharge values (**-signed data) are available.

To estimate the model performance of the SWAT 2000 model, only daily river discharge was used.

Data about reservoirs were incorporated in the Ybbs catchment. The Lake “Lunzer See” was considered as reservoir with daily measured outflow data.

4.1.3 Data from waste water treatment plants (WWTP)

The water inlet from WWTP’s will be considered in the SWAT 2000 model, too. The incorporation into the model is possible as measured values or as constant daily, monthly or annual loadings.

In the Ybbs catchment, the water inlets from WWTP´s will be considered as a constant monthly load. 7 WWTP have been implemented with monthly loadings between 80 and 2500 m^3/d.

In the Wulka catchment, the water inlet from wwtp will be considered as monthly measured values for 5 WWTP´s (3/1995-2000),(2/1981-2000). Especially in this catchment the contribution of the wwtp is considerally high. In the river Eisbach the total river discharge consists of 30% inlets from WWTP´s.

The total simulated river discharge includes the proportion of the upstream inlets from WWTP and can lead to uncertainties in the model performance, especially when the loadings are considered as constant loadings. The inlets can influence the correctness of the calculated water balances, if the water was imported via the drinking water supply.

4.1.4 Data for the MONERIS model

- Run-off data: Daily run-off values measured at the end of each sub-catchment basin were used. For Wulka was considered the period 1997-1999 and for Ybbs – 1997-2000 accordingly. *Source: Hydrological Central Bureau, Austria.*
- Data about point sources: In the Austrian case studies the point sources are WWTP. The implemented data are taken from the exploitation reports from the considered WWTPs. The water discharges implemented in the model are calculated as average from the yearly average discharges. The considered periods are: for Wulka 1997-2001, for Ybbs 1998-2001. Because of lack of data for some small WWTPs in Ybbs valley, the discharges are estimated according to the EU norms (q=150l/cap/day). *Source: Eploitation reports; EU norms.*
- GIS data: For calculation the surface area from which a certain flow is formed were used the same digital maps which are used for the SWAT model; i.e Corine Landcover (30m raster).
- Statistical data: Data about population in the municipalities concerned in the study are taken from *Statistic Austria.*

4.2 Case study region - HUNGARY

The climatic data are the main input of the SWAT 2000 model. To generate the climatic conditions daily climatic data of the period 1997-2001 were used. The necessary data sets for the SWAT calculation (precipitation, minimum and maximum temperature, solar radiation, relative humidity and wind speed data on daily time distribution) were only available at three meteorological stations situated in the near surrounding of the watershed (Figure 4-3). Additionally, further 11 precipitation stations having only daily measured values were employed for the simulation of the precipitation-events. For every sub-basin, the data of the nearest precipitation station were applied as representative values. Considering the whole watershed, the average precipitation value was calculated as an average value weighted with the area of the sub-basins. Precipitation correction or interpolation was not considered. The potential evapotranspiration was calculated by the Penman-Monteith method.

The DIFGA model calculating the water balance requires only daily precipitation data. A precipitation correction (degree-day-factor method) was carried out in case of snow melting. To run DIFGA, all stations with daily values were taken into account, and the average value was computed as a weighted average. The weighting is based on the distance between the precipitation station, and the centre of the subbasins.

The MONERIS model requires only five years average data regarding the whole catchment. This value was calculated with interpolation (krigging method) based on monthly precipitation data at more than 20 gauge stations in and in the surroundings of the watershed (Figure 2-27).

The SWAT model determines the watershed based on the digital elevation model. To the watershed delineation an elevation map of 50 x 50 m grid was used. The outlets of the sub-basins have been defined at the monitoring stations with their coordinates and the model has determined automatically the corresponding subcatchments (Figure 4-3). The main river has been also designated by SWAT based on the elevation model. The other methods don’t utilize elevation map.

The soil and landuse maps in their original form show the borders of the areas corresponding to different landuse and soil types without their properties. The required parameters were estimated on the base of literature. The other two models don’t require detailed landuse and soil characterisation.

The hydrologic data were used to control and assess the performance of the SWAT 2000 model. These data, as inputs were used in calculation of different flow components both in DIFGA and MONERIS models. Therefore, daily measured river discharges at four different sampling stations were applied.

Water from agricultural drainage systems and other human water uses (drinking water production from shallow groundwater, and irrigation) were not considered in the models, because they are insignificant compared to the total discharge. Only the water discharges of the wastewater treatment plants were taken into the calculations. Their coordinates and average daily wastewater discharges define the plants.

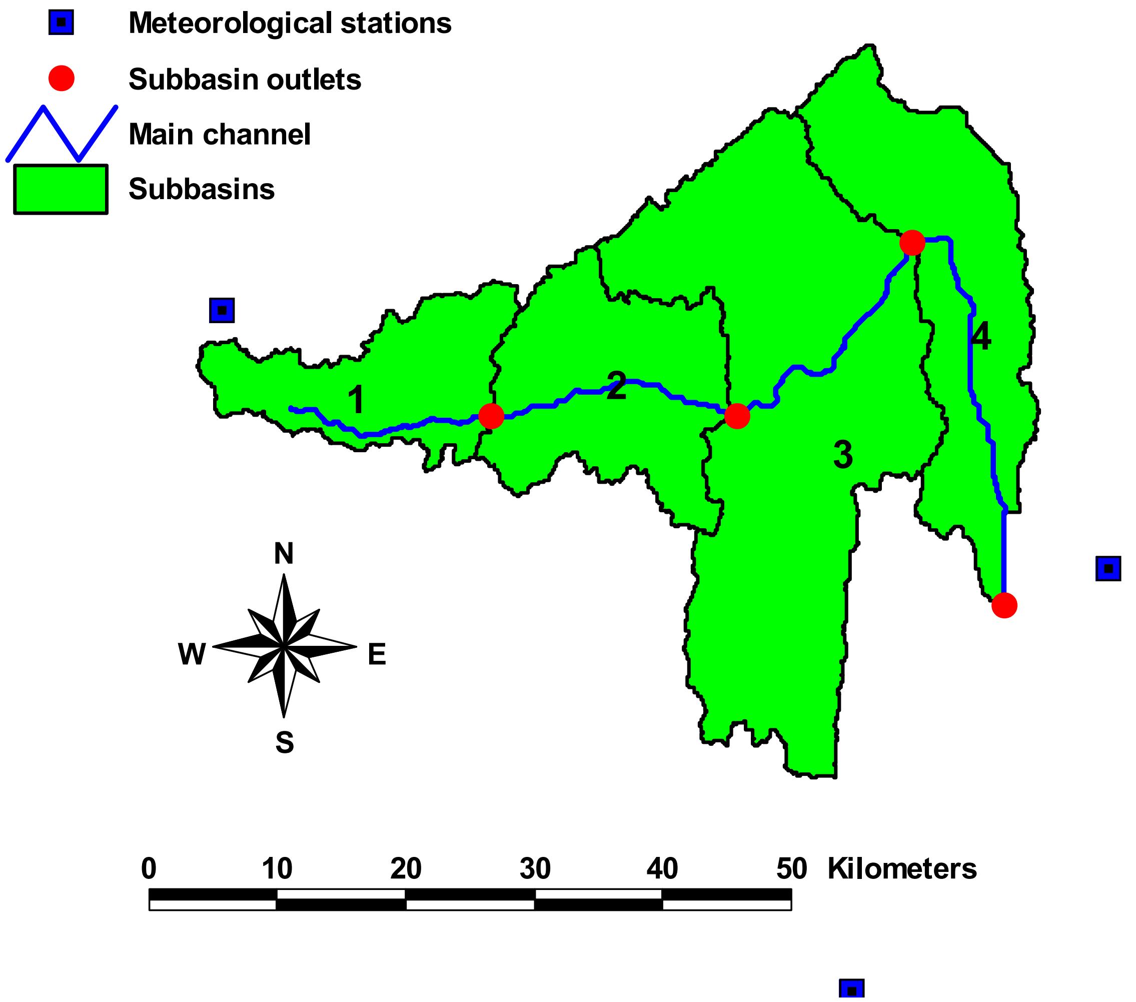


Fig. 4-3: Subbasins, outlets and meteorological stations for SWAT

4.3 Case study region - ROMANIA

4.3.1 Hydrologic Response Units (HRU's) for the SWAT 2000 application

In order to achieve SWAT requirements for Land Use and Soil Distribution over the Neajlov Catchement it was used a multiple Hidrologic Response Units (HRUs) approach with 15% Land Use over each subcatchement area and 15% Soil Class over Land Use. The result was a number of 31 HRUs comprising two types of land use (Agricultural Generic – AGRL and Forest Deciduous – FRSD) and 12 types of soils.

Subcatch.	No. of HRUs	Land Use type	Soil type	Subcatch.	No. of HRUs	Land Use type	Soil type
1	1	AGRL	brp	9	1	AGRL	bri
2	1	AGRL	svrgm	9	2	AGRL	clf
3	1	FRSD	bpgm	10	1	AGRL	clmp
3	2	FRSD	brp	10	2	AGRL	clma
3	3	AGRL	brp	11	1	AGRL	sm
4	1	AGRL	brp	11	2	AGRL	bri
5	1	AGRL	brp	12	1	AGRL	clmp
5	2	AGRL	brn	12	2	AGRL	clfp
6	1	AGRL	brn	13	1	FRSD	brp
6	2	AGRL	clmp	13	2	FRSD	brepi
6	3	AGRL	bri	13	3	FRSD	brps
7	1	FRSD	brp	13	4	AGRL	br
7	2	AGRL	brp	13	5	AGRL	clma
7	3	AGRL	brn	14	1	AGRL	svrgm
8	1	AGRL	brn				
8	2	AGRL	bri				

Tab. 4-1: HRUs distribution over the Neajlov catchement

4.3.2 Climatic data

The weather data were collected from the monitoring station Videle, located inside the Neajlov basin. The period filled with data is June 1994 – December 2001. With the exception of air relative humidity, which is on a monthly basis the other data, are on a daily basis.

Month	Precipit.	Air temp. (ave)	Air temp. (max.)	Air temp (min)	Soil temp. (ave.)	Soil temp. (max.)	Soil temp (min.)	Dew point	Global rad.	Wind (ave. speed)
	mm	*gr. C*	*gr. C*	*gr. C*	*gr. C*	*gr. C*	*gr. C*	*gr. C*	*cal / cm2*	*m/s*
Jan	32.5	-2.0	1.3	-4.8	-0.6	7.2	-2.7	-3.9	121.9	1.6
Feb	24.6	1.7	6.3	-2.4	2.1	11.5	-1.4	-2.0	227.4	1.8
Mar	39.7	5.9	11.4	1.1	5.8	16.8	1.0	-0.4	283.7	2.2
Apr	52.5	12.3	18.5	6.5	12.4	26.8	4.9	5.9	411.1	2.0
May	48.3	19.1	25.9	12.6	19.0	37.1	8.9	10.6	476.1	2.1
Jun	63.6	24.0	31.3	17.0	24.0	44.9	12.2	14.7	551.2	1.5
Jul	36.4	24.5	31.8	17.4	26.0	48.2	13.5	15.3	523.4	1.7
Aug	39.5	23.4	30.7	16.5	27.0	49.2	14.0	15.9	464.1	1.5
Sep	54.6	17.7	24.3	11.6	20.1	37.4	10.4	10.1	387.2	1.9
Oct	25.3	11.6	17.5	6.3	13.3	27.9	5.8	6.8	226.8	1.5
Nov	35.3	5.1	9.8	1.2	6.3	16.4	1.6	1.7	143.0	1.6
Dec	42.8	-0.4	2.9	-3.0	0.2	8.3	-2.9	-1.6	93.8	1.9
TOTAL	495.6	11.9	17.6	6.6	13.0	27.6	5.4	6.1	325.8	1.8

Tab. 4-2: Monthly average of weather parameters (multiannual average: 1995- 2001)
(red – maximum values, green – minimum values)

Along the year the rainfall amount has not a very clear pattern although there could be distinguished two periods of high levels of precipitation, the first one in the April - June period and the second one in September. From the table it has to be observed that the wind speed is reaching the maximum in the spring period. Also it has to be mentioned the delay between the global radiation maximum value (June) and the air / soil temperature (July / August) and also the delay between highest air temperatures (July) and highest soil temperatures (August). The minimum values of air and soil temperatures, with exception of minimum soil temperature are recorded in January, while the minimum value of global radiation is recorded in December. The minimum value of precipitation level is recorded in February and the minimum value of wind speed is recorded in June.

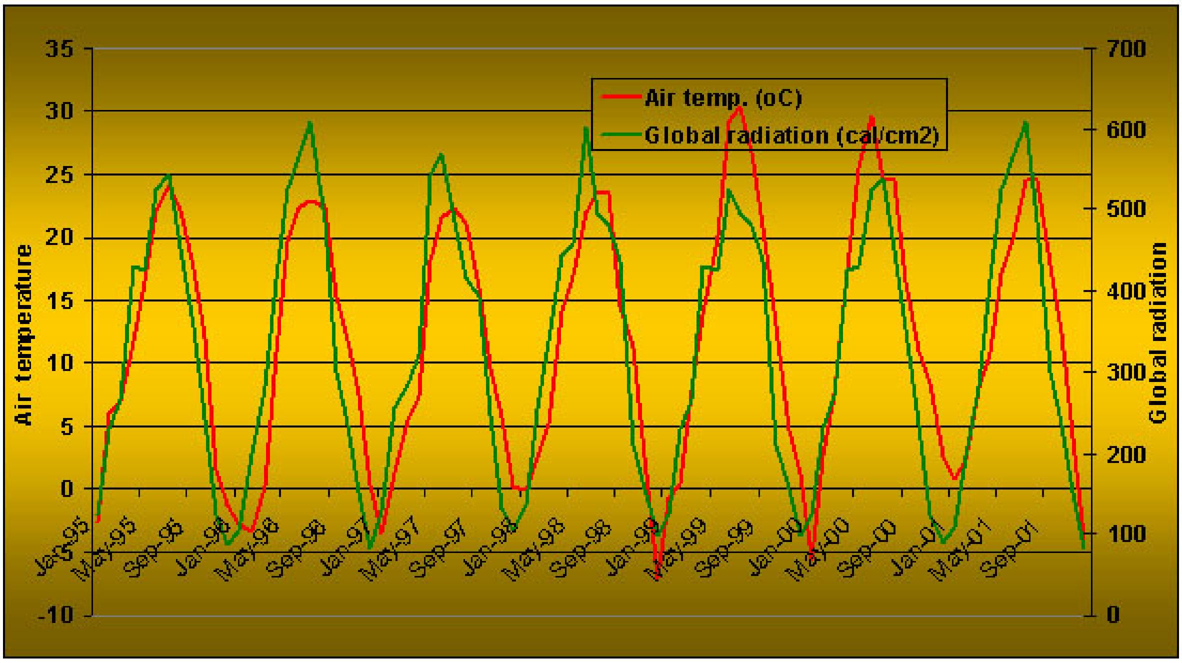


Fig. 4-4: Monthly average for air temperature and global radiation

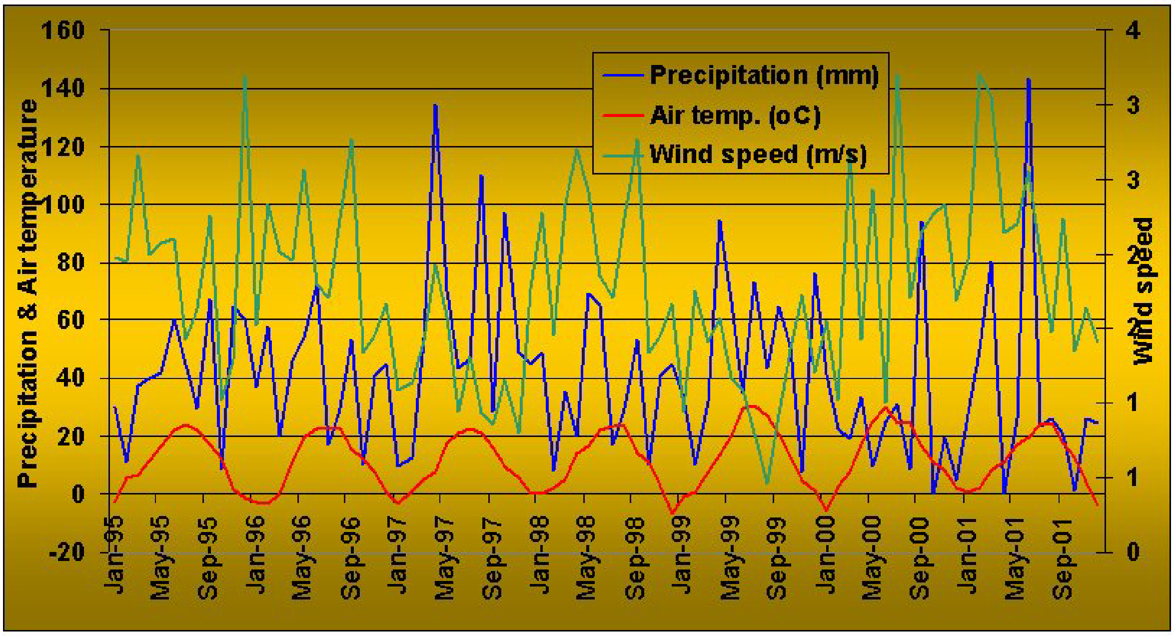


Fig. 4-5: Monthly average for air temperature, precipitation and wind speed

Year	Precipitation	Ave. air temp.	Max.air temp.	Min. air temp.	Global radiation	Wind speed
	mm	*gr. C*	*gr. C*	*gr. C*	*cal / cm2*	*m/s*
1995	495.8	11.4	16.8	6.0	317.0	2.0
1996	483.8	10.6	15.6	5.7	329.5	1.9
1997	699.6	10.4	15.7	5.2	323.3	1.2
1998	443.9	10.8	16.7	5.5	342.3	2.0
1999	588.2	13.9	20.5	8.6	322.8	1.2
2000	308.8	13.7	20.0	8.5	316.7	2.0
2001	449.6	11.5	17.8	6.5	329.8	2.1
Average	**495.7**	**11.8**	**17.6**	**6.6**	**325.9**	**1.8**

Tab. 4-3: Annual averages of weather parameters

The annual average for the study period indicates a maximum level of precipitation for year 1995, in the same year being recorded also the smallest values of average and minimum air temperature, and wind speed. The highest values of air temperature were recorded for year 1999, when there were also recorded the minimum values wind speed. The minimum value of precipitation amount was recorded in 2000, when was also recorded the maximum value of global radiation, and near maximum values for air temperatures and wind speed.

4.3.3 River discharge data

The river discharge data were collected from three locations (Calugareni, Vadu Lat and Moara din Groapa) along the Neajlov River for the 1995 – 2001 period, on a daily basis.

River discharge (m3/s)	Calugareni	Vadu Lat	Moara din Groapa
Average	7.26	3.84	0.84
Maximum	193 (5 April 1997)	154 (3 April 1997)	69.90 (3 April 1997)
Minimum	1.74 (30 July 2000)	1.70 (2 – 13 July 2000)	0.20 (2 Spetember 1996)

Tab. 4-4: Characteristic values of the discharge at the measuring points

Station	1995	1996	1997	1998	1999	2000	2001	Average
Calugareni	4.74	9.85	9.73	8.73	7.37	6.14	4.55	**7.3**
Vadu Lat	3.42	5.52	4.53	3.87	3.59	3.15	2.85	**3.8**
Moara din Groapa	0.64	0.94	1.06	0.92	0.81	0.78	0.75	**0.8**

Tab. 4-5: Annual averages of the measured river discharge

The highest values of river discharge were recorded in 1996 for Calugareni and Vadu Lat stations and in 1997 for Moara din Groapa station, while the minimum values were recorded in 2001 for Calugareni and Vadu Lat and in 1995 for Moara di Groapa. The absolut maximum values for discharges were recorded in April 1997, when was recorded the second maximum value for precipitation (134 mm).

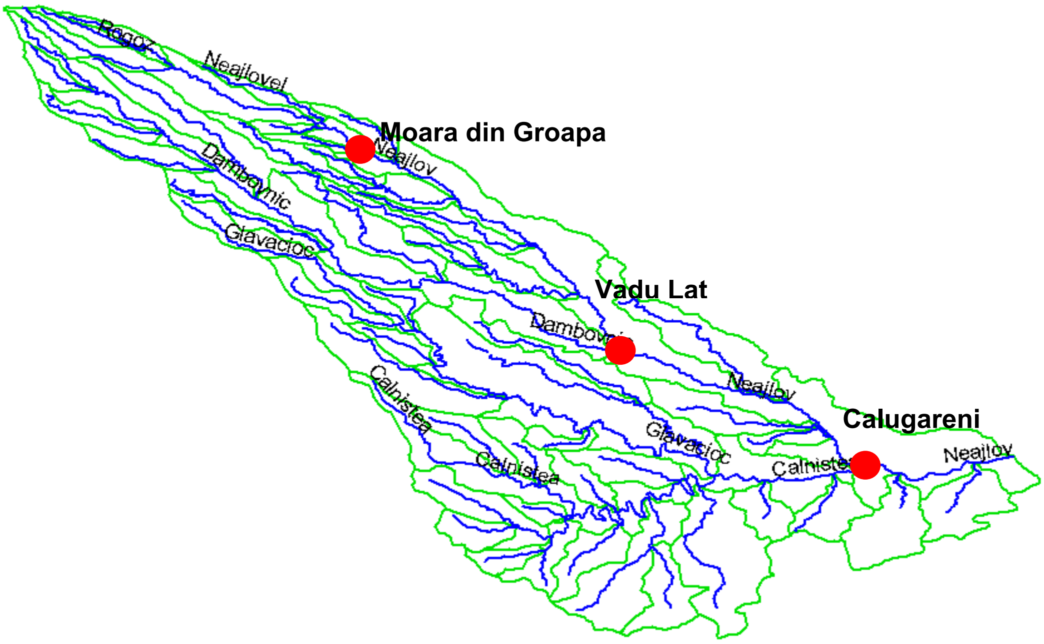


Fig. 4-6: Location of the river discharge monitoring stations inside the Neajlov catchement

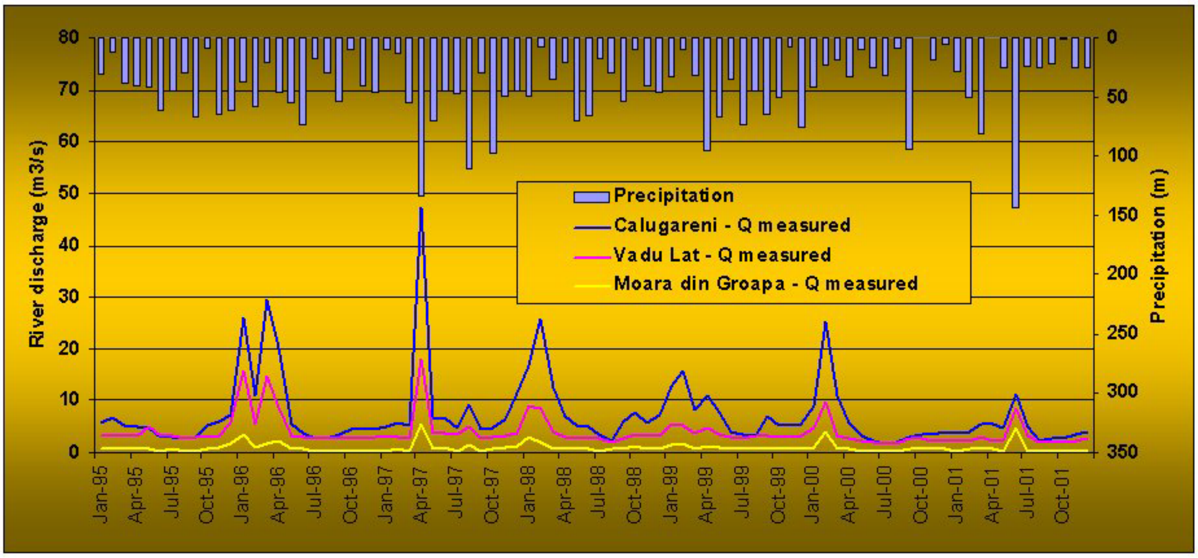


Fig. 4-7: Relation between measured river discharge and precipitation level

5 Calibration and validation of the SWAT 2000 model

5.1 Calibration of the SWAT 2000 model - AUSTRIA

5.1.1 Introduction and main declarations

The calibration process of the SWAT 2000 model is needed to decrease deviations of the results between those simulated by the model and the measured or reported ones. The calibration process is dedicated to refine and redefine model parameter, which influence the model behaviour in order to get an optimal fitting of the model regarding to the regional hydrologic and climatic conditions.

Both watersheds, the Ybbs catchment and the Wulka catchment, have been partitioned into 5 subcatchments. For every subcatchment a separate SWAT project was defined and calibrated on its own. The calibration was started at the most upstream subcatchment and all tributary catchments. Afterwards, the subcatchment-related model parameter have been transferred to the next downstream subcatchment. If the model performance decreased, the parameter have been changed and calibrated again. The daily time step was used for the SWAT 2000 model calibration.

5.1.2 Calibration period

For both watersheds, the calibration period of **1995 – 1997** was used. One experience was, that the model needs a certain time of about 1- 1,5 years to get to a stady state. In dependence of starting values, for instance for the amount of water in the shallow aquifer or in the soil, this time could have been decreased. In order to eliminate this unsteady model conditions, the simulations in the calibration process were done for the period **1993 – 1997**.
The estimation of the simulation performances was done for the calibration period 1995 – 1997.

5.1.3 Estimation of the model efficiency

The fitting of the model or the simulation performance was estimated by the Nash-Sutcliffe-Coefficient (**NSC**) (Nash&Sutcliffe, 1970).
The *Initial variance* F_0^2 of the measured values (River discharge) is given as:

$$F_0^{\,2} = \sum (q - \bar{q})^2 \qquad \text{(Eq. 5.1)}$$

with q … observed (measured) discharge
$\bar{q}$ … mean of the observed (measured) discharge

The *Residual variance* F^2 is given as:

$$F^2 = \sum (q' - q)^2 \qquad \text{(Eq. 5.2)}$$

with q' … computed discharge
q … observed discharge

The *Efficiency of the model* R^2 is given as:

$$R^2 = \frac{F_0^2 - F^2}{F_0^2} \qquad \text{(Eq. 5.3)}$$

Additionally, the volumetric error **VE** of the simulated river discharge was taken into account:

$$VE = \frac{V'}{V} * 100\% \qquad \text{(Eq. 5.4)}$$

with V' … Total amount of water of the simulated river discharge in the period
V … Total amount of water of the observed river discharge in the period

5.1.4 The Ybbs catchment

For the Ybbs catchment a SWAT-Project with the following delineations was defined:

- 73 Subbasins
- 428 HRU´s (Hydrologic Response Units)
- 7 landuse classes (after threshold application)
- 16 soil classes (after threshold application)
- 7 point sources (WWTP)
- 1 Reservoir (Lunzer See)

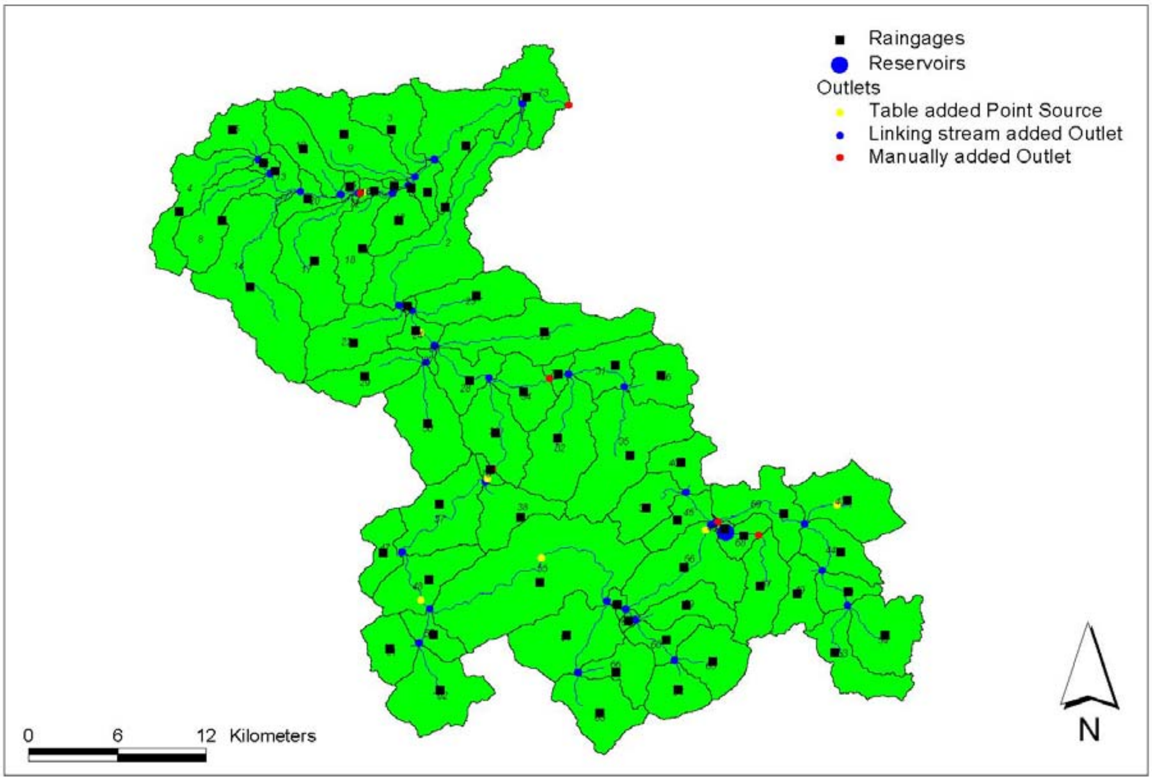


Fig. 5-1: SWAT definitions for the Ybbs catchment

Figure 5-1 shows the ready-defined SWAT-project for the Ybbs catchment. The point sources have been implemented as tables containing the location information. The manually added Outlets representing the river gauging stations in order to be able to compare the simulated river discharges against the measured river discharges. The Lunzer See was considered as Reservoir.

Due to the number and the location of the precipitation stations (see Figure 2-6) in some subbasins problems with precipitation events (no interpolation) and the corresponding river discharges occurred. Thus, a daily Kriging interpolation of the precipitation values for a period of 30 years was done over the whole basin. In result, a grid was made and for every subbasin the average precipitation value was estimated. In that way, for every subbasin a virtual raingage station with daily

precipitation values for 30 years (see Figure 5-1) in the centroid of the subbasin was built.
For a better fit in snow fall and snow melt elevation bands have been defined.

1. Trial and error method for calibration
The calibration was started with the trial and error method for the 5 subcatchments. Due to the large number of model parameters the model efficiency could be obtained, was not satisfying. It resulted in NSC´s around zero or below for the daily printout frequency.
Mainly, the following parameters had been refined:

Input-file	Parameter	Description
.sol*	SOL_Z	Soil layer depth [mm]
	SOL_K	Saturated hydraulic conductivity [mm/h]
	SOL_AWC	Soil available water capacity [mm]
.sub	TLAPS	Temperature laps rate [°C/km]
	ELEVB	Elevation bands [m]
	ELEVB_FR	Fraction of the subbasin in the Elevation band
.gw	ALPHA_BF	Baseflow alpha factor
.bsn	SFTMP	Snow fall temperature [°C]
	SMTMP	Snow melt temperature [°C]
	SMFMX	Maximum melt rate during summer [mm/°C*d]
	SMFMN	Minimum melt rate during winter [mm/°C*d]
	TIMP	Snow pack temperature lag factor
	SNOCOVMX	Minimum snow water content, that corresponds to 100% snow cover
	SNO50COV	Snow water equivalent that corresponds to 50% snow cover

Tab. 5-1: Calibration parameter used for the trial and error method in the Ybbs catchment

*…The soil parameter calibration was done using the for FAO-soil map.

2. Use of an automatic calibration tool for calibration
In June 2002 an automatic calibration tool (van Griensven, 2002), which was developed for the ESWAT model, could be applied for the SWAT 2000 model. This tool uses the Shuffled Complex Evolution Algorithm (SCE-UA) (Duan, 1992) for optimisation, where several objective functions are aggregated to a Global Optimisation Criterion, that has to be minimised.
For every subcatchment the SCE-UA-Algorithm was applied. Several combinations of calibration parameters were used to determine the optimal parameter values. After finishing the optimisation, the optimised parameter have been entered into the model and the model efficiency was estimated. A visual control of the fitting of the hydrograph was done too.
In case, that the fitting was not satisfying, some of the “optimised” parameter has been selected again together with a selection of some other calibration parameters, and have been re-entered to the optimisation algorithm again.
In that way, for every subcatchment between 7 and 20 optimisation calculations have been performed.

The following model parameter have been optimised with the SCE-UA-algorithm:

Input-file	Parameter	Description
.sol*	SOL_Z	Soil layer depth for every layer [mm]
	SOL_K	Saturated hydraulic conductivity for every layer [mm/h]
	SOL_AWC	Soil available water capacity for every layer [mm]
.gw	ALPHA_BF	Baseflow alpha factor
	GW_DELAY	Groundwater delay [d]
	GW_REVAP	Groundwater “re-evaporation” coefficient
	RCHRG_DP	Deep aquifer percolation fraction
	REVAPMN	Threshold value for “revap”/percolation to deep aquifer to occur [mm]
	GWQMN	Threshold value for return flow (base flow) to occur [mm]
.mgt	CN2	Curve number for moisture condition II
.rte	CH_K2	Effective hydraulic conductivity for the main channel [mm/h]
	CH_N2	Manning´s “n” value for the main channel
Input-file	Parameter	Description
.bsn	SMTMP	Snow melt temperature [°C]
	SFTMP	Snow fall temperature [°C]
	SMFMX	Maximum melt rate during summer [mm/°C*d]
	SMFMN	Minimum melt rate during winter [mm/°C*d]
	TIMP	Snow pack temperature lag factor
	SNOCOVMX	Minimum snow water content, that corresponds to 100% snow cover
	SNO50COV	Snow water equivalent that corresponds to 50% snow cover
	SURLAG	Surface runoff lag time [d]

Tab. 5-2: Calibration parameter used for the SCE-UA-optimisation algorithm in the Ybbs catchment

*… The soil parameter calibration was done using the fao-soil map.

In Appendix A3 the results of the optimisation calculations for the Ybbs-subcatchments with the SCE-UA-Algorithm are summarised.
After applying the SCE-UA-Algorithm for every subcatchment, the parameter set with the best model efficiency and the best visual fitting was selected.

On basis of the fraction of the runoff components resulting from the DIFGA model, the calibration of the SWAT model was carried on with the optimised parameter sets. **In that way, the distribution of the components Direct Runoff, fast Groundwater Flow and slow Groundwater Flow of the DIFGA model were set equal to the components Surface runoff, Lateral Flow and Groundwater Flow of the SWAT model.**
At first, the surface runoff was adjusted again, changing the Curve Numbers of the landuse classes. Afterwards, the Hydraulic Conductivity was redefined in order to catch nearly the value for the Lateral Flow, which was estimated for the fast Groundwater Flow with DIFGA. At last, the groundwater parameters have been redefined in order to align the Base Flow of SWAT with the slow Groundwater component of DIFGA.

The calibration process (Trial and error method / automatic calibration) was done using the fao-soil map for soil information. After getting the detailed soil map from the BAW, the SWAT-Project was redefined with the new, more detailed soil map and the calibrated parameter listed in Table 5-2 were applied (with exception of the soil parameter). The soil parameter of the new soil map were refined, too.

In that way, the following model performance for the Ybbs catchment could be obtained:

Subcatchment	Lunz a.S.	Opponitz	Ybbsitz	Krenstetten	Greimpersdorf
NSC 1995-1997 Subcatchments	**0.58**	**0.47**	**0.63**	**0.55**	**-**
NSC Greimpersdorf 1995-1997	**0.22**	**0.37**	**0.39**	**0.56**	**0.37**
NSC Greimpersdorf 1995-1997 (MKG)	**0.66**	**0.59**	**0.77**	**0.42**	**0.20**
NSC Greimpersdorf Summer 1995-1997	**0.23**	**0.32**	**0.40**	**0.58**	**0.33**
VE [%]	**115**	**102**	**106**	**120**	**103**

Tab. 5-3: Calibration results for the subcatchments and the Ybbs catchment

The first row of Table 4-3 shows the calibration results that have been obtained in the subcatchments, which have been calibrated on its own.

The second row shows the model efficiency after implementing all the subcatchments with its parameter values into the SWAT project of the whole watershed. The NSC´s decreased about 0.01…0.24 in every subcatchment. This behaviour is caused by the model definition of the HRU´s. A threshold value for the soil fraction in regard to the watershed area will be defined. Afterwards, all soils with a fraction smaller than the threshold value will not be considered in the determination of the HRU´s. Thus, soil which are of an important, but regional relevance for subcatchments, are of a smaller importance or will not be considered for the HRU definition of the whole watershed.

When instead of the usual “Variable storage” method (Row 1,2,4) the “Muskingum” method (**MKG**) (Row 3) was used as the water routing method, differences in form of higher NSC´s occurred in the subcatchments, but not at the main outlet “Greimpersdorf”. The reason therefore is to be seen in a smoothing of the hydrograph in dependence of two Muskingum calibration parameters, when the Muskingum method is used. But in fact, the water routing method influences the dynamics of the simulation, i.e. the appearance of peaks, but not the annual water balance and its components.
The Calibration was finished using the “Variable Storage” water routing method.

Due to the high mountains in the South of the Ybbs watershed snow melt could not fitted so well. Therefore, the NSC was also estimated only for the summer months (Table 5-3, Row 4). In the calibration period the influence of the not-well fitted snow fall and snow melt was not as important as in the validation period (See chapter 5.2.2).

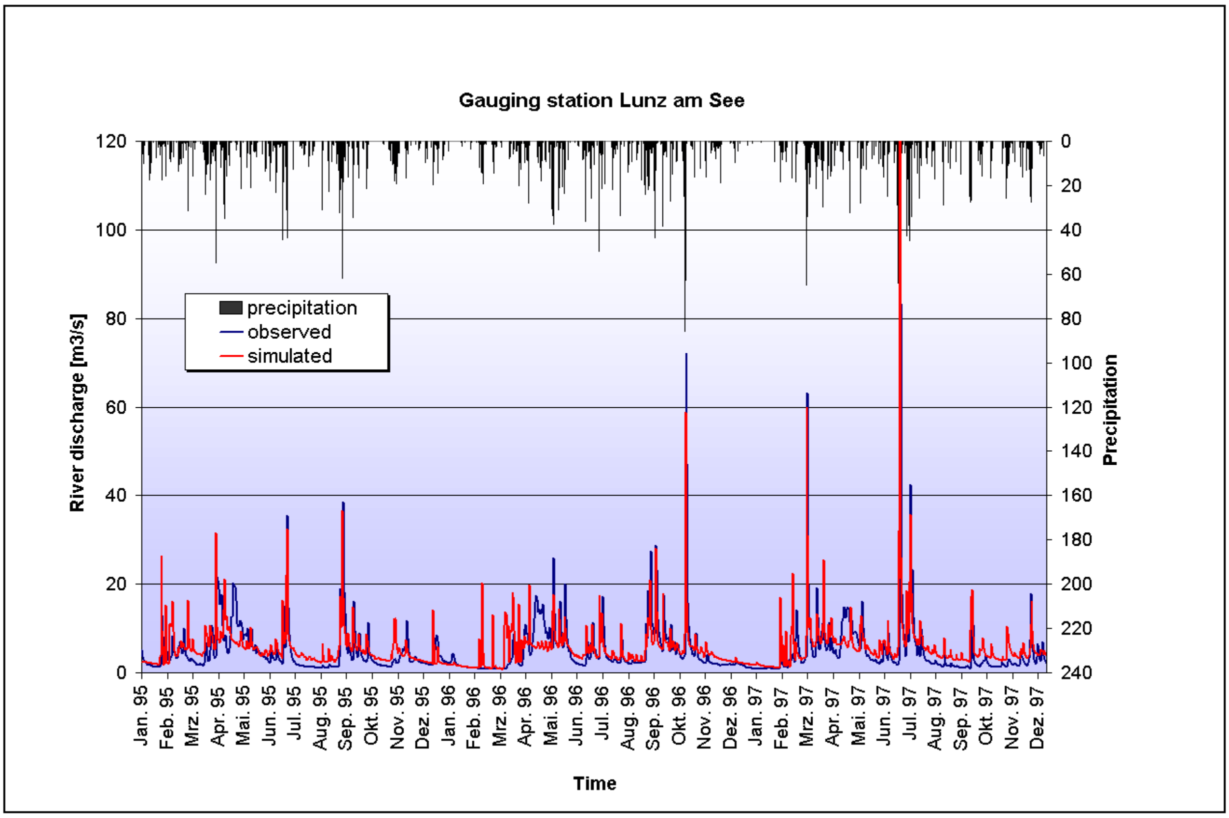


Fig. 5-2: Comparison of the observed and the simulated hydrograph at the gauging station Lunz am See (1995-1997)

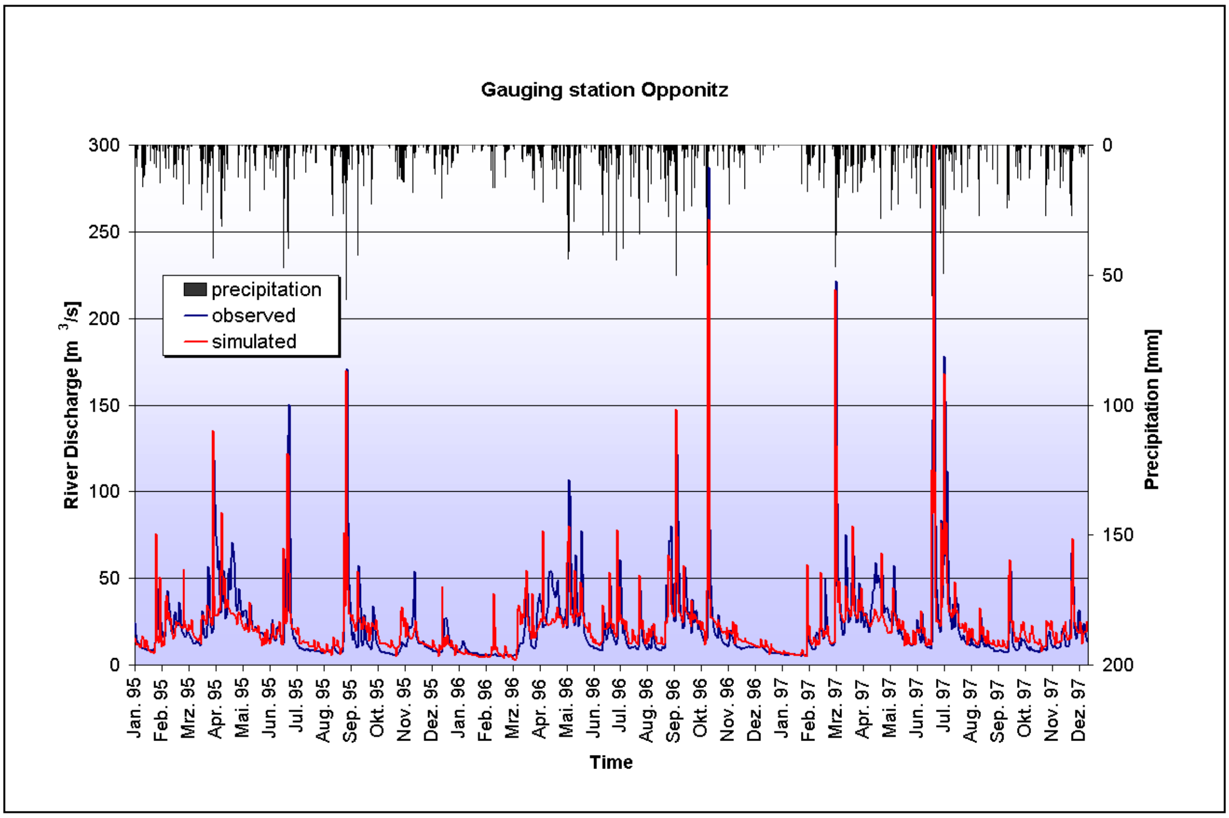


Fig. 5-3: Comparison of the observed and the simulated hydrograph at the gauging station Opponitz (1995-1997)

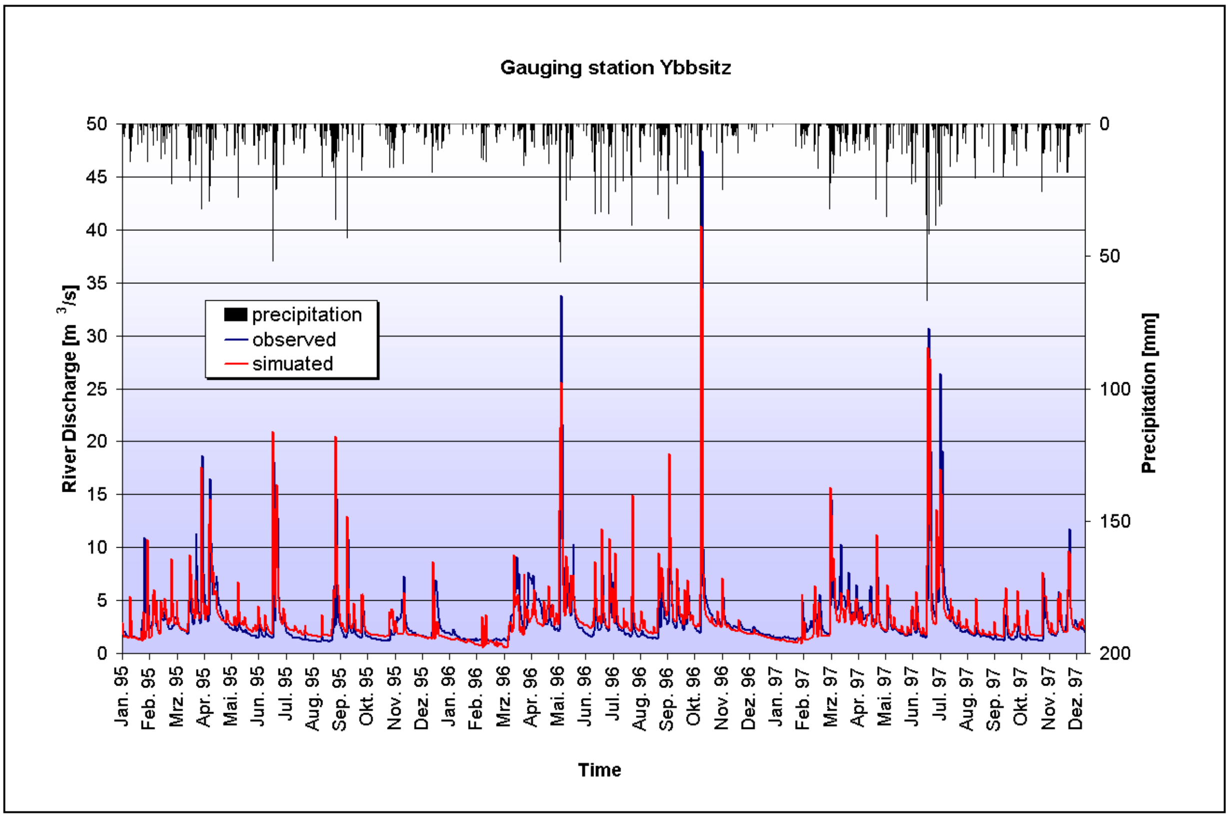


Fig. 5-4: Comparison of the observed and the simulated hydrograph at the gauging station Ybbsitz (1995-1997)

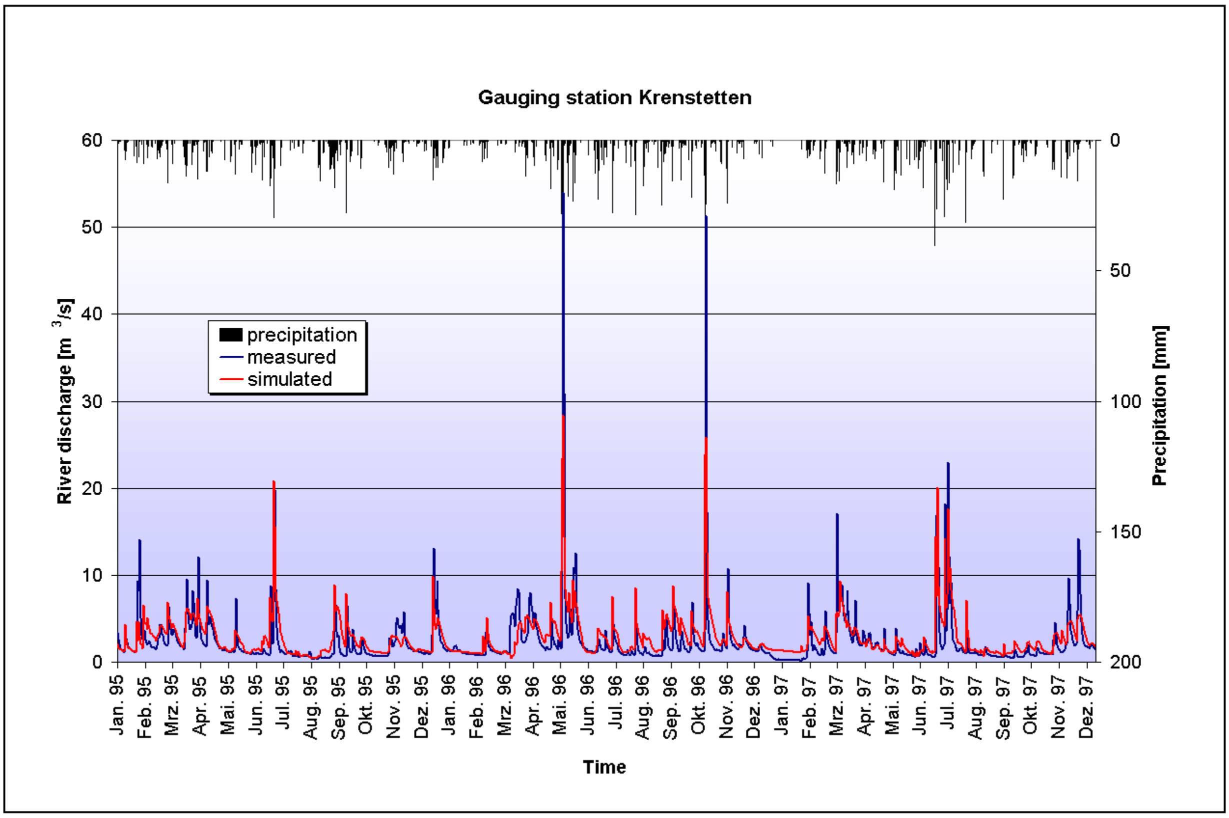


Fig. 5-5: Comparison of the observed and the simulated hydrograph at the gauging station Krenstetten (1995-1997)

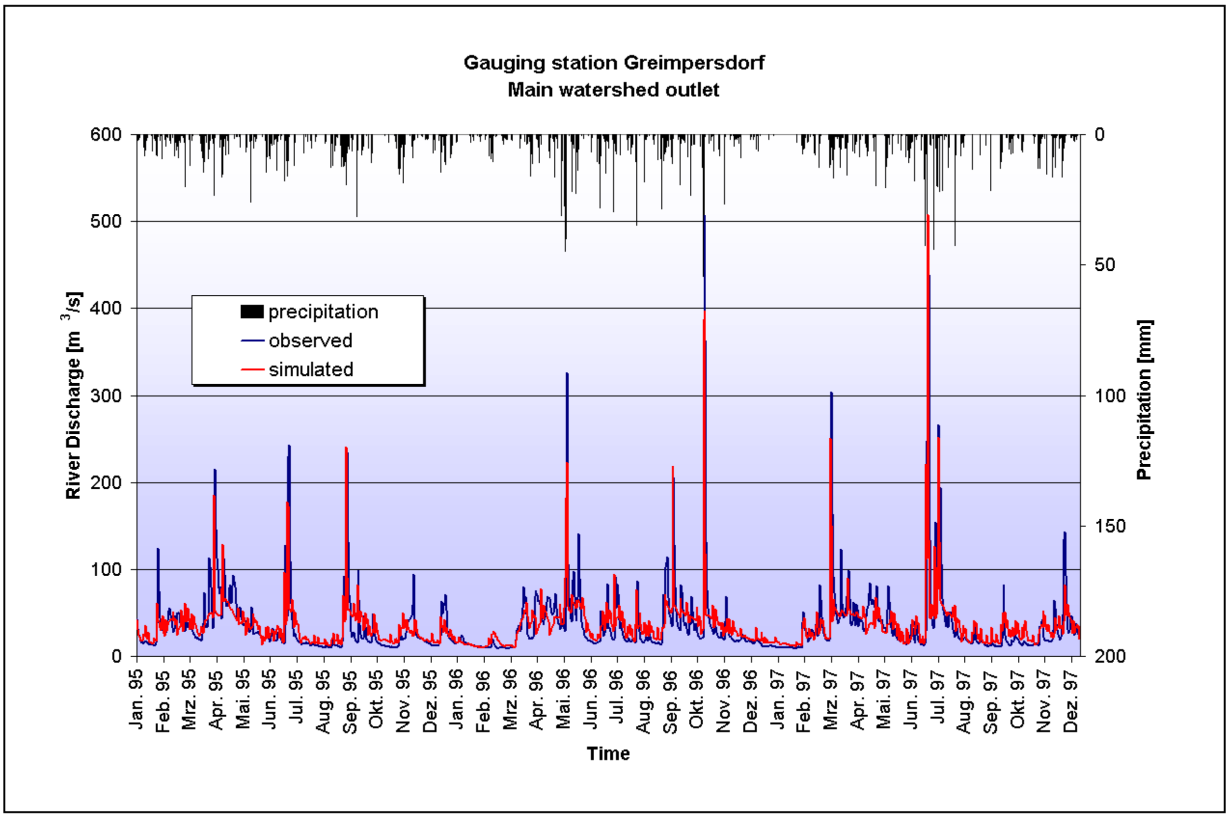


Fig. 5-6: Comparison of the observed and the simulated hydrograph at the gauging station Greimpersdorf (1995-1997)

Figures 5-2 to 5-6 show the hydrographs of the subcatchments and the main outlet of the Ybbs catchment. As to be seen, the model is able to catch the dynamics of the (sub)catchment. The peaks of the Surface Runoff are a little bit underestimated, but the timing of occurance is correctly modelled. Due to lacks in precipitation measurements there are some peaks, which have been modelled, but not registrated in the observed river discharge.
In the period March till May there are deviations between the observed and the simulated Hydrographs, especially in the upstream subcatchments Lunz am See and Opponitz. This deviations can be explained with a not optimal definition of the snow-related model parameter.

In order to estimate the model fit in different hydrologic regimes, the NSC´s for the Ybbs catchment and its subcatchments were calculated in dependence of the average annual river discharge Q_{av} of the subcatchment (Table 5-4).

Fractions of Qaverage	Q<20%	Q<30%	Q<40%	20%<Q<40%	30%<Q<50%	40%<Q<100%	50%<Q<100%	100%<Q<200%	Q>200%	200<Q<400 %	Q>400%	Qaverage [m³/s]
Lunz am See	0.99			0.94		0.67		0.27	0.12			5
Opponitz		0.99			0.98		0.75	0.35	0.29			20
Ybbsitz			0.94			0.6		0.31		0.42	0.35	3
Krenstetten				0.35		0.81		-0.28	0.59			2
Greimpersdorf					0.98		0.5	0.22	0.35			35
Average		0.97		0.81		0.67		0.17		0.35		

Tab. 5-4: River discharge – dependent calculation of the Nash&Sutcliffe coefficients (NSC) for the subcatchments of the Ybbs catchment, based on fractions of the average river discharge (1995-1997)

For every subcatchment the average annual river discharge Q_{av} was taken. Five classes, which should represent the different hydrological conditions, have been defined:

- Class 1: Low flow condition. As value the discharge was chosen which was smaller than 20% of Q_{av}. In case, that there are no measurements for this river discharge, the limit discharge was set to 30% or 40% of Q_{av}.
- Class 2: Higher Low flow condition: As value the discharge was chosen higher than 20% and smaller than 40% (or 30% - 50%) of Q_{av}.
- Class 3: Higher Low flow till mean flow condition: The limit discharge was chosen higher than 40% (or 50%) and lower than 100% of Q_{av}.
- Class 4: Mean flow till lower high flow conditions: The limit discharge was chosen higher than 100% and lower than 200% of Q_{av}.
- Class 5: High flow conditions: The limit discharge was chosen higher than 200% of Q_{av}. In the subcatchment Ybbsitz the high flow conditions were extended about the class, where the limit of the discharge was set higher than 200% and smaller than 400%; and the the limit discharge higher than 400%. This was done due to a limited number of measurements representing the low flow conditions to be able to account 5 classes of flow conditions for this subcatchment too.

As Table 5-4 shows, the SWAT model has a very good model performance in low flow conditions. The mean flow to lower high flow conditions are modelled quite poor, and in lower high flow conditions the model is able to reproduce the average (sub)catchment behaviour. In high flow conditions, the model shows again a poor till acceptable model performances.

This analysis indicates, that the model is well defined to reproduce low flow conditions (Baseflow). Surface runoff events caused by high precipitation events, and which lead to high flow conditions, have been modelled quite in an acceptable way. Concerning the mean flow conditions, there is still a need in an adjustment of the SWAT model. The reason therefore can be seen in an insufficient modelling of runoff events caused mainly by the Lateral flow of the faster Groundwater runoff. Changes in the responsible model parameter (Soil hydraulic conductivity) should be reconsidered.

5.1.5 The Wulka catchment

For the Wulka catchment a SWAT-Project with the following delineations was defined:

- 45 Subbasins
- 106 HRU´s (Hydrologic Response Units)
- 7 landuse classes (after threshold application)
- 5 soil classes (after threshold application)
- 2 point sources (WWTP)

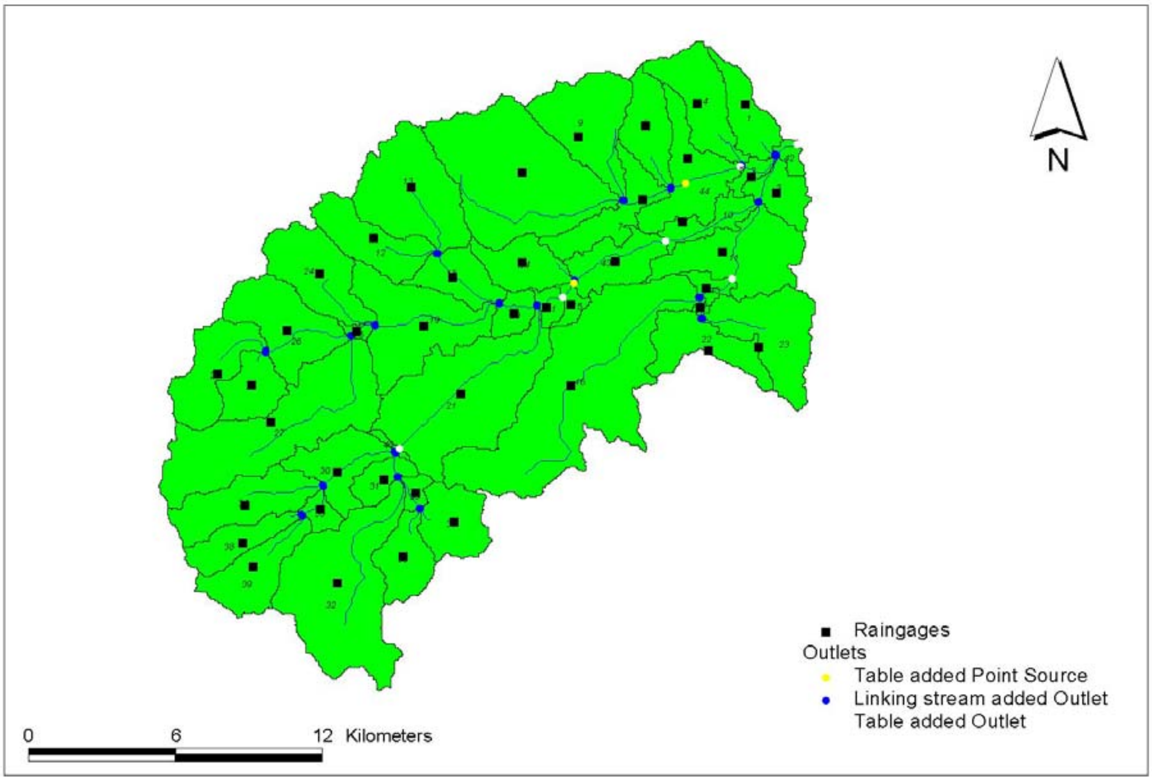


Fig. 5-7: SWAT definitions for the Wulka catchment

Figure 5-7 shows the ready-defined SWAT-project for the Wulka catchment. The point sources have been implemented as tables. Only the two point sources with the most important influence (high contribution to the total river discharge) have been considered. The table added Outlets representing the river gauging stations in order to be able to compare the simulated river discharges against the measured river discharges.

Due to the number and the location of the precipitation stations (see Figure 2-16) in some subbasins problems with precipitation events (no interpolation) and the corresponding river discharges occurred. Thus, a daily Kriging interpolation of the precipitation values and the creation of virtual raingage stations was done in the same way then in the Ybbs catchment.

<u>1. Trial and error method for calibration</u>

The calibration was started, as in the Ybbs catchment, with the trial and error method for the 5 subcatchments. Due to the large number of model parameters the model efficiency that was obtained, was not satisfying.

The parameter have been calibrated, are listed in Table 5-5.

2. Use of an automatic calibration tool for calibration

Also for the Wulka catchment the Shuffled Complex Evolution Optimisation Algorithm was used. For every subcatchment the optimisation was applied. Several combinations of calibration parameters were used to determine the optimal parameter values. In case, that the fitting was not satisfying, some of the "optimised" parameter has been selected again together with a selection of some other calibration parameters, and have been re-entered to the optimisation algorithm again. For every subcatchment between 10 and 20 optimisation calculations have been performed.

The calibration of the (sub)catchment(s) was done successfully. In a later process, one Aquifer parameter was changed, and the due to errors in the simulated river discharge the evapotranspiration in the soil profile was increased. Additionally, tile drained areas were implemented into the SWAT-Projects of the Wulka catchment.

This caused a decrease of the model performances again.

In the last month, a new soil map was obtained by the partner BAW. Now, the activities are concentrated on the implementation of the new soil map with the consideration of tile drained areas into the SWAT-Project of the Wulka catchment. The calibration of the SWAT-Project for the Wulka catchment which containes the new soil map was not successfully finished yet. Therefore, the results of the calibration process of the preliminary SWAT-Project will be presented.

Subcatchment	Walbersdorf	Wulka-prodersdorf	Trausdorf	Oslip	Nodbach	Schützen
NSC 1995-1997 Subcatchments	0.39	0.09	-	0.35	-0.25	-
NSC Schützen 1995-1997	0.48	0.21	0.17	0.27	0.16	0.40
VE [%]	101	102	103	93	71	101

Tab. 5-5: Calibration results for the Wulka subcatchments and the Wulka catchment

In Table 5-5, the results of the catchment and the subcatchments are listed as the NSC´s and the VE´s. The subcatchment Trausdorf was not calibrated as an own subcatchment, because the increase in the areal extend compared to Wulkaprodersdorf is not so important.

The first row shows the model efficiency of the subcatchments which have been calibrated as an own SWAT project. Thus, the subcatchment Trausdorf and the main outlet of the Wulka catchment, Schützen, are without results.

The NSC´s of the subcatchments are very diverse. The fitting of the model is quite poor. Especially, the tributary catchment Nodbach and the subcatchment Wulkaprodersdorf are adjusted quite poor. Because of the change in the aquifer parameter and the evapotranspiration of the soil, the river discharge tend to decrease nearly to zero. Additionally, the implementation of the drained areas caused high peaks in the river discharge, which were not measured in that extent.

Implementing all the found model parameter from the subcatchments into the SWAT project of the whole watershed, the results in the NSC´s (see second row) have been stable or have been increased. The model performance decreased again from the most upstream subcatchment Walbersdorf to the main outlet Schützen. For all the other subcatchments and tributaries, the NSC's decreased drastically. The total Volume of the river discharges were modelled well with exception of the tributary Nodbach.

Generally, the model is able to reproduce the hydrologic behaviour of the catchment. Runoff peaks can be reproduces by surface runoff and runoff from drainages, but some of the dynamics couldn´t be matched. Especially the runoff peak in Sept. 96 was overestimated. The “flowout”-period in the end of 1996 indicates an insufficient definition of the drained soils. In 1997, there are additional difficulties with the river discharge. The reason therefore is to be seen in an overestimation in the soil evaporation.

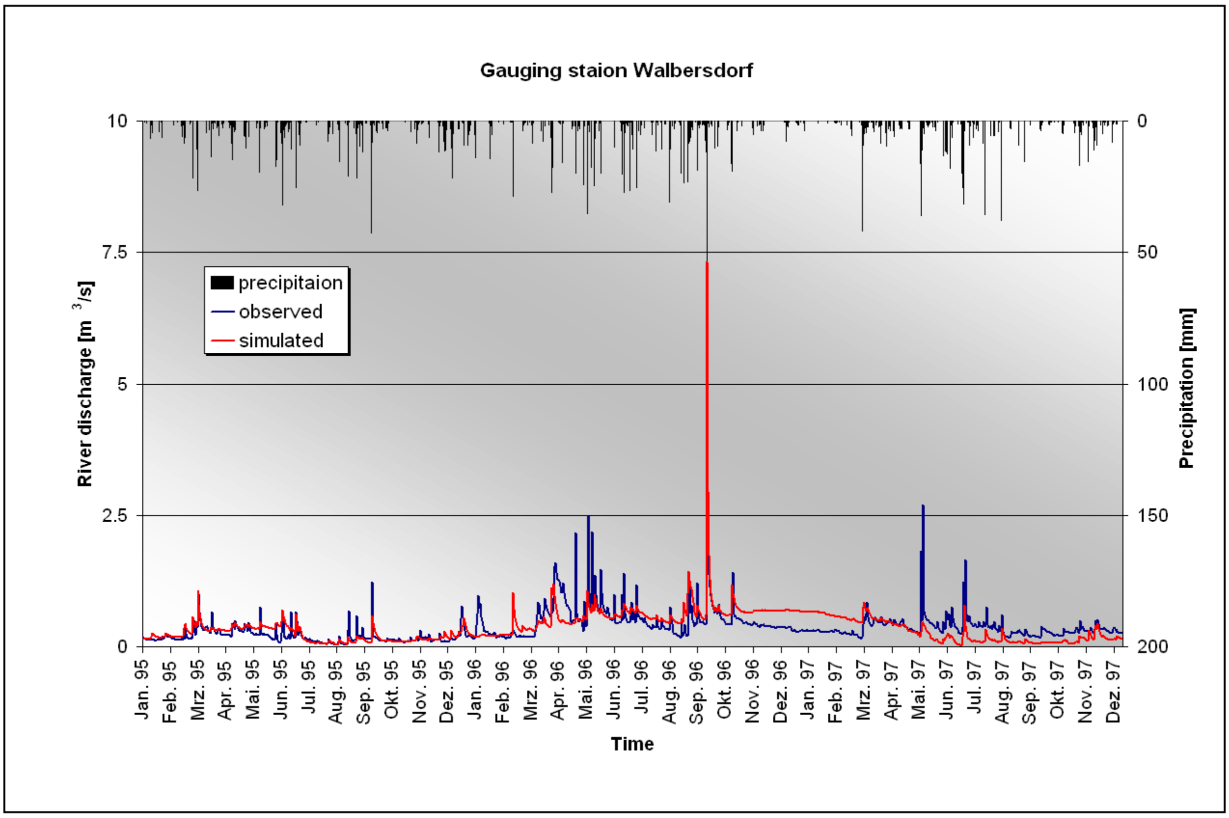


Fig. 5-8: Comparison of the observed and simulated hydrograph of the gauging station Walbersdorf (1995-1997)

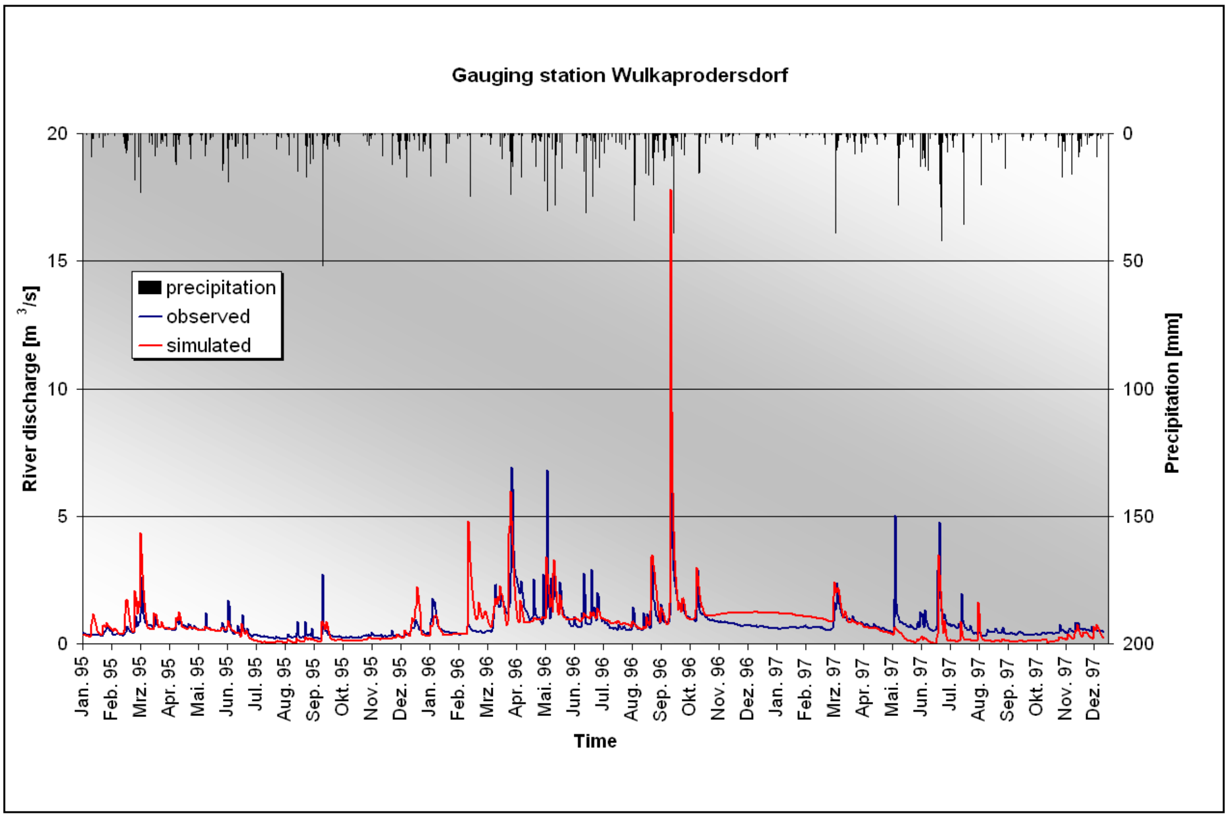


Fig. 5-9: Comparison of the observed and simulated hydrograph of the gauging station Wulkaprodersdorf (1995-1997)

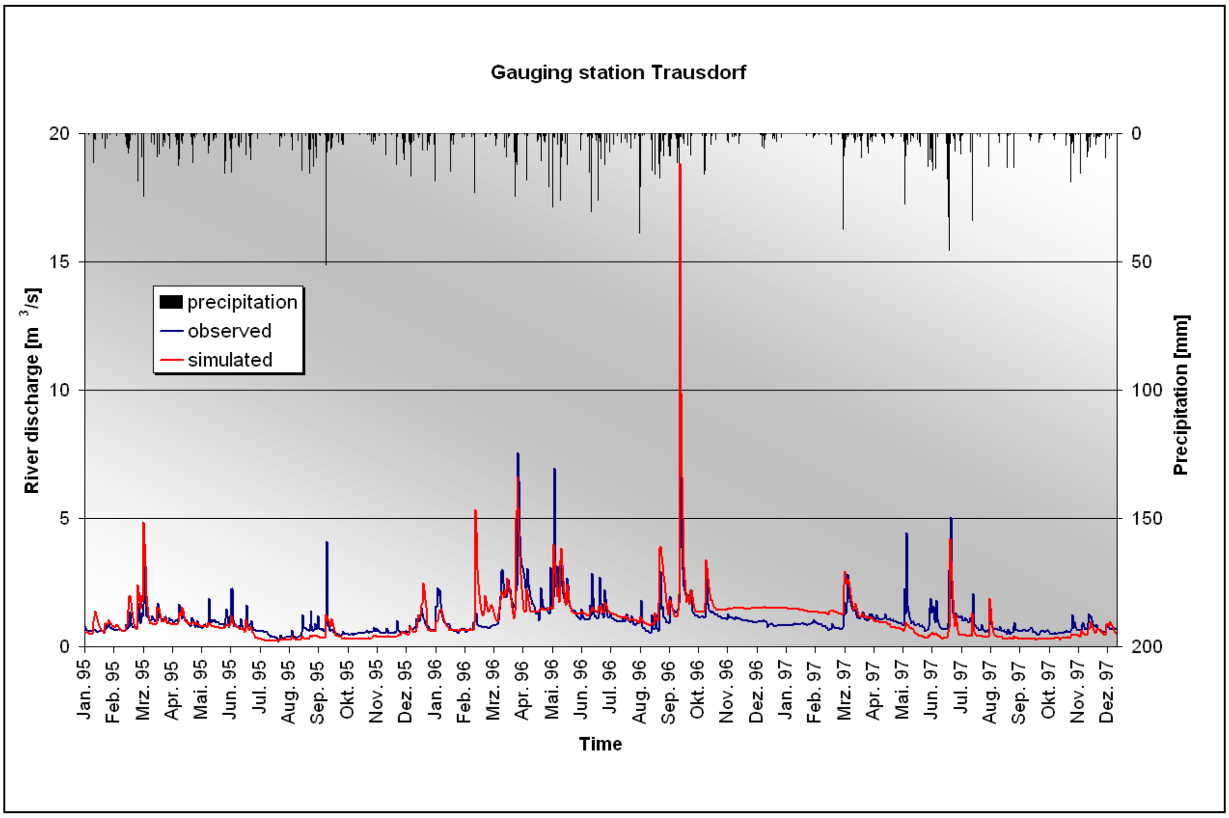


Fig. 5-10: Comparison of the observed and simulated hydrograph of the gauging station Trausdorf (1995-1997)

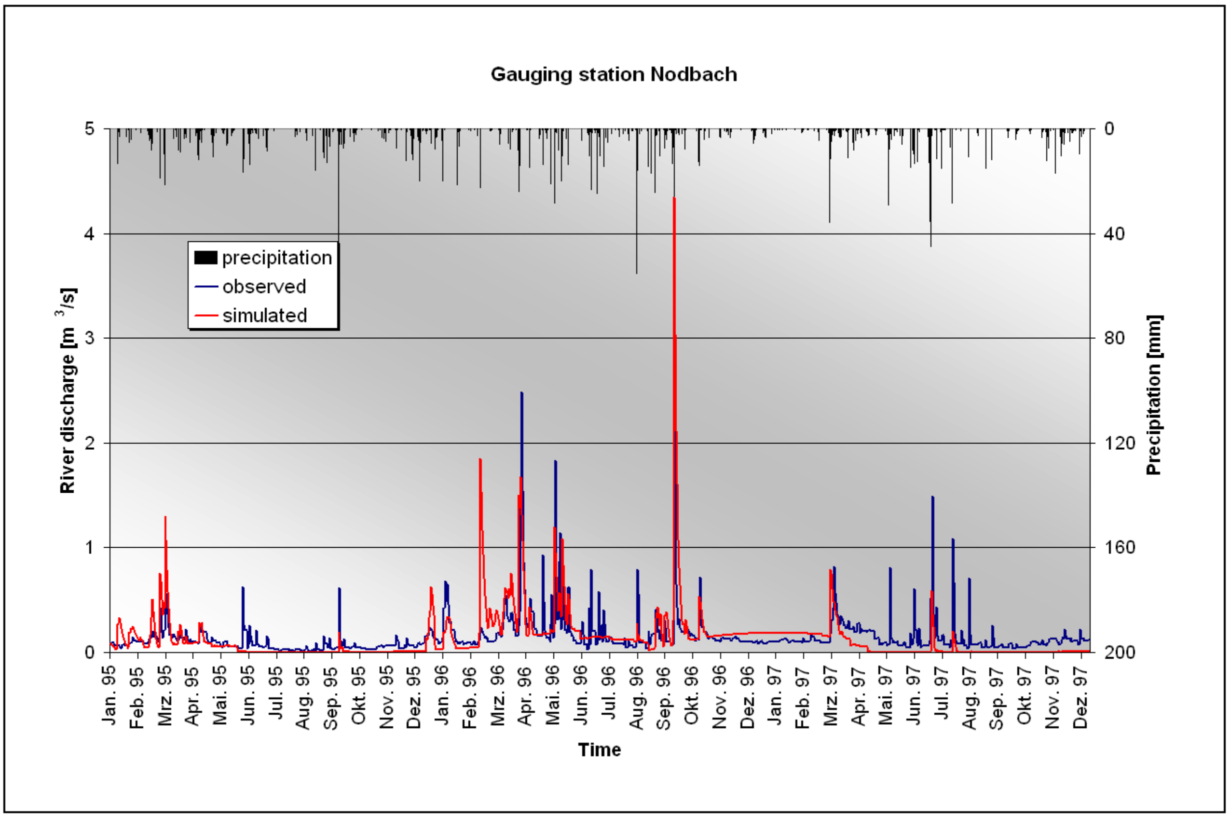


Fig. 5-11: Comparison of the observed and simulated hydrograph of the gauging station Nodbach (1995-1997)

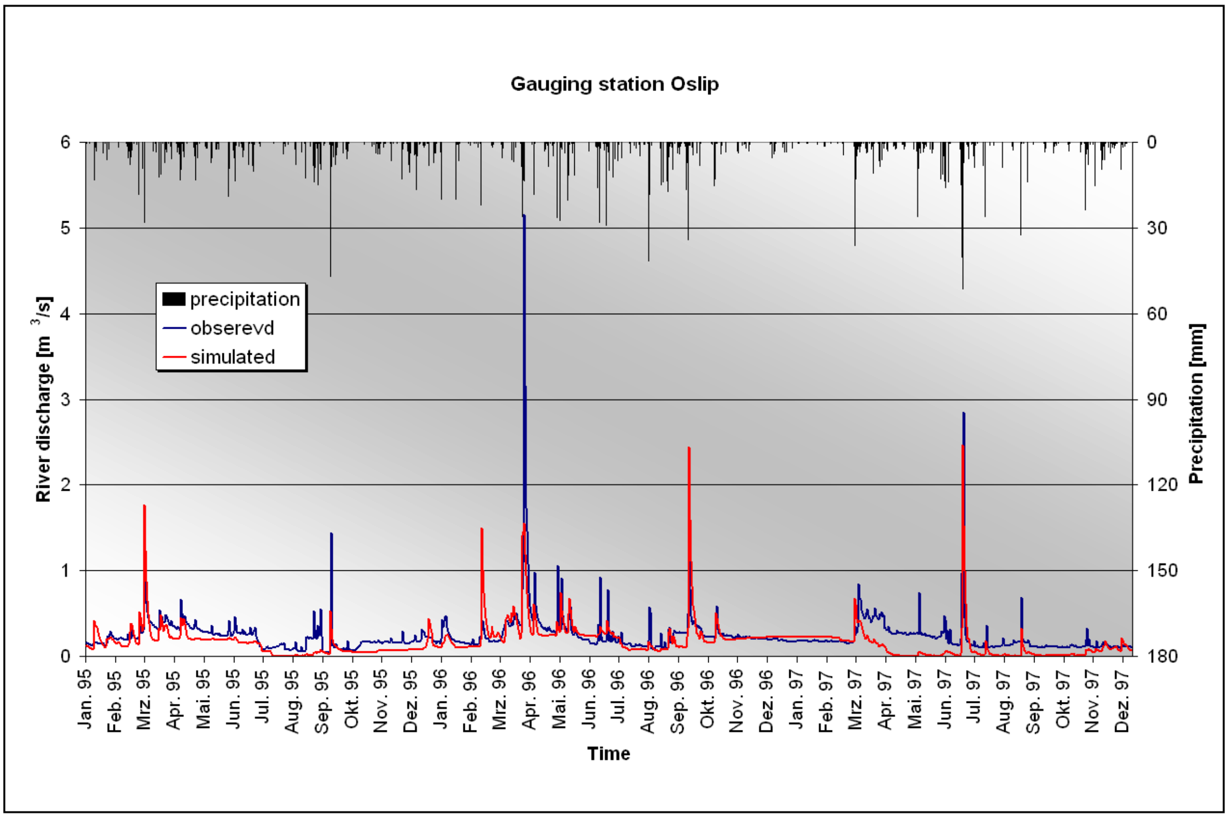


Fig. 5-12: Comparison of the observed and simulated hydrograph of the gauging station Oslip (1995-1997)

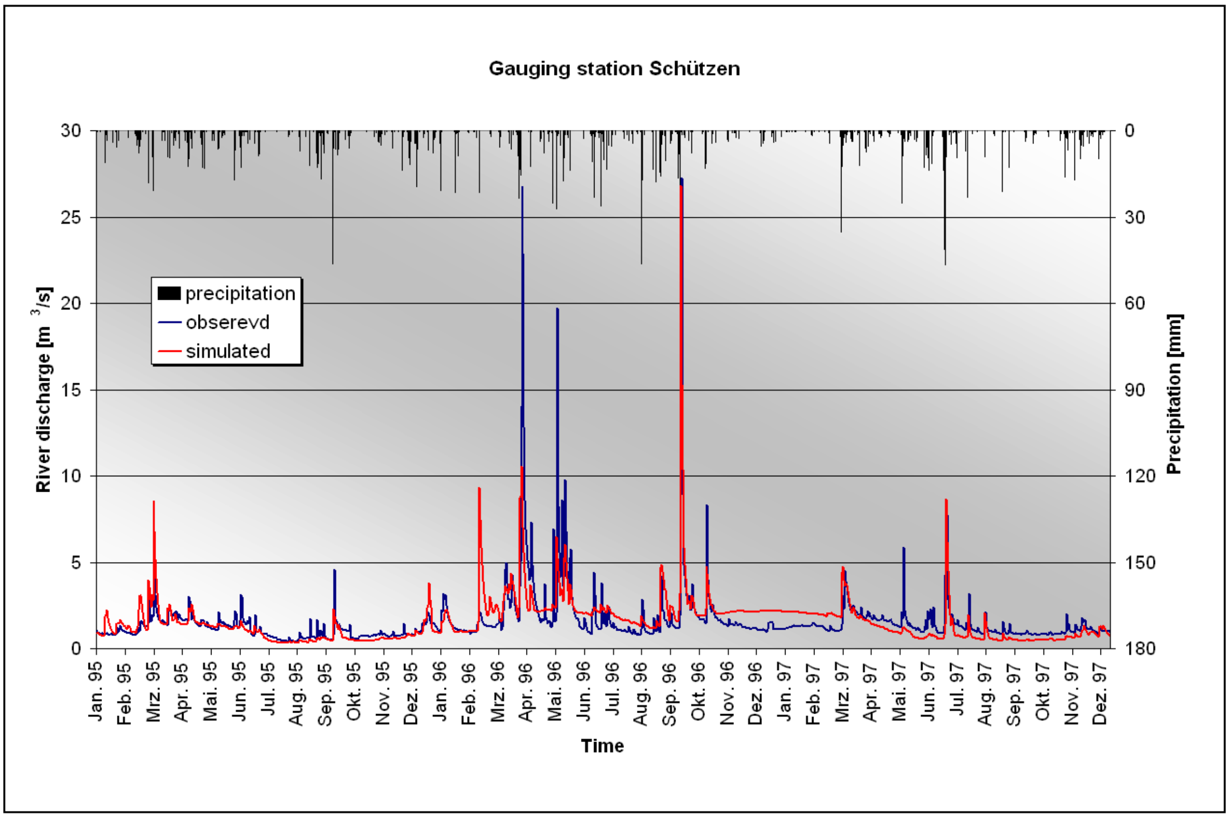


Fig. 5-13: Comparison of the observed and simulated hydrograph of the gauging station Schützen (1995-1997)

Generally, the main outlet Schützen (Figure 5-13) shows the best model behaviour in regard to the model performance and adjustment.

In order to estimate the model fit in in different hydrologic regimes, the NSC´s for the Wulka catchment and its subcatchments have been estimated in dependence of the average annual river discharge Q_{av} of the subcatchment (Table 5-6).

Fractions of Qaverage	Q<20%	Q<30%	Q<40%	20%<Q <40%	30%<Q <50%	40%<Q< 100%	50%<Q <100%	100%<Q <200%	Q>200%	Qaverage [m³/s]
Walbersdorf	0.48			0.19		0.16		-0.1	0.84	0.37
Wulkaprodersdorf		0.28			0.63		0.05	-0.21	0.29	0.76
Nodbach	-0.19			-0.25		-0.04		-0.1	0.24	0.15
Oslip	-1			0.1		-0.44		0.32	0.4	0.24
Schützen		0.93			0.55		0.23	-0.1	0.43	1.6
Average		0.10		0.24		-0.01		-0.04	0.44	

Tab. 5-6: River discharge – dependent calculation of the Nash&Sutcliffe coefficients for the subcatchments of the Wulka catchment, based on fractions of the average river discharge (1995-1997)

The classes of hydrological regimes have been defined in the same way than in the Ybbs catchment. The comments to the definition of the classes is to be find in chapter 5.1.4, Table 5-5.

The model performance in dependence of the flow regime (Table 5-7) is absolutely dependent on the model parameter definition for every subcatchment.
The subcatchment Walbersdorf shows a acceptable model performance in low flow conditions and a good model performance in high flow conditions. Flow conditions

ranging from higher low flow conditions to lower high flow conditions are modelled quite poor.
In the subcatchment Wulkaprodersdorf the model performances decreased nearly in all flow conditions except the higher low flow conditions.
The tributary catchments Nodbach and Oslip show a model performance poorer than the long term mean. Only the high flow conditions are modelled quite acceptable.
At the main watershed outlet Schützen the low flow conditions are modelled quite good, and also the high flow conditions are captured well by the model. The higher low flow conditions and mean flow conditions are modelled in an acceptable way, but in the lower high flow conditions the model performance decreased again to values poorer than the long term mean.

Generally, the Wulka catchment shows the best model performance in high flow condition. That means, processes generating runoff peaks (surface runoff, tile drainage flow) are modelled quite good. Low flow conditions and higher low flow conditions are modelled poor or in an acceptable way. That indicates insufficient model parameter definitions in regard to the groundwater flow. The mean flow conditions and lower high flow conditions are modelled quite poor, what means that the model performances decreased to negative values. Further investigations on the model parameter which are responsible for subsurface runoff (lateral flow) seems to be still important.

5.2 *Validation of the SWAT 2000 model - AUSTRIA*

5.2.1 Validation period

In dependence of the data availability the validation period was chosen as the time series before the calibration period.
In the Ybbs catchment the data of the measured daily outflow of the Lake “Lunzer See” exists till the end of 1997. Thus, the validation interval was determined with the period **1990-1994**.
In the Wulka catchment the data availability of the potential evapotranspiration measurements covers an interval from 1991-1999. Therefore, the period **1992-1994** was used for the model validation in this catchment.

5.2.2 The Ybbs catchment

The validation was made for every subcatchment, which was calibrated. The simulation period for the SWAT 2000 model was chosen with 1989-1997.
During Validation, for all the subcatchments and the whole Ybbs catchment the “Variable Storage” water routing method was used.

Subcatchment	Lunz a.S.	Opponitz	Ybbsitz	Krenstetten	Greimpersdorf
Calibration NSC 1995-1997	**0.23**	**0.37**	**0.39**	**0.56**	**0.37**
Validation NSC 1990-1994	**0.10**	**0.38**	**0.39**	**0.57**	**0.27**
Simulation NSC 1990-1997	**0.16**	**0.36**	**0.39**	**0.57**	**0.38**
Simulation NSC Summer 1990-1997	**0.34**	**0.45**	**0.51**	**0.65**	**0.43**

Table 5-7: Validation results of the Ybbs catchments and its subcatchments

Table 5-7 shows the results of the validation of the Ybbs catchment and its subcatchments. In the first row, the calibration results are listed again to have the possibility of a comparison with the validation results.

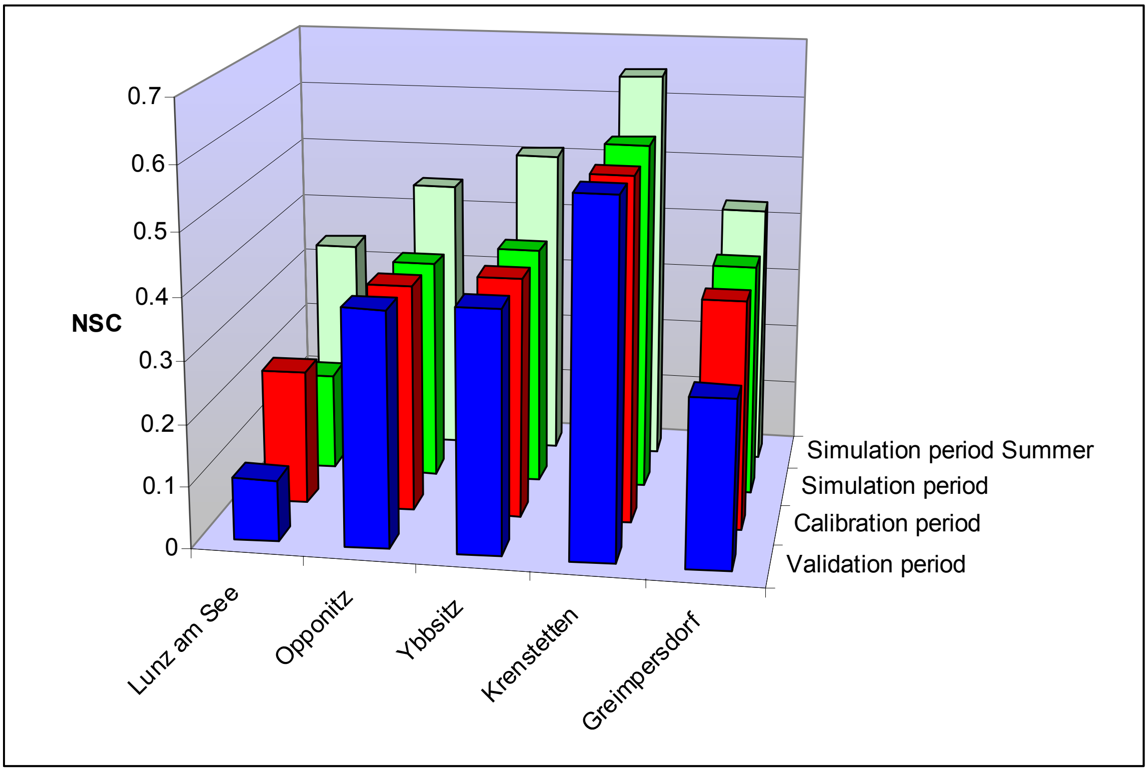


Fig. 5-14: NSC´s of the Ybbs catchment and its subcatchments

The comparison between the NSC of the calibration and the validation period shows, that the validation calibration period give nearly the same model performance than the calibration period. However, because of the validation results and the results for the simulation period 1990-1997 the model is able to reproduce the behaviour of the Ybbs catchment.

The best model performance was noted for the subcatchment Krenstetten. In this subcatchment, the less snow cover and the less complex geological situation seems to be better reproduceable by the model. But also the model performances of the subcatchments Opponitz, Ybbsitz and of the main watershed outlet indicate an acceptable model performance. The poor model performance in the subcatchment Lunz am See is caused by are discussed already in chapter 5.1.4.2.

In general, the model efficiency is better during the Summer months. Due to the large number of snow fall and snow melt parameter, which can be varied, the fitting of the model is poorer in the upper subcatchments (Lunz and Opponitz) with a big influence of snow.

5.2.3 The Wulka catchment

In the Wulka catchment the validation was also performed for every subcatchment, which was calibrated. The simulation period for the SWAT 2000 model was chosen with 1992-1999.
For validation, for all the subcatchments and the whole Wulka catchment the "Variable Storage" water routing method was used.

Subcatchment	Walbersdorf	Wulka-prodersdorf	Trausdorf	Oslip	Nodbach	Schützen
Calibration NSC 1995-1997	0.48	0.21	0.17	0.27	0.16	0.40
Validation NSC 1992-1994	0.42	-0,15	0.18	0.17	-	0.14
Simulation NSC 1992-1997	0.46	0,12	0.17	0.23	-	0.36

Tab. 5-8: Validation results of the Wulka catchment and its subcatchments

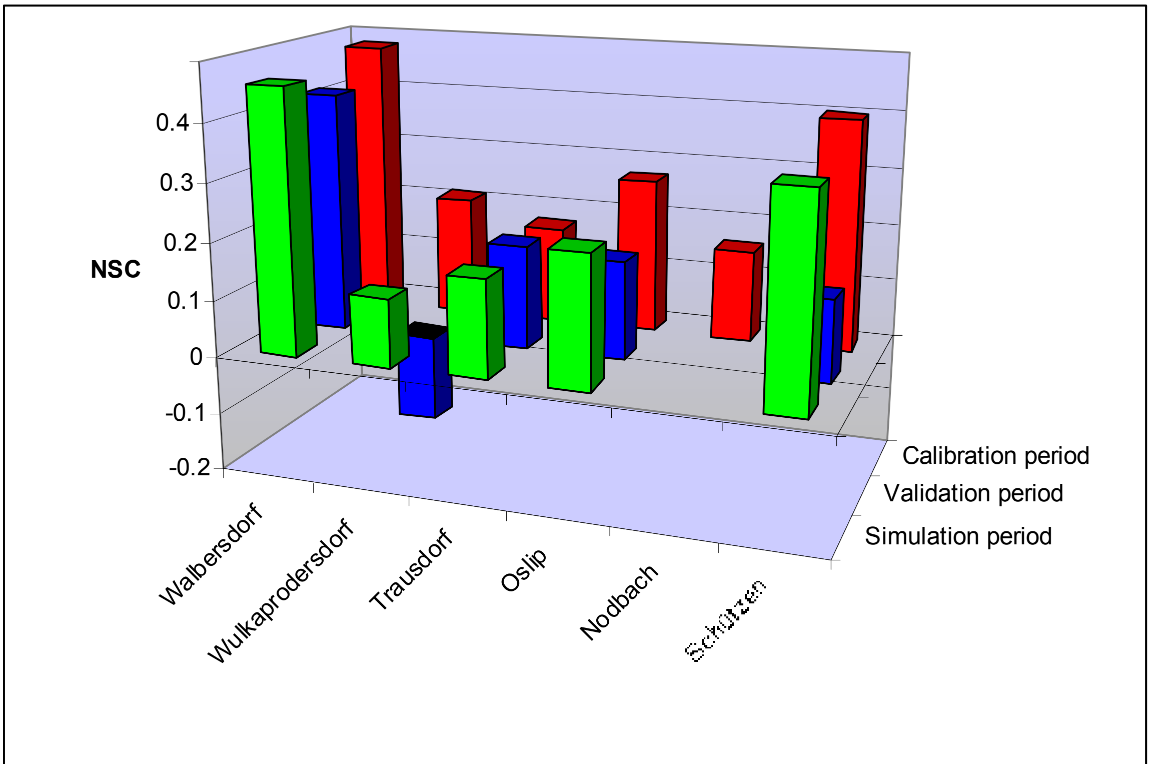


Fig. 5-15: NSC´s of the Wulka catchment and its subcatchments

Table 5-8 shows the validation results of the Wulka catchment and its subcatchments.
Generally, the calibration period show better results than the simulation and the validation period (see Figure 5-15). But because of the results for the simulation period 1992-1997 the model points out to be able to fit the hydrologic behaviour of the watershed.
The best model performance was noted for the first subcatchment Walbersdorf. The simulation performance decreased from the upstream subcatchment to the main outlet. At the main watershed outlet Schützen, the calibration and the simulation

period shows an acceptable model performance. But the validation period indicates that the model parameter definition is still insufficient. This was also clarified by the model performances of the tributary catchments Nodbach and Oslip, and by the subcatchment Wulkaprodersdorf. The model performances of the calibration, the validation and the simulation period are quite poor.

5.3 Calibration and validation of the SWAT 2000 model -HUNGARY

The daily time step was used for the SWAT 2000 model calibration. The total catchment was divided into four sub-catchments. For every sub-catchment separate SWAT project was defined and calibrated according to the measurement at its own outlet. The calibration started at the most upstream sub-catchment. After the calibration of the first area, the sub-catchment-related model parameter-set was applied to the next downstream sub-catchment as initial values and modified subsequently until the computed and the measured time series were suited in an acceptable level. Only the relevant and sensitive parameters were changed in their possible range. The calibration procedure was done for the first three years (1997-1999). In the calibration both the period average and the daily discharges were compared with the measured values. As a control of the calibration the Nash-Sutcliffe coefficient (R^2) was also calculated.

The verification was carried out for the last two years (2000-2001, not used for calibration) at all sub-basin outlets. The model calibration procedure was considered successful, when the difference between the simulated and observed discharge values was acceptable for the years of verification, too. The results of the calibration and the verification are presented in the next chapter.

No calibration was made for the other models, because they are based on the measured discharges. DIFGA separates the observed flow time series into different components and MONERIS calculates the groundwater flow as a difference of the measured flow and the sum of the other simulated flow components. So these methods depend on the observed values.

Details for the calibration and validation period was given together with the water balance results in chapter 6.4.1.

5.4 Calibration of the SWAT 2000 model – ROMANIA

The calibration of the model was made using daily stream discharge recordings from three locations (Calugareni, Vadu Lat and Moara din Groapa) along the Neajlov River for the period 1995 - 2001.

Parameter	Digitised	Computed
Catchement area (km^2)	3795	3721
Number of subcatchments	45	53

Tab. 5-9: Comparison between digitized and computed catchment

For the model calibration were made about 160 SWAT runs with different adjustments in which a series of parameters were refined. The main refined parameters were: Potential Heat Units (PHU - total number of heat units or growing degree days needed to bring plant to maturity); Soil evaporation compensation factor (ESCO - this factor adjusts the depth distribution for evaporation from the soil to account for the effect of capillary action, crusting and cracks); Curve Number (CN - SCS runoff curve number for moisture condition); Available Water Capacity (AWC - this is the volume of water that should be available to plants if the soil, inclusive of rock fragments, was at field capacity (mm H_2O/mm soil)); Minimum re-evaporation depth (REVAPMN - threshold depth of water in the shallow aquifer for "revap" or percolation to the deep aquifer to occur (mm H_2O)); Groundwater return flow threshold (GWQMN - the depth of water in the shallow aquifer at which return flow is occuring); Average slope steepness (SLOPE - the GIS interfaces assigns the same value to this variable for all HRUs within a subcatchment (m/m)); Average slope length (SLSUBBSN - the GIS interfaces assigns the same value to this variable for all HRUs within a subcatchment (m)); Baseflow alfa factor (ALPHA_BF - characterizes the groundwater recession curve (days)).; Evapotranspiration computation method (Penman - Monteith, Priestley – Taylor and Hargreaves).

The best results, were obtained reducing CN with 25, AWC with 0.03 and by setting CHK1 at 2 mm/hr, CHK2 at 50 mm/hr, GWQMN at 0, GWDELAY at 250, ABF at 0.25, REVAPMN at 0.3 and CHN1 and CHN2 at 0.01for all subcatchments. The efficiency of the model was computed using the Nash – Sutcliffe coefficient:

$$R^2 = 1 – [\Sigma (Qm – Qp)^2] / [\Sigma (Qm – Qavg)^2], \text{ where}$$

R^2 = coefficient of efficiency;
R^2 = 1 = best fit (Qm = Qp);
Qm = measured value of river discharge;
Qp = predicted value of river discharge;
Qavg = average measured value of river discharge.

After the calibration procedure the Nash and Sutcliffe coefficient has increased from –8.6 to 0.47 for Calugareni, from –2.26 to 0.31 for Vadu Lat and from –0.59 to 0.18 for Moara din Groapa. For all three locations the river discharge is having a period of high water levels during the winter and early spring, generated by the high levels of snowfall and snowmelt (Figure 5-17). This period is very well reflected by the model. The main difference between the measured and calibrated discharge is recorded in the autumn when the measured discharge is having a slow increasing trend while the calibrated discharge is keeping the lowering trend. This fact could be generated by the presence of only one meteorological station, which recorded smaller levels of rainfall compared with the catchment average for that period.

Location	Average (m3/s)	Maximum (m3/s)	Minimum (m3/s)
Calugareni	7.8	172.5	0.12
Vadu Lat	3.79	58.98	0.12
Moara din Groapa	0.93	18.98	0.11

Tab. 5-10: Average, minimum and maximum computed discharge for the Neajlov River at calibration points

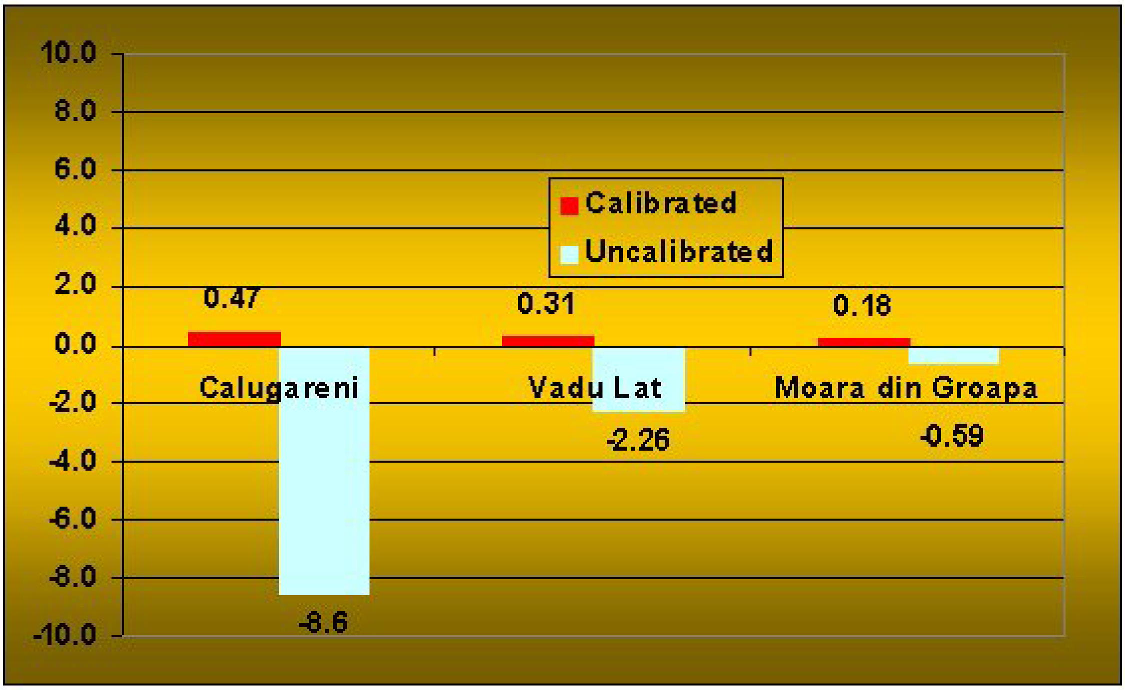


Fig. 5-16: Nash-Sutcliffe coefficient for calibration points (daily basis)

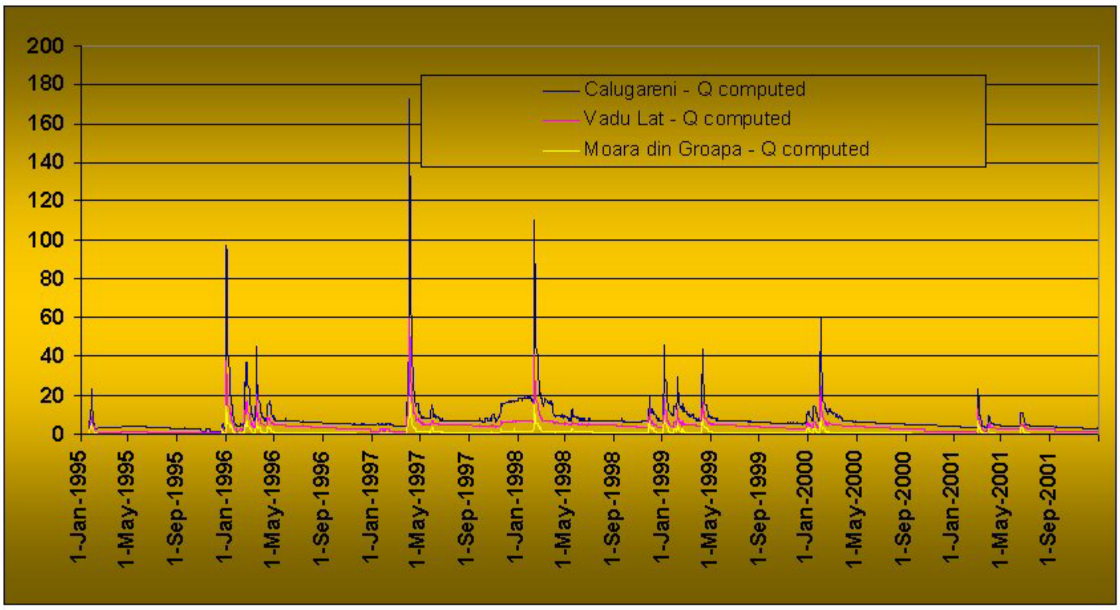


Fig. 5-17: River discharge at calibration points

Discharge (m3/s)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Monthly Average
Calugareni - measured	11.3	13.4	11.0	14.5	5.4	5.1	3.4	3.5	4.2	4.8	5.0	6.2	7.3
Calugareni - computed	10.9	13.5	9.1	13.6	6.7	6.5	5.9	5.6	5.3	5.0	5.6	6.7	7.8
Vadu Lat - measured	6.1	5.3	4.9	6.0	3.2	3.7	2.8	2.7	2.6	2.8	2.8	3.4	3.8
Vadu Lat - computed	4.4	5.5	4.2	6.6	3.9	3.7	3.4	3.1	2.8	2.5	2.6	2.8	3.8
Moara din Groapa - measured	1.4	1.5	0.8	1.5	0.6	1.1	0.4	0.5	0.5	0.5	0.5	0.7	0.8
Moara din Groapa - computed	1.4	1.7	1.1	1.7	0.9	0.9	0.7	0.6	0.5	0.5	0.6	0.7	0.9

Tab. 5-11: Comparison of monthly average measured and computed river discharge

The computed Nush – Sutcliffe coefficient on monthly basis is showing significant improvements for SWAT model efficiency. The obtained values are: 0.77 for Calugareni, 0.45 for Vadu Lat and 0.40 for Moara din Groapa.

The comparison of monthly average of computed and measured river discharge, calculated on a daily basis, is showing the best fit for Moara din Groapa station, which has the same month for maximum and minimum river discharge. Vadu Lat station has the minimum measured river discharge in September while the minimum computed is in October. The Calugareni station has the same month of maximum river discharge for both computed and measured values.

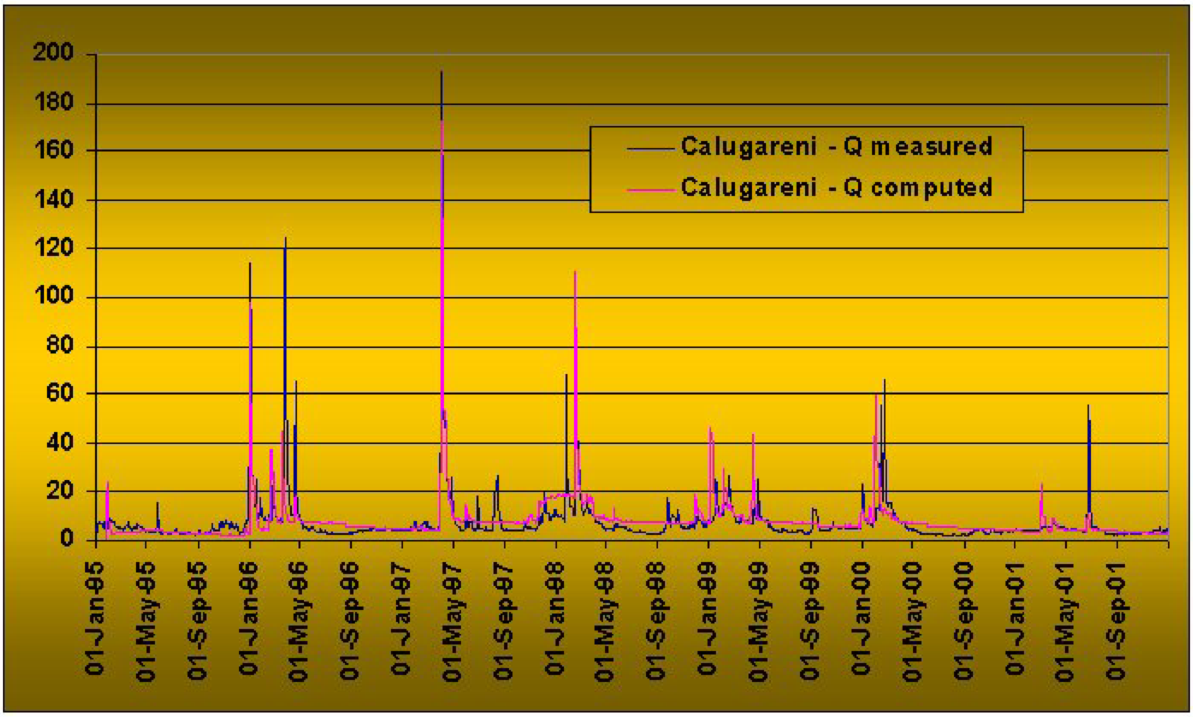


Fig. 5-18: Comparison between measured, uncalibrated and calibrated river discharge values at the Calugareni station

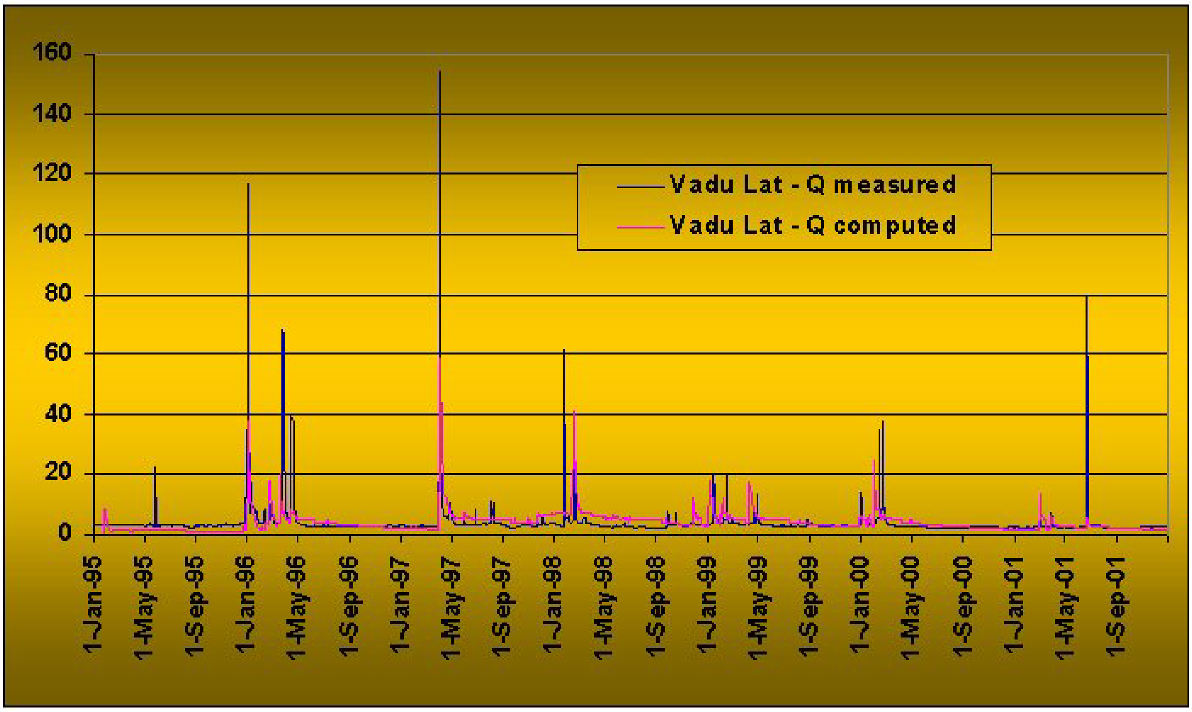


Fig. 5-19: Comparison between measured, uncalibrated and calibrated river discharge values at the Vadu Lat station

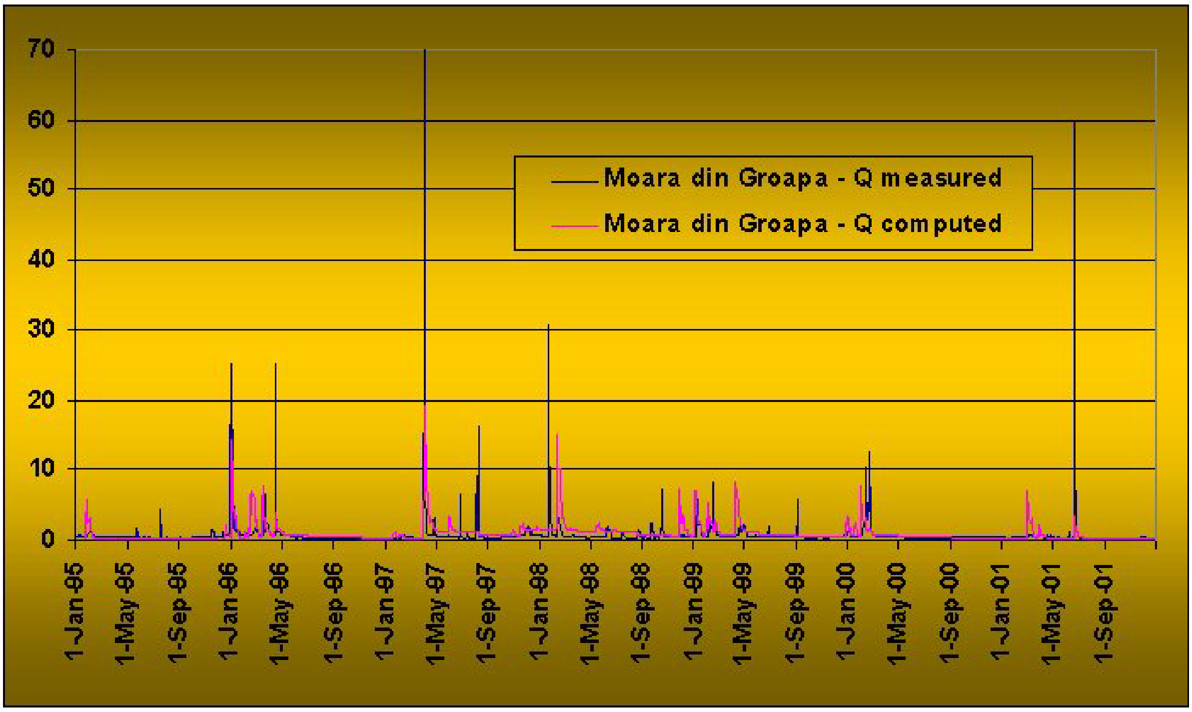


Fig. 5-20: Comparison between measured, uncalibrated and calibrated river discharge values at the Moara din Groapa station

Finally it has to be mentioned that the calibration of SWAT model was based on the different proportion of runoff (surface, lateral and groundwater) resulted from the hydrograph separation made with DIFGA.

5.5 Validation of the SWAT 2000 model – ROMANIA

One method used for validation of SWAT results at the Neajlov basin scale was the classic formula expressed by E. A. Bruckner (1887) and modified by Lvovici (1963):

$$x = y+z + \Delta w$$

or

$$x = u+s+z + \Delta w$$

where

x – precipitation amount on basin;
y – total runoff
s – surface runoff;
u – aquifer recharge (both shallow and deep);
z – evapotranspiration;
Δw – consumption / accumulation of water resources.

In the discussed case the human impact was neglected. Also it has to be mentioned that for long term analysis the term Δw could be neglected.

This formula was used by Ujvari (1972) which has computed the water balance for the Neajlov basin based on data provided by the national hydrological station network.The results of the comparison between Ujvari's results and SWAT results are showed in the table bellow.

Period	Area (km2)	Mean height (m)	q (m3/s)	x (mm)	y (mm)	s (mm)	z (mm)	u (mm)
Calugareni								
1950 - 1967	3795	125	6.48	595	58	48	537	10
1995 - 2001	3720	122	7.3 / 7.8	495	52	11	413	41
Moara din Groapa								
1950 - 1967	372	202	1.28	655	109	89	546	20
1995 - 2001	343	211	0.84 / 0.93	495	86	33	412	53

Tab. 5-12: Comparison between literature data (1950 - 1967) and SWAT output results (1994 - 2001)

Legend: q – river discharge (measured/computed), x – precipitation amount, Y – total runoff, s – surface runoff, z – evapotranspiration, u – groundwater runoff

The comparison shows an good correlation for the geomorphological features of the Neajov river at both stations. The river discharge and the evapotranspiration is showing also acceptable values being proportionally reduced due to the lesser amount of precipitation. The main difference is generated by the different proportions of hydrograph components. While in the 1950 – 1967 period the main contribution to streamflow was generated by the surface runoff (82% from water yield for Calugareni and 81% for Moara din Groapa) in the 1995 – 2001 period the main contribution to streamflow is generated by the groundwater runoff (79% from water yield for Calugareni and 61% for Moara din Groapa). These values were generated by the calibration of SWAT model with the results of DIFGA model separation.

Another way to validate the results of the model is to use the classification of rivers in function of the ratio of different water balance components, as shown in the bellow picture (Diaconu, 1994). The rules for river classification are:

- If the surface runoff is representing more than 60% of the water yield then the river flow is considered to be surface dominated (noted with “S”);
- If the groundwater runoff is representing more than 60% of the water yield then the river flow is considered to be groundwater dominated (noted with “U”);
- If the surface runoff is representing 40 - 60% of the water yield and groundwater runoff is representing 60 – 40% from the water yield than the river flow is considered to be mixed (noted with “M”);
- If the source of surface runoff is rainfall in proportion greater than 60% than the river flow is belonging to the subtype “p” ;
- If the source of surface runoff is snowmelt in proportion greater than 60% than the river flow is belonging to the subtype “z” ;
- If the the source of surface runoff is rainfall in proportion of 40 - 60% and snowmelt in proportion of 60 – 40% than the river flow is belonging to the subtype “m” ;

Component	Values (mm)
Surface runoff	15
Groundwater runoff	52
Water yield	66
Rainfall	415
Snowmelt	80
Precipitation	495
River category	Up

Tab. 5-13: River category from Neajlov basin (based on SWAT reults)

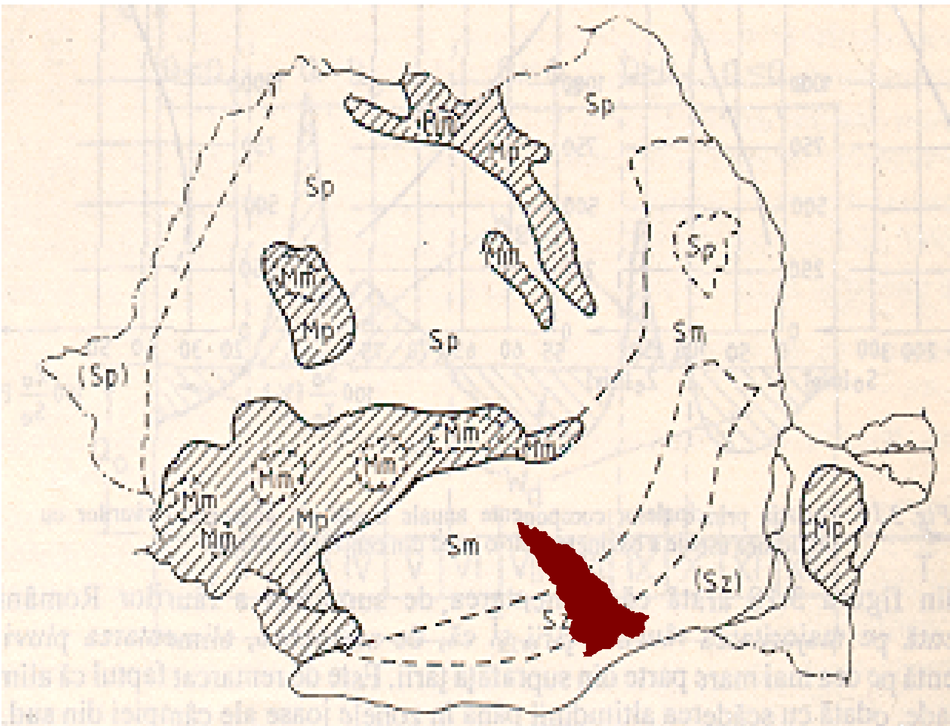


Fig. 5-21: River categories extent based on streamflow sources ratio

The results of the comparison between the literature and SWAT output is showing that in literature the Neajlov river is belonging to the type “S“ (main source of the river flow is the surface runoff), same as all extracarpatic rivers of Romania, while after the calibration of SWAT model with DIFGA results the Neajlov river is belonging to the type “U” (main source of the river flow is the groundwater). There is also difference for the subtype class, because while in the literature the subtype is “m” or “z” (the source of surface runoff is mixed or is snowmelt) in the SWAT output the Neajlov basin is belonging to the subtype “p” (main source of surface runoff is rainfall). This situation could be explained by the lower values of air temperature (for example 21.5 ^{0}C multiannual average in July) from literature compared with those used for SWAT run (24.5 average on 8 years for July), which has as a consequence smaller values for snowfall and snowmelt processes in the SWAT simulation.

6 Calculation of the water balance for every case study region

6.1 The runoff components definition of the different models

Table 6-1 shows the components of the different models in order to enable the comparison of the calculated results.

	SWAT	***Moneris***	***DIFGA***
River Discharge	WY	Q	Q
Urban Runoff	(Point Sources)	$Q_{URB}+Q_{PS}$	-
Transmission Losses	TLOSS	-	-
Baseflow	GWQ	Q_{GW}	QG1+QG2
Lateral Flow (Interflow)	LATQ		
Surface Runoff	SURQ	Q_{RO} (+ Q_{AD})	QD
Drainage Runoff	TILEQ	Q_{DR}	

Tab. 6-1: Comparison of the model components of the DIFGA, SWAT and Moneris model

In order to compare the results have been calculated with the different model types, Table 6-1 shows the different components are produced by the models.

The different model definitions of the runoff components contributing to the groundwater leading to difficulties in comparison of this components to each other. While the SWAT model is simulating the three runoff components seperatly (but the Baseflow and Lateral Flow are summerised to the Groundwater Flow), in the Moneris model the Baseflow and the Lateral Flow are included in the Groundwater Flow. The situation in the DIFGA model is a little bit more difficult. The Surface Runoff and a part of the Lateral Flow are merged together in the Direct Runoff; but furthermore the fast Groundwater (QG1) contains also a part of the Lateral Flow. The Baseflow is defined as the slow Groundwater and the other part as the fast Groundwater.

The Urban Runoff is considered in the SWAT model as the contribution of point sources (daily, monthly or yearly constant loading or measured values). A separate description as a runoff component is not possible. A quantification of the influence is possible by simulations with and without the contribution of the point sources, and a comparison of these scenarios. The Urban Runoff will be considered in the Moneris model as the Runoff from point sources and the Runoff from paved areas.

The consideration of the contribution of drained areas is provided by the SWAT model and the Moneris model. The Moneris model calculates the fraction of drainage runoff in relation to the soil type (clay, silt-content). In the SWAT model a consideration of drained areas will be done by definition for certain HRU´s.
For the Wulka catchment the definition of drained areas was tested. The model performance was so poor, that the simulation was done without consideration of drained areas yet.

As a main difference between the models there has to be mentioned, that the Moneris model calculates with net catchments, means that the watershed area of the previous subcatchment will be subtracted from the watershed area of the next subcatchment.
The DIFGA model uses subcatchments including the previous one. The calculation can be also performed for netcatchments.
The SWAT model calculates only for whole subcatchments which include the watershed area of the previous one.

6.2 Average annual water balance - AUSTRIA

6.2.1 The SWAT 2000 model

The average annual water balance was estimated for both catchments, the Ybbs catchment and the Wulka catchment, for the simulation period 1991-1997.

	Ybbs		Wulka	
	[mm/a]	[% of p/r]	[mm]	[% of p/r]
Precipitation	1377		708	
Evapotranspiration	376	27	576	81
Snow fall	128	9	45	6
Snow melt	96	7	27	4
Surface runoff	181	19	5	5
Lateral Flow	324	35	12	10
Base Flow	425	45	43	40
Tile Drainage	0	0	20	19
Water Yield	930	101/67	107	106/15
Measured Discharge	923	100	101	100
Transmission losses	7	-1	1	-1
Point sources	7	1	28	26
Sublimation	31	2	18	3

Tab. 6-2: Average annual water balances for the Ybbs catchment and the Wulka catchment for the period 1991-1997

Table 6-2 shows the results of the water balance calculations. The fractions given in the columns 2 and 4, are related to either to the precipitation value (p - blue script) or to the total water yield (r - red script). The fraction of total amount of water during the simulation period was compared to the total measured river discharge (green script).

As to be seen, the total amount of water runs out of the catchment, the Wulka catchment has an total Water Yield of nearly 15% related to the total Water Yield of the Ybbs catchment.

6.2.1.1 The Ybbs catchment

In the Ybbs catchment, the average annual precipitation has an amount of about 1377mm. The average annual evapotranspiration amounts with 375mm about 27 % of the average precipitation. That means, considering storage processes, 67 % of the precipitation is contributing to the runoff generation in the catchment.
The Snow fall and snow melt processes seemed to have been underestimated. The amount of the precipitation falls as snow, is only 9%. In the catchment, there is no permanent snow cover modelled. The snow melt rate amounts 7% of the precipitation. The residue is lost by sublimation.
Looking to the HRU´s , the following characteristics can be descriped.

Soil	Landuse	Surface runoff [mm]	Ground-water flow [mm]	Curve Number of the Landuse	Hydrological group of soil	Average slope [%]	Min…Max slope [%]
Amst.	BROM	119	462	75	C	8	8…9
Amst.	CORN	146	390	79	C	8	8…9
Amst.	SGBT	158	353	80	C	8	8…9
Gaming A.	BROM	303	702	75	C	35	2…50
Gaming A.	FRST	106	751	65	C	30	30
Gaming A.	SGBT	149	373	80	C	2	2
Gaming A.	URMD	786	226	90	C	23	20…29
Gaming K.	BROM	106	901	59	B	41	26…62
Gaming K.	FRST	103	1070	55	B	40	20…56
Gaming K.	URMD	889	355	90	B	20	20
Gaming F.	BROM	351	798	75	C	46	32…62
Gaming F.	FRST	211	937	65	C	43	20…62
Gaming H	BROM	106	431	75	C	14	9…21
Gaming H	SGBT	156	367	80	C	12	10…14
Gaming M1	BROM	39	677	59	B	28	14…37
Gaming M1	FRST	25	669	55	B	28	26…29
Gaming M1	URMD	486	176	90	B	29	29
Gaming M2	BROM	327	385	84	D	30	25…37
Gaming M2	FRST	150	669	70	D	30	26…34
St. Peter	BROM	169	497	75	C	17	2…50
St. Peter	CORN	138	333	79	C	6	4…9
St. Peter	FRST	225	1023	65	C	36	20…52
St. Peter	SGBT	152	329	80	C	7	2…14
St. Peter	URMD	777	244	90	C	23	19…29

Tab. 6-3: Average annual contribution of the HRU´s to Surface Runoff and Groundwater Flow

Table 6-3 shows the behaviour of the different HRU – types in regard to contribution to the Surface Runoff and the Groundwater Flow (Lateral Flow + Base Flow).
The Terms of Table 5-3 in regard to the Landuse classes are the following:

- BROM - Meadow ⇒ Landuse class Evergreen land
- CORN – Corn ⇒ Landuse class Spear Fruit
- SGBT – Sugar Beet ⇒ Landuse class Root Crop
- FRSD – Forest ⇒ Landuse class Forest (mixed, deciduous, coniferous)
- URMD – Residential ⇒ Landuse class Urban area

The Soil types are aggregated in regard to the hydrologic group and the location of the soils.
Table 6-3 shows on one hand the contribution of every landuse type to the surface runoff respectively to the groundwater flow (means here lateral flow + baseflow) in dependence of the soil type, which is underlying the landuse type. On the other hand the location of the landuse types and the soil types is indicated by the average subbasin slopes. Generally, in the sum (surface runoff + groundwater runoff) the contribution of the HRU's are located near the main watershed outlet, is not as high as the contribution of the HRU's located in the upstream part of the watershed. This is caused by the rising precipitation with rising elevations / rising slopes.
Fig. 6-1 shows the dependencies graphically which are listed in Table 6-3:

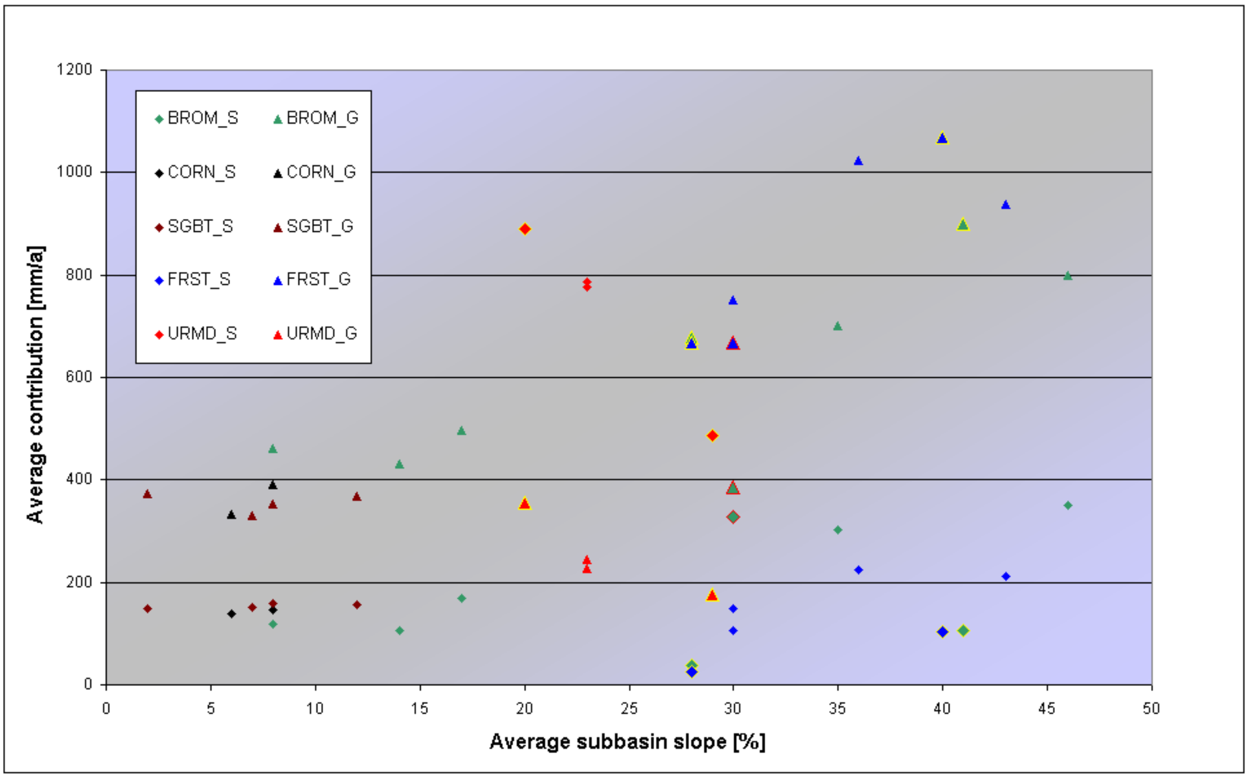


Fig. 6-1: Average annual contribution of the HRU's in dependence of the subbasin slope and the soil hydrologic group (group B: yellow border, group C: no border, group D: red border)

The amount of Surface Runoff and Groundwater Flow of the HRUs is dependent on both, the location in the catchment (expostition to precipitation) and the landuse/soil class.
The Curve Number (CN) of the landuse type depends on the Hydrological group of the soil (Column 5), rises from A (saturated conductivity of the soil > 250mm/h $\Rightarrow$ low CN) to D (saturated conductivity of the soil < 10mm/h $\Rightarrow$ high CN). The variation in the CN for different landuse types (with the same soil type) take the different coverage index (i.e. LAI) into account (high coverage $\Rightarrow$ low CN; sparsely coverage $\Rightarrow$ high CN).
In Table 6-3 the amount of Surface Runoff increases with the rising Curve Number (CN) of the Landuse types and hydrological group of the soil. Complementary, the amount of Groundwater flow decreases with the rising Curve Number.

The Surface Runoff is the highest one in the HRUs with Residential characteristics (URMD) due to the fraction of imperved areas. This is the only landuse type, where the amount of surface runoff exceeds the amount of groundwater flow.
The landuse type Pasture (BROM) is represented in all parts of the watershed. The contribution to the surface runoff rises with rising average subbasin slopes, but not as drastic as the increase in the contribution to the groundwater flow. The soil types of the hydrological group B (D) are characterised by a lower (higher) contribution to the surface runoff and a higher (lower) contribution to the groundwater flow.
The landuse types are representing the arable land, mainly are located in the part of the watershed with low elevations /low subbasin slopes. The contribution to the groundwater flow is higher than the contribution to the surface flow, but due to small changes in the subbasin slopes there is no significant change in the amount of the contribution.
The location of the landuse type forest (FRST) can be indicated in the upstream parts of the catchment. The contribution to the surface runoff is compareable to those of the other landuse types, but due to the higher amount of precipitation in the upper parts (southern parts) of the catchment, the specific contribution to the surface runoff is lower, and the contribution to the groundwater runoff is with approximately 5 times much more higher than those of the other landuse types.
Generally, the contribution to the Surface Runoff is nearly equal for all landuse types (with exception of the residential areas). With rising subbasin slopes, the contribution to the surface runoff increases as well. The contribution to the groundwater flow rises with increasing average subbasin slopes, too.

The main water balance components of the subcatchments of the Ybbs catchment

For every subcatchment of the Ybbs catchment, a separate SWAT-Project was defined and a water balance was calculated. A comparison of the main water balance components of the subcatchment is listed in Tab. 5-4:

Catchment size [km^2]	**Lunz** Subbasin1 *115*	**Opponitz** Subbasin2 *504*	**Ybbsitz** Tributary *98*	**Krenstetten** Tributary *159*	**Greimpersdorf** Main outlet *1117*
Annual average precipitation [mm/a]	**1830**	**1687**	**1382**	**983**	**1377**
Evapotranspiration [mm/a]	**374**	**368**	**389**	**399**	**376**
Surface runoff [mm/a]	**356**	**199**	**151**	**88**	**181**
Lateral Flow [mm/a]	**526**	**533**	**294**	**279**	**324**
Baseflow [mm/a]	**517**	**510**	**520**	**153**	**425**

Tab. 6-4: Main components of the water balance for the subcatchments of the Ybbs catchment

The Wulka catchment

Due to the increase in the elevation there is an increase in the annual precipitation from the main watershed outlet Greimpersdorf to the most upstream subcatchment Lunz. Complementary, the evapotranspiration dereases with the increase in the elevation. From the upstream subcatchments to the main watershed outlet, the nearly equal distribution between lateral flow and baseflow is diplaced towards a higher amount of the baseflow. Also the amount of surface runoff decreases moving from the upstream subcatchments to the main outlet.

6.2.1.2 The Wulka catchment

In the Wulka catchment, the average annual precipitation has an amount of about 708mm. Thus, this value is nearly identically with those in Table 6-4 (long-term average annual precipitation – 701mm).
The average annual evapotranspiration amounts with 576mm about 81 % of the average precipitation. This is, compared to the Ybbs catchment, a nearly 1.5 times higher total evapotranspiration, and in regard to the amount of precipitation about 80% of the water in the catchment is lost by ETR. That means, considering storage processes, only 11 % of the precipitation is available for runoff generation in the catchment.
The Snow fall and snow melt processes play a subsidiary role in the Wulka catchment. The amount of the precipitation falls as snow, is only 6%.
Looking to the HRU´s , the following characteristics can be descriped.

Soil	Landuse	Surface runoff [mm]	Ground-water flow [mm]	Curve Number of the Landuse	Hydrological group of soil	Average slope [%]	Min…Max slope [%]
Bodless	BROM	3	117	50	B	11	6…17
Bodless	CORN	5	105	55	B	9	6…17
Bodless	FRSD	1	64	45	B	16	6…23
Parabraun	CORN	12	99	60	A	8	8
Parabraun	FRSD	0	121	36	A	16	8…23
Rendzina	FRSD	0	79	36	A	9	4…12
Rendzina	TOMA	16	67	65	A	7	4...9
Schwarzerde	BROM	4	91	50	B	6	6
Schwarzerde	CORN	9	18	55	B	5	1...13
Schwarzerde	FRSD	1	27	45	B	8	4...13
Schwarzerde	SGBT	8	20	60	B	5	4...5
Schwarzerde	TOMA	10	14	65	B	4	4
Steppenboden	BROM	1	52	55	B	2	1...3
Steppenboden	CORN	8	50	55	B	3	1...5
Steppenboden	SGBT	4	48	60	B	2	2
Steppenboden	TOMA	6	36	65	B	3	3...4
Steppenboden	URMD	100	1	60	B	2	2

Tab. 6-5: Average annual contribution of the HRU´s to Surface Runoff and Groundwater Flow

Table 6-5 shows the behaviour of the different HRU – types in regard to contribution to the Surface Runoff and the Groundwater Flow (Lateral Flow + Base Flow).
The Terms of Table 6-5 in regard to landuse classes are the same than in Table 6-3 additionally these soil types:

- Bodless ⇒ Soil-type Luvisol
- Parabraun ⇒ Soil-type Cambisol
- Rendzina ⇒ Soil-type Rendzina
- Schwarzerde ⇒ Soil-type Chernosem
- Steppenboden ⇒ Soil type Phaeozem
- FRSD – Forest ⇒ Landuse class Forest (mixed, deciduous,
- TOMA – Tomato ⇒ Landuse class Vine

As compensation for the not-existing landuse class vine in the SWAT 2000 model the landuse class Tomato was used to simulate surface runoff.

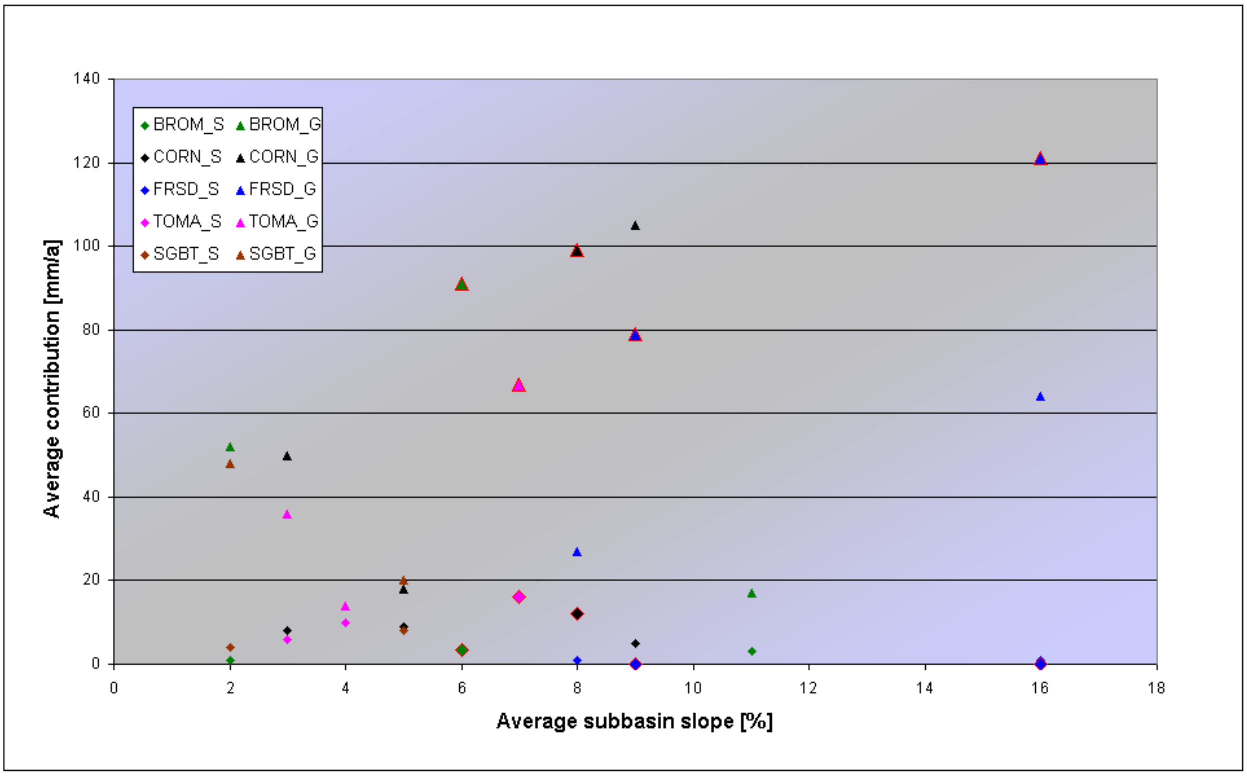


Fig. 6-2: Average annual contribution of the HRU's in dependence of the subbasin slope and the soil hydrologic group (group A: red border, group B: no border)

The Surface Runoff is the highest one in the HRUs with Residential characteristics due to the fraction of imperved areas. The HRU´s characterising the arable land have a higher amount of surface runoff compared to the contribution to the surface runoff of the HRU's with forest or pasture. With rising average subbasin slopes there is a small significant increase in the amount of the contribution to the surface runoff, but only in the HRU's fo the arable land. For pasture or forest, the contribution to the surface runoff is nearly stable respectively nearly zero.

Due to the smaller average subbasin slopes the contribution to the groundwater flow is generally higher than in the Ybbs catchment. Whether the contribution to the groundwater flow is relatively small in the HRU's with Vine and root crop, the contribution of the other HRU's is relatively high, especially of the forested HRU's.

The location of the landuse types can be indicated again by the average subbasin slope / subbasin elevation. The HRU's with arable land are located prior in the regions with a smaller average subbasin slope, whether the HRU's with pasture and especially the HRU's with forest are located in the parts of the catchment are dominated by higher average subbasin slopes.

Generally, the non-agricultural areas have a smaller contribution to the surface runoff. The contribution to the groundwater flow is especially in the HRU's with forest and pasture in relation to the surface runoff, higher than in the HRU's with arable land.

6.2.1.3 The main water balance components of the subcatchments of the Wulka catchment

For every subcatchment of the Wulka catchment, the main components of the calculated water balance will be shown and compared in Table 6-6:

Catchment size [km²]	**Walbersdorf** Subbasin1 *76*	**Wulkaprod.** Subbasin2 *213*	**Nodbach** Tributary *59*	**Oslip** Tributary *64*	**Schützen** Main outlet *384*
Annual average precipitation [mm]	**804**	**746**	**659**	**676**	**708**
Evapotranspiration [mm]	**648**	**634**	**547**	**545**	**576**
Surface runoff [mm]	**17**	**3**	**11**	**5**	**5**
Lateral Flow [mm]	**25**	**14**	**2**	**13**	**12**
Baseflow [mm]	**52**	**28**	**29**	**76**	**43**
Tile Drainage [mm]	**0**	**24**	**27**	**14**	**20**
Point sources [mm]	**0**	**0**	**0**	**64**	**28**

Tab. 6-6: The main water balance components calculated with the SWAT model of the subcatchments of the Wulka catchment

From the most upstream subbasin Walbersdorf to the main watershed outlet Schützen there is a decrease in the in the average annual precipitation and average annual evapotranspiration. The highest amount of surface runoff is estimated in the subcatchment Walbersdorf, the catchment with the highest average subbasin slope. The contribution to the surface runoff decreases as well as the amount of the lateral flow downstream. Beginning from the subcatchment Wulkaprodersdorf, the influence of drainage areas is important, especially in the subcatchments Wulkaprodersdorf and Nodbach the amount is as high as the amount of the baseflow. The contribution of the point sources to the river discharge becomes an important factor in the tributary Oslip and also at the main watershed outlet Schützen.

6.2.2 The Moneris Model

The average annual water balance was estimated for the Ybbs catchment for the period 1997-2000 and for the Wulka catchment for the period 1997-1999.

	Ybbs			**Wulka**		
	[m³/s]	**[mm/a]**	**[%]**	**[m³/s]**	**[mm/a]**	**[%]**
Direct precipitation	**0.13**	**4**	**0.4**	**0.01**	**1**	**0.7**
Tile drainage	**0.03**	**1**	**0.1**	**0.10**	**8**	**8.3**
Groundwater	**27.36**	**781**	**91.3**	**0.71**	**59**	**59.3**
Overland flow	**1.68**	**48**	**5.7**	**0.01**	**1**	**0.7**
Point sources	**0.24**	**7**	**0.8**	**0.35**	**29**	**29.1**
Urban areas	**0.12**	**3**	**0.4**	**0.04**	**3**	**3.3**
Total river discharge	**29.80**	**851**	**100**	**1.20**	**99**	**100.0**

Tab. 6-7: Water balance results calculated with the Moneris model for the Wulka catchment and the Ybbs catchment

As Table 6-7 shows, the Moneris model calculates only two important runoff components for the Ybbs catchment. With 91% the contribution of the Groundwater flow is the dominating one, and the Surface runoff (Overland flow) is the second important with nearly 6%. All the other runoff components are of a subsidiary importance.
In the Wulka catchment, the two main runoff components are the Groundwater flow (60%) and the Inlets from WWTP contributing to the total river discharge (20%). The Runoff from drained areas (8%) is of has not such a important amount, but has to be considered in regard to nutrient emission. And the Runoff from urban areas (3%) has also to be considered.

6.2.3 Estimation of the ratio groundwater to total runoff with Difga2000

The groundwater ratio of the outflow was estimated with an automated (software package: Difga2000) baseflow-separation with two linear storages ((Schwarze 2000)). Baseflow separation with Difga2000 computes three runoff components (QG2/) slow groundwater runoff, (QG1) fast groundwater runoff and (QD) direct runoff, an example for the separation can be seen in Figure 6-3.

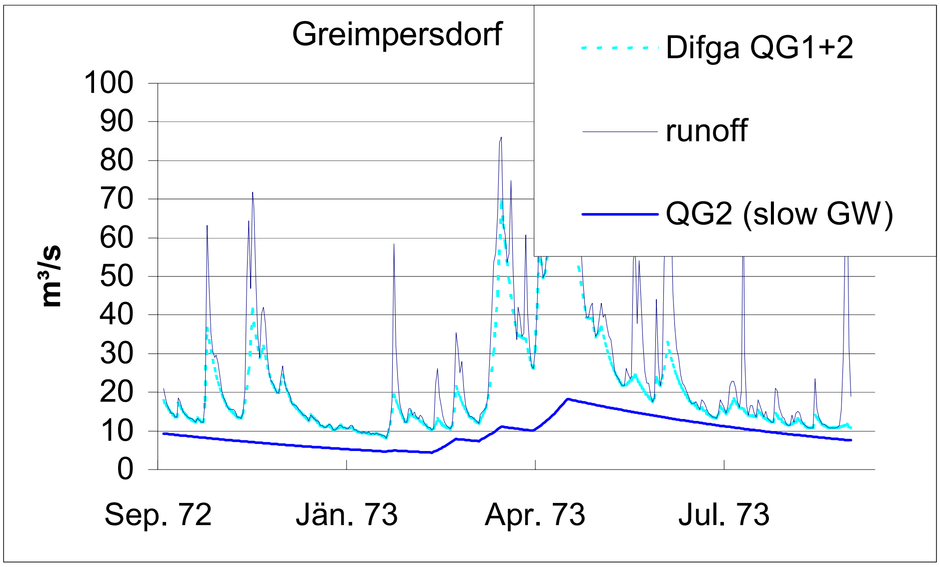


Fig. 6-3: separation of runoff with Difga2000.

The two linear storages of the model are characterised by the parameters fast groundwater-storage and slow groundwater-storage.

6.2.3.1 Results Ybbs catchment:

Ybbs	QG1+2	QG2	QG1	QD	cg1	cg2
Lunz Ois	68.8	22.6	46.2	31.2	10	170
Opponitz	70.5	30.1	40.4	29.4	11	170
Ybbsitz	77.1	37.9	39.2	22.9	11	190
Krenstetten	67.6	20.4	47.2	32.5	9	120
Greimpersdorf	71.3	29.0	42.3	28.6	9	170

Tab. 6-8: brutto groundwater-discharges of the Ybbs catchment in %, parameters

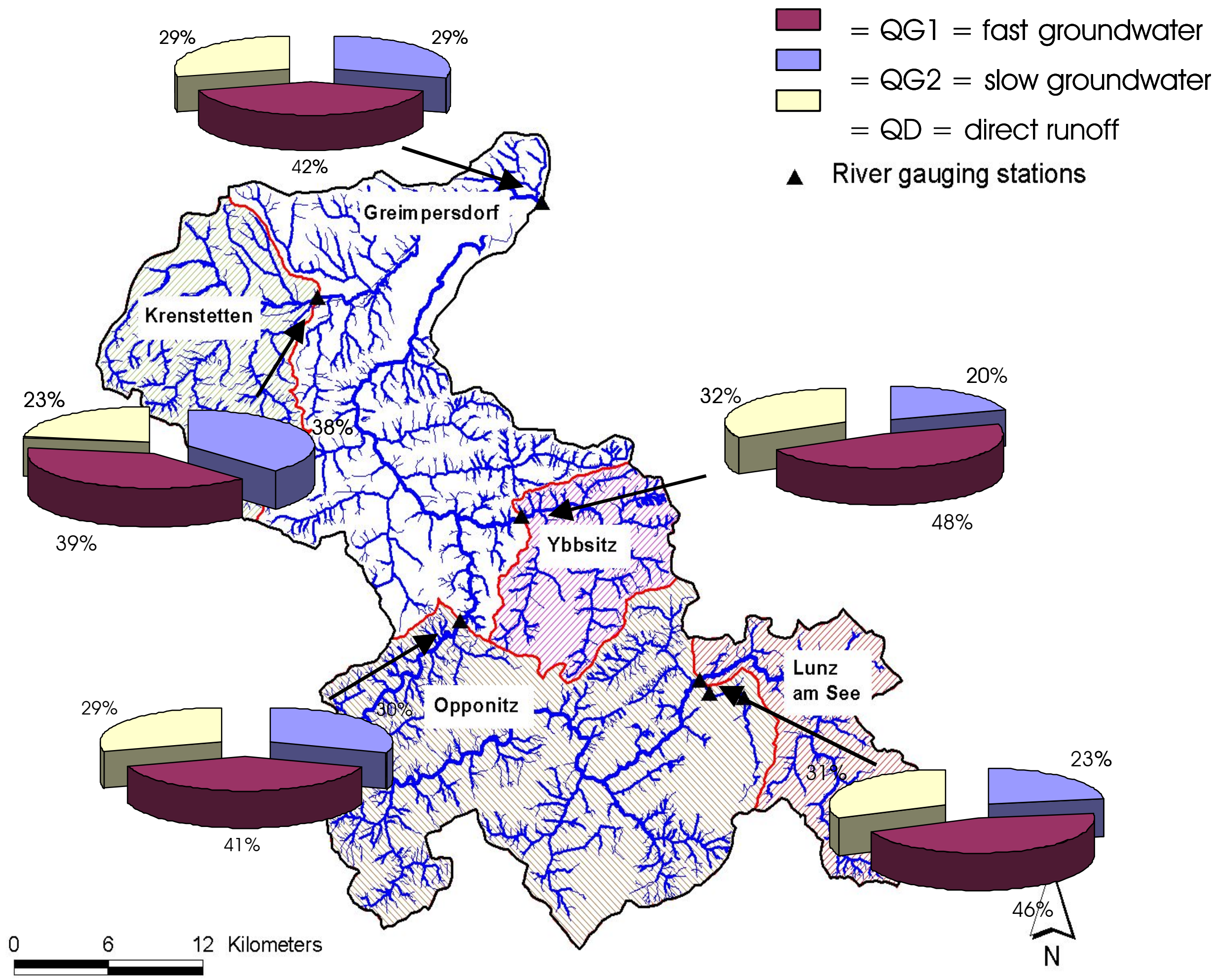


Fig. 6-4: Catchments (brutto, including subcatchments) and subcatchments and their composition of flow, Ybbs

seasonal variation:

The mean seasonal variation (mean monthly values of the time series available, years 1971-97) of the calculated runoff-components can be seen in Figure 6-5 for the total Ybbs catchment, gauging station Greimpersdorf. The values are given in mm/month.

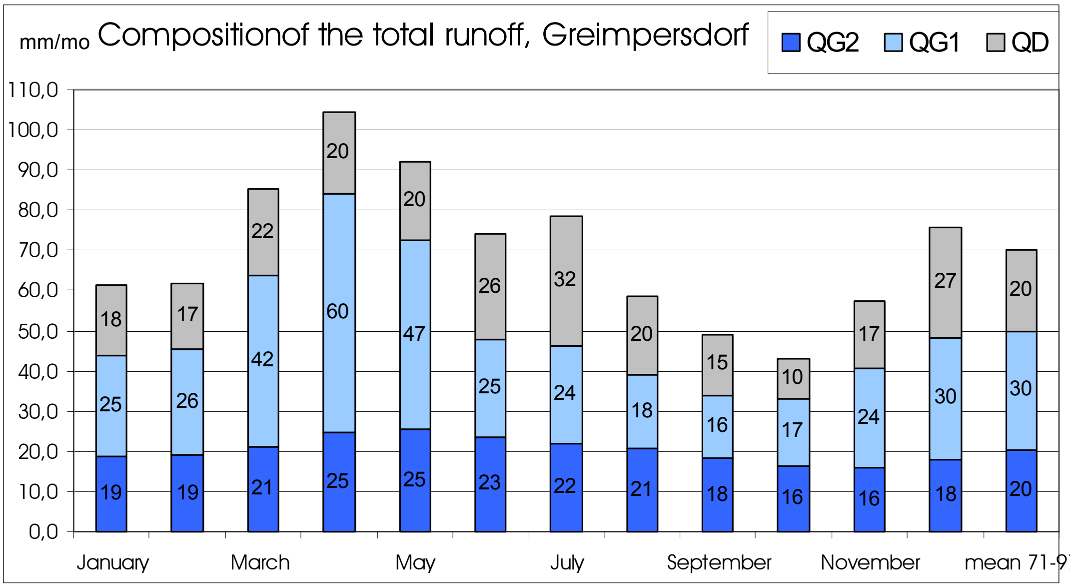


Fig. 6-5: seasonal variation of composition of flow in the Ybbs catchment

The variation of the proportions of runoff components can be seen in Figure 6-6, given in % of total runoff.

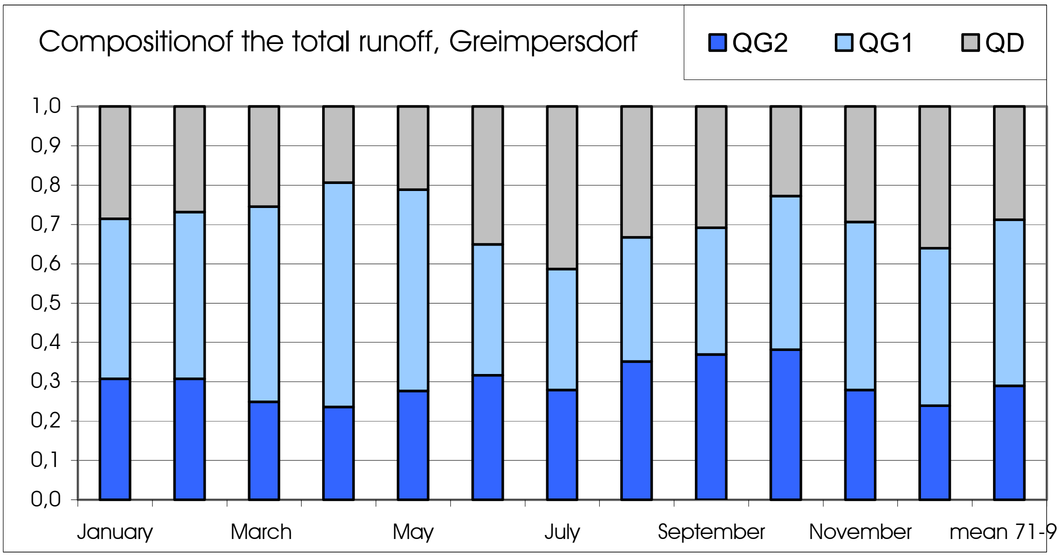


Fig. 6-6: mean seasonal variation of runoff components, Ybbs catchment, in %

The seasonal variation differs from subcatchment to subcatchment, as shown in Figure 6-6. Seasonal variation in the smaller subcatchments can be more pronounced.

6.2.3.2 Results Wulka:

Wulka (brutto)	QG1+2	QG2	QG1	QD	cg1	cg2
Walbersdorf	82	39.5	42.5	18.0	13	250
Wulkaprodersdorf	80.4	41.2	39.2	19.6	13	350
Nodbach	73.7	24.9	48.8	26.3	13	180
Oslip /Eisbach	76.3	29.8	46.5	23.7	12	130
	54.2	5.8	48.4	45.8	8	100
Schützen incl. TWP	82.4	40.7	41.7	17.6	12	340
excl. TWP	58.2	15.9	42.3	16.1	11	330

Tab. 6-9: groundwater-discharges of the Wulka catchment in %, storage parameters

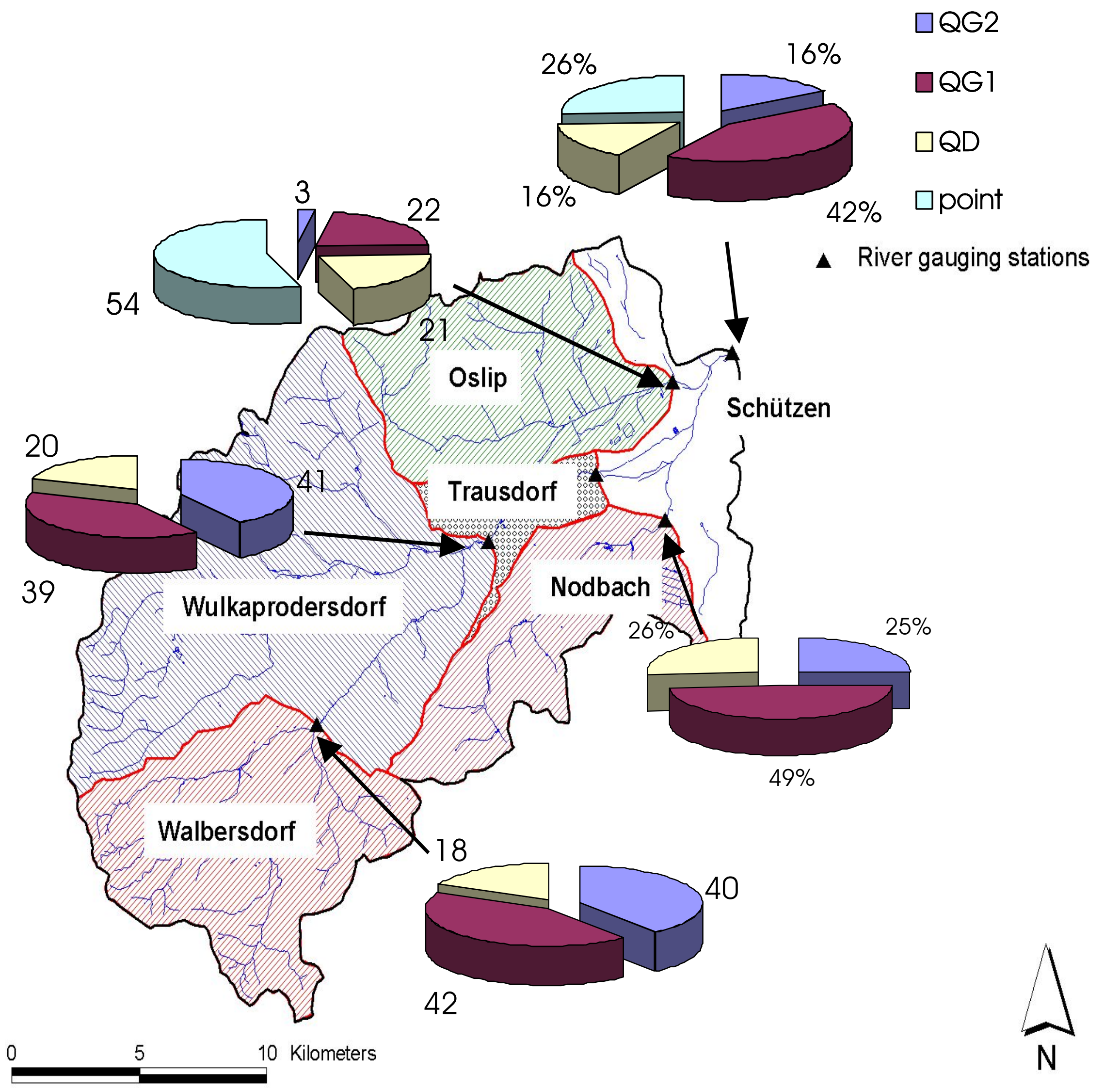


Fig. 6-7: Catchments (brutto, including subcatchments) and subcatchments of the Wulka basin and their composition of flow

seasonal variation:

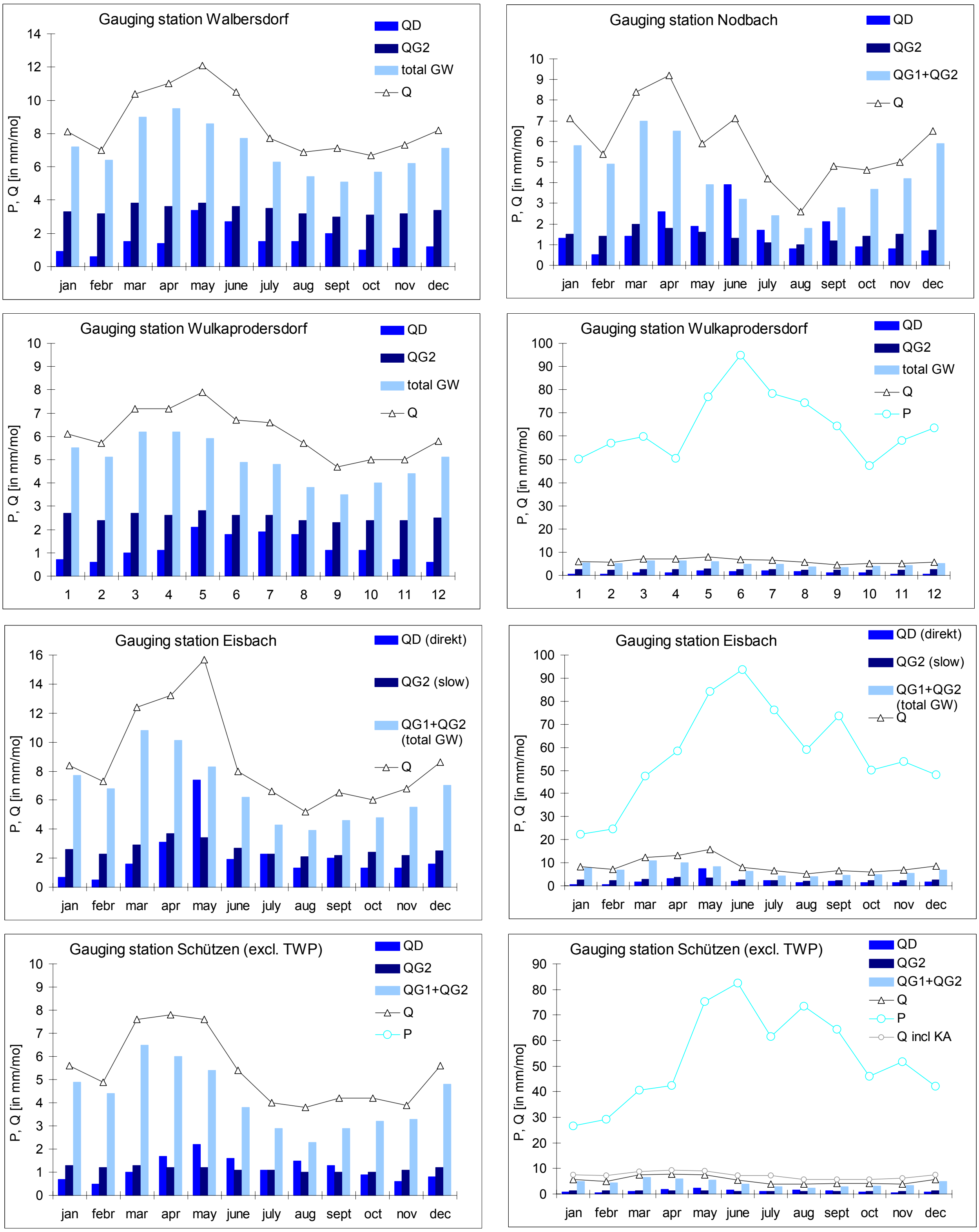


Fig. 6-8: seasonal variation of composition of flow in the Wulka catchment

6.2.3.3 problems with runoff-separations

- Rainfall during recession period results in wrong results
- no representative precipitation data in some cases (arithmetic mean of measured rainfall in the basin of Lunz is smaller than measured runoff)
- for correct water-balances a correction of the precipitation data (e.g. (Koenig 1994): 7 % for rain, 33 % for snow) is necessary because of measurement errors. In the Ybbs catchment 10 and 30% were choosen, but it was not possible to calculate positive evapotranspiration in the alpine (upper Ybbs catchments) of Lunz and Opponitz.
- Snowmelt (simulation)
  - The snow-coverage was simulated with a simple degree-day factor (higher in spring (4mm/°C/day), and less in winter, when the albedo is small).
  - DDF too simple for the upper Ybbs-catchments
  - the water-balance of Lunz and Opponitz is not always correct.
  - no problems at all at the Wulka-catchment.
  - Snowmelt cannot be calibrated with snow-coverage-data, because of a lack of snow-coverage and temperature data in space and time.
- Immobile part of groundwater is not included in estimations via runoff-separations, but it plays an not- negligible role in nutrient transport and concentration.

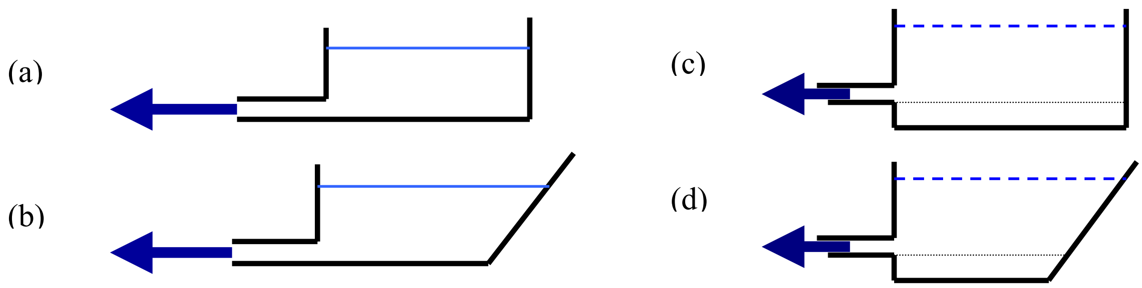


Fig. 6-9: Possible groundwaterstorages and their presentation:

(a) linear
(b) not linear (e.g.: scape of the valley or characteristics of outflow)
(c) model of a storage with immobile groundwater
(d) non-linear storage with immobile groundwater

groundwater runoff is usually not exponential, i.e. the runoff is not linearly depending from storage-volume as in case (a) in Figure 6-9.
Also 2 linear storages (as used in Difga 2000) may not give the right outflow characteristics, but the error is not negligible.

- Problems with hydropowerplants in the Ybbs-catchment
- wastewatertreatmentplants in the Wulka catchment, the drinkingwater is imported from other regions and should be substracted. As no daily data were available, monthly data were used.
  For the gauging station Schützen the ration of wastewater was 26%.

In the catchment of Eisbach (Oslip) the ratio of wastewater to total runoff was 55%. After subtracting the wastewater negative values for runoff were obtained for several days and corrected manually, thus the hydrograph became “unnatural” and the results of baseflow separations in times of low runoff are questionable, as seen in Figure 6-10.

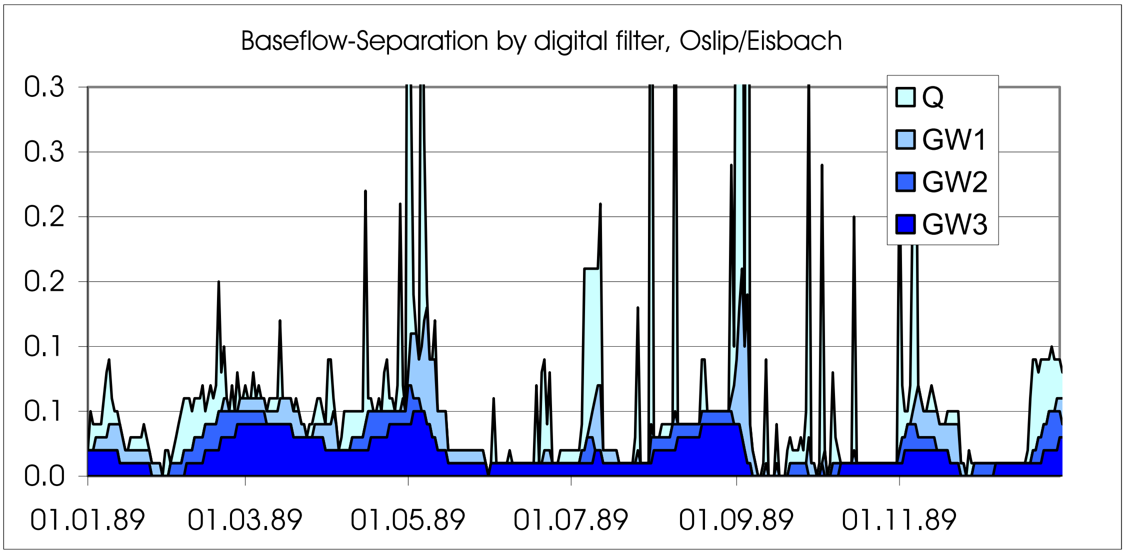


Fig. 6-10: corrected runoff and baseflow-separation in Oslip

6.2.3.4 Validation with other separation methods

The results of Difga2000 was compared with values of other baseflow separation techniques for the watersheds Ybbs and Wulka and were compared to values of literature.

The methods of Wundt and Lillich use characteristic water discharges and can be termed “statistical-empirical” approaches (cited in (Hölting 1980); (Mattheß 1994)).

Results of the Lillich approaches were almost identical to the result obtained with Difga2000. The results of Wundt can be identified as the minimum groundwater-runoff. Wundt claims that the monthly medium low-flow during summer is the minimum subsurface runoff. Runoff during winter and spring are higher. The approach of Wundt was slightly adapted in a way that the smallest daily runoff/month was calculated and the monthly averages for all years and all months were assumed to be the minimum groundwater runoff. The approach of Lillich states, that in the case of missing long term measurements the ratio of subsurface runoff can estimated from single measurements as well by taking measurements of outflow at least 3 days after a precipitation event. We took the discharge on the 3th day after rainfall as the groundwater runoff.

Furthermore, baseflow separations with a simple single linear storage model were done by manual calculation and by an automated separation technique (software package: Base Flow Filter Program, (Arnold 1995)).

The results of manual baseflow separation seems to be less certain, because of insufficient calculated recession-events (and their big variance) and the more or less at random chosen outflow value. The digital filter of Arnold can be passed over stream flow data three times (forward, backward and forward) gives 3 values for three passes of filter. Each pass results in less base flow as a percentage of total flow (up to 30 percent for two passes). This option gives a flexibility to adapt the separation to site conditions, it can be regarded as a maximum and minimum estimation for the groundwater-ratio. The results of the first run are very similar to the results of DIFGA2000.

The separations using the different approaches and long term flow measurements mean values for groundwater discharges were calculated for both catchments and selected subcatchments as shown in Table 6-10 to 6-12 for the Ybbs catchment and Table 6-13 and 6-14 for the Wulka catchment.

gauging station (brutto) (river, timeseries)	Q [mm/a]	Lillich [mm/a]	Wundt [mm/a]	linear [mm/a]	difga [mm/a]	digital filter1 [mm/a]	df. 2 [mm/a]	d.f.3 [mm/a]
Lunz a. See (Ois, 1977-97)	1208	n.c.	n.c.	n.c.	n.c.	815	653	569
Lunz am See (Seebach, Ab.)	1795	1283	977	n.c.	1279	1240	993	865
Opponitz (Ybbs, 1971-97)	1203	808	572	532	847	834	696	627
Ybbsitz (kleine Ybbs, 1981-97)	846	643	467	n.c.	667	643	558	517
Krenstetten (Urlbach, 1992-97)	443	281	164	251	299	280	226	200
Greimpersdorf (Ybbs, 1971-97)	850	638	392	510	607	581	483	435

Tab. 6-10: comparison of different groundwater-estimations for the Ybbs catchment

gauging station (brutto) (river, timeseries)	Q [mm/a]	Lillich [%]	Wundt [%]	linear [%]	difga [%]	digital filter1 [%]	df. 2 [%]	d.f.3 [%]
Lunz a. See (Ois, 1977-97)	1208	n.c.	n.c.	n.c.	n.c.	67%	54%	47%
Lunz am See (Seebach)	1795	71%	54%	n.c.	69%	67%	53%	47%
Opponitz (Ybbs, 1971-97)	1203	67%	48%	44%	71%	75%	65%	61%
Ybbsitz (kleine Ybbs, 1981-97)	846	76%	55%	n.c.	77%	64%	52%	46%
Krenstetten (Urlbach, 1992-97)	443	64%	37%	57%	68%	69%	58%	52%
Greimpersdorf (Ybbs, 1971-97)	850	75%	46%	60%	71%	67%	53%	47%

Tab. 6-11: comparison of different groundwater-estimations for the Ybbs basin in %

gauging station netto (river)	Lillich	Wundt	linear	Difga	digital filter1	dig.l f. 2	df. 3
gauging station (river)	**mm/year**	**mm/year**	**mm/a**	**mm/a**	**mm/year**	**mm/a**	**mm/a**
Lunz am See (Ab-Seebach)	1283	977	n.c.	1279	1223	979	854
Opponitz netto	784	551	532	825	814	682	616
Ybbsitz (kleine Ybbs)	643	467	n.c.	667	643	558	517
Krenstetten (Urlbach)	281	164	251	299	280	226	200
Greimpersdorf netto	531	190	734	383	335	270	240
Ybbs catchment / mean	560	343	506	543	518	434	393

Tab. 6-12: comparison of groundwater-estimations for the Ybbs catchment – netto
n.c…. not calculated, netto means excl. upper gauging stations

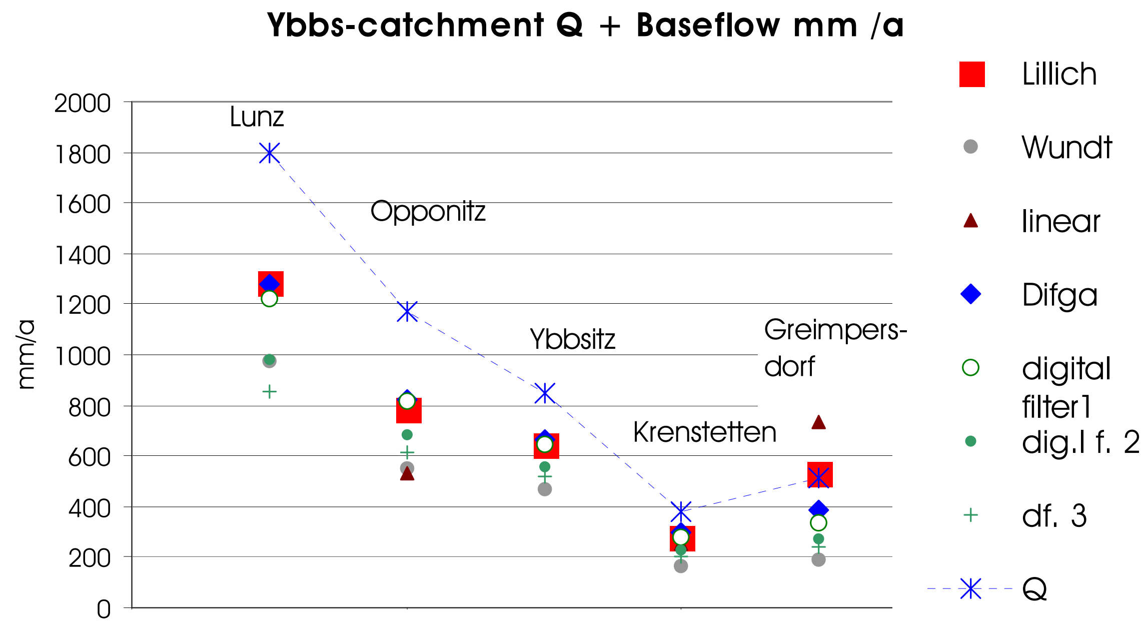


Fig. 6-13: Baseflow in the Ybbs catchment in mm/a, netto

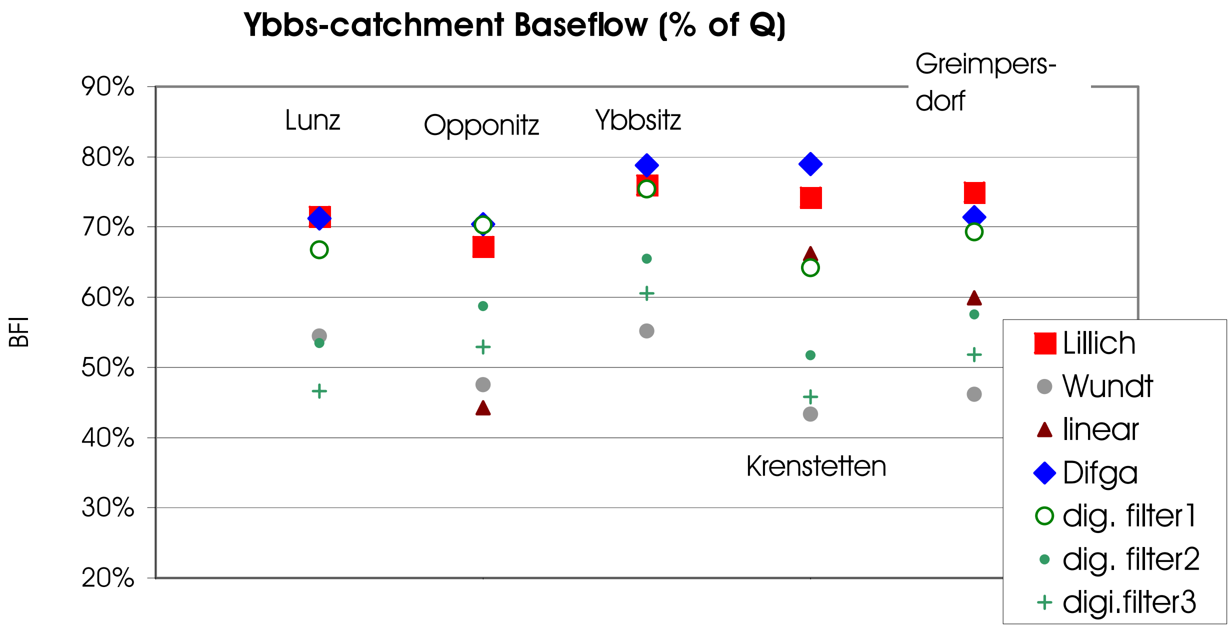


Fig. 6-14: Baseflow in the Ybbs catchment in % of total flow

gauging station (river, timeseries)	Q [mm/a]	Lillich [mm/a]	Wundt [mm/a]	linear [mm/a]	difga [mm/a]	digital filter1 [mm/a]	df. 2 [mm/a]	d.f.3 [mm/a]
Walbersdorf (Wulka, 1983-97)	103	n.c.	n.c.	n.c.	84.5	82.6	73.5	68.3
Wulkaprodersdorf (Wulka, 1971-97)	73.6	64.0	47.1	n.c.	59.2	58.3	52.1	48.8
Trausdorf an der Wulka (Wulka, 1977-97)	89.6	n.c.	n.c.	n.c.	n.c.	71.6	63.1	58.0
St. Margareten (Nodbach, 1992-2000)	70.6	52.8	35.2	n.c.	52.8	49.9	41.6	37.4
Oslip (1986-97) (Eisbach, 1986-1996)	110.8 50.5*	73.9 n.c.	53.9 12.4	77.4 n.c.	79.9 27.3	72.6 26,5	62.1 18,8	56.5 15,2
Schützen (1971-97) (Wulka, 1981-97*)	86.7 64.5*	39.8	32.3	29.1	71.6 50.5*	42.4	35.0	31.0

Tab. 6-13: comparison of different groundwater-estimations for the Wulka in mm/a

*runoff excl. waste water treatment plant, n.c.…. not calculated

gauging station (river, timeseries)	Q [mm/a]	Lillich [%]	Wundt [%]	linear [%]	difga [%]	digital filter1 [%]	df. 2 [%]	d.f.3 [%]
Walbersdorf (Wulka, 1983-97)	101.9	n.c.	n.c.	n.c.	82%	81%	72%	67%
Wulkaprodersdorf (Wulka, 1971-97)	73.6	87%	64%	n.c.	80%	80%	71%	67%
Trausdorf an der Wulka (Wulka, 1977-97)	89.6	n.c.	n.c.	n.c.	n.c.	80%	70%	65%
St. Margarethen (Nodbach, 1992-200)	70.8	75%	50%	n.c.	74%	71%	59%	53%
Oslip (incl. points. 86-97) (Eisbach, excl. ps. 86-96)	110.8 50.5*	78% n.c.	57% 25%	82% n.c.	76% 54%	77% 53%	66% 37%	60% 30%
Schützen (1971-97) (Wulka, 1981-97*)	86.7 64.5*	62%	50%	45%	82% 78%*	66%	54%	48%
Wu+Osl+Nod (theor)	248.7	84%	61%		25%	78%	68%	63%

Tab. 6-14: comparison of different groundwater-estimations for the Wulka basin in %

*runoff excl. waste water treatment plant, n.c.…. not calculated

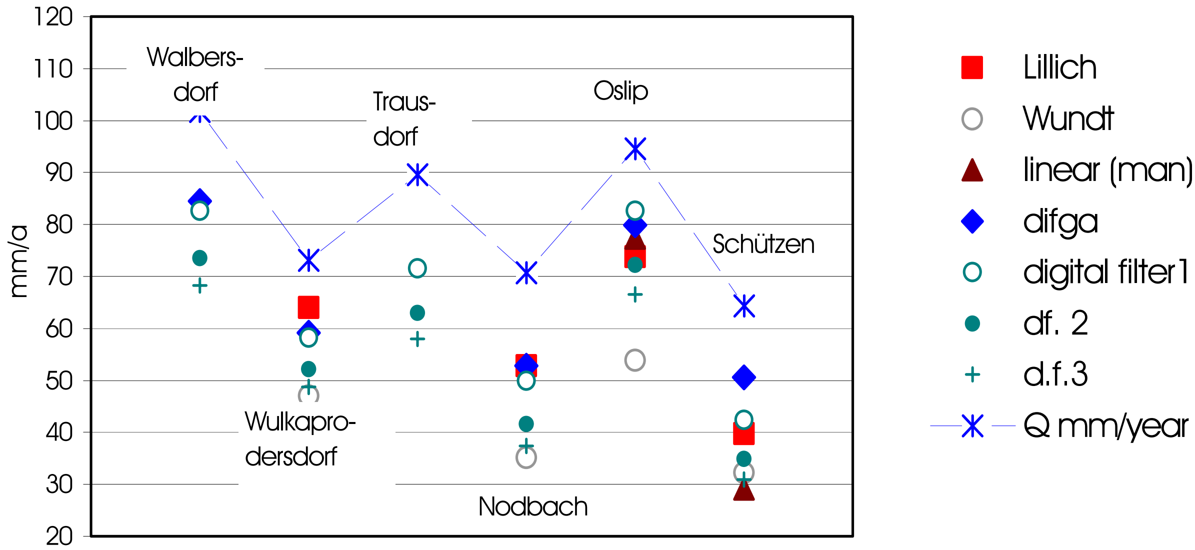


Fig. 6-15: Baseflow [mm/a] in the Wulka catchment (brutto, incl. subcatchments)

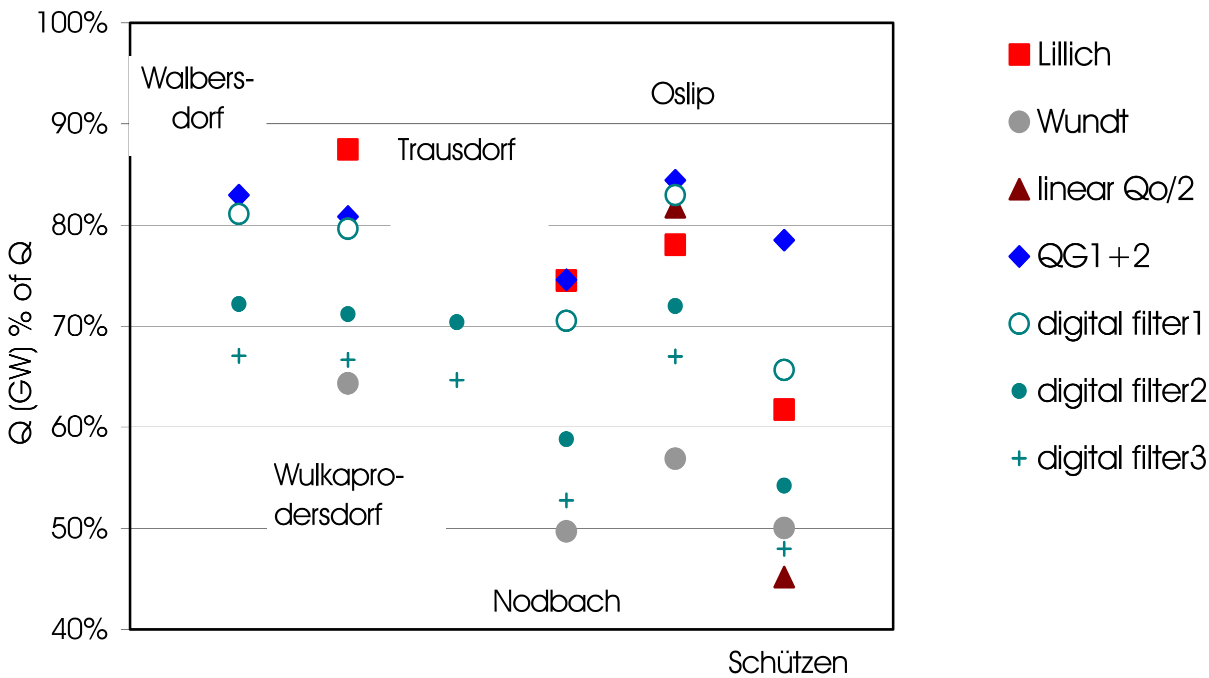


Fig. 6-16: Baseflow in the Wulka catchment (brutto) in % of total flow

In Figure 6-15 and Figure 6-16 the content of the tables given before are shown.

Netto values of discharge (downstream gauges excluding upper subcatchments) for Schützen would be negative.

Wulka (Netto)	QG1+2	QG2	QG1	QD
Walbersdorf	84.5	40.7	43.8	18.5
Wulkaprodersdorf m³/s	0.2	0.1	0.1	0.1
Wulkaprodersdorf mm	29.3	15.9	13.4	7.9
Nodbach	66.0	22.3	43.7	23.6
Oslip /Eisbach inkl. WWTP	84.5	33.0	51.5	26.3
Oslip /Eisbach excl. WWTP	27.4	2.9	24.4	23.1
Schützen incl. TWP	-130.4	-55.4	-75.0	-38.3
excl. TWP	-8.2	-1.2	-7.0	-7.8

Tab. 6-15: netto groundwater-discharges of the Wulka catchment [mm/a]

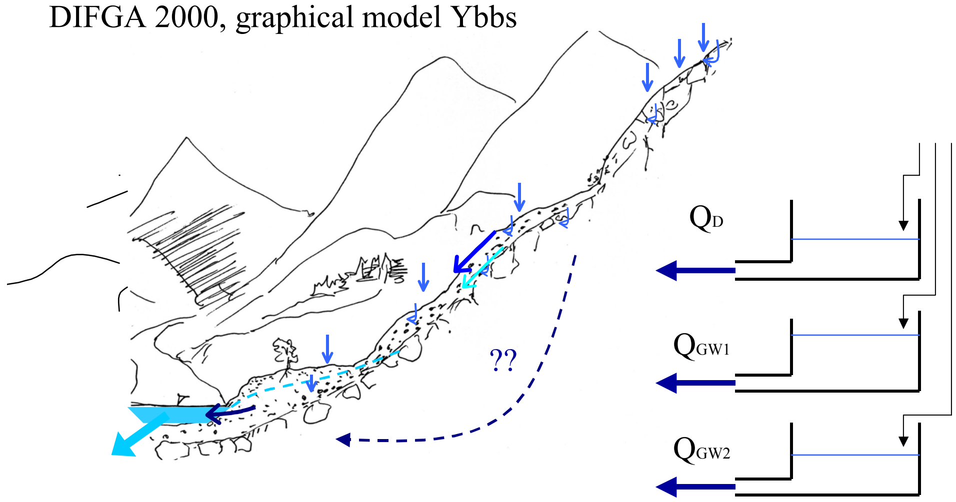
Wulka % (Netto)	QG1+2	QG2	QG1	QD
Walbersdorf	82%	40%	43%	18%
Wulkaprodersdorf*	79%	43%	36%	21%
Nodbach	74%	25%	49%	26%
Oslip /Eisbach inkl. WWTP	76%	30%	47%	24%
Oslip /Eisbach excl. WWTP	54%	6%	48%	46%
Schützen	neg.	neg.	neg.	neg.

***) values not reliable, becouse total values too small.**

Tab. 6-16: netto groundwater-discharges in % of the Wulka catchment

6.2.3.5 Validation by graphical models

DIFGA 2000, graphical model Ybbs



$Q_D : Q_{GW1} : Q_{GW2} =$ $Q = Q_{GW1} + Q_{GW2} + Q_D$

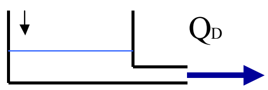
29% : 42% : 29% (Greimpersdorf, Ybbs)

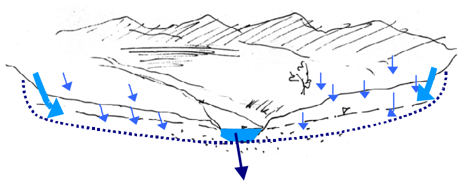
Fig. 6-17: Ybbs catchment and Difga2000

DIFGA 2000

Graphical model

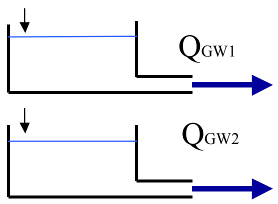
Direct flow:





$Q = Q_{GW1} + Q_{GW2} + Q_D$

Groundwaterrunoff:



$Q_{GW} = Q_{GW1} + Q_{GW2}$

$Q_P : Q_D : Q_{GW1} : Q_{GW2} =$ 16% : 16% : 42% : 16%

Schützen, Wulka

Fig. 6-18: Wulka catchment and Difga2000

6.2.3.6 Validation by literature

As result we received a ratio of 64% groundwater of the total runoff for the Ybbs catchment and 71% for the Wulka catchment.
These results agree with result taken from literature for Australia, 63% (Su 1995); 60-80% according to Weser and Leine (cited in Wittenberg 1997), more than 80% according to Herrmann (cited in Wittenberg 1997). Eltahir and Yeh (Eltahir and Yeh 1999) analyse outflow variances and give a value of 75% for groundwater discharge.
In (Arnold 1995) results of different publications are cited.
The groundwater-ratios of manual separations from 11 American catchments were compared with 2 automated techniques, PART and the recursive digital filter model, also used in this study. The results for the baseflow-ratio were between 32 und 89%, the mean value was 66 %:

	publication (author)	**manual**	**part**	**rec. Dig. Filter**		
		by author		**1**	**2**	**3**
1	Becher and Root, 1981	66	65.6	67	53	47
2	Becher and Root, 1982	80	80.4	79	53	64
3	Carswell and Lloyd, 1979	66	70	71	70	48
4	Dingmann and Mayer, 1954	67	66	68	57	54
5	Dingmann and Ferguson, 1956	66	71	72	58	60
6	Olmsted and Hely, 1962	67.8	70.3	74	64	60
7	Steward et al., 1964	75	80.6	80	72	66
8	Stuart et al., 1967	49	62	64	48	40
9	Taylor et al. 1983	89	89	85	71	72
10	Waller, 1976	67	73	70	58	51
11	Wood, 1980	38.5	46.9	55	39	32
		66.5	**70.4**	**71.4**	**58.5**	**54.0**

mean (over all): 66.1 %

In Arnold, Muttiah et al. (2000) extremly high and low values for the baseflow-ratios are cited; over 90% of total flow in the region of Atlantic Coastal Plain, William and Pinder, 1990 and only 50% in Central-Texas (Arnold et al. 1993).
The results of Swat, the digital filter model and the estimated GW- recharge (with modified hydrograph recession curve displacement technique) do agree well.
Arnold and Allen (1996) calculates for the Illionois basins baseflow-runoff in mm:

	P	Q	GW (meas./calc.)	(=%)
Goose Creek, 1957	944	241	97/121	(=40/50%)
Hadley Creek, 1957	1009	354	48/66	(=14/19%)
Panther Creek, 1952	822	249	182/153	(=73/61%)

In (Sommerhäuser, A. et al.) the dominant rule of groundwater-flow in comparison to overland and direct flow for rock is described. Hydrochemical and geochemical investigations demonstrated, that 60- 80 % of total flow in peak runoff must result from indirect components, caused by the potential-gradient of infiltrated precipitation-water.

6.3 *The detailed water cycle - AUSTRIA*

6.3.1 The Ybbs catchment

The detailed water cycle was produced by the SWAT 2000 model, shows Figure 6-19.

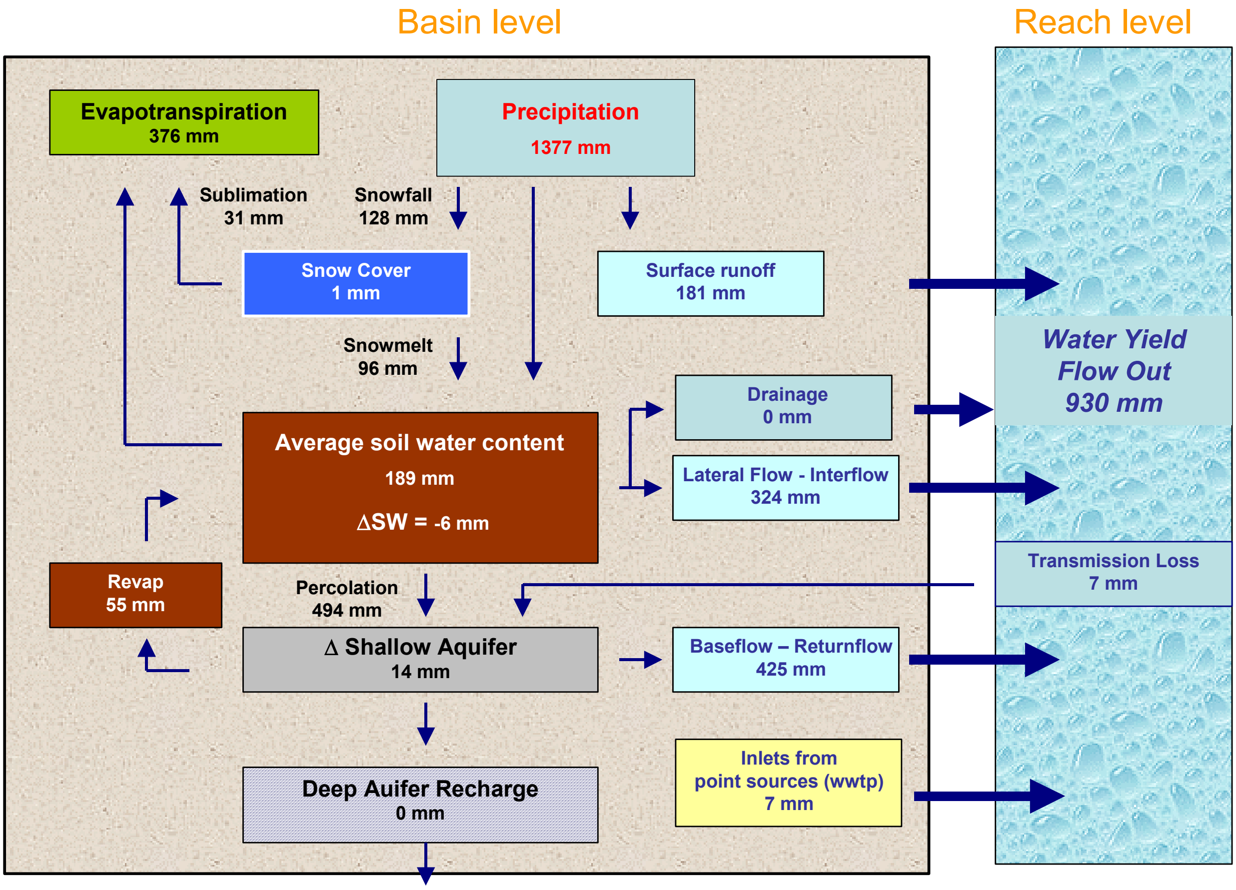


Fig. 6-19: Water cycle scheme for the Ybbs catchment

The Water content in the soil (SW) is calculated as:

$$\Delta SW=P-Sub-SC-ETR-SR-LF-Perc+Revap \qquad \text{(Eq 6.1)}$$

with

P…	Precipitation
Sub…	Sublimation
SC…	Snow Cover
ETR…	Evapotranspiration
SR…	Surface Runoff
LF…	Lateral Flow
Perc…	Percolation

The Water Content in the Shallow Aquifer (SHAQ) is calculated as:

$$\Delta SHAQ=Perc-BF-DAQ-Revap+TLOSS \qquad \text{(Eq. 6.2)}$$

with BF… Baseflow
DAQ… Deep Aquifer Recharge
TLOSS… Transmission Loss

6.3.2 The Wulka catchment

Also, for the Wulka catchment a detailed water cycle was produced by the SWAT model.

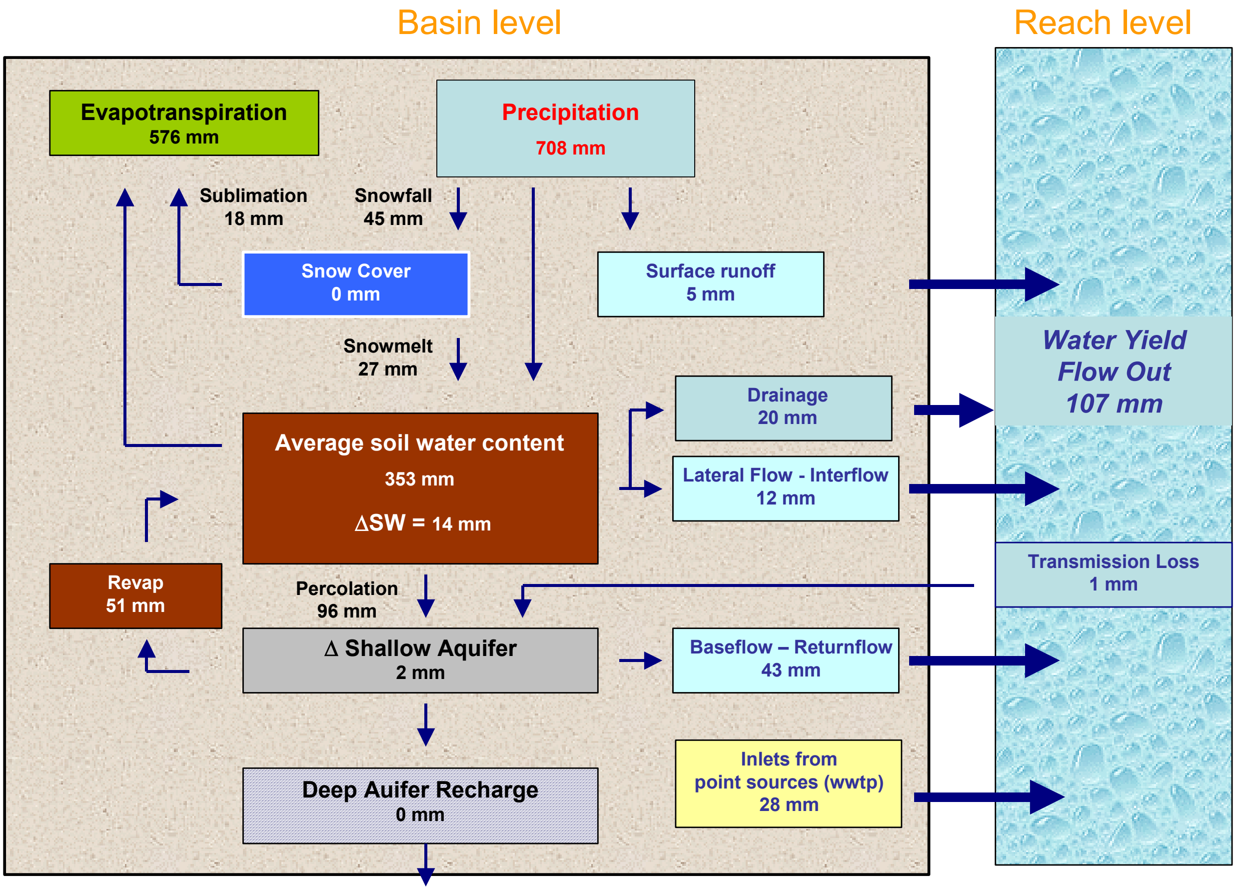


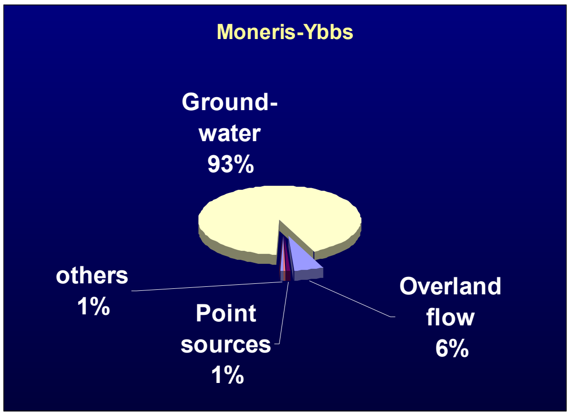
Fig. 6-20: Water cycle scheme of the Wulka catchment

In comparison to the Ybbs catchment, the total Water Yield in the river amounts only about 10% of the Water Yield in the Ybbs catchment. The contribution of the WWTP in the Wulka catchment is with about 35% immense in regard to the Ybbs catchment (1%).
In the Wulka catchment, there is no permanent snow cover modelled. Snow fall and Snow melt processes are subsidiary with 6% resp. 4%.

The fraction of drainage flow in the Wulka catchment is with about 19% of the river discharge of an adequate importance like the contribution of the point sources to the river discharge.

6.3.3 The runoff components - AUSTRIA

For both catchments, the Ybbs catchment and the Wulka catchment, the distribution of the runoff components was compared between the models Moneris, SWAT and DIFGA.



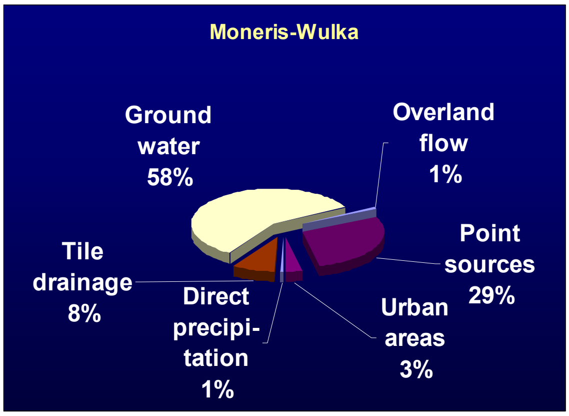
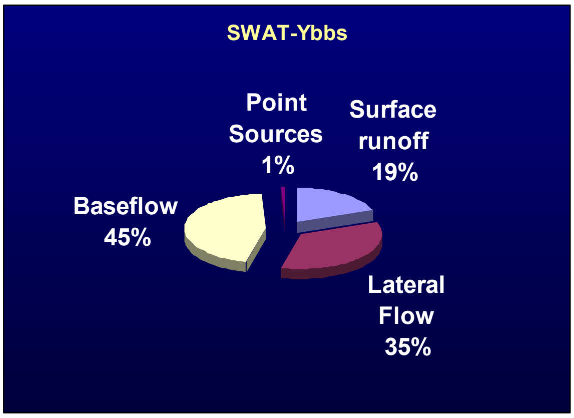


Fig. 6-21: Runoff components calculated by Moneris for the Ybbs catchment (left) and the Wulka catchment (right)



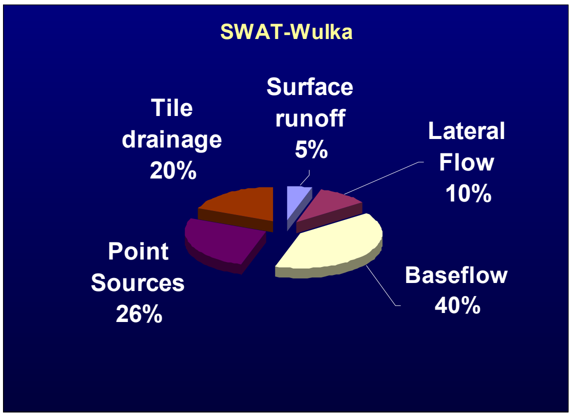
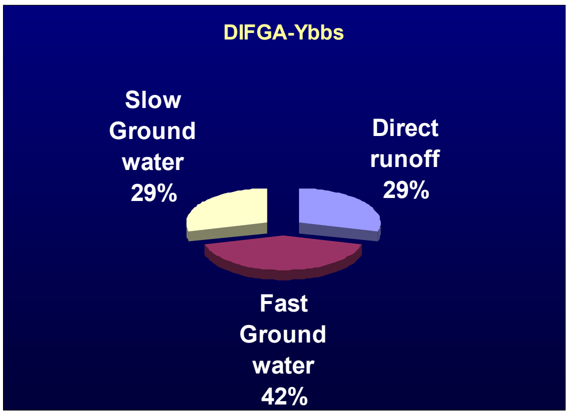


Fig. 6-22: Runoff components calculated by SWAT for the Ybbs catchment (left) and the Wulka catchment (right)



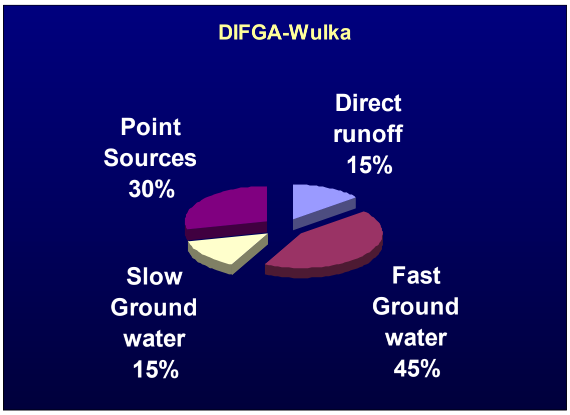


Fig. 6-23: Runoff components calculated by DIFGA for the Ybbs catchment (left) and the Wulka catchment (right)

The Ybbs catchment

DIFGA-SWAT

As mentioned in the chapter 5.1, the SWAT model was calibrated with the assistance of the DIFGA results. The direct runoff was calibrated to be equal the surface runoff in SWAT. As well, the fast groundwater and the slow groundwater in DIFGA should be equal to the lateral flow and to the Baseflow of SWAT.

For the Ybbs catchment, this way of simulation was successful, as to be seen in Figures 6-22 and 6-23. The Distribution of the three runoff components is nearly equal. Due to the different definition of fast and slow subsurface flow in the two models, the sum of the two subsurface flow components will be compared. The Difga model calculates this fraction (slow groundwater + fast groundwater) with 71% a little bit more less than the SWAT model (baseflow + lateral flow) with 80%. Complementary, the surface runoff is higher calculated by the Difga model (direct runoff) than this calculated by the SWAT model (surface runoff). Contributions by point sources can be neglected.

Moneris-DIFGA-SWAT

The dominating contribution to the runoff was calculated by Moneris is the groundwater runoff with 93%. In comparison to the other models this is the highest fraction. The reason for this estimation can be an underestimation of all the other processes contributing to the runoff, especially the surface runoff. The fraction of the surface runoff (overland flow + urban areas) seems to be underestimated with 7% in regard to the other model results.

The contribution of the point sources is as well as resulted from the other models neglectable.

The Wulka catchment

DIFGA-SWAT

For the Wulka catchment, an accordance between the SWAT and the DIFGA results could obtained. The contribution of the groundwater flow in SWAT (baseflow + lateral flow) is with 51% nearly equal to this of the DIFGA model (slow groundwater + fast groundwater) with 60%. The contribution of the surface runoff in the SWAT is more less than in the DiFGA model. But the contribution of the tile drainage to the runoff was not considered in DIFGA.

The point sources play a major role in contributing to the river runoff. With a fraction of 26% the influence on the total river discharge is very important.

Moneris-DIFGA-SWAT

The fraction of the groundwater flow of the Moneris model (58%) is compareable to those calculated by the other models. The contribution to the surface runoff in the Moneris model (4%)is in a good correlation to the surface runoff in SWAT (5%). The tile drainage runoff was calculated with Moneris (9%) is only half as big as the one calculated with SWAT (19%). This is caused by the different estimation methods in both models. The Moneris model calculates the runoff from drainage areas as prior defined fractions of the soiltypes, whether the SWAT model calculates drainage outflow out of the definition of drainage areas in the HRU’s. The deviations in the fraction inlets from point sources are caused by different estimation intervals.

Generally, the Ybbs catchment could be simulated in an acceptable way with the SWAT 2000 model. The data requirements for the SWAT model are large, and most of the data could be obtained. The only assumption was not done yet, was the

consideration of river power plants in the Ybbs catchment. The information about the location of the power plants on the Ybbs river could be obtained some months ago. The information about the characterisation of the power plants, means about upper or lower retention water level elevation, the corresponding volume of the water or the water surface area, are not available in that detail, which is needed for an implementation into the SWAT 2000 model. Thus, the Ybbs catchment was delineated without the consideration of the hydro power plants.
In the beginning of the next year, the implementation is planned to be made on basis of cross sections had been obtained from the local authorities too.
The MONERIS model seems to underestimate the surface runoff components and to overestimate the groundwater runoff.
The DIFGA model was running well, but problems occurred in the handling of the snow fall and snow melt. Especially the subcatchments upstream were affected.

For the Wulka catchment due to the implementation of drainage areas only a poor model performance could be obtained for the SWAT model.
The MONERIS model gives similar results which are compareable to those of SWAT and DIFGA.
Difficulties in the application of DIFGA in the Wulka catchment occurred with the immense contribution of the point sources to the total river discharge.

Ybbs catchment	SWAT		DIFGA		Moneris	
	mm/a	%	mm/a	%	mm/a	%
Precipitation	1377	-	1487		1395	
Evapotranspiration	376	27	635	42	550**	39
River discharge	930	67	852	57	851	61
*Surface runoff / QD**	181	19	244	29	51	6
*Lateral Flow (Interflow) / QG1**	324	35	360	42	-	-
*Baseflow (Groundwater Flow) / QG2**	425	45	248	29	781	92
Tile Drainage	-	-	-	-	1	0
Point Sources	7	1	-	-	7	1

Tab. 6-17 : Comparison of the model results for the Ybbs catchment

Wulka catchment	SWAT		DIFGA		Moneris	
	mm/a	%	mm/a	%	mm/a	%
Precipitation	708	-	664		648	
Evapotranspiration	575	81	571	90	550**	85
River discharge	107	15	93		99	15
*Surface runoff / QD**	5	5	14	15	4	4
*Lateral Flow (Interflow) / QG1**	12	10	37	45	-	-
*Baseflow (Groundwater Flow) / QG2**	43	40	14	15	59	60
Tile Drainage	20	19	-		8	8
Point Sources	28	26	28	30	29	29

Tab. 6-18 : Comparison of the model results for the Wulka catchment

The Evapotranspiration of the Moneris model (**) was set as constant.

6.4 Water balance – HUNGARY

The water balance calculations were performed with three different methods (SWAT, DIFGA, MONERIS) for all sub-catchments for the period 1997-2001. SWAT calculated the daily river discharges at the sub-basin outlets, the annual and period average regional values of the hydrological components and the annual and period average values of the runoff components and their proportions on the total runoff volume. DIFGA simulated the separated daily flow components at the sub-basin outlets, the annual and period average regional values of the evapotranspiration and the annual and period average values of the runoff components and their proportions on the total runoff volume. MONERIS computed the annual and period average regional values of the evapotranspiration and the annual and period average values of the runoff components and their proportions on the total runoff volume.

6.4.1 The SWAT 2000 model

The simulation of the daily values is acceptable in the dry periods but poor during the precipitation events. Significant problems are the miscalculated peak-volumes. The reasons of the inaccurate calculations are two-folds: (i) inaccuracy at the extension of the local meteorological data scattered in the watershed as regional value for the whole sub-basin and (ii) lack of detailed information about the soil properties. The daily simulated and measured hydrographs are presented in the Figures 6-24 to 6-27. Concerning the annual values of the different runoff components and their proportion in the total runoff the most important process is the groundwater flow, which represents 80 % of the total volume. The ratio of surface flow is about 15 %, in rainy years it may be higher. The lateral flow has only a minor significance. The detailed hydrological cycle and information about the different runoff components are shown in the Figure 6-28 to 6-30.

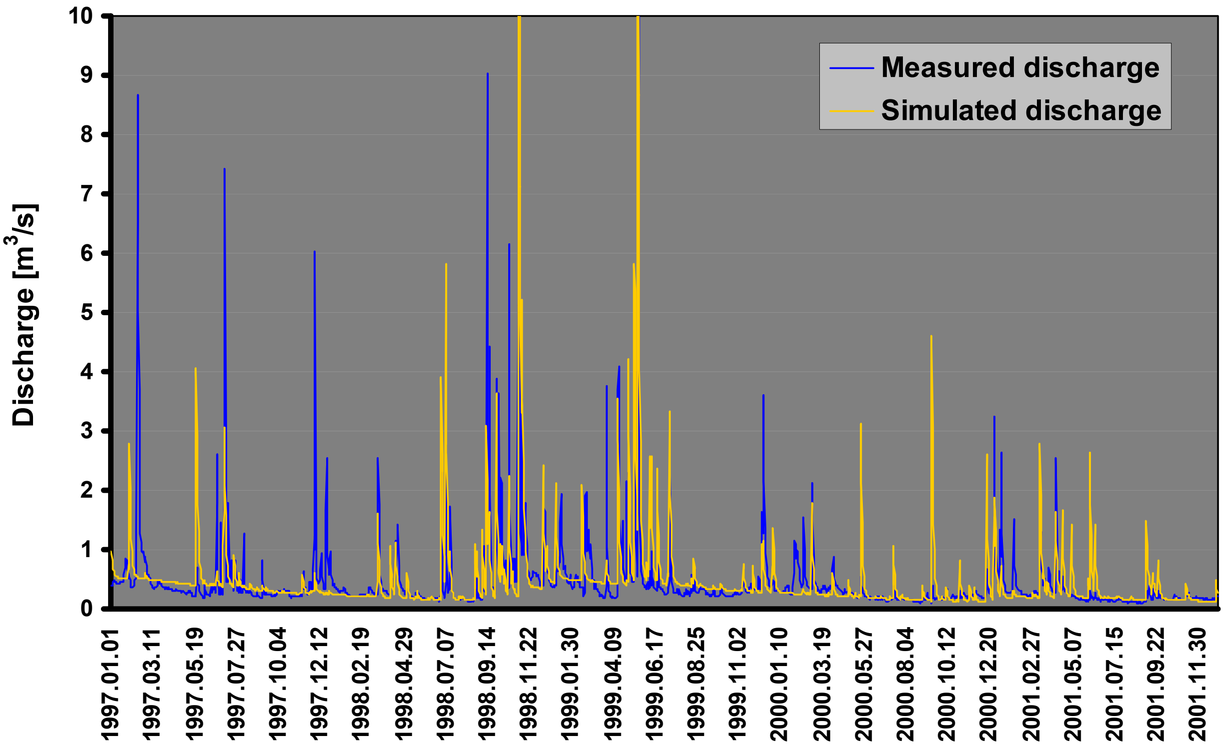


Fig. 6-24: Simulated and measured discharges at Zalalövő station

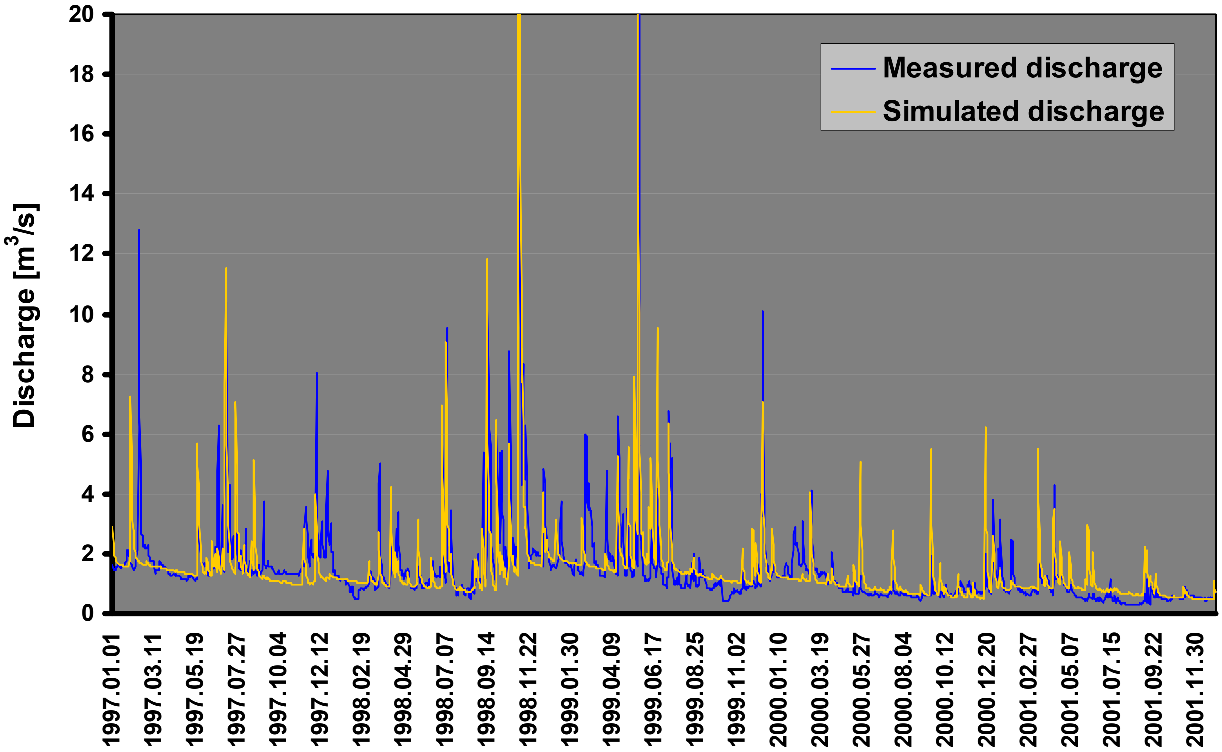


Fig. 6-25: Simulated and measured discharges at Zalaegerszeg station

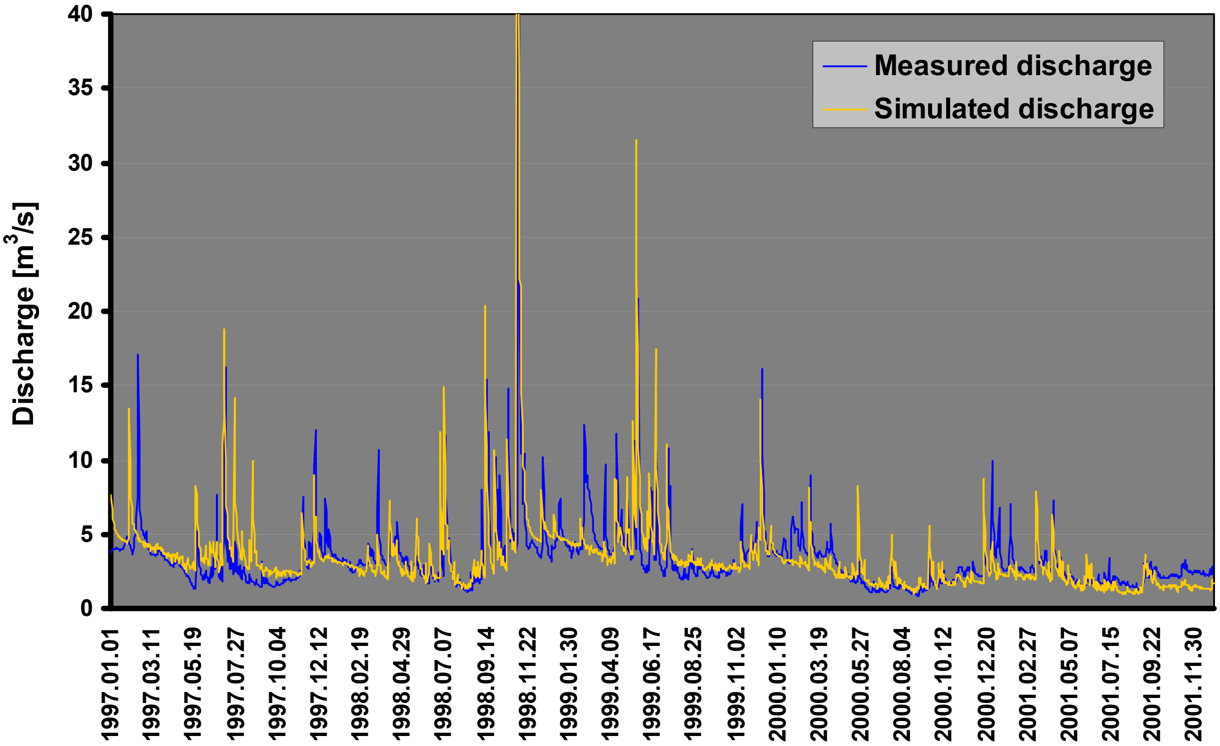


Fig. 6-26: Simulated and measured discharges at Zalabér station

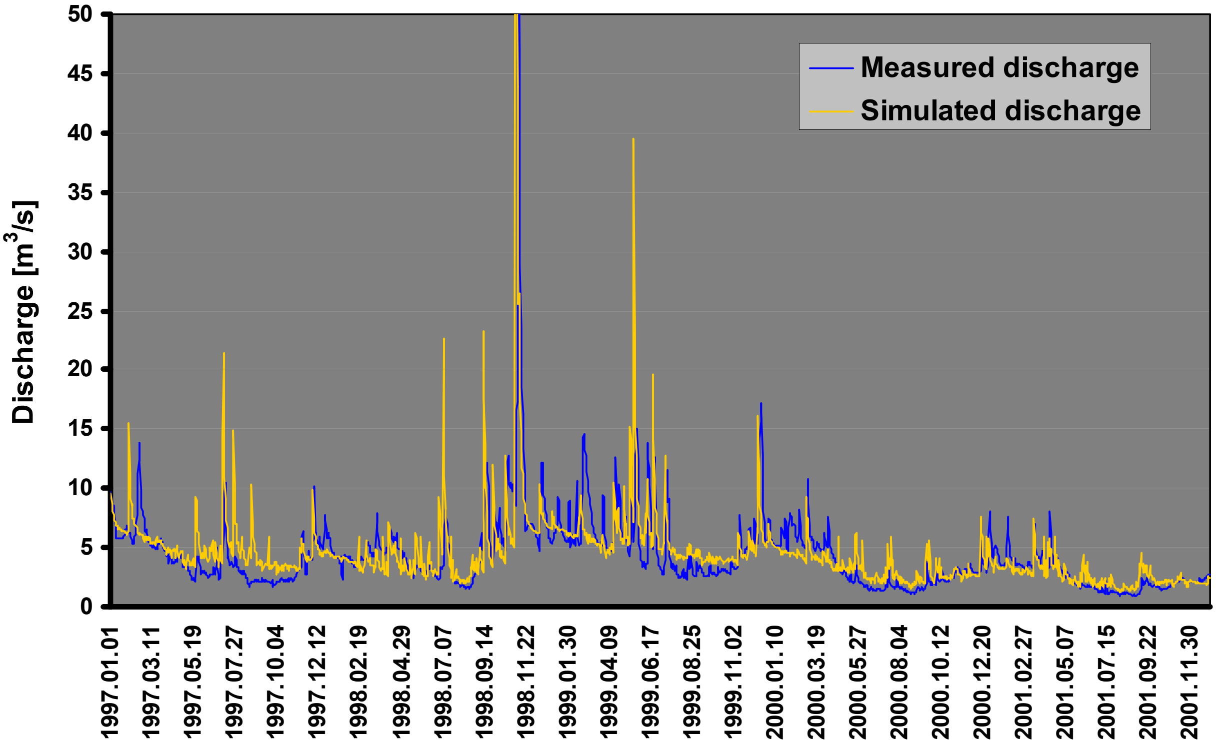


Fig. 6-27: Simulated and measured discharges at Zalaapáti station (watershed outlet)

6.5 The detailed water cycle - HUNGARY

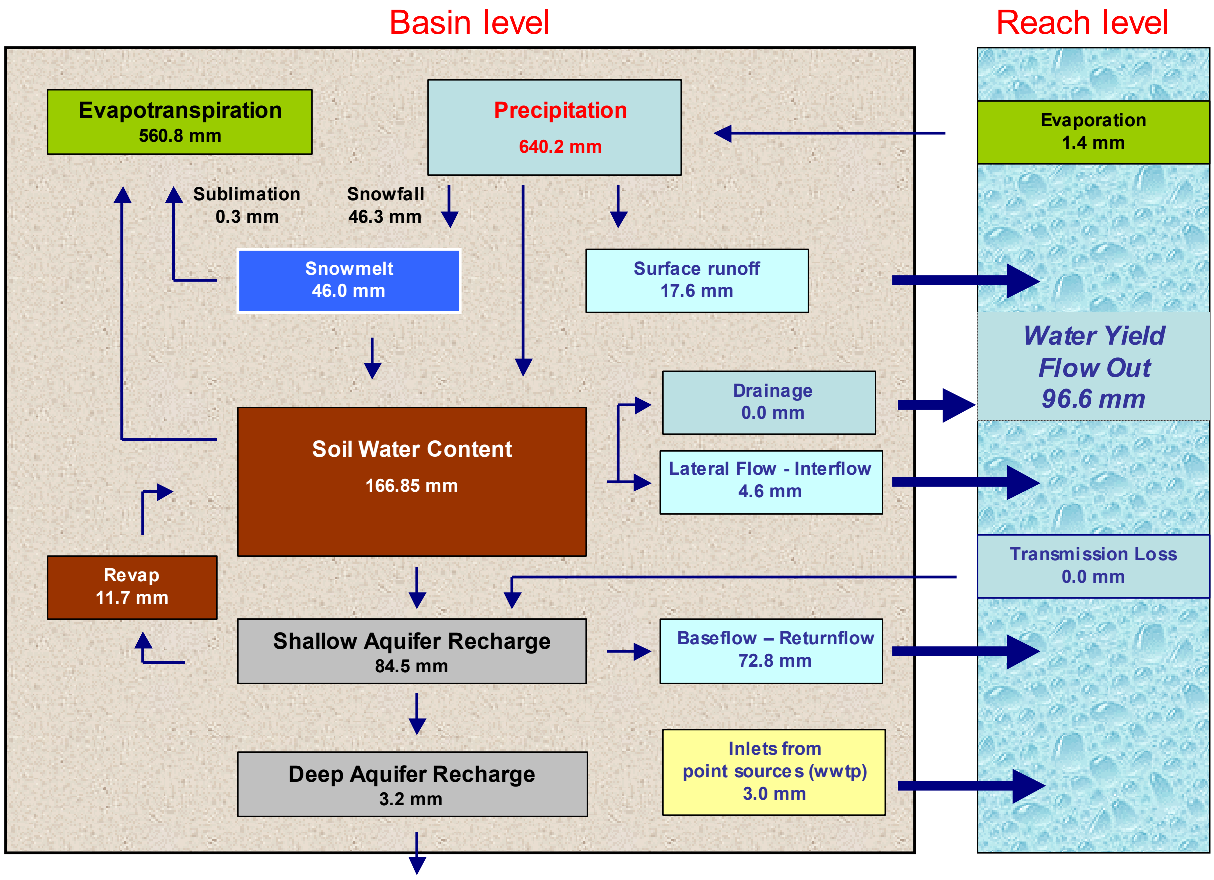


Fig. 6-28: Detailed hydrological cycle for the period 1997-2001

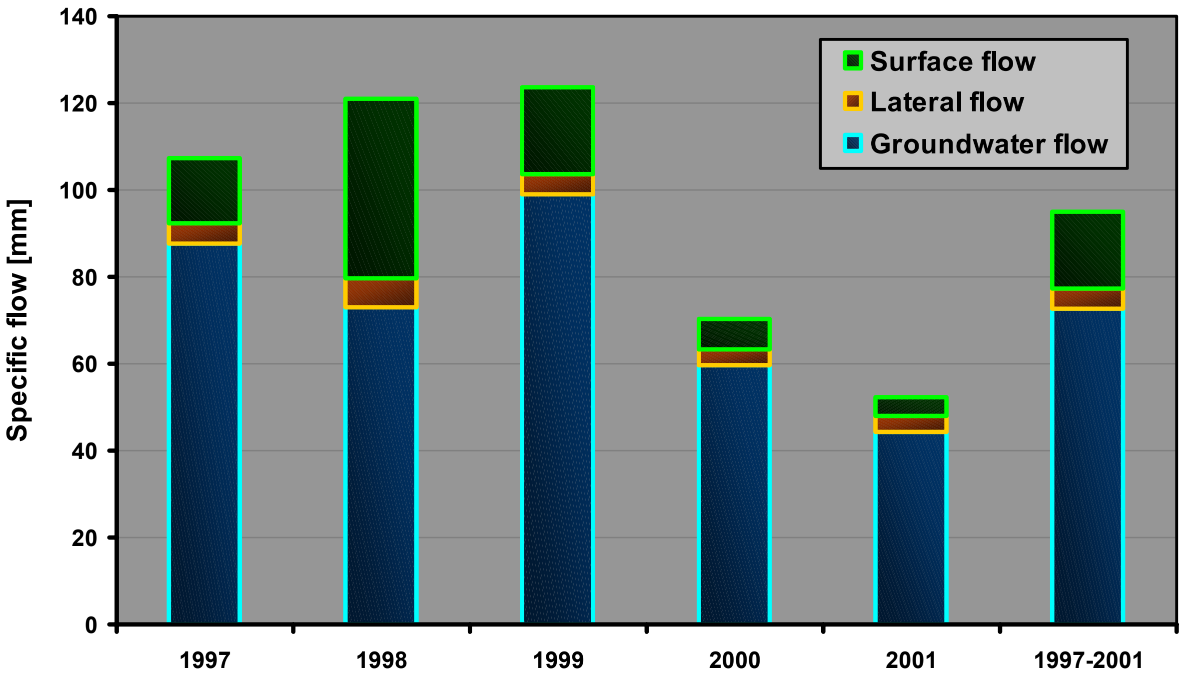


Fig. 6-29: Runoff components of the total catchment area

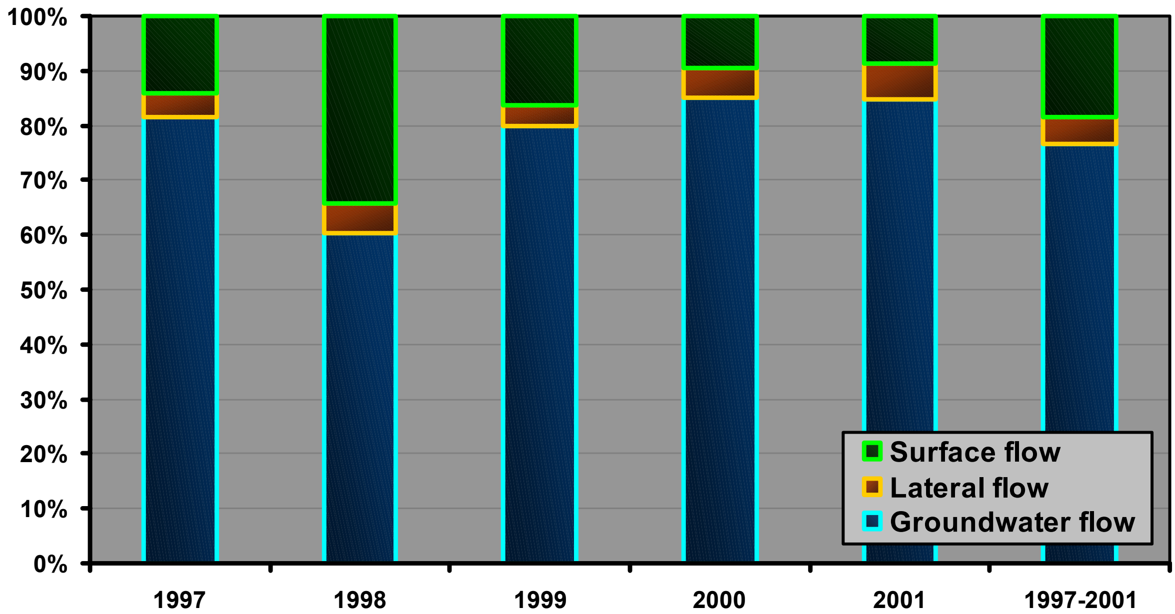


Fig. 6-30: Proportion of the runoff components of the total catchment area

6.5.1 Results of MONERIS model

Regarding the results of MONERIS model the subsurface runoff (sum of groundwater and interflow) has the greatest significance. It is more than 90 % of the total water yield (Figure 6-31 and 6-32). All surface runoff components are very low. The surface runoff from the non-paved areas is almost negligible, since its effect on the total river discharge is less than 1 %.

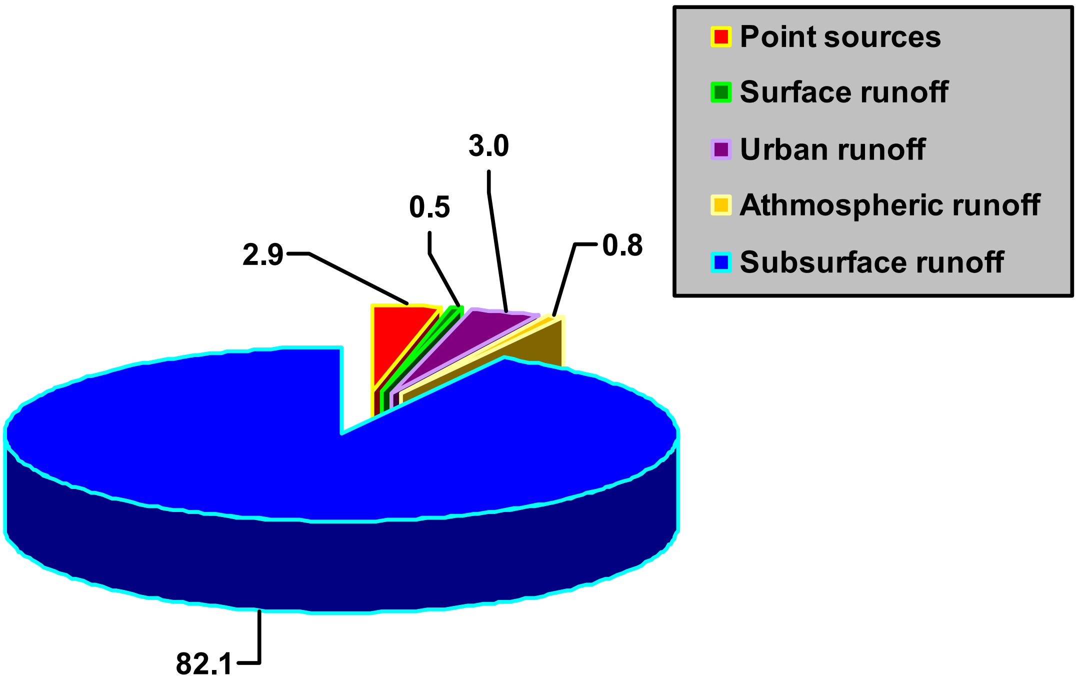


Fig. 6-31: Runoff components of the total catchment area for the period 1997-2001 (in mm/a)

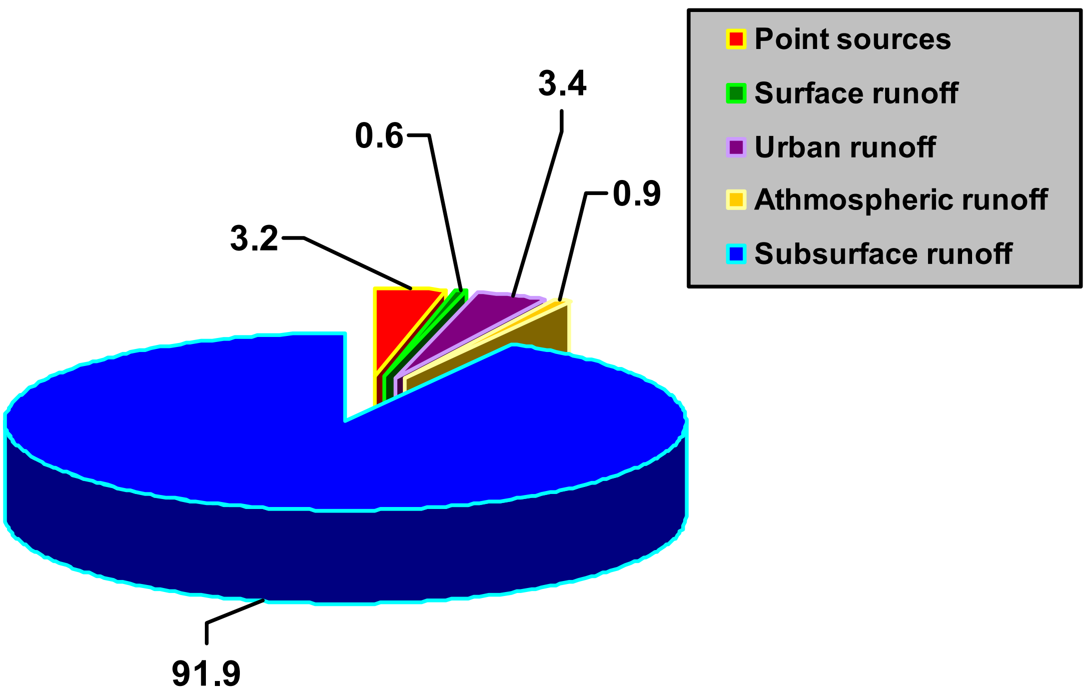


Fig. 6-32: Proportion of the runoff components of the total catchment area for the period 1997-2001 (in %)

6.5.2 Results of DIFGA model

The separation of the measured discharge time series at the watershed outlet is shown in the Figure 6-33. The detached surface runoff time series include only the peaks of the hydrograph. The fast groundwater flow has surprisingly significant dynamics. These components are superposed on the slow groundwater flow having long recession time. The annual average values of the slow groundwater flow are about 50 % of the total measured flow. Consequently this is the most significant flow component (see 6-34 and 6-35). Since the fast subsurface discharge volume is also important, the amount of water entering into the river is determined by the groundwater, while the proportion of the surface runoff is rather low. Only in wet years like 1998 and 1999 is the surface runoff more than 20 %. In contrast, in dry years (2000 and 2001) its proportion does not reaches 10 % of the total runoff.

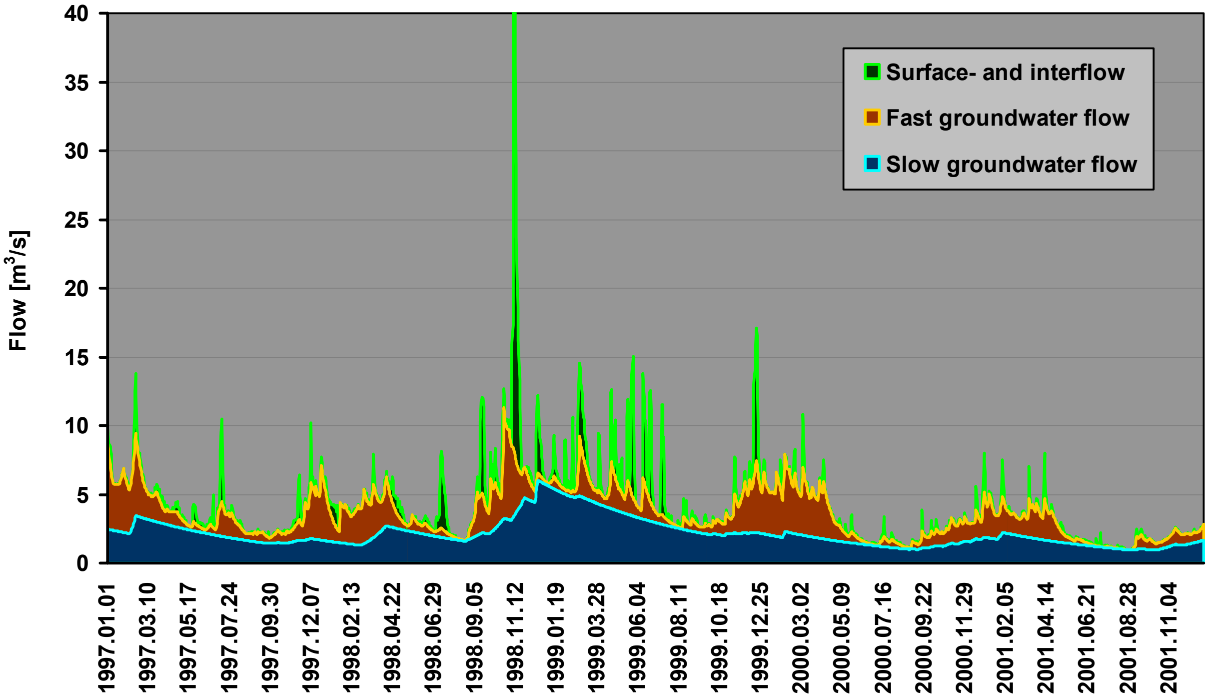


Fig. 6-33: Separated runoff hydrographs at Zalaapáti station

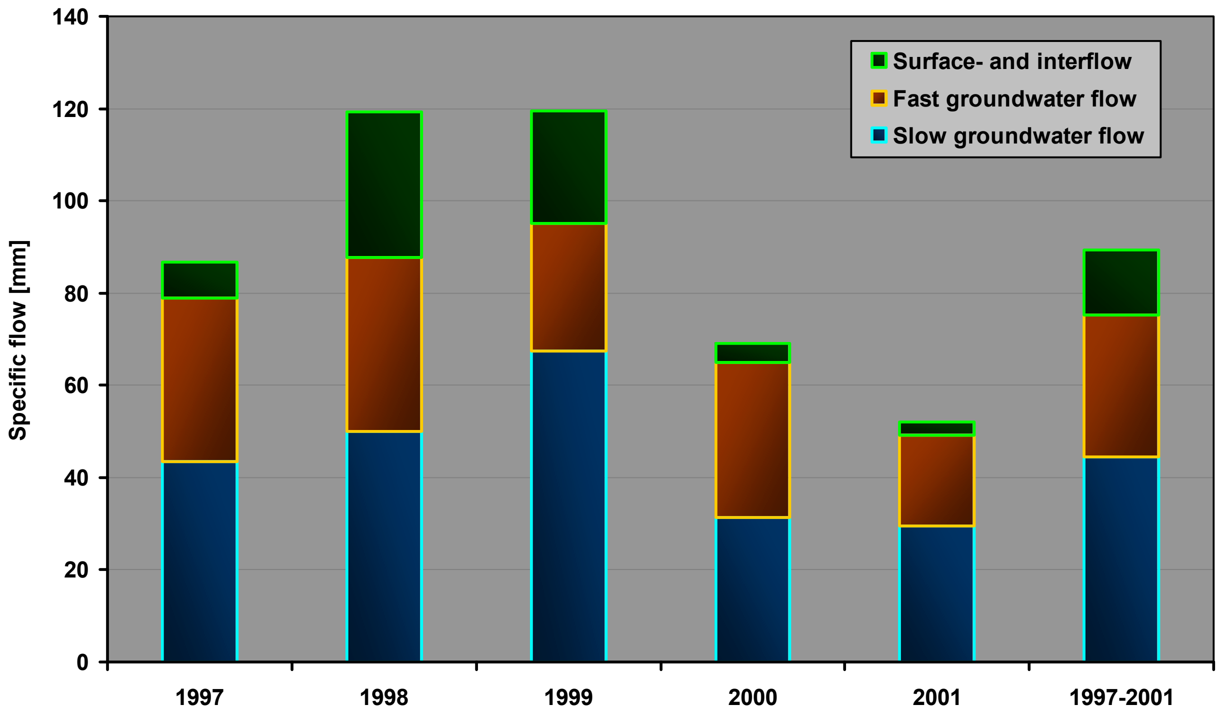


Fig. 6-34: Runoff components of the total catchment area

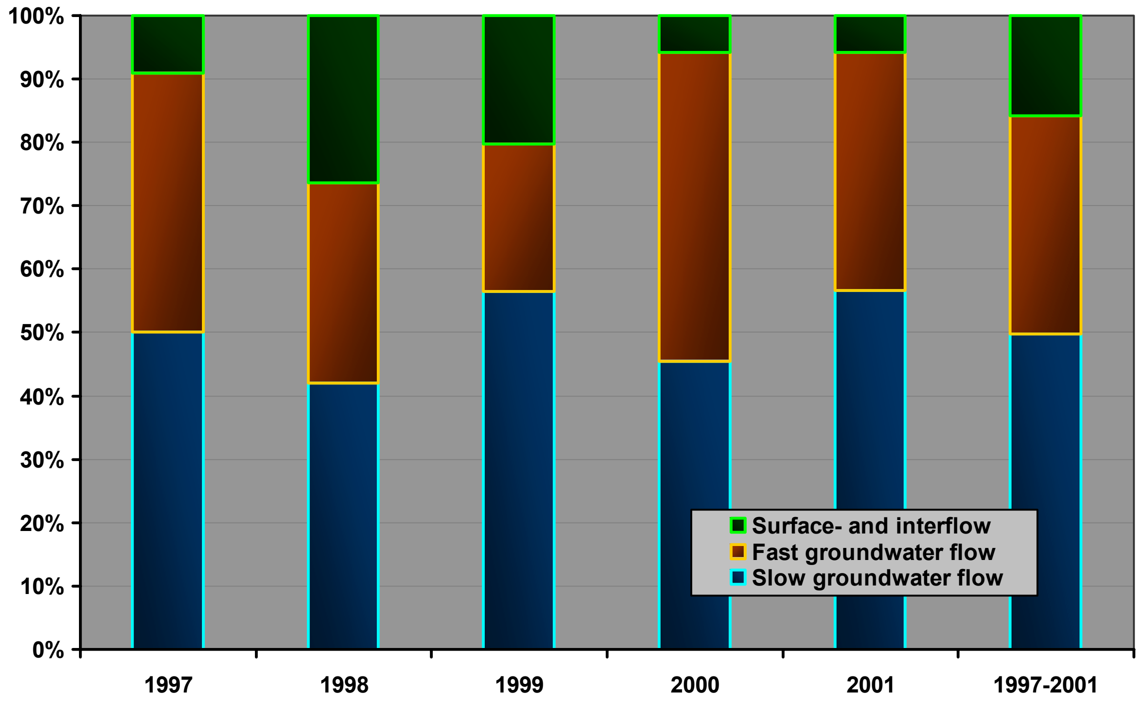


Fig. 6-35: Proportion of the runoff components of the total catchment area

Component	Value mm/a	Proportion %
Total runoff	89.3	
Surface runoff and interflow	14.1	15.8
Fast groundwater flow	30.8	34.5
Slow groundwater flow	44.4	49.7

Tab. 6-19: Runoff components of the whole basin and their proportion for the period 1997-2001

6.5.3 Comparison of the different methods

Each element of the different methods is not fully comparable, because the physical meaning of the runoff components is not the same in the models. SWAT calculates the surface runoff, lateral flow and groundwater flow separately. In the DIFGA the surface runoff incorporates the interflow, but it divides the groundwater flow into two components. MONERIS calculates the surface flow using different paths (urban, non-urban runoff and direct precipitation) and it merges the interflow and the groundwater flow as one subsurface component. So the results aren't comparable to each other directly.

Therefore only two main components are comparable: the total surface and the total subsurface runoff volume. Consequently, the groundwater and lateral flow of SWAT and the slow and fast groundwater component of DIFGA were added and compared. The sum of surface runoffs of MONERIS was treated as integrated result. In case of DIFGA it was assumed that the fast groundwater component includes the interflow partway and the direct runoff component primarily represents the surface flow. The compared values are represented in the **Table 3.** Water yields originated from point sources of SWAT and MONERIS are also presented.

The estimation methods of the average precipitation are different in each model (see Chapter 2). DIFGA and MONERIS results are practically the same, but SWAT calculated slightly lower values than the others. Only SWAT simulates the evapotranspiration on physical base (not using the other water balance components), while DIFGA and MONERIS calculate it as a simple difference of the precipitation and the total runoff. The evapotranspiration of SWAT is a bit lower than the other values. The total flow is simulated in SWAT only, the other models use the measured discharges for the water balance calculations. The average runoff of SWAT is a bit overestimated.

Regarding the runoff components MONERIS calculates the highest subsurface flow (92 % of the total river flow) and the lowest surface runoff volume. This value in DIFGA and SWAT is 84 % and 79 %. Since SWAT simulates the precipitation-runoff events poorly and the direct flow component of DIFGA includes the interflow runoff partway, the real value of the surface runoff may be below the SWAT and DIFGA results, about 15 % of the total runoff. Accepting the value of lateral flow of SWAT (5 %) the groundwater flow is about 80 % of the total river flow. MONERIS underestimates the surface runoff volume markedly.

In an other comparison the sum of surface runoff and lateral flow by SWAT is still higher than the direct flow component of DIFGA, however, the fast groundwater flow in DIFGA and lateral flow in SWAT could partly overlap each other.

Component	SWAT		DIFGA		MONERIS	
	Value mm/a	Proportion %	Value mm/a	Proportion %	Value mm/a	Proportion %
Precipitation	640.2		656.5		656.0	
Evapotranspiration	560.8		569.8		566.8	
River discharge	98.0 *		89.3		89.3	
Point sources	3.0	3.0	-	-	2.9	3.3
Baseflow	72.8	74.3	44.4	49.7		
			30.8	34.5	82.1	91.9
Lateral flow (Interflow)	4.6	4.7				
Surface runoff	17.6	18.0	14.1	15.8	4.3	4.8

* excepted the water loss from evaporation of the water bodies

Tab. 6-20: Average values of the main hydrological components of the total catchment area and the proportion of the different flow components for the period 1997-2001

Finally we concluded that the empirical water balance method of MONERIS underestimates the surface runoff, consequently overestimates the subsurface flows. This is in harmony with our practice got from the discharge time series analyses. It is also verified by the results two other model, although the verification of SWAT was rather poor, and the water balance components are less comparable.

Therefore it is suggested certain precaution accepting the original water balance method of MONERIS, when it is applied in the whole Danube Basin.

6.6 *Water balance – ROMANIA*

6.6.1 The SWAT 2000 model

Component	Value (mm)
Precipitation (PRECIP)	495
Snowmelt (SNOMELT)	80
Sublimation	1
Surface runoff (SURQ)	15
Infiltration	480
Lateral flow (LATQ)	1
Groundwater discharge (GWQ)	52
Deep aq. recharge (DA_RCGHG)	0
Percolation (PERC)	76
Total water yield (WYLD)	66
Evapotranspiration (ET)	409
Potential ET (PET)	1036
Transmission losses (TLOSS)	1.3
Soil water content (SW)	85
Reevaporation (REVAP)	24

Tab. 6-21: Average values of water balance components resulted from SWAT run

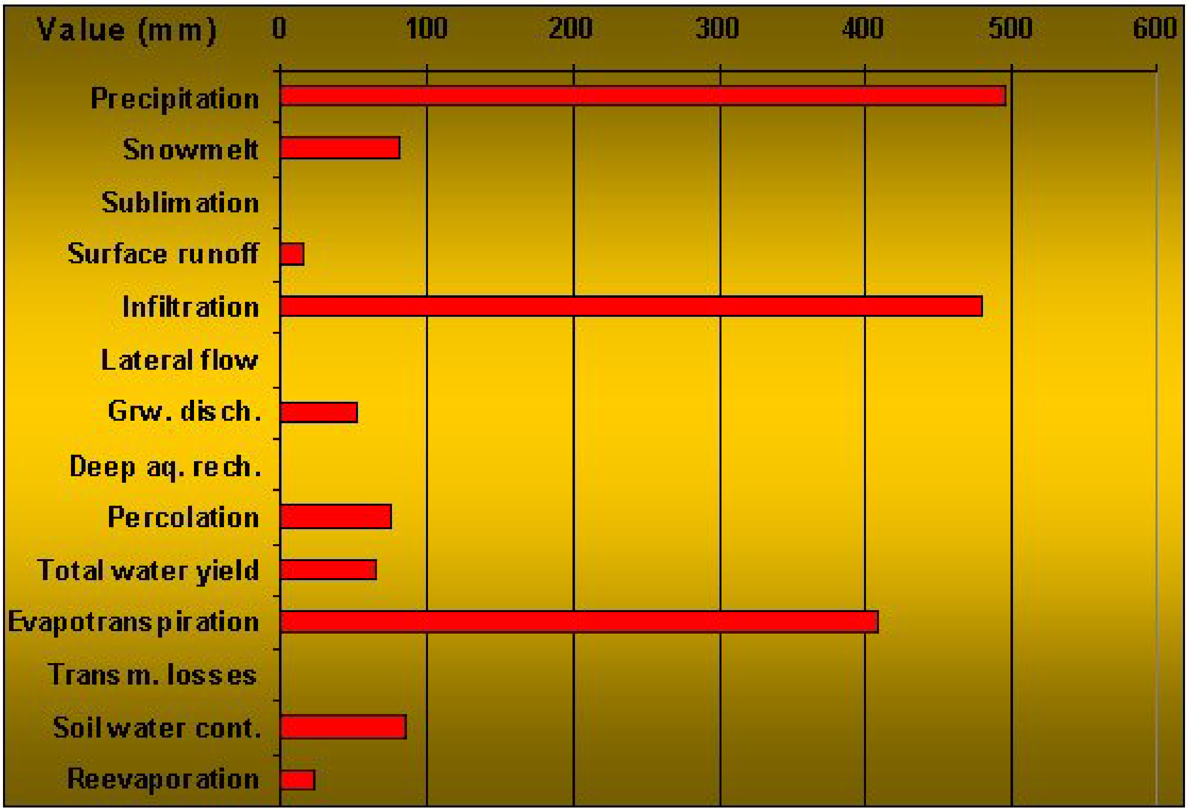


Fig. 6-36: Average values of water balance components resulted from SWAT run

6.6.1.1 Evapotranspiration

Definition: Actual evapotranspiration from the basin / subbasin during the time step (mm).

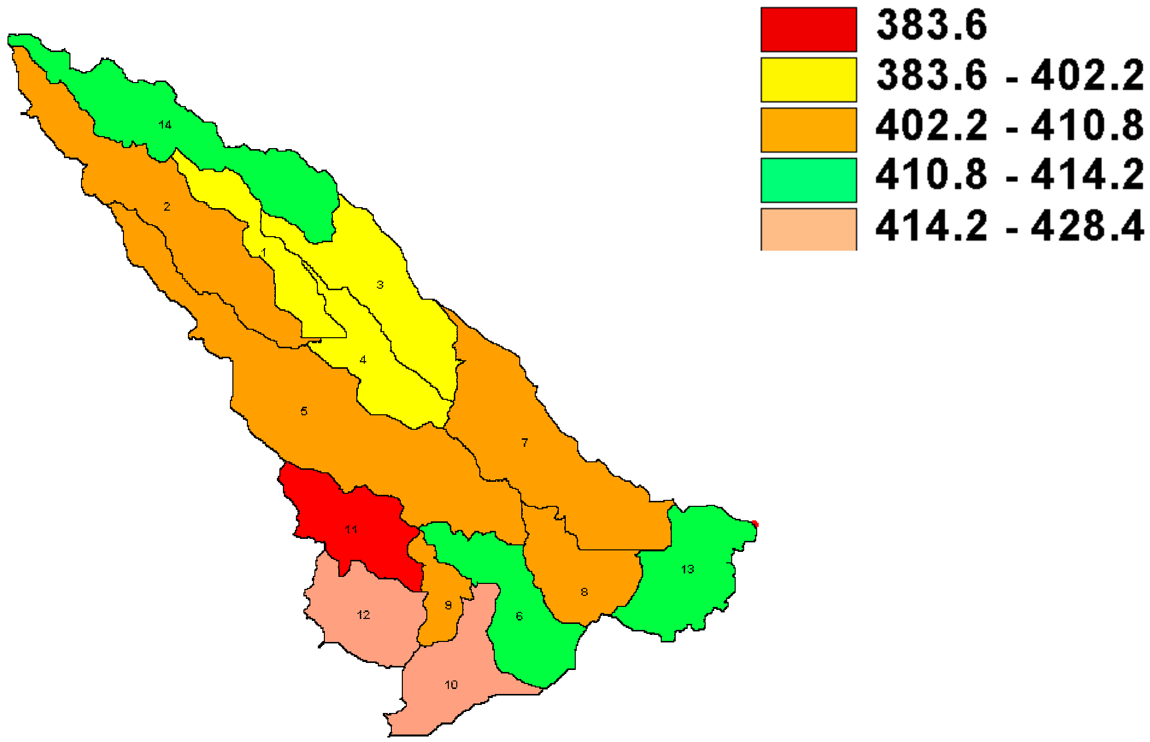


Fig. 6-37: Evapotranspiration spatial distribution

Month	ET
Jan	7.0
Feb	15.6
Mar	27.5
Apr	39.6
May	70.5
Jun	108.9
Jul	46.4
Aug	32.0
Sep	32.6
Oct	17.8
Nov	9.3
Dec	6.6
Annual average	413.7

Tab. 6-22: Evapotranspiration monthly average

6.6.1.2 Snowmelt

Definition: Amount of snow or ice melting during time step (water- equivalent mm H_2O).

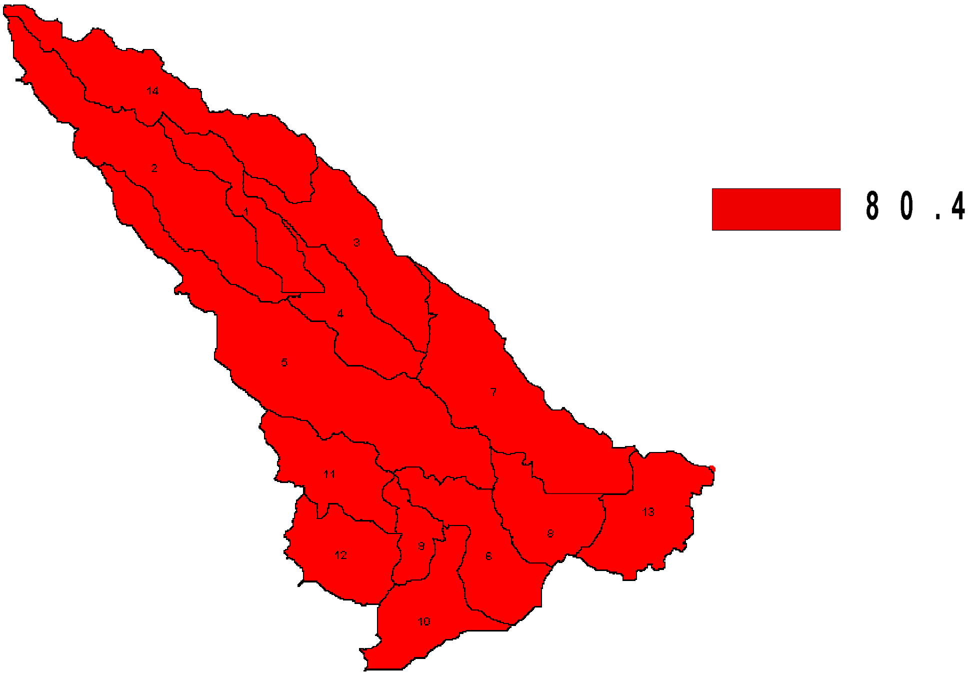


Fig. 6-38: Spatial distribution of snowfall

Month	SNOMELT
Jan	23.4
Feb	22.5
Mar	12.3
Apr	0.0
May	0.0
Jun	0.0
Jul	0.0
Aug	0.0
Sep	0.0
Oct	1.0
Nov	4.7
Dec	16.4
Annual average	80.4

Tab. 6-23: Snowfall monthly average

6.6.1.3 Surface runoff

Definition: Surface runoff contribution to stream flow during time step (mm H_2O).

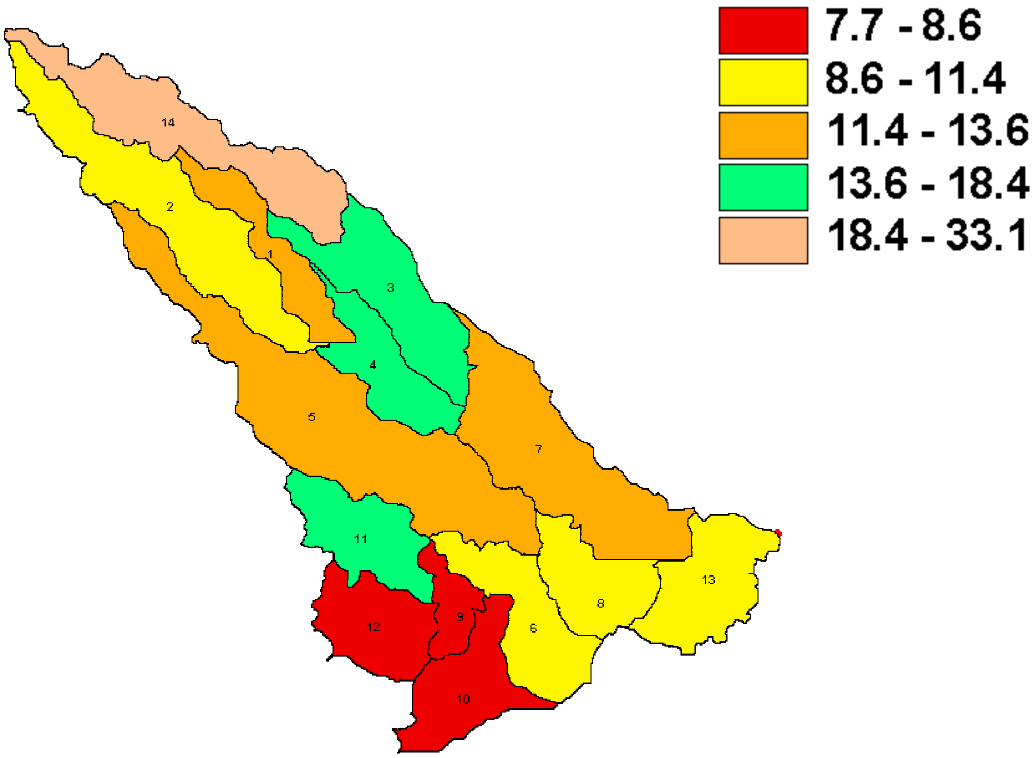


Fig. 6-39: Spatial distribution of surface runoff

Month	SURQ
Jan	2.8
Feb	3.4
Mar	0.9
Apr	3.8
May	0.1
Jun	0.2
Jul	0.0
Aug	0.0
Sep	0.0
Oct	0.0
Nov	0.1
Dec	0.1
Annual average	11.4

Tab. 6-24: Surface runoff monthly average

6.6.1.4 *Groundwater shallow aquifer recharge*

Definition: Groundwater contribution to streamflow (mm). Water from the shallow aquifer that returns to the reach during the time step.

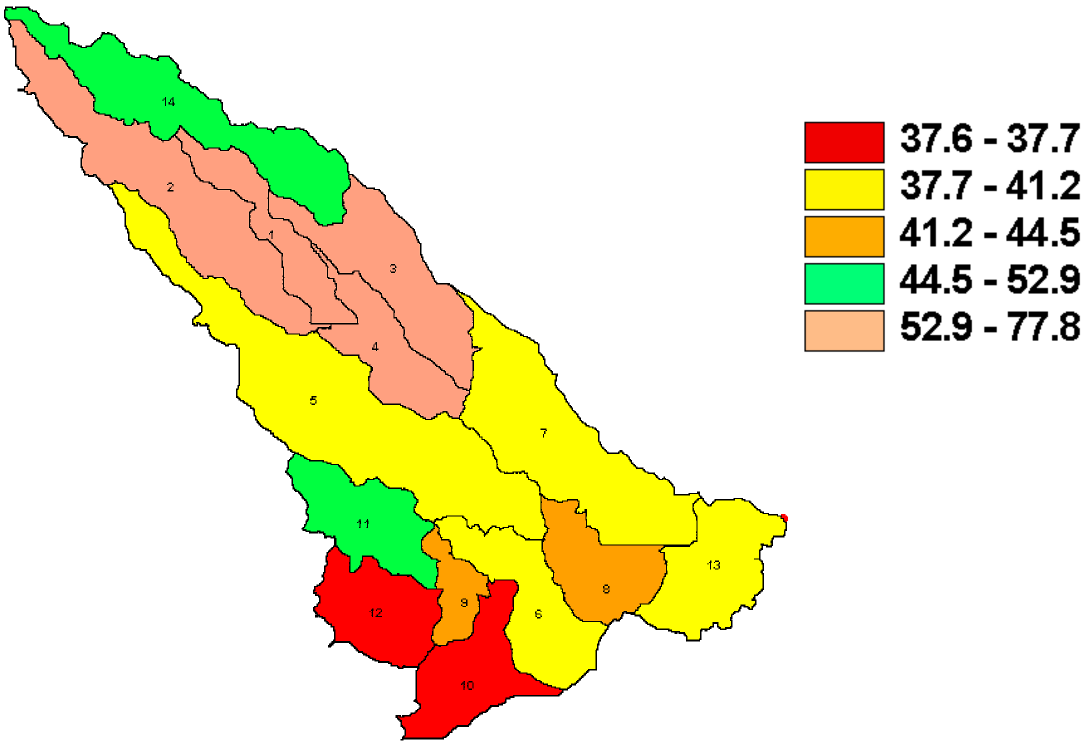


Fig. 6-40: Spatial distribution of groundwater shallow aquifer recharge

Month	GW_Q
Jan	4.3
Feb	4.5
Mar	4.5
Apr	3.5
May	3.0
Jun	2.8
Jul	2.8
Aug	2.7
Sep	2.6
Oct	2.8
Nov	3.2
Dec	4.1
Annual average	40.7

Tab. 6-25: Groundwater shallow aquifer recharge monthly average

6.6.1.5 Water yield

Definition: Water yield (mm H2O). The net amount of water that leaves the subbasin and contributes to stream flow during the time step.

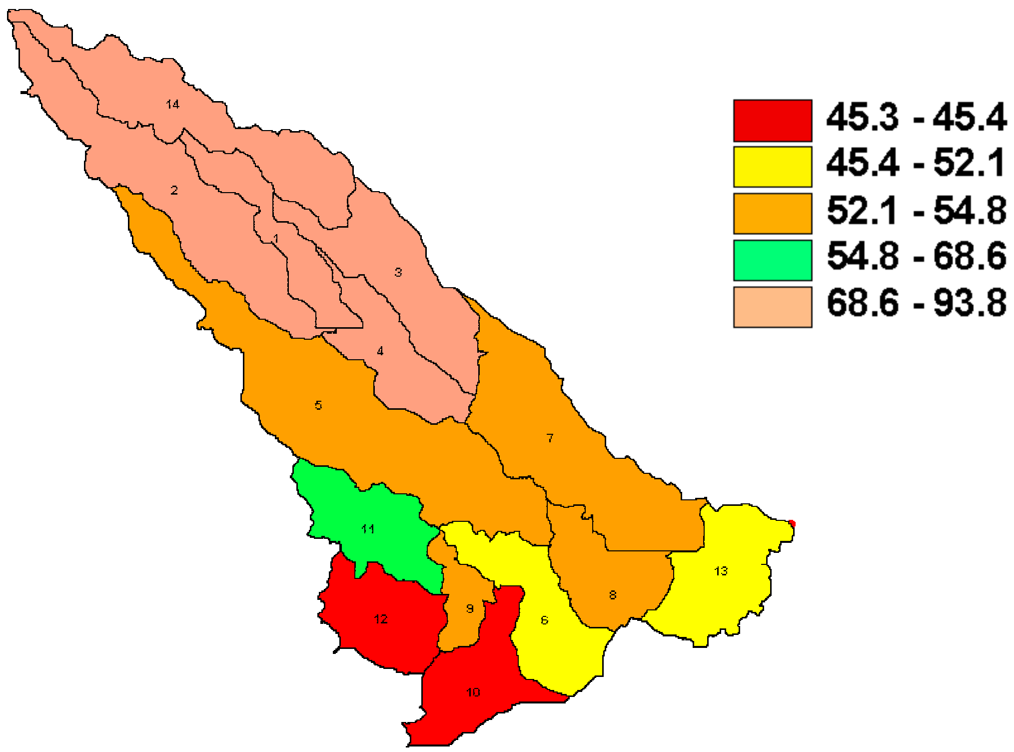


Fig. 6-41: Spatial distribution of water yield

Month	WYLD
Jan	7.1
Feb	7.8
Mar	5.3
Apr	7.3
May	3.2
Jun	3.0
Jul	2.8
Aug	2.7
Sep	2.6
Oct	2.8
Nov	3.3
Dec	4.2
Annual average	52.1

Tab. 6-26: Water yield monthly average

6.6.1.6 Soil water content

Definition: Soil water content (mm). Amount of water in the soil profile at the end of the time period.

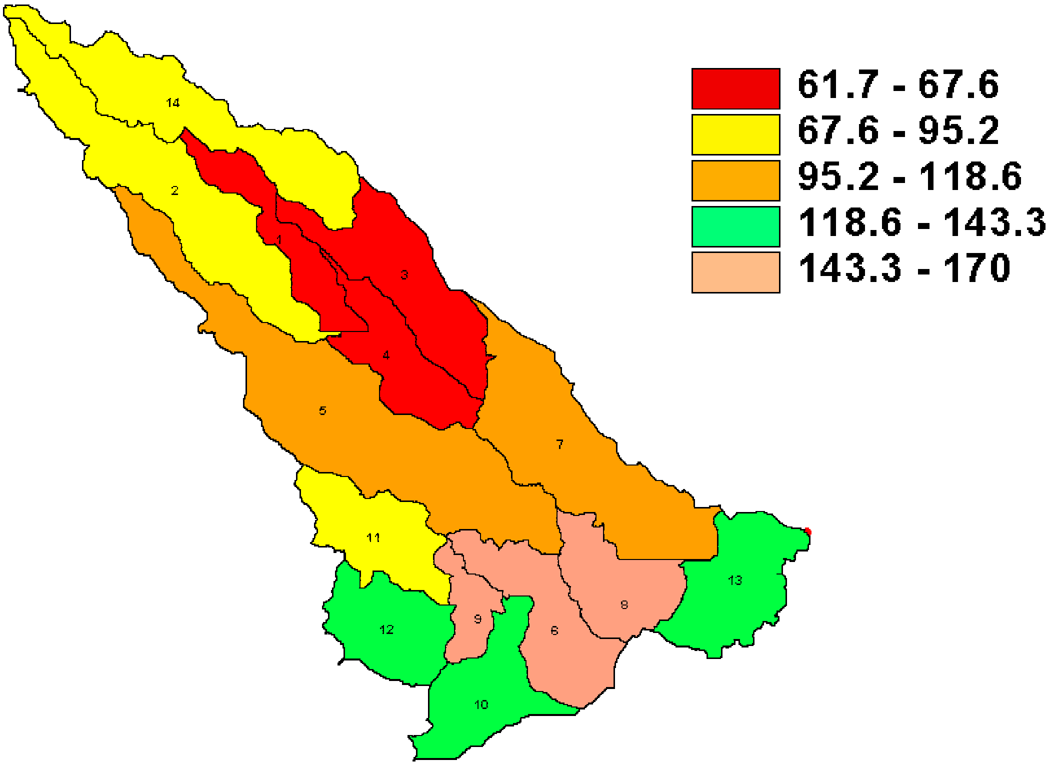


Fig. 6-42: Spatial distribution of soil water in each study case

Month	SW
Jan	182.5
Feb	174.5
Mar	185.3
Apr	170.2
May	144.5
Jun	96.7
Jul	86.7
Aug	94.2
Sep	116.3
Oct	123.7
Nov	144.0
Dec	165.4
Annual average	140.3

Tab. 6-27: Soil water content monthly average

6.6.2 Reach level

Location	Average (m3/s)	Maximum (m3/s)	Minimum (m3/s)
Calugareni	7.26	172.5	0.12
Vadu Lat	3.84	58.98	0.12
Moara din Groapa	0.84	18.98	0.11

Tab. 6-27: SWAT computed river discharge

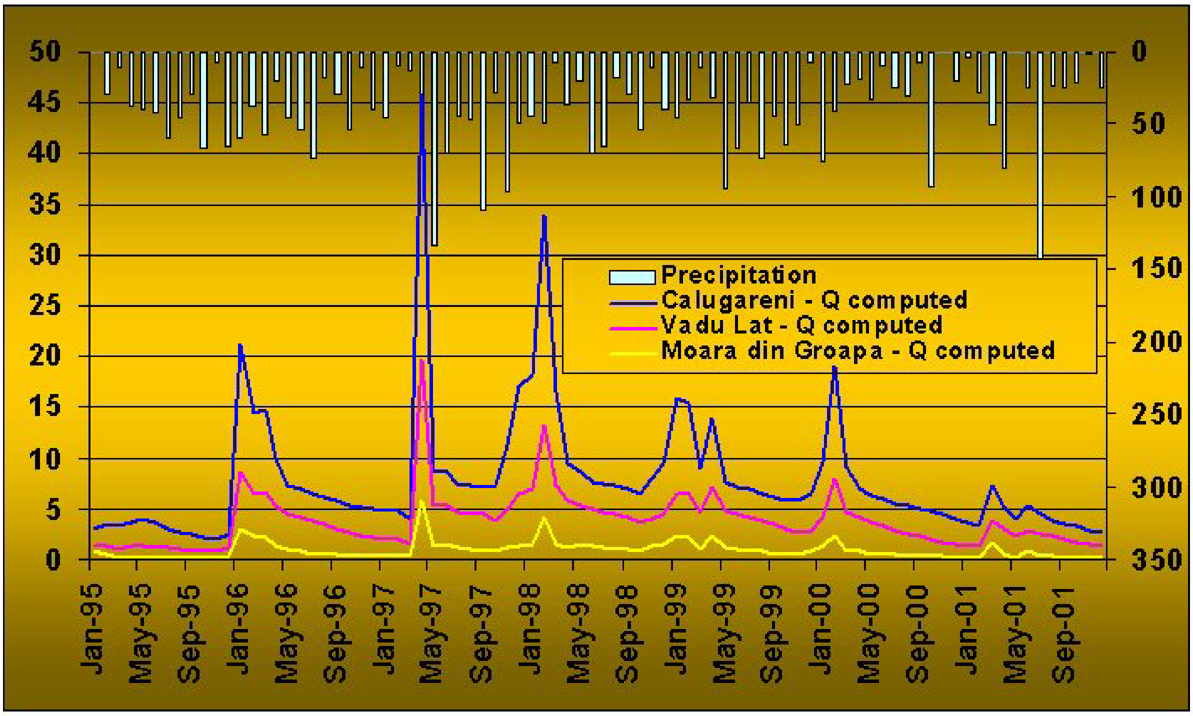


Fig. 6-43: River monthly discharge for the period January 1995 – December 2001

In order to compute the river discharge the SWAT simulation was run for the period 1st January 1995 to 31st December 2001. The printout frequency of the SWAT model was set to daily. The graphic is showing in generally three moments of maximum river discharge. First moment (February) is generated by the partially snowmelt and low level of evapotranspiration. The second moment (April) is generated by the increased amount of rainfall and also to the maintenance of low level of evapotranspiraton. The third moment (December) is generated on a background of a relatively high level of precipitation and on the very low level of evapotranspiration. The graphic also shows a period (July - October) of low levels of river discharge, due to the very high values of temperature (during the summer) and to the low level of rainfall (beginning of autumn).

6.7 *The detailed water cycle – ROMANIA*

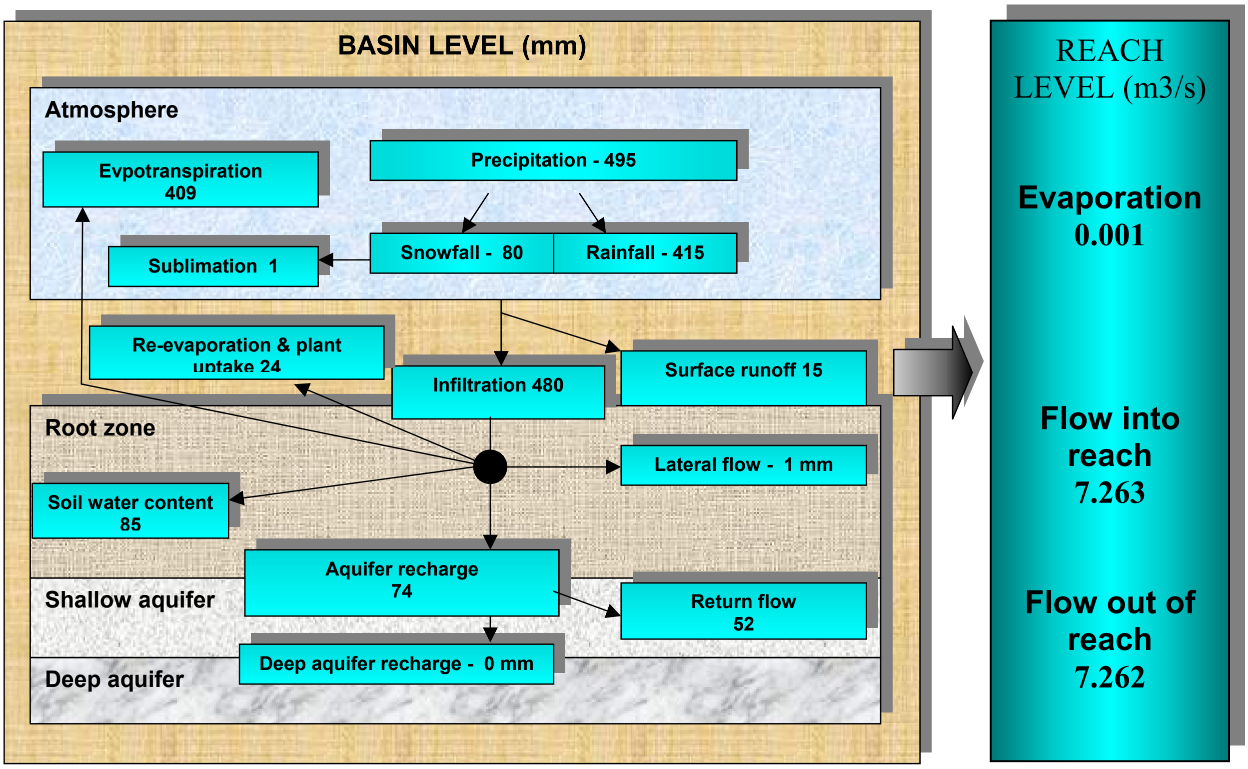


Fig. 6-44: Detailed hydrological cycle for the study case

6.7.1 Discussion

The results of the SWAT model application will be discussed from two points of view: the first part of the discussion will be dedicated to the analysis of the water balance components spatial distribution and the second part will be dedicated to the water balance components repartition along the year.

First of all, it has to be mentioned that the relief of the Neajlov basin is characteristic for Getic piedmont – a plain with low slope (from 0.08 % in subbasin 10 to 0.8 % in subbasin 14), covered by loess, with compacting micro-depressions and large parallel valleys oriented from NW to SE. The altitude is gradually decreasing from north (300 m) to south (about 60 m). Due to the major influences of the altitudinal gradient on geomorphologic, climatic and anthropic factors the water balance components of the Neajlov basin are changing in accordance with the transition from steppe landscapes (in the southern / lower part of the basin) to the sylvo-steppe (in the central part) and to the hilly landscapes (in the northern / upper part). At the basin level in most of the cases the output results are showing this tight correlation between the different water balance components values and the altitudinal gradient. However, there are few exceptions from the rule generated by local condition.

As a consequence of the particular soil and land use pattern for certain subbasins (as described in the “HRU distribution chapter”) these subbasins have a different behavior compared with the surrounding basins.

The dominant land cover within the HRU’s for each subcathcement was the AGRL (Agricultural Land Generic) type which was present in all subcatchments and the FRSD (Forest Deciduous type) which was present in the subcatchements 3, 7 and 13.

In the case of soils within each subbasin, the situation is more complex. The subcatchements 1 – 8 and 13 - 14 are dominated by HRUs with brown red argiloiluvial soils (brp, brepi, brn, bri), which are belonging to the Luvisols class, with patches of “svrgm” soils, which are belonging to the Planosols, while the subcatchements 9 – 13 are dominated by levigated chernozems (clmp, clf, clma, clfp) which are belonging to the Pheozems class, with patches of brown red soils.

A. Luvisols are characterized by the importance of the clay illuviation processes that have occurred within the initial parent material. The main consequence of this mechanism is a morphological differentiation between:
- ✓ upper horizons with loss of clay and iron oxides, with lighter colors, weaker structure and generally permeable (E horizons); and
- ✓ lower horizons with accumulation of clay and iron oxides, with well developed polyhedric or prismatic structure, stronger colors and less permeable (BT horizons).

B. Chernozems, defined as soils occurring under grassland-forest transition, grasses and forbs, usually develop in cool to cold, subarid to subhumid climates (Soil Science Glossary, 1976). The cool climate region combined with the grasslands creates a favorable environment for chernozems to develop (Greenlee,1976). They develop highly under dryland grasses and low under wetland grasses, trees and shrubs (Soils Science Glossary, 1976).

The soil distribution is characterized by the spatial distribution of soil types in two major regions:

1. The northern, southern and eastern regions are dominated by luvisoils and planosoils. The texture of the soil profile is in generraly silt loam-silt loam-silty clay –loam or sandy loam-loamy sand-sandy clay loam-loam.
2. The Southwestern region dominated by chernozems. The texture of the soil profile is in generally loam-clay loam-silt loam or silty clay loam-clay loam-loam.

Due to the complexity of spatial distribution of hydrologic balance components it has been made an cluster analysis in order to group the subbasins in functional classes. In order to perform the cluster analysis it has been used the complete linkage method for amalgamation with the simple Euclidian algorithm for distance measurement. The variables used for clusterisation were: water yield (WYELD), groundwater shallow aquifer recharge (GWQ), surface runoff (SURQ), evapotranspiration (ET), percolation (PERC), and soil water content (SW). The analysis was performed both for subbasins and variable behavior. For each of these variables were defined 5 classes of values in accordance with the SWAT results (with class 1 meaning the lowest value of the variable and class 5 meaning the highest value of each variable). So, each of the subbasins were characterized by 6 values, each of these variables having 5 classes of values.

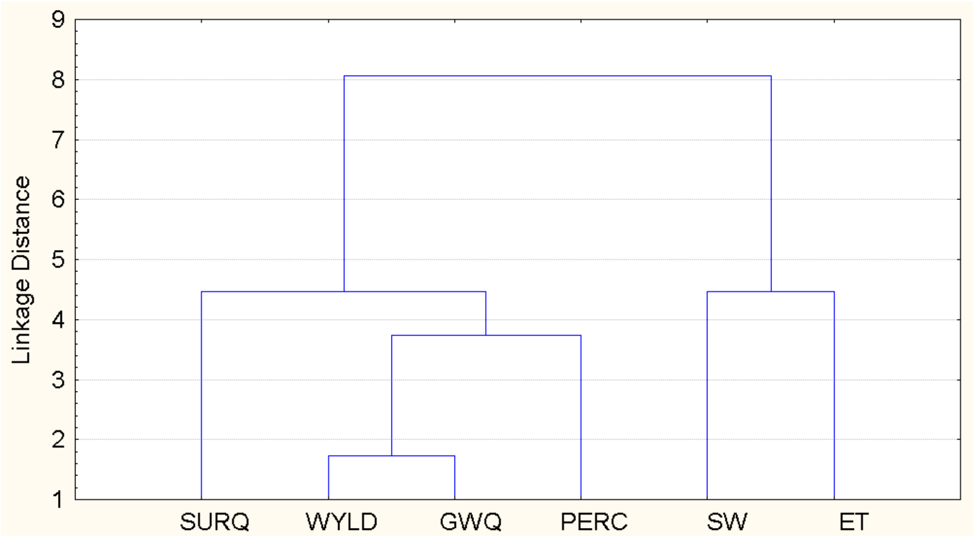


Fig. 6-45: Cluster analysis performed for water balance components

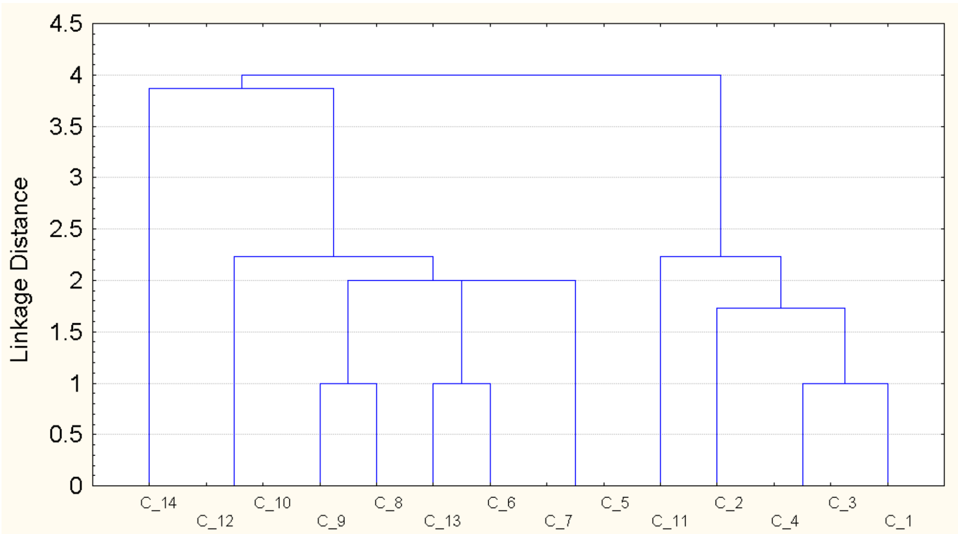


Fig. 6-46: Cluster analysis performed for subbasins behavior

The results of cluster analysis for variables show a strong behavioral similitude within 2 pairs of variables, which confirms the realistic results of the model run. Pair one is formed by the water yield and groundwater runoff, which confirms that the groundwater runoff represents about 78 % from the water yield, after which they are connected with percolation and surface runoff showing their intercorrelation. The second pair is formed by soilwater content and evapotranspiration, which confirms that the soils with high water content are also having a great level of evapotranspiration.

For the subbasins cluster analysis the situation is more complex due to the greater number of cases (14) and their variability. In order to have a clearer image of the functional similarities between different subbasins there were defined few levels of aggregation. For each level of aggregation there were defined groups of subbasins with similar variability of water balance components. The following levels of aggregation were defined:

- Level 1 (Linkage distance between 0 and 1) with a number of 8 groups of subbasins.
- Level 2 (Linkage Distance 1 – 2.2) with a number of 3 groups of subbasins;
- Level 3 (Linkage Distance 2.2 - 4) with a number of 1 group of subbasins;

For further operation it was chosen the level 2 of aggregation, which comprised 3 groups of subbasins, defined after the geographic location of the majority of subbasins from each group. The defined groups were:

- Group 1 (Central Group), comprising subbasins: 1 – 5 and 11;
- Group2 (Southern Group), comprising subbasins: 6 –10 and 12 - 13;
- Group 3 (Northern Group), comprising subbasin: 14;

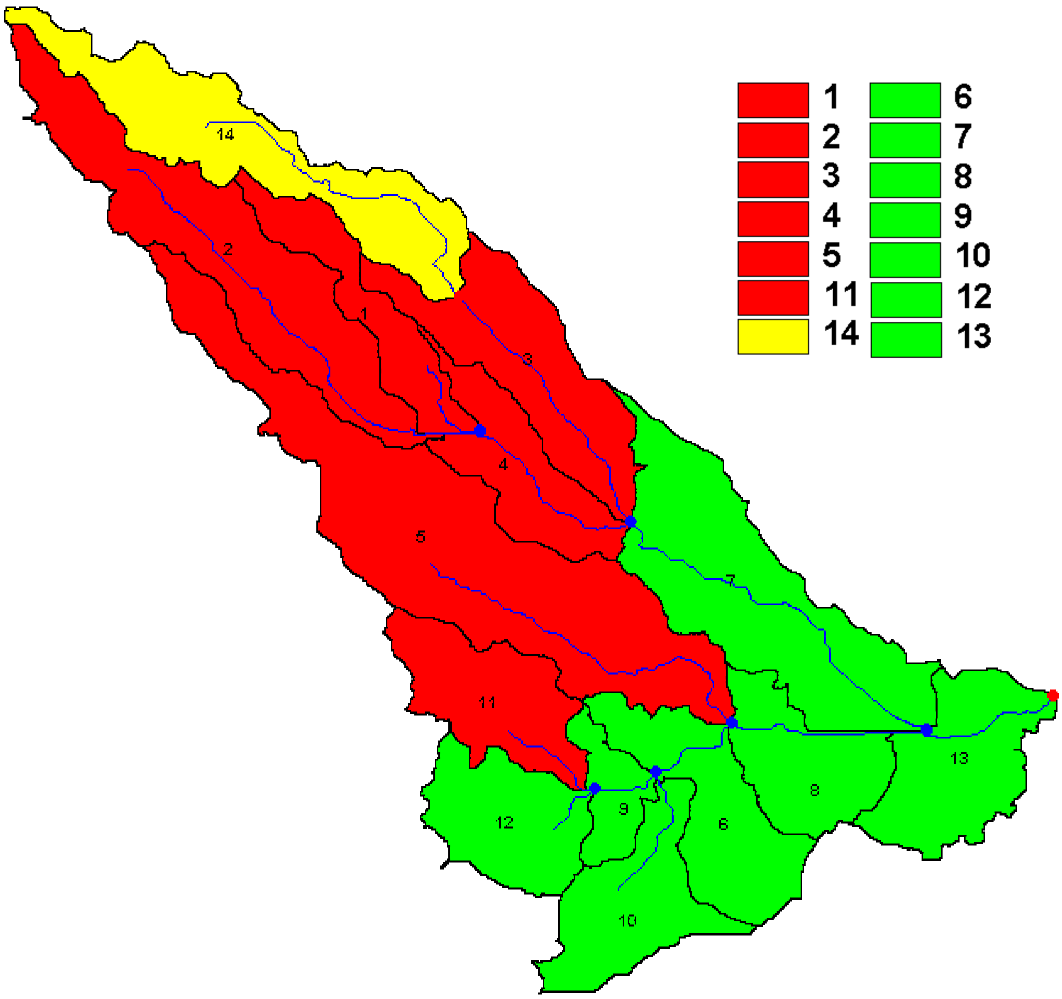


Fig. 6-47: Subbasins functional groups based on cluster analysis

Group 1 is characterized by the lowest value of evapotranspiration (400m), while the groundwater runoff is having the maximum values for entire catchement (66 mm), leading togheter with the surface runoff (14.5 mm) to a high value for water yield (80mm).

Group 2 is characterized by lowest values of surface runoff (10 mm). The infiltration level is having the greatest values for this group (485 mm), but is balanced by a higher level of evapotranspiration (416 mm). This group is characterized also by extreme values for entire catchement for soil water content (146 mm), water yield (50 mm) and groundwater recharge (40 mm).

Group 3 (located in the northern part of the catchment) is characterized by high values of surface runoff (33 mm annual average) and by high values of total water yield (86 mm annual average). The infiltration (462 mm) for this group is lower than the catchment average (480 mm) and the evapotranspiration is higher (412 mm). These factors together with the soil properties are showing a very rapid circulation of water from upslope to the river, mainly through groundwater runoff (60% from water yield) but with a significant contribution of surface runoff (38 % from water yield) for these two groups.

Component	Group1	Group2	Group3	Catchement average
Precipitation (PRECIP)	495.7	495.7	495.7	495.7
Snowmelt (SNOMELT)	80.4	80.4	80.4	80.4
Potential Evapotranspiration (PET)	1036.6	1036.6	1036.6	1036.6
Evapotranspiration (ET)	400.6	416.0	412.7	409
Soil Water (SW)	80.3	146.8	85.5	85
Percolation (PERC)	84.4	73.8	55.4	76
Surface runoff (SURQ)	14.5	10.0	33.1	15
Groundwater recharge (GW_Q)	66.3	40.7	52.9	52
Water Yield (WYLD)	80.8	50.8	86.0	66
Infiltration	481.2	485.7	462.6	480
Lateral Flow (LATQ)	1	1	1	1

Tab. 6-28: Group average values for main water balance components (annual average values for 1995 – 2001)

The repartition of the water balance components during the year is reflecting the same general pattern for all groups, with exception of groundwater aquifer recharge and lateral flow.

So, for each group, the evapotranspiration is having the highest value in June (101/109/107 mm) when the air and soil temperatures are about to reach their maximum level (July - August), having for this period a value of 24^0C (air temperature) and 27^0C (soil temperature). The evapotranspiration for June is greatest than the one from July or August due to the high humidity of the soil layer after the spring season generated both by the high rainfall amounts in April - May (about 50 mm/month) period and by the still low temperatures.

The snowmelt process is having the same pattern and values for all catchements and groups being present at the begining of the year between January and March and at the end of the year between october and december. The maximum level of snowmelt is recorded in January (23.4 mm), the minimum in October (1 mm) and the annual average is of 80 mm.

The surface runoff has two characteristic periods. The first period between November and April is characterized by an increased value of surface runoff that has a maximum value of 4.6 mm for Calugareni and 3.4 mm for Vadu Lat in April with a second maximum for these outlets in February (4.3 / 3 mm). For Moara din Groapa stationn the maximum is reached in February (9.1 mm) and the second maximum in April (7.6 mm), reflecting it's location in the upper part of the catchment where the effect of spring floods at the entire catchement level is dimished These values are the result of correlation between the main driving forces of surface runoff such as: strong water saturation of soil, low level of evapotranspiration and increased amount of rainfall and snowmelt. The other months of the year are characterized by low values of surface runoff (0 – 1 mm) depending on each case.

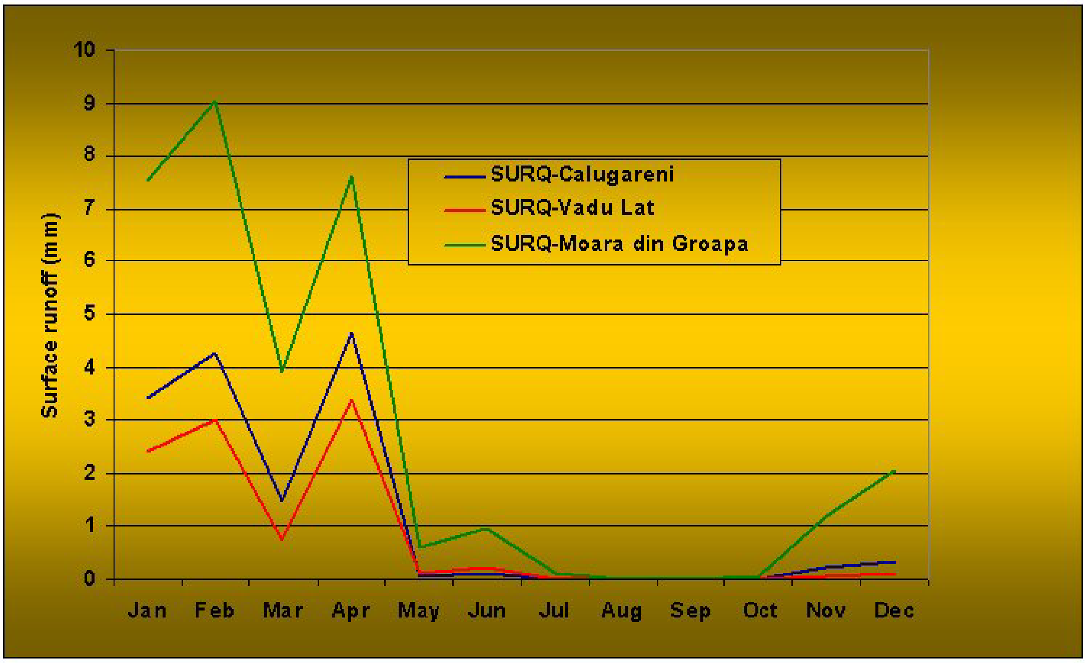


Fig. 6-48: Surface runoff monthly average (1995 – 2001)

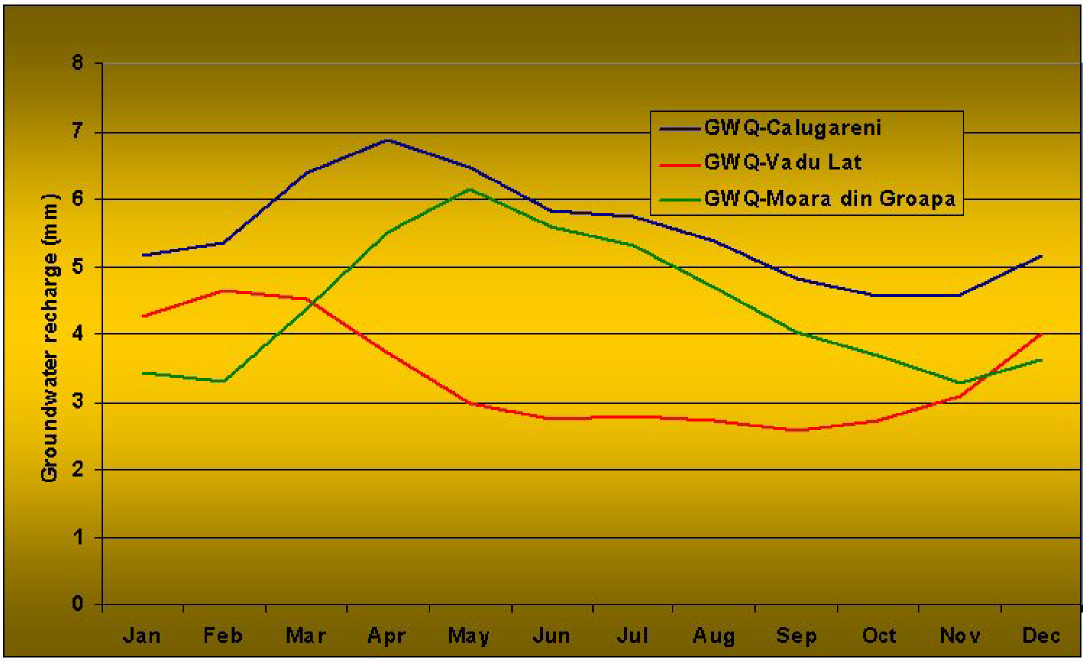


Fig. 6-49: Groundwater recharge monthly average (1995 – 2001)

The groundwater shallow aquifer recharge is characterized by a different pattern for each of the calibration points. During the year for Calugareni outlet the curve is having at the begining of the year a smooth increasing trend to the maximum value in April (6.9 mm) followed by a smooth decrease untill November (4.6 mm) when the values of groundwater shallow aquifer are starting to increase again. Moara din Groapa outlet is following the same pattern, but the maximum value is reached in May (6.1 mm). Vadu Lat outlet is showing a different pattern, with the maximum value in February (4.6 mm), followed by a sharper decrease untill May (3 mm) and by a period of constant low levels between June and November (2.6 – 2.8 mm)

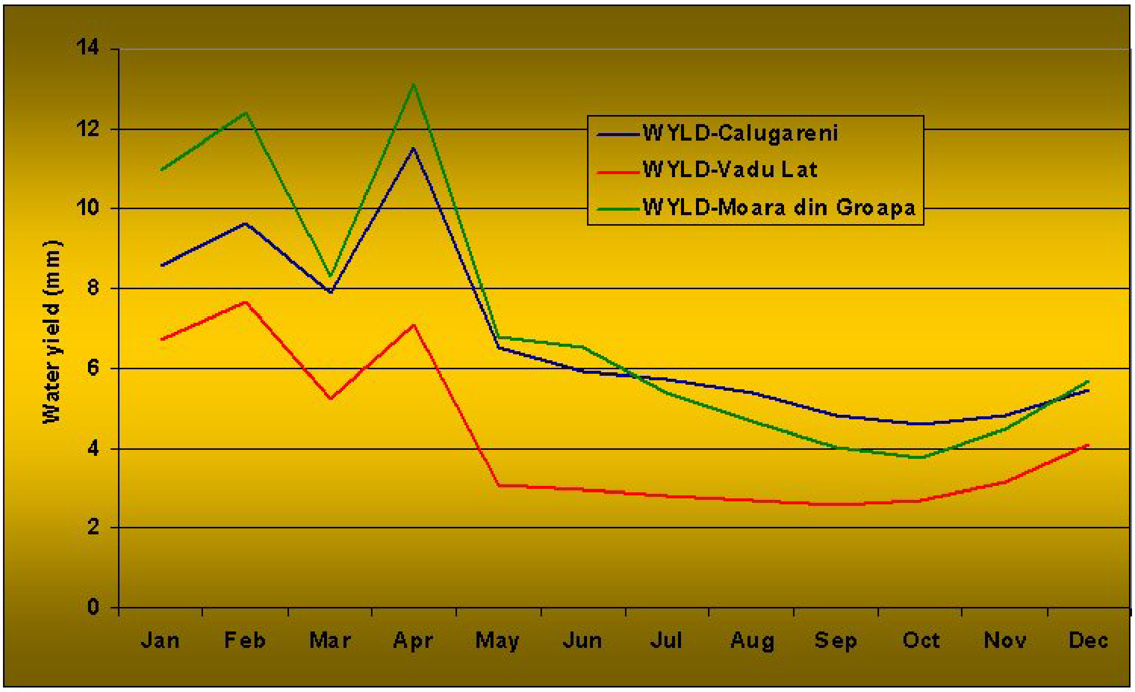


Fig. 6-50: Water yield monthly average (1995 – 2001)

The water yield, which is representing the net amount of water that leaves the subbasins and contributes to stream flow during the simulation time step, is recording two characteristic periods due to the variation of it's components (surface, lateral and groundwater flow). The first period, which is the period of high values, between January and April, has the absolute maximum values in February (7.7 mm) for Vadu Lat outlet and April (11.5 for Calugareni outlet and 13.1 for Moara din Groapa outlet) and the secondary maximum in February for Calugareni (9.6 mm) and Moara din Groapa (12.4 mm) outlets and April (7.1 mm) for Vadu Lat outlet. The remanent period of the year is characterized by low values of water yield (2.6 – 6.5 mm depending on each case).

Finally we should say that the results of SWAT run on the Neajlov catchment are underlying very well both the spatial and temporal variation of water balance components, in a realistic manner and further more the SWAT results together with the results of the validation and calibration process are confirming the reliability of the computed water balance for the Neajlov river, and through that it allows to extend the SWAT modeling activity to the analysis of the different ecological processes which are deployed inside the basin.

6.7.2 MONERIS Model

For MONERIS model there were defined 9 catchments correspondin to the sampling points. For each of the catchment there was calculated the water balance for the average values of precipitation and river discharge for period 1995 – 2001. It has to be mentioned that due to the lack of a series of data (i.e. sewers and tile drainage data) the computation of water ballance is not finished. The missing data were filled with the predefined data of the model.

Outlet name	Catchment area (km2)	Net catchment area (km2)
Suseni	97.9	97.9
Slobozia	264.8	166.9
Roata Mica	653.9	389.1
Vadu Lat	1349.2	364.9
Calugareni	3679.4	2330.2
Oarja	65.9	65.9
Furduiesti	141.7	75.8
Morteni	208.1	66.4
Moara din Groapa	330.4	122.3

Tab. 6-29: Area of the catchments used for MONERIS computations

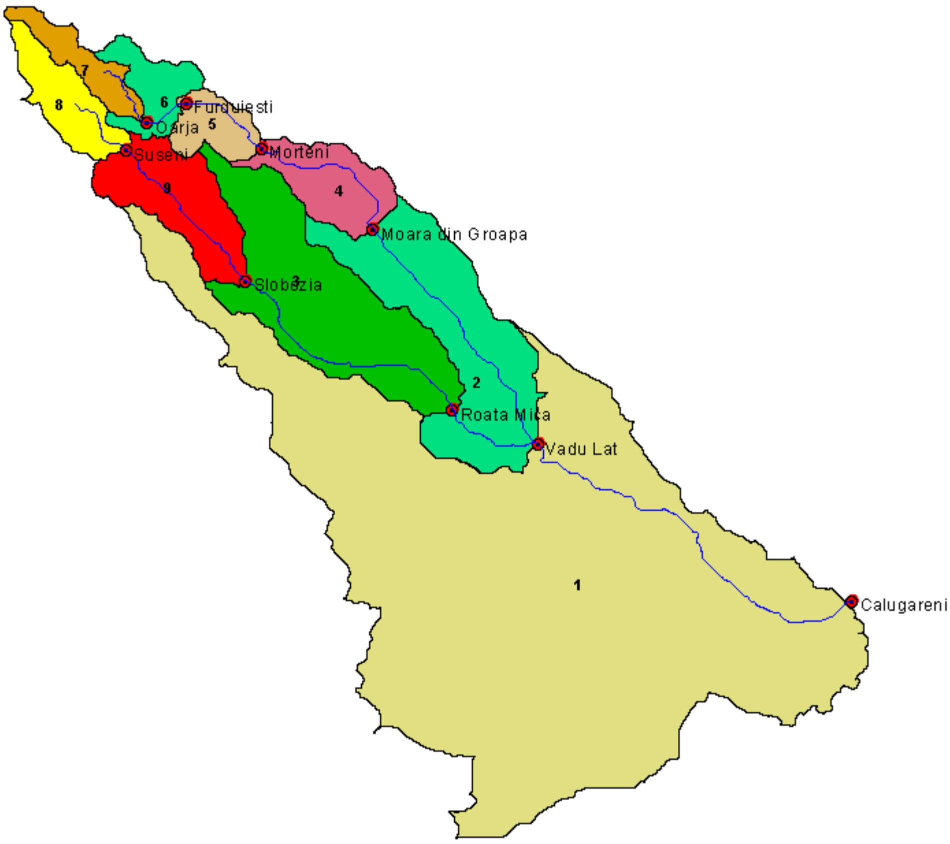


Fig. 6-51: Catchments used for MONERIS computation

Outlet name	Runoff total catch.	Specific runoff	Direct precipit.	Tile drainage	Grw.	Overl. flow	Point sources	Urban areas
	[m³/s]	[l/(s*km²)]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]
Suseni	0.56	5.75	0.10	0.04	0.37	0.00	0.00	0.05
Slobozia	0.99	1.60	0.05	0.00	0.30	0.00	0.16	0.08
Roata Mica	2.00	1.55	0.07	0.01	0.85	0.01	0.32	0.07
Vadu Lat	4.32	0.60	0.04	0.01	0.72	0.00	0.40	0.04
Calugareni	8.99	2.22	0.39	0.04	7.32	0.10	0.05	0.33
Oarja	0.43	6.46	0.01	0.00	0.38	0.00	0.17	0.04
Furduiesti	0.64	1.51	0.01	0.00	0.16	0.00	0.18	0.05
Morteni	0.80	0.78	0.01	0.00	0.12	0.00	0.05	0.03
Moara din Groapa	1.51	2.16	0.01	0.00	0.65	0.00	0.44	0.04

Tab. 6-30: Water balance results with MONERIS

6.7.3 DIFGA Model

The DIFGA model was applied on the same location as the SWAT model. In order to distinguish between the hydrograph components for the DIFGA model there were used daily discharge data from three river discharge measuring station belonging to the National Institute of Hydrology and Meteorology (NIHM), all of them located on the main channel of the Neajlov River (Calugareni, Vadu Lat and Moara din Groapa). The results of DIFGA model were used for calibration of SWAT model based on following corespondences:

QG1 + QG2 = GWQ + LATQ, where

QG1 (DIFGA) – fast component of groundwater;
QG2 (DIFGA) – slow component of groundwater;
GWQ (SWAT) – groundwater shallow aquifer recharge;
LATQ (SWAT) – lateral flow

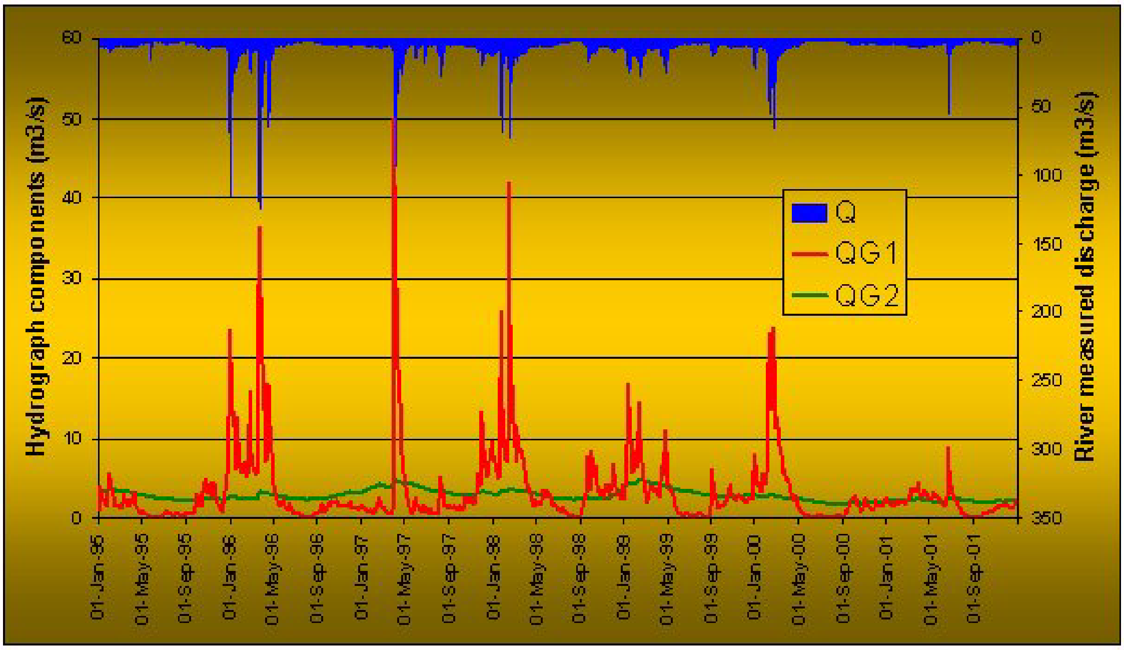


Fig. 6-52: Hydrograph separation for Calugareni station

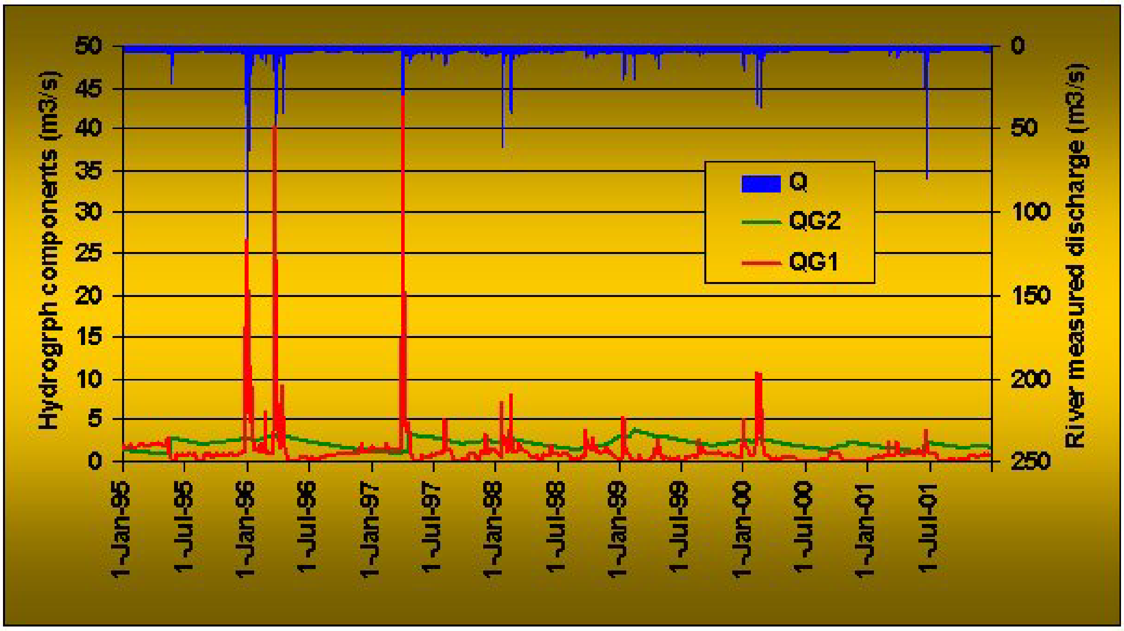


Fig. 6-53: Hydrograph separation for Vadu Lat station

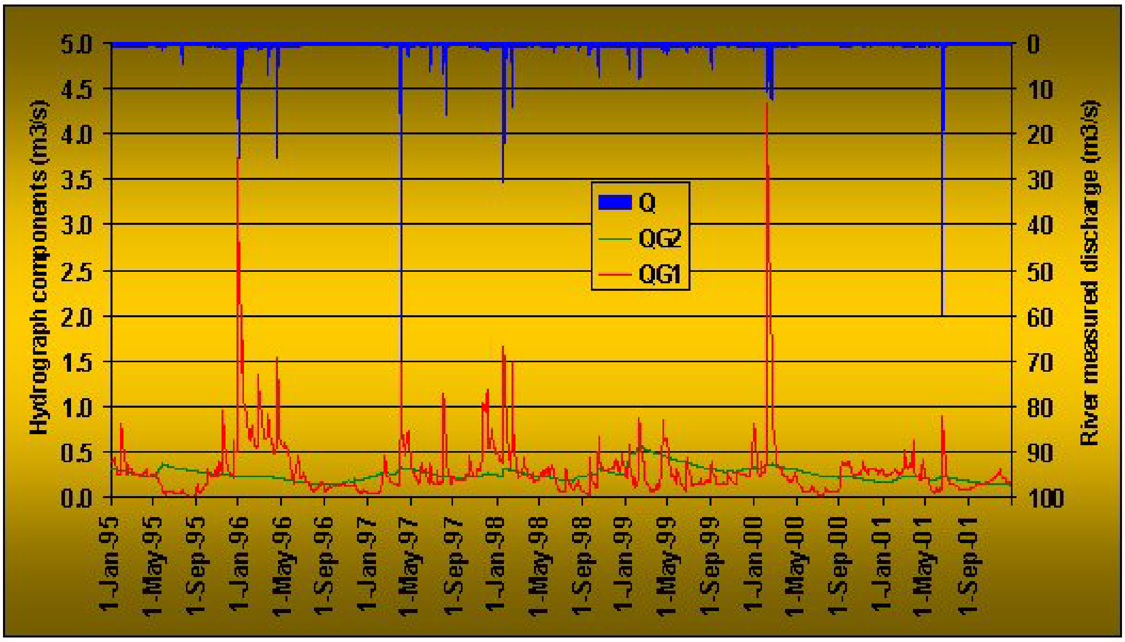


Fig. 6-54: Hydrograph separation for Moara din Groapa station

Station	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Aver.
	Precip.	32.51	24.69	39.76	52.57	48.30	63.60	36.41	39.51	54.67	25.36	35.39	42.89	41.31
Calug.	***Disch.***	11.30	13.38	10.95	14.47	5.40	5.10	3.40	3.47	4.17	4.79	4.98	6.22	7.30
	Grw.	8.82	10.97	8.80	10.01	4.93	3.93	3.19	2.81	3.59	4.60	4.77	5.63	6.00
	Surf.	2.49	2.41	2.15	4.46	0.47	1.17	0.21	0.66	0.58	0.19	0.21	0.59	1.30
Vadu Lat	***Disch.***	6.13	5.27	4.87	6.02	3.20	3.69	2.75	2.68	2.61	2.78	2.80	3.40	3.85
	Grw.	4.31	4.01	4.10	4.49	2.80	2.85	2.69	2.55	2.51	2.69	2.76	3.16	3.24
	Surf.	1.82	1.26	0.78	1.53	0.40	0.85	0.06	0.13	0.10	0.08	0.04	0.24	0.61
Moara din Groapa	***Disch.***	1.40	1.50	0.75	1.54	0.58	1.14	0.40	0.54	0.48	0.53	0.53	0.74	0.84
	Grw.	0.73	0.92	0.61	0.67	0.50	0.44	0.36	0.36	0.38	0.43	0.51	0.60	0.54
	Surf.	0.67	0.58	0.14	0.88	0.07	0.70	0.04	0.18	0.10	0.09	0.02	0.14	0.30

Tab. 6-31: monthly average for hydrograph components (1995 – 2001) (m3/s)

*Precip.- precipitation; disch. – measured discharge; grw. – groundwater fast and slow flow; surf. – direct runoff

As a general pattern the table shows a general period of high water levels (river discharge, groundwater flow and surface runoff) between January and April for all three outlets and a period of low water levels between May and December.

6.7.4 Comparison of results of different models applied

6.7.4.1 Water balance ratio

For comparison of the results of the different models applied (SWAT, DIFGA and MONERIS) there were choosed the average values of surface and groundwater runoff for the simulated period (1995 – 2001)

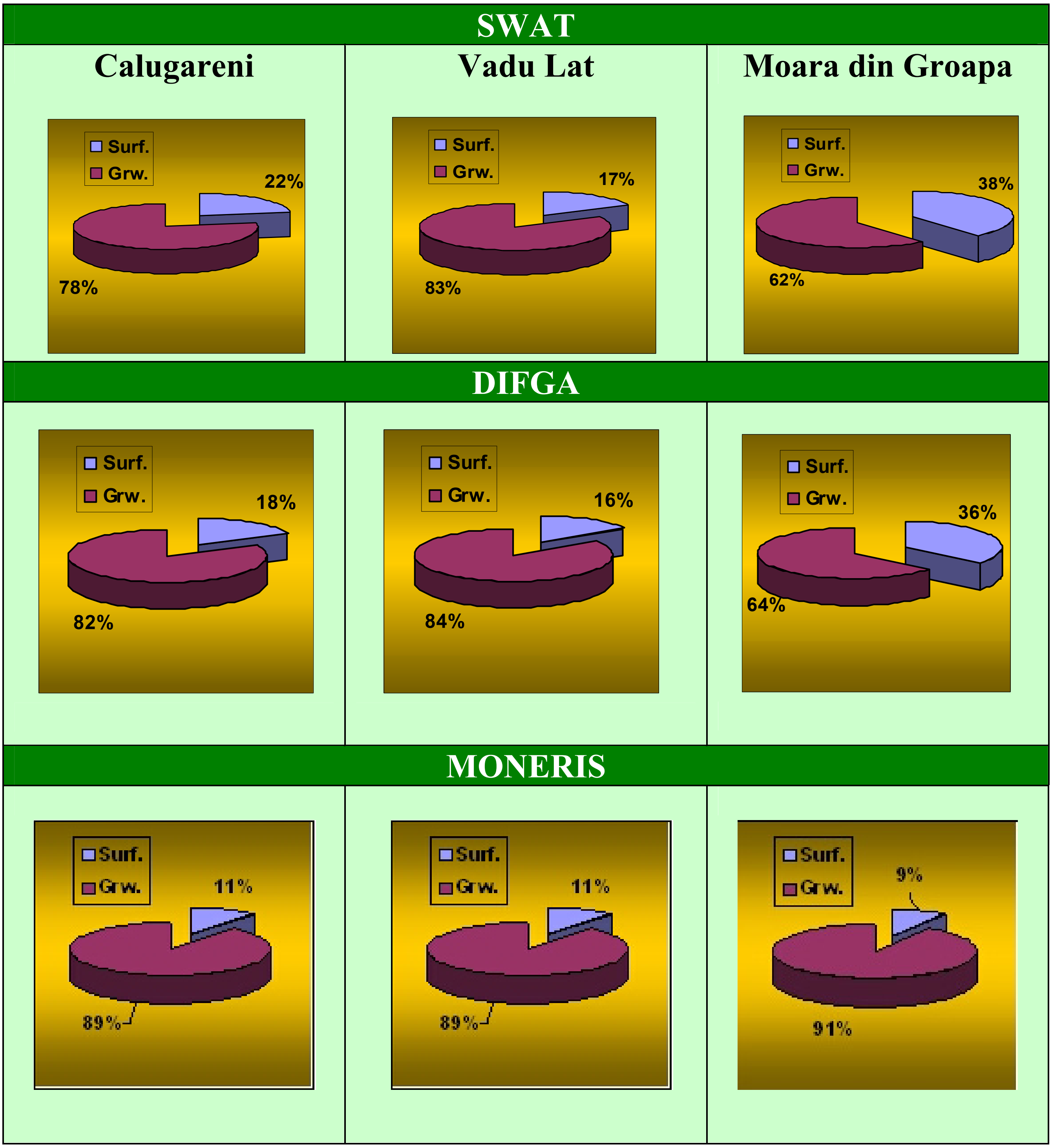


Fig. 6-55: Comparison of surface and groundwater runoff ratio resulted from different model application
***grw. – groundwater runoff; surf. – surface runoff**

7 Summary

The application of the GIS-based emission model MONERIS for the whole Danube Basin is part of WP 5 of the daNUbs project. The MONERIS model was designed for the application in large river basins. Its based on empirical equations and due to heterogeneities and spatial variations as input data five-years annual average values will be used. The empirical assumptions were derived mostly from German river basins.

Out of this two factors it seemed to be purposive to estimate the water and nutrient balances in the case study regions using also other models and methods. On the basis of this calculations the weak points of the MONERIS model should be indicated. As a result from further investigations (Nutrient balances for Danube countries) the emphasis in the water balance estimations was on the description of the different runoff components.

At first a conceptual model based on physical equations was used. The SWAT 2000 model was chosen due to its international acceptation and its free availability. As input data average daily values of a 7 years time series were used, in detail the precipitation, the air temperature and of the solar radiation, the relative humidity and wind speed. The application of the SWAT 2000 model showed already at the beginning the immense effort in regard to the time was spent and the data were needed as input for model parameter definition to achieve an acceptable model performance. Furthermore, it was noted that with the multitude of partly uncertain model parameters its possible for the model to match the observed data with different, alike feasible model parameter sets.

With the assistance of the hydrograph separation technique, a completely other method for the estimation of the runoff components, it was tried to accommodate this problems. Therefore, the DIFGA 2000 model was applied in the case study regions. The feasibility of the estimated distribution of the runoff components was verified using other runoff separation methods and the literature, too. Thus, the runoff components distribution was a main clue in the calibration of the SWAT 2000 model.

In addition the water balance for the 4 case study regions was estimated using the MONERIS model.

The main characteristics of the case study regions and the results of the water balance calculations using the different methods are assembled in table 7.1.

The comparison of the different model results is difficult due to the different terms in the runoff components definitions of the model assumptions. The estimated runoff components are summarised in table 7.1.

From the model applications and the model results the following statements can be deduced:

- The application of conceptual models based on physical equations requires a large demand on input data.
- The calibration effort of such models of a physical nature is rather time consuming, whereby with different feasible parameter sets plausible model results are achievable. Thereby, the modelled distribution of the runoff components can vary obviously.
- Snow melt processes only hardly can be considered in the SWAT 2000 model.
- The runoff separation technique requires long term time series of about 30 years (daily values) to achieve acceptable results.

- The estimation of the groundwater in the SWAT 2000 model which does not contribute to the runoff and the assessment of the evapotranspiration is difficult.
- A comparison of the results obtained with DIFGA 2000 showed a good correlation with other separation techniques.
- In the MONERIS model the hydrogeology is consists of four types of aquifers. A classification of the heterogeneous natural conditions may lead to uncertainties in distribution of the runoff components. But the effect on the water balance calculations can be considered as small.
- The runoff from drained areas in the MONERIS model is only a function of the hydro morphology of the soils and does not consider actual land use.
- The base flow was calculated with MONERIS was partly higher estimated in all case study regions as with the other methods.
- The comparison of the different model results is affected by the fact that the calculation of the water balance is done for net catchments in the MONERIS model, where only the increase of the catchment area between two gauging stations is considered, and for the whole subcatchment area which belongs to a gauging station in the SWAT model.
- The detailed analysis showed that the runoff components vary obviously in amount and distribution in dependency of the seasonal conditions.

The question, which differences in the nutrient balances occur due to the different model results, can be answered only with additional simulations of the nutrient balance and the comparison with the results of the investigations in the case study regions. According to this results recommendations for modifications of the MONERIS approaches probably can be given.

		Ybbs			Wulka			Zala			Neajlov		
catchment area	km²	1117			384			1529			3720		
average precipitation	mm/a	1377			709			656			496		
avergae terrain slope	%	31			8			3,15			0,55		
average discharge	m³/s	32,7			1,23			4,32			7,26		
avergae discharge	mm/a	904			99			87			60		
landuse characteristic	--	forest (52), pasture (32), arable land (12)			arable land (54), forest (28)			arable land (62), forest (34)			arable land (78), forest (10)		
soil charactersitic	--	rendzina, luvisol			luvic chernozem, orthic luvisol			loam, sandy loam			luvisoil, chernozem		
geoligical characteristic	--	consolidated rock, sediment			sediment			loess, glacial sediment			--		
Model results		SWAT	DIFGA	MONERIS	SWAT	DIFGA	MONERIS	SWAT	DIFGA	MONERIS	SWAT	DIFGA	MONERIS
period		1992 - 1997	1971 - 1997	1995 - 1997	1992 - 1997	1971 - 1997	1995 - 1997	1997 - 2001	1997 - 2001	1997 - 2001	1995 - 2001	1995 - 2001	1995 - 2001
evapotranspiration	mm	376		550	575		550	426		567	409		419
baseflow	%	45		93	40		58	72,8		91,9	78		89
lateral flow	%	35			11			4,6			0		
fast groundwater QG1	%		42			42			34,5			45	
slow groundwater QG2	%		29			16			49,7			37	
surface flow	%	19			5			17,6			22		
direct discharge(incl. tile drainage)			29			16			15,8			18	
surface runoff *)				6			5			4,9			11
modelled discharge	mm/a	930	852	851	107	93	99	76	89	89	66	62	75
point sources	%	1		1	26	26	29	3		3,2			
tile drainage	%				19		8						

*) surface runoff from none paved areas + runoff from urban areas + direct flow

Tab. 7.1: comparison of the model results

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Appendix A1: Legend of the geological map

(Fig.2-13)/(Fig. 2-21)

Geology

1 Kuenstliche Anschuettung
2 Holozaene Talaue; Jungpleistozaen bis Postglazial
3 Austufe (Kies - Sand, Aulehm); Postglazial im Donautal
4 Zwischenstufe; Postglazial im Donautal
5 Unteres Alluvialfeld (Kies - Sand, Aulehm); Postglazial im Donautal
6 Juengere Flaechen der holozaenen Talaue im mittleren Ybbstal
7 Aeltere Stufe der holozaenen Talaue im mittleren Ybbstal
8 Sumpf, Vernaessung
9 Unaufgeschlossenes Gelaende, Hangschutt
10 Schwemmkegel, -faecher
11 Schuttkegel, -faecher
12 Schutt und Blockwerk
13 Murenkoerper
14 Felssturz
15 Aufgelockrter Fels
16 Rutschhang
17 Instabiler Hangbereich, Buckelhang
18 Abgeglittene Scholle
19 Quelltuff, Kalksinter
20 Erratika
21 Hangbrekzie im Allgemeinen
22 Niederterrasse (Kies - Sand); Wuerm i.a.
23 Moraene
24 Oberes Hochflutfeld (Kies - Sand, Aulehm); NT3 Wuerm im Ennstal
25 Untere Niederterrasse (Kies - Sand); NT2 Wuerm im Ennstal
26 Obere Niederterrasse (Kies - Sand); NT1 Wuerm im Ennstal
27 Niederterrasse tieferes Niveau (Kies - Sand); Wuerm im Ybbstal des Vorlandes
28 Niederterrasse hoeheres Niveau (Kies - Sand); Wuerm im Ybbstal des Vorlandes
29 "Deckenlehm":Loess, Lehm
30 Hochterrasse (Kies - Sand, Lehmbedeckung); Riss
31 Endmoraene, Spaetriss
32 Sander; Spaetriss
33 Moraene, Moraenenwall; Spaetriss
34 Terrassenschotter; Hochriss oder aelter
35 Moraene, Schotter, verlehmter Hangschutt; Hochriss oder aelter
36 Fruehrisszeitliche Talfuellung (Schotter)
37 Juengere Deckenschotter, meist mit Lehmbedeckung; Mindel
38 Aeltere Deckenschotter, meist mit Lehmbedeckung; Guenz
39 Hoehenterrasse I
40 Hoehenterrasse II
41 Hoehenterrasse III
42 Oberpliozaene Schotterbildungen
43 Oncophoraschichten; Ottnang
44 Sandstreifenschlier; Eggenburg-Ottnang
45 Aelterer Schlier, "Oligozaenschlier"
46 "Oligozaenschlier der gestoerten Molasse; Rupel - Eger
47 Melker Sande; Rupel - Eger
48 Kristallinsandstein von Wallsee
49 Pielacher Tegel
50 Tertiaeres Strandblockwerk
51 Buntmergelserie; Oberalb - Eozaen
52 Brekzie; Paleozaen - Eozaen
53 Grobkonglomerat ("Wildflysch"); Paleozaen - Eozaen
54 Konradsheimer Konglomerat; Eozaen
55 Vorkommen von gruenen Sandsteinen
56 Blasensteinschichten (Aptychenkalk,Fleckenmergel); Malm - Neokom
57 Arzbergkalk (Bunte Kalke,Kalkmergel,Kieselkalk); Malm
58 Konradsheimer Schichten (Brekzienkalk); Malm
59 Scheibbsbachschichten (kieselige Kalke,Brekzien,Radiolarite)
60 Lampelsbergschichten (gruenlicher Kieselton bis Kieselkalk); Dogger
61 Zeller Schichten (gruenlichgraue Mergelkalke); Dogger
62 Grestner Schichten (dunkler Mergelschiefer, Sandkalk, lokal Kohle); Lias - Dogger
63 Schuppenzone: Buntmergelserie und Unterkreideflysch
64 "Oberkreideflysch" i.a.; Oberkreide - Paleozaen
65 Bunte Flyschchiefer (Oberste Bunte Schiefer, Obere Bunte Schiefer, Untere Bunte Mergel)
66 Altlengbacher Schichten; Campan - Paleozaen
67 Muerbsandstein fuehrende Folge; Obermaastricht -Illerd
68 Obere Sandsteinfolge; Mittel- bis Obermaastricht
69 Kalkiger und silizklastischer Flysch; Unter- bis Mittelmaastricht
70 Untere Sandsteinfolge; Campan - Untermaastricht
71 Pernecker Schichten, Oberste Bunte Schiefer; Campan - Untermaastricht
72 Zementmergelserie; Santon - Campan

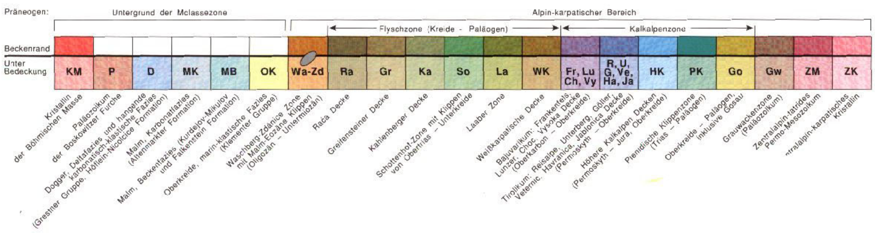
Appendix A2:
Legend of the geological map

(Fig.2-13)/(Fig. 2-21)

73 Duennbankige Zementmergelbasisschichten
74 Seisenburger Schichten, Obere Bunte Schiefer; Turon - Coniac
75 Reiselsberger Sandstein, Flysch nicht differnziert; tiefere Oberkreide
76 Flysche - Gault, Untere Bunte Mergel
77 Flysch - Neokom
78 Flysch von Kreilloed (grobkoerniger Flysch); Maastricht
79 Ybbsitzer Flysch, nicht differenziert
80 Steinkeller Schichten, "Zementmergelserie"; Santon - Campan
81 Bunte Schiefer mit glimmerreichen Sandsteinen, Ybbsitzer Schichten; Cenoman - Coniac
82 Hubbergsandstein, Ybbsitzer Schichten; Cenoman - Coniac
83 Flysch - Gault
84 Flysch - Neokom
85 Fasselgrabenschichten (Aptychenkalke); Oberer Malm
86 Dogger - Malm
87 Serpentinit, Basalt, Ophikarbonat ("Ophioloite der Ybbsitzer Klippenzone)
88 Umbachschichten (Sandstein, Tonmergel, Grobschuettung); mittlere - obere Kreide
89 Riesenschollen oder Gleitbretter kalkalpiner Gesteine
90 Losensteiner Schichten (graue Tonmergel und Sandsteine, Geroelle); Alb - Turon
91 Graue Neokommergel; Unterkreide
92 Aptychenschichten - Ammergauer Schichten; Unterkreide
93 Losensteiner Schichten (graue Tonmergel und Sandsteine, Geroelle); Cenoman - Turon
94 Tannheimer Schichten (graue und bunte Ton- Kalkmergel); Apt - Alb
95 Rossfeldschichten (kalkhaltiger, geschichteter Sandstein); juengeres Neokom
96 Schrambachschichten (hellbrauner Ton bis Kalkmergel, Fleckenmergel); Neokom
97 Bunter Oberjurakalk; Dogger - Malm
98 Aptychenschichten -Ammergauer Schichten - Steinmuehlkalk (bunter Flaserkalk, Bankkalk, Mergelkalk); Tithon - Neokom
99 Dogger i.a.
100 Lias - Dogger i.a.
101 Allgaeuschichten ("Liasfleckenmergel", graue Fleckenmergel); Lias - Dogger
102 Schattwalder Schichten (dunkelrote Schiefertone); Rhaet - Lias
103 Koessener Schichten i.a.;Rhaet
104 Hauptdolomit; Nor
105 Opponitzer Schichten (gelblichgrauer Kalk und Mergel, Rauhwacke, Breckzie); Karn
106 Lunzer Schichten (kalkfreier feinkoerniger Sandstein und Arkose, Schieferton); Karn
107 Rossfeldschichten (kalkhaltiger, geschichteter Sandstein); juengeres Neokom
108 Schrambachschichten (hellbrauner Ton- bis Klakmergel, Fleckenmergel); Neokom
109 Oberalmer Schichten (bunter toniger Kalk, Mergel); Tithon - Berrias
110 Aptychenschichten - Ammergauerschichten - Steinmuehlkalk (bunter Flaserkalk, Bankkalk, Mergelkalk); Tithon - Neokom
111 Ruhpoldinger Schichten (Kieselkalk, Radiolarite); Malm
112 Vilserkalk, Laubensteinkalk, Weissenhauskalk, Reitmauerkalk (bunter Spatkalk, Filamentkalk); Dogger
113 Klauskalk (roter Cephalopodenkalk); Lias
114 Lias - Dogger i.a.
115 Kirchsteinkalk, Scheibelbergkalk (grauer Kieselkalk, Hornsteinkalk); Lias
116 Hierlatzkalk (bunter Crinoidenkalk); Lias
117 Oberrhaetkalk, Rhaetriffkalk, Koenigsbergkalk (Ooidkalk, Onkoidkalk, Riffkalk); Rhaet
118 Koessener Schichten i.a. (grauer Kalkstein, Mergel); Rhaet
119 Uebergangsschichten
120 Puchenstubenerschichten (grauer Kalk, Dolomit); Rhaet
121 Plattenkalk (brauner Kalk, Dolomit); Nor - Rhaet
122 Ubergangschichten
123 Hauptdolomit; Nor
124 Opponitzer Schichten (gelblichgrauer Kalk und Mergel, Rauhwacke, Brekzie); Karn
125 Lunzer Schichten (kalkfreier feinkoerniger Sandstein und Arkose, Schieferton, Kohle); Karn
126 Aonschichten (duennschichtiger dunkler Mergelkalk), Reingrabner Schichten (Schieferton)
127 "Muschelkalk"; Anus -Cordevol
128 Goestlinger Schichten (duenngeschichteter Mergelkalk); Cordevol
129 Reiflinger Schichten (grauer, geschichteter Kalk), Raminger Kalk (brauner Biogenkalk); Oberes Anis - Cordevol
130 Steinalmkalk - Wettersteinkalk (heller Algenkalk, Riffschuttkalk, Riffkalk); Anis - Cordevol
131 Gutensteiner Kalk (grauer Kalk, Dolomit); Anis
132 Kalke unbestimmten Alters
133 Mylonit, mylonitischer Gneis bzw. Granit
134 Fein- bis mittelkoerniger Granit (Typus Mauthausen)
135 Dioritschollen
136 Diorit
137 Weinsberger Granit
138 Schiefergneiseinschluesse im Weinsberger Granit
139 Haeufige Gaenge und Stoecke von fein bis mittelkoernigem Granit im Weinsberger Granit
140 Heller Orthogneis
141 Baendergneis
142 Schiefergneis der Momotonen Serie

Appendix A3:
Legend of the geological map

(Fig.2-23)



Appendix A4: Compilation of the calibration parameter values

The Ybbs catchment

Lunz am See								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Rendzina	layer 1	**201**	**150**	**0.16**			
		layer 2	**1260**	**150**	**0.19**			
Landuse parameter	*Landuse type*	CN_2						
	Forest	**60**						
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.25	**125**	**0.075**	**0.25**	**250**	**300**		
River channel parameter	CH_K2	CH_N2						
	150	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	1	**1**	**3.4**	**1**	**0**	**0.05**	**50**	**0.5**

Opponitz								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Rendzina	layer 1	**201**	**150**	**0.16**			
		layer 2	**1260**	**150**	**0.19**			
	Bodless	layer 1	**600**	**200**	**0.18**			
		layer 2	**1500**	**200**	**0.17**			
Landuse parameter	*Landuse type*	CN_2						
	Forest	**55**						
	Urban	**78**						
	Pasture	**59**						
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.25	**175**	**0.025**	**0.5**	**200**	**200**		
River channel parameter	CH_K2	CH_N2						
	150	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	3	**1**	**3**	**1**	**0**	**0.05**	**250**	**0.5**

Ybbsitz								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Rendzina	layer 1	**201**	**150**	**0.16**			
		layer 2	**1260**	**150**	**0.19**			
	Auboden	layer 1	**305**	**100**	**0.23**			
		layer 2	**1500**	**100**	**0.16**			
Landuse parameter	*Landuse type*	CN_2						
	Forest	**60**						
	Pasture	**58**						
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.15	**100**	**0.02**	**0.25**	**250**	**0**		
River channel parameter	CH_K2	CH_N2						
	150	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	1	**1**	**3**	**1**	**0**	**0.25**	**119**	**0.149**

Krenstetten								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Bodless	layer 1	**600**	**50**	**0.18**			
		layer 2	**1500**	**25**	**0.17**			
	Parabraun	layer 1	**600**	**200**	**0.15**			
		layer 2	**1500**	**150**	**0.12**			
Landuse parameter	*Landuse type*	CN_2 (B)	CN_2 (C)					
	Root crop		**83**					
	Spear fruit		**85**					
	Pasture	**59**	**72**					
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.25	**150**	**0.1**	**0.25**	**300**	**300**		
River channel parameter	CH_K2	CH_N2						
	150	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	2	**0.34**	**3.4**	**1**	**0**	**0.5**	**50**	**0.05**

The Wulka catchment

Walbersdorf								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Bodless	layer 1	**700**	**5**	**0.3**			
		layer 2	**1500**	**1**	**0.3**			
	Parabraun	layer 1	**700**	**30**	**0.15**			
		layer 2	**1500**	**30**	**0.18**			
	Schwarzerd	layer 1	**700**	**1**	**0.3**			
		layer 2	**1500**	**1**	**0.3**			
Landuse parameter	*Landuse type*	CN_2 (A)	CN_2 (B)					
	Forest	**36**	**50**					
	Spear fruit		**55**					
	Pasture		**50**					
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.08	**160**	**0.02**	**0.35**	**40**	**70**		
River channel parameter	CH_K2	CH_N2						
	0	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	1	**0.8**	**4.5**	**0**	**0**	**0.05**	**50**	**0.5**

Wulkaprodersdorf								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Bodless	layer 1	**300**	**5**	**0.3**			
		layer 2	**1500**	**1**	**0.3**			
	Parabraun	layer 1	**700**	**50**	**0.15**			
		layer 2	**1500**	**50**	**0.18**			
	Schwarzerd	layer 1	**700**	**1**	**0.3**			
		layer 2	**1500**	**1**	**0.3**			
	Steppbod	layer 1	**700**	**50**	**0.25**			
		layer 2	**1500**	**50**	**0.2**			
Landuse parameter	*Landuse type*	CN_2 (A)	CN_2 (B)					
	Forest	**36**	**45**					
	Root crop		**60**					
	Spear fruit		**55**					
	Pasture		**50**					
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.08	**160**	**0.02**	**0.45**	**150**	**150**		
River channel parameter	CH_K2	CH_N2						
	0	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	1	**0.8**	**4.5**	**0**	**0**	**0.05**	**50**	**0.5**

Oslip								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Rendzina	layer 1	**700**	**150**	**0.16**			
		layer 2	**1500**	**150**	**0.19**			
	Parabraun	layer 1	**700**	**50**	**0.15**			
		layer 2	**1500**	**50**	**0.18**			
	Schwarzerd	layer 1	**700**	**1**	**0.3**			
		layer 2	**1500**	**1**	**0.3**			
	Steppbod	layer 1	**700**	**50**	**0.3**			
		layer 2	**1500**	**50**	**0.2**			
Landuse parameter	*Landuse type*	CN_2 (A)	CN_2 (B)					
	Forest	**45**						
	Spear fruit	**55**	**65**					
	Vine	**57**						
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.08	**160**	**0.02**	**0.35**	**40**	**40**		
River channel parameter	CH_K2	CH_N2						
	0	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	1	**0.8**	**4.5**	**0**	**0**	**0.05**	**50**	**0.5**

Nodbach								
Soil parameter	*Soil type*	Layer	sol_depth [mm]	sol_k [mm/h]	sol_awc [mm/mm]			
	Schwarzerd	layer 1	**700**	**1**	**0.3**			
		layer 2	**1500**	**1**	**0.3**			
	Steppbod	layer 1	**700**	**50**	**0.3**			
		layer 2	**1500**	**50**	**0.2**			
Landuse parameter	*Landuse type*	CN_2						
	Forest	**45**						
	Spear fruit	**65**						
	Vine	**65**						
	Pasture	**55**						
Groundwater parameter	alpha_bf [d]	gw_delay [d]	gw_revap [-]	rchrg_dp [-]	revapmn [mm]	gwqmn [mm]		
	0.08	**160**	**0.02**	**0.5**	**0**	**150**		
River channel parameter	CH_K2	CH_N2						
	0	**0.05**						
Basin parameter	surlag [d]	smfmn [mm/°C*d]	smfmx [mm/°C*d]	sftmp [°C]	smtmp [°C]	timp [-]	snocovmx [mm]	sno50cov [mm]
	1	**0.8**	**4.5**	**1**	**0**	**0.8**	**50**	**0.5**