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Abstract/Sammandrag

This report is the manual for the nutrient transport model HBV-NP. It contains detailed description of the model, its different versions, of data required by the model and the format of input and output files. It also contains instructions for running the model and using the post-processing program for source apportionment.

The HBV-NP model simulates nitrogen (N) and phosphorus (P) transformation and transport in a catchment. The basic computation units are subbasins, which are parts of a larger catchment. The model simulates the nutrients in fractions; inorganic nitrogen, organic nitrogen, soluble reactive phosphorus and particulate phosphorus. In addition, the sum of these fractions can be obtained as total nitrogen and total phosphorus.

The model handles nutrient loads from different land use, rural households, industrial and urban point sources, storm water, bank erosion, release from lake bottoms and atmospheric deposition. The model considers mixing of water in soil, shallow groundwater, rivers and lakes, and nutrient transformation processes in shallow groundwater (only nitrogen), rivers and lakes.

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Contents

1 Introduction

This is a manual for the nutrient transport model HBV-NP. The manual should be used together with the IHMS Manual (Gardelin, 2006), which describes how to use the hydrological part of the model. The hydrological model is necessary for simulating nutrients with HBV-NP, but its use is not included in this manual.

The HBV-NP model simulates nitrogen (N) and phosphorus (P) transformation and transport in the landscape at the catchment scale (from 1 km^2 to more than 1 000 000 km^2). The basic computation units are subbasins, which are part of a district. The model simulates the nutrient fractions inorganic nitrogen (inorg-N), organic nitrogen (org-N), soluble reactive phosphorus (SRP) and particulate phosphorus (part-P). In addition to the fractions, the sum of these fractions as total nitrogen (tot-N) and total phosphorus (tot-P) can also be obtained. Input and output are mostly in the form of ASCII text files.

The model handles nutrient loads from different land use, rural households, industrial and urban point sources, storm water, bank erosion, release from lake bottoms and atmospheric deposition on lakes. The model considers mixing of water in soil, shallow groundwater, rivers and lakes, and nutrient transformation processes in shallow groundwater (only N), rivers and lakes.

2 Model description

The HBV-NP model can be used in three different versions (called nversions). There are two which only simulates N and one that simulates both N and P. The differences between the nversions are described in Chapter 6. In this chapter the HBV-NP model is described in general terms (Sec. 2.1 and 2.2). The transformation processes, including their equations and parameters are then described in detail (Sec. 2.3).

2.1 General description of the HBV-NP model

The HBV-NP simulates nitrogen (N) and phosphorus (P) concentration in the catchment. The objectives are usually to estimate transport, retention and source apportionment, to separate human impact from natural background, or to evaluate climate and management scenarios. A simulation with HBV-NP results in estimates of daily discharge and its concentration of nutrients, in addition to nutrient transport. Depending on input data and parameter values, different scenarios can be simulated. For instance the background nutrient transport can be simulated assuming other land uses and without anthropogenic point sources. The results from a simulation can be used to calculate retention and source apportionment. Further, different simulations can be compared to study the effect on nutrient transport or concentration by changes in climate or management, or to extract the anthropogenic nutrient transport. The model is based on the hydrological HBV model (Bergström 1995; Lindström et al. 1997), which step by step has been equipped with a nitrogen submodel (Bergström et al. 1987, Brandt 1990, Arheimer and Wittgren 1994, Arheimer and Brandt, 1998) and a phosphorus submodel (Andersson et al., 2005).

HBV-NP is a dynamic mass-balance model, which is run with a daily time-step, including all nutrient sources in the catchment coupled to the water balance. The district (catchment) is divided into several coupled subbasins (Figure 1). This subbasin division gives the spatial distribution of the model results. Calculations are made for each subbasin separately, and for each water body in the model the nutrient concentration can be described by the equation:

$$\frac{d(cV)}{dt} = \sum \{c_{in} V_{in}\} + S - \Phi - cV_{out}$$

where

c = concentration of the nutrient fraction
V = water volume of shallow groundwater, river or active part of lake
in = inflow (for groundwater: soil leakage from various land uses, for P through micropores and macropores separately; for river: generated runoff, surface flow; for lakes/wetlands: upstream rivers and local discharge, precipitation on the surface)
out = outflow from shallow groundwater, river or lake, evaporation
S = nutrient source; atmospheric deposition on water surfaces, bank erosion in rivers, emissions from point sources or rural households
Φ = retention (or an internal source if it is negative).

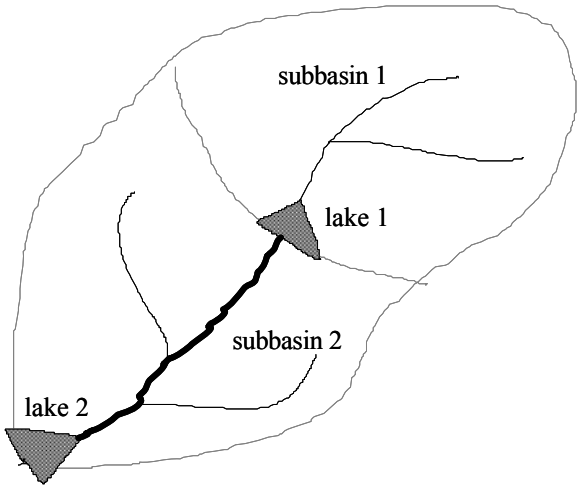

Figure 1. A schematic picture of a district with two subbasins, each with an outlet lake. The fat line is the main river of subbasin 2, while the thin line tributaries together compose the local river. Subbasin 1 has no main river.

The hydrological part (i.e. the HBV-96 version of the HBV model, Lindström et al., 1997) consists of routines for precipitation and evapotranspiration, accumulation and melt of snow, accounting of soil moisture, shallow groundwater and runoff response, and finally lakes and routing in the catchment.

In the nutrient submodels, soil leakage concentrations are assigned to the water percolating from the unsaturated zone to the shallow groundwater (the response box) of the hydrological HBV model (Figure 2). Different concentrations are applied to water originating from different combinations of land use and soils. The arable land may be further divided into a variety of crops and management practices (e.g. type of fertilizer used). The nutrient leakage concentration for arable land is achieved from field-scale models, e.g., SOILN (Johnsson et al., 1987) or ICECREAM (Tattari et al., 2001). In addition to soil-leakage, which is a diffuse source, nutrients also originate from point sources, such as industries, wastewater treatment plants, and storm water, and from other diffuse sources; stream bank erosion and rural households. Atmospheric deposition is added to lake surfaces, while deposition on land is implicitly included in the soil-leakage. The model simulates residence, transformation and transport of nutrients in shallow groundwater, rivers, wetlands and lakes. The equations that account for the nutrient turnover processes are mainly based on empirical relations between physical parameters and concentration dynamics. Only lakes at the outlet of a subbasin or in the main river course simulate transformation of nutrients. Lakes in the interior of a subbasin are simulated as part of the response box. Wetlands are another type of water body with nutrient transformation. Wetlands can be located within a subbasin, thus receiving a part of the subbasin's local runoff, or in the main river receiving all water from the subbasin and upstream basins.

In the case of low water in the soil, in the river or in the lake, addition of rural household nutrients and/or point sources, which normally contribute with a constant amount each day, can cause high concentrations in the water. This would give unnatural peaks in the concentration time series. To somewhat avoid these effects, a function has been

implemented that does not add these sources during low water but delay them and add them up to a month later, spread over 30 days.

The model includes a number of parameters, which can be calibrated against observed time series of river discharge and riverine nutrient concentrations. For large-scale catchment applications, the calibration procedure is usually made step-wise for shallow groundwater, rivers and lakes, with simultaneous consideration to several monitoring sites in a region. Simultaneous calibration of water balance and nutrient concentrations may also be performed (Pettersson et al., 2001).

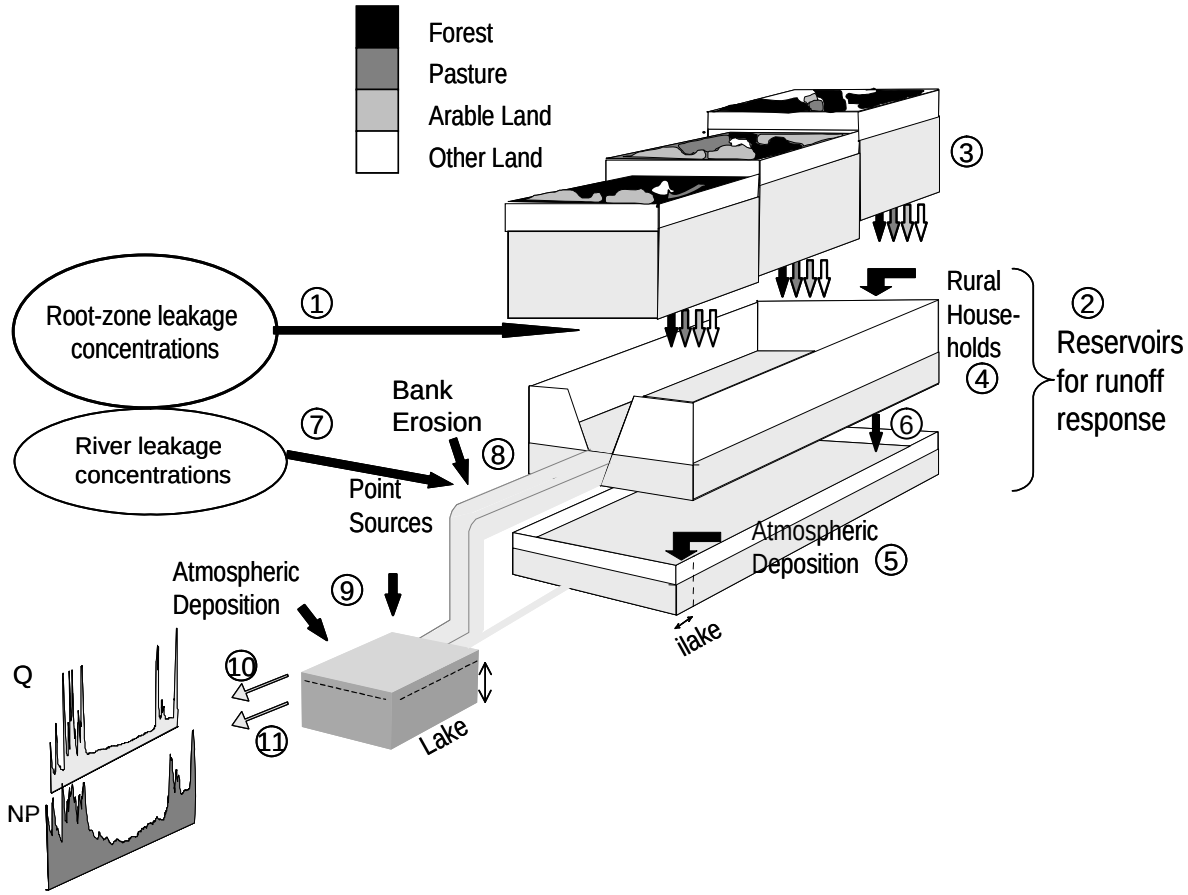

Figure 2. Structure of one subbasin in the HBV-NP model.

2.2 Water and nutrient flow through the model

The general water and nutrient flow through the model is illustrated in Figure 2. The numbers in parenthesis refers to the circled numbers in Figure 2. Nutrient leakage from different land uses are considered first when it has percolated through the root zone (about 1 m). These nutrients are added to the model's upper response box by applying the root-zone leakage concentration (1) to the water entering the upper response box from the unsaturated soil above (3). There is one upper and one lower reservoir for runoff response (2). Nutrient loads from rural households (4) and atmospheric deposition on local lakes (5) are also added to the response boxes. Water percolates to the lower response box (6). The boxes are assumed to be well mixed and then nutrient transformation is simulated in both boxes. This is the nutrient transformation in shallow groundwater, but also ditches and small brooks can be considered a part of transformation.

A fraction of the water percolated from the unsaturated zone is assumed to come from agricultural land. The fraction corresponds to agricultural area. The nitrogen load from agricultural leakage is found by multiplying the leakage concentration with that fraction of water. The same method can be used for other land use leakages (e.g. forests, mires, etc.) if root-zone leakage concentrations are known. Another possibility commonly used is to add these land use loads to the river of the model (7). This method is used when the concentrations used as input are derived from measurements in small rivers and not root zone leakage. The concentration is multiplied with respective land uses fraction of the percolating water to get the load, but the load is added to the river instead of the response boxes.

The concentration of phosphorus from agricultural leakage can be multiplied with the fraction of water that enters the response box corresponding to agricultural area the same way as for nitrogen. It is also possible to further divide leakage of P from arable land into micro- and macropore flow, each with its own leakage concentration. The micropore concentration is then applied to the water percolating from the unsaturated zone like before. The macropore flow is assumed to take a faster route to the river. Therefore, a part of the outflow from the response boxes is assumed to come from macropore flow. The macropore P concentration is thus added to the outflow from the response boxes. How much water assumed to go through macropores depends on the precipitation and soil moisture and soil type. For P, also soil surface erosion and surface water nutrient transport may be considered separately. Soil surface erosion of agricultural land is calculated in the model with the USLE method using curve numbers (Sivertun et al., 1988; Williams, 1995). The particulate phosphorus load from soil erosion and the SRP of surface flow is added to the river.

The outflow from both response boxes can go through a response function which delays the outflow before it becomes the local runoff from the subbasin. The local runoff is added to the local river. Loads from other land uses (7) than agricultural land (typically forest, clearcut forest, mire, glacier, bare mountain, mire in mountain and other open land) may also be added to the local river water. A river from upstream basins that run through a subbasin is called a main river (see Figure 1). Bank erosion (8) can be an additional source of particulate phosphorus to both river types.

In the river, water and nutrients can be delayed with a new advection routine. If this is used the ordinary HBV response function of the water from the response boxes is not used. The advection routine calculates the delay depending on river length and daily flow velocity for both the local and the main river (Sec. 2.2.2 and Rosberg, 2003).

River water from upstream basins flows together with the local river water into a point at the outlet of the subbasin. In the case of an upstream bifurcation, only the water flow in the branch to this subbasin is added with its nutrient concentration. The HBV-NP model can only handle branches that are modelled, i.e. no recorded water flow/nutrient concentration is possible to use as inflow.

If no lake is present at the outlet of the subbasin, point sources (9) are added to the river water at the subbasin's outlet point. If a lake is present the river water enters the lake. Nutrient loads of atmospheric deposition on the lake surface together with industrial, urban (waste water treatment plant) and storm water point sources are added to the lake (9). The inflow and loads to the lake are added to the passive ("upper") part of the lake. The active

("lower") part of the lake has a pre-set volume. The passive lake part fills the active lake part, and both are considered well mixed. Transformation of nutrients takes place only in the active part of the lake. It is possible that the lake is a source of nutrient, e.g. release of phosphorus from bottoms. The outflow of the lake (10) is determined by HBV routines (could be rating curve or regulation table or other method). The nutrient concentration (11) on the other hand is a combination of the concentration of the active and passive part of the lake and is determined by a calibration parameter.

2.2.1 Wetlands

Wetlands are a measure to reduce nutrient load, and therefore not included in the general description above. Which water and nutrients that flow through a wetland are important for its functioning, which is why different wetland types are modelled in HBV-NP. There are three types of wetlands implemented in the model. The first type (called wlake) is placed at the subbasin outlet like an outlet lake. There can not be a wlake wetland in the same subbasin as an outlet lake. Neither can it be used together with lakes in the main river of the subbasin. The water and nutrient flow of a wlake is the same as for an ordinary outlet lake, but different transformation processes are used.

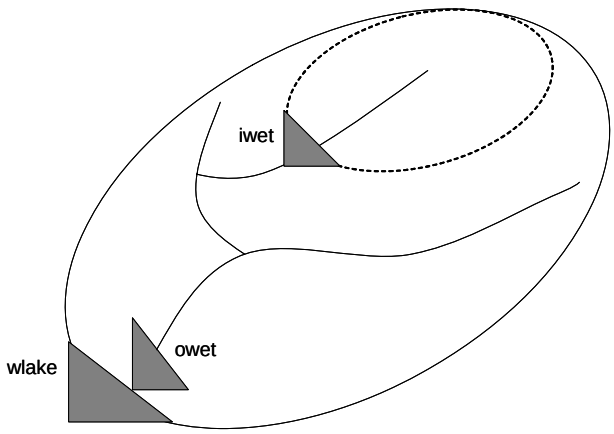

Figure 3. The different types of wetland in a subbasin.

The other types of wetland can be used together with river lakes and output lakes. They can be placed inside the subbasin receiving a part of the local runoff (called iwet) or at the subbasin outlet receiving the water from both local and main river (called owet). The owet wetland is thus placed directly before the output lake if such is present. Wetlands are typically put on agricultural land, which area should be decreased when the wetlands are constructed so that the leakage from arable land decreases. On the other hand, the modelled wetlands receive water from all land uses and can not be placed to receive only runoff from agricultural land. The iwet and owet wetland receives water and nutrient, apply their nutrient transformation and then restore the water to the place (local runoff, river) where it was taken. Then the computation continues as before in the river or outlet lake.

2.2.2 River advection routine

In the river, water and nutrients can be delayed with a new advection routine. If this is used it replaces the ordinary HBV response function of the water from the response boxes (*maxbas/maxbaz*) and the HBV delay and damping of river flow (*lag/damp*). The

advection routine calculates the delay depending on river length and daily flow velocity for both the local and the main river (Rosberg, 2003). One of the main characteristics of the advection routine is that the delay of concentration depends on the transport time through the river length. Further, advection is calculated separately for local rivers and main rivers. Local input is treated as a diffuse continuous source distributed evenly along the entire river length, while upstream input is treated as a continuous point source at the upper end of the main river.

2.3 Nitrogen and phosphorus transformation processes

The transformation processes occur in shallow groundwater (upper and lower response reservoir), rivers and lakes. The equations used are conceptual in nature and include calibration parameters to adjust the transformation to that of the catchment. The nitrogen equations are described in Arheimer et al. (1997), Arheimer and Brandt (1998) and Ejhed and Brandt (2002). The phosphorus equations are published in Andersson et al. (2005). In addition, wetland has nutrient transformation, which is described in Arheimer and Wittgren (1994) and Tonderski et al. (2005).

2.3.1 N transformation in shallow ground water (local transformation)

Several biogeochemical processes (e.g. denitrification, mineralization, plant uptake) affect the nutrients in soil water and groundwater. In the HBV-NP model these are combined to two equations, one that reduces the inorg-N and one that increases the org-N. These transformations are modelled independently. The shallow groundwater is modelled as upper and lower response boxes, and the nutrient transformation is calculated for each box.

The transformations act locally, i.e. within a subbasin, and are conceptually described in the model as:

$$Local\ retention = locret * conc\_inorg\_basin * wvolume\_basin * tmean2 / 10^6$$

where the local retention is the net reduction of inorg-N (kg d^{-1}), *locret* is a calibration parameter, *conc_inorg_basin* is the concentration of inorg-N in the response box (mg L^{-1}), *wvolume_basin* is the volume of the groundwater storage (i.e. the volume of water in the upper or lower response reservoirs) (m^3) and *tmean2* is the mean-value of the air temperature the last two days (^oC). The local retention is computed every day as an amount of inorg-N that is subtracted from the pool of nitrogen in the response box.

The biological production of org-N in soil water and groundwater is described as:

$$Local\ production = locorg * tmean10 * ((tmean10-tmean20)/tmean10) * ciorg * area\_basin / 10^4$$

where the local production is the biological production of org-N (kg d^{-1}), *locorg* is a calibration parameter, *tmean10* is the mean air temperature the last 10 days (^oC), *tmean20* is the mean air temperature the last 20 days (^oC), *ciorg* is a weighed concentration of inorg-N leakage from the subbasin (mg L^{-1}) and *area_basin* is the subbasin area (km^2). The equation describes a production of org-N each day with increasing temperature, i.e. when the 10-days mean air temperature exceeds the 20-days mean air temperature. When the temperature is negative or decreasing, no production of org-N is assumed to occur. *ciorg*

represents the nutrient status of the subbasin area; a nutrient rich area has higher biological production than a nutrient poor area. It is constant for the subbasin.

2.3.2 N transformation in rivers

N transformation in rivers can be included in the HBV-NP model set-up. However, for Swedish conditions retention of inorg-N and production of org-N in the watercourse are usually small. The processes are modelled only for the main river course.

*River retention = rivret * conc_inorg_river * tmean10 * sumq / 10^5*

The river retention is the net reduction of inorg-N (kg d^{-1}) in the river, *rivret* is a calibration parameter, *conc_inorg_river* is the concentration of inorg-N in the river (mg L^{-1}), *tmean10* is the mean-value of the air temperature the last ten days (^oC) and *sumq* is discharge from upstream subbasins (m^3 s^{-1}).

*River production = rivorg * tmean10 * (tmean10 - tmean20)/tmean10 * ciriv * sumq / 10^8*

The river production is the biological production of org-N in rivers (kg d^{-1}), *rivorg* is a calibration parameter, *tmean10* is the mean air temperature the last 10 days (^oC), *tmean20* is the mean air temperature the last 20 days (^oC), *ciriv* is an area-weighted inorg-N concentration from all upstream subbasins (kg m^{-3}) and *sumq* is discharge from upstream subbasins (m^3 s^{-1}). The equation describes a production of org-N each day with increasing temperature, i.e. when the 10-days mean air temperature exceeds the 20-days mean air temperature. When the temperature is negative or decreasing, no production of org-N is assumed to occur. *ciriv* is a constant similar to *ciorg* but for the whole upstream area.

2.3.3 N transformation in lakes

Nitrogen transformation in lakes relates to all existing lakes in the main river (rlake) and subbasin outlet (olake). Local lakes (ilake) are modelled as a part of the lower response box, and their possible transformation is therefore a part of the local transformation. The main river and outlet lakes in a subbasin are by the nutrient transformation calculation treated as one large lake. The lake volume in the equations below is thus the combined volume of these lakes. The lake volume at the simulation start is calculated from the mean depth and surface area, but after that the lake volume is varying according to inflow, outflow and evaporation.

To simulate short-term variations in nutrient concentration in the lake caused by hydrological conditions mainly during high flow events, the lake volume is divided into an active and a passive part. The passive water volume can be thought of as an upper part of the lake, with short residence time and no significant nutrient transformation. The division of the lake volume (Figure 4) into an active and a passive water volume is made according to:

*Maximum active water volume = deeplake * initial_lake_volume*

where *deeplake* is a calibration parameter and the *initial_lake_volume* is calculated from area and mean depth for lakes in the main river and outlet (m^3). The passive volume is the remaining of the total water volume in the lake if the total is larger than the maximum active water volume (Figure 5). If the total lake volume at on time is less than the maximum active water volume, the active water volume is equal to the total volume and no

passive volume is present at that time. Lakes with an area less than 1 km^2 are assumed to be totally mixed, and are not split into an active and a passive part.

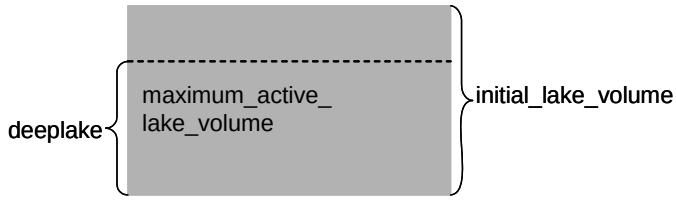

Figure 4. Picture of a lake at the model start.

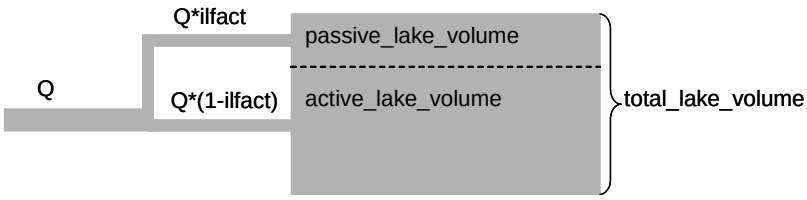

Figure 5. Picture of the lake during the model run.

Runoff from the local subbasin and runoff from upstream subbasins is mixed with the water in the passive lake. Nitrogen from point sources (industries, wastewater treatment plants etc.) is assumed to be discharged into the passive lake as well as atmospheric deposition on the lake surface. This water is then allowed to fill the active part up to its maximum volume if it can.

In the active part of the lake, biogeochemical processes are allowed to affect the concentration of nitrogen. Such processes can be denitrification, mineralization, plant uptake, biological production and sedimentation. The lake retention equation is similar to the retention in shallow ground water. The lake retention depends on lake area instead of volume because denitrification in sediment is assumed to be the dominating process. The effect of the biogeochemical processes on inorg-N is in the model described as:

*Lake retention = lakeret * conc_inorg_lake * tmean5 * lakearea*

where lake retention is the net change in inorg-N concentration from retention and mineralization in the lake (kg d^{-1}), *lakeret* is a calibration parameter, *conc_inorg_lake* is the concentration of inorg-N in the active volume (mg L^{-1}), *tmean5* is the mean air temperature during the last 5 days (^oC) and *lakearea* is the total area of lakes in the main river and outlet (km^2).

The temperature and nutrient status of the lake determine the production/retention of organic nitrogen in the lake. For organic nitrogen no division of the lake volume in an active and a passive part is made. The transformation thus occurs on the whole lake volume. Production/retention of org-N in the lake is in the model described as:

*Lake production = lakeorg * tmean10 * cilake * initial_lake_volume / 10^8*

where lake production is the biological production of org-N in the lake (kg d^{-1}), *lakeorg* is a calibration parameter, *tmean10* is the mean air temperature during the last 10 days (^oC), *cilake* an approximate concentration of inorg-N in the lake (based on upstream land use

and the turnover time of the lake) (g L^{-1}) and *initial_lake_volume* is the initial volume of lakes in the main river and at the outlet (m^3). *cilake* is assumed to be a measure of the nutrient status of the lake. The equation for lake production describes a net production of org-N as well as a net retention. If the mean air temperature of the last 10 days (*tmean10*) exceeds the mean air temperature the last 20 days (*tmean20*) the expression for biological organic production is positive. If the opposite is true, the organic material in the lake is reduced by the amount of lake production as the effect of sedimentation and mineralization is then expected to exceed the biological production. If the temperature (*tmean10*) is below zero no retention/production occur.

Sedimentation of org-N in the lake is described by the equation:

*Lake sedimentation = sedorg * conc_orgn_lake * lakearea * 10^3*

where lake sedimentation is the sedimentation of org-N in the lake (kg d^{-1}), *sedorg* is a calibration parameter, *conc_orgn_lake* is the concentration of org-N in the total volume (mg L^{-1}), and *lakearea* is the total area of lakes in the main river and outlet (km^2).

If the turnover time of the lake is less than one day no lake transformation is applied.

The concentration of lake outflow depends on the concentration of both the passive and the active volume. The contribution to lake outflow (Figure 5) from the passive volume of the lake as a fraction of the total outflow is described by *ilfact*:

*Ilfact = lakexp * passive_lake_volume / total_lake_volume*

where *lakexp* is a calibration parameter and the quotient is between the passive lake volume (*passive_lake_volume*) and the total lake volume (*total_lake_volume*), both in cubic meters. The rest of the outflow comes from the active volume (Figure 5).

2.3.4 N transformation in wetlands

The wetlands are considered to be totally mixed each day as they are assumed to be rather small and shallow. The wlake wetland type (see Sec. 2.2.1) is thus not divided into a passive and an active part and the transformation process occurs in the entire wetland volume. The retention of inorg-N in a wetland is described as:

*Wetland retention = wret * conc_inorg_wetland * tmean5 * wetland_area*

where wetland retention is the net change in inorg-N concentration in the wetland (kg d^{-1}), *wret* is a calibration parameter, *conc_inorg_wetland* is the concentration of inorg-N in the wetland (mg L^{-1}), *tmean5* is the mean air temperature during the last 5 days (^oC) and *wetland_area* is the wetland area (km^2).

The wlake wetland type will use the lake production and lake sedimentation if the parameters are set. It is recommended that set these parameters to zero in a subbasin with a wlake. The other wetland types only include wetland retention.

2.3.5 P transformation in shallow ground water

No transformation processes of phosphorus in the shallow ground water are considered in the model.

2.3.6 P transformation in rivers

The transformation in rivers is calculated separately for local rivers and the main river. When it is referred to the river below it is either the local rivers or the main river that is intended. Three processes are considered; biological production including adhesion of SRP to soil particles, sedimentation/resuspension and exchange of SRP with river bed.

The biological production and adhesion of SRP to particles causes in the model both retention of SRP and production of part-P. It is described by:

*River production = rivpp * conc_SRP_river * temptfcn * river_length / river_velocity*

where river production is the production of part-P and the retention of SRP (mg L^{-1} d^{-1}), *rivpp* is a calibration parameter, *conc_SRP_river* is the concentration of SRP in the river (mg L^{-1}), *river_length* is the length of the river (m), *river_velocity* is the velocity of the water in the river (m d^{-1}). *temptfcn* is a temperature dependent function used for this river transformation and it is formulated as:

$$temptfcn = \Theta^{ABS(tmean20 - temp\_coeff)}$$

where Θ is a given constant (=0.85), *tmean20* is the mean air temperature during the last 20 days (^{o}C), *temp_coeff* is a given constant (=15) and *ABS* is the absolute value function. The temperature function is used to simulate both the effect of varying solar radiation and of temperature on the biological production.

Particulate phosphorus is constantly settling on the river bed and being resuspended. This is described by the equations:

$$River\ sedimentation = ((bankful\_river\_flow - river\_flow) / bankful\_river\_flow)^{sedrelease} * river\_volume * conc\_pp\_river / 10^3$$

$$River\ resuspension = (river\_flow / bankful\_river\_flow)^{sedrelease} * accumulated\_pp / 10^3$$

where river sedimentation is the sedimentation of part-P from the river (kg d^{-1}) if positive, otherwise the sedimentation is zero. *bankful_river_flow* is the discharge (m^3 d^{-1}) in the river at bankful channel (see Sec. 4.4), *river_flow* is the current discharge in the river (m^3 d^{-1}), *sedrelease* is a calibration parameter, *river_volume* is the volume of the river (m^3) and *conc_pp_river* is the concentration of part-P in river (mg L^{-1}). River resuspension is the resuspension of part-P from the river bed (kg d^{-1}) and *accumulated_pp* is the part-P that has accumulated in the river bed (g). These two processes redistribute the part-P load during the year and between years. Note that these processes do not include permanent sedimentation or erosion, i.e. in these processes the river is assumed to be in a long-term steady state. Sedimentation and resuspension are turned off when *sedrelease* is set to zero.

The river volume is calculated as:

*river_volume = river_depth * (4*river_depth) * river_length*

where *river_volume* is in cubic meter, *river_depth* is varying with time (Sec. 4.4) and *river_length* is an input parameter which is constant. The river mean width is assumed four times the depth. All lengths are measured in meter.

Exchange with sediment may give temporary increase or decrease in concentration of SRP. The process is described by:

*Sediment exchange = rivsrp * (radius / cross_area) * (conc_bed – conc_srp_river)* river_volume / 2*

If Sediment exchange>0 Sediment exchange = Sediment exchange / flush_out_ratio

where sediment exchange is the change in river SRP concentration (mg L^{-1} d^{-1}), *rivsrp* is a calibration parameter, *radius* is the hydraulic radius of the river (m), *cross_area* is the cross-sectional area of the river (m^2), *conc_bed* is the SRP concentration of the river sediment (mg L^{-1}), *conc_srp_river* is the SRP concentration in the river (mg L^{-1}) and *river_volume* is the volume of the river (m^3). The *radius/cross_area* quotient is not allowed to be larger than 0.95 or less than 0.05. The sediment exchange can be both positive and negative. If sediment exchange is positive, which occur when there is increasing SRP concentration in the river, the sediment exchange is reduced by the *flush_out_ratio,* a given constant of 30 (equation two above). Due to adhesion to soil particles the release rate of SRP from the sediment is assumed 30 times slower than the rate of SRP flow into the sediment. See Sec. 4.4 for equations for some of the river variables.

Bank erosion is a source of river phosphorus, and not a transformation. It is calculated separately for local and main rivers, which has the calibration parameters *berloc* and *bermain*.

*Bank load = (berpar / 1000000) * river_flow $^{0.6}$ * river_length * river_ depth * soildens * enrich /1000*

where bank load is the load from bank erosion (kg d^{-1}), *berpar* is the parameter which is called *berloc* for the local river and *bermain* for the main river, *river_flow* is the current discharge in the river (m^3 d^{-1}), *river_length* is the length of the river (m), *river_depth* is the depth of the river (m), *soildens* is a constant the soil density (=1250 kg m^{-3}), and *enrich* is the enrichment factor, a parameter for the concentration of phosphorus in the eroded soil.

Bank erosion is described in Sec. 4.3, while some river variables are described in Sec. 4.4. The river equations are presented in more detail in Rosberg (2003).

2.3.7 P transformation in lakes

Definitions of lake, water flows and volume is found in Sec. 2.3.3. In the active part of the lake, biogeochemical processes are assumed to affect the concentration of phosphorus. Such processes can be release from sediments, mineralization, plant uptake, biological production and sedimentation. The effect of these processes on phosphorus is in the model described by four transformation equations.

A lake can have retention of SRP or release of SRP from sediments. This is modelled with the same equation differing only in the sign of the calibration parameter (*lakesrp*).

*Lake retention/release = lakesrp * cslake * $\Theta^{ABS(temp20 - temp\_coeff)}$ * lakearea * 10^3*

where lake retention/release is the net change in SRP in the lake (kg d^{-1}), *lakesrp* is a calibration parameter (positive or negative), *cslake* an approximate concentration of SRP in the lake (based on upstream land use and the turnover time of the lake) (mg L^{-1}), Θ is a given constant (=0.86), *ABS* is the absolute value function, *tmean20* is the mean air temperature during the last 20 days (^{o}C), *temp_coeff* is a given constant (=15) and *lakearea* is the total area of lakes in the main river and at the outlet (km^2). *cslake* is assumed to be a measure of the nutrient status of the lake. It is a constant for each subbasin.

In spring, i.e. when the mean temperature of 10 days is higher than the mean temperature of 20 days, an additional uptake of SRP by phytoplankton is modelled by

$$Lake\ uptake = srpupt * cslake * \Theta^{ABS(temp20 - temp\_coeff)} * initial\_lake\_volume / 10^8$$

where lake uptake is the decrease in SRP in the lake (kg d^{-1}), *srpupt* is a calibration parameter, *cslake* an approximate concentration of SRP in the lake (kg L^{-1}), Θ is a given constant (=0.86), *ABS* is the absolute value function, *tmean20* is the mean air temperature during the last 20 days (^{o}C), *temp_coeff* is a given constant (=5) and *initial_lake_volume* is the total lake volume as calculated from the mean depth (m^3).

No lake retention/release or lake uptake transformation processes are active when the turnover time of the water is less than one day.

Sedimentation of particulate phosphorus is described by:

$$Lake\ sedimentation = lakepp * conc\_pp\_lake * lakearea * 10^3$$

where lake sedimentation is the sedimentation of particulate phosphorus in the lake (kg d^{-1}), *lakepp* is a calibration parameter, *conc_pp_lake* is the concentration of part-P in the active volume (mg L^{-1}) and *lakearea* is the total area of lakes in the main river and at the outlet (km^2).

Production of particulate phosphorus is described by:

$$Lake\ production = prodpp * cslake * \Theta^{ABS(temp20 - temp\_coeff)} * lakearea * 10^3$$

where lake production is the increase in part-P in the lake (kg d^{-1}), *prodpp* is a calibration parameter, *cslake* an approximate concentration of SRP in the lake (mg L^{-1}), Θ is a given constant (=0.86), *ABS* is the absolute value function, *tmean20* is the mean air temperature during the last 20 days (^{o}C), *temp_coeff* is a given constant (=15) and *lakearea* is the total area of lakes (km^2). This equation is assumed to simulate an addition of phosphorus from bottoms of long-time eutrophic lakes.

2.3.8 P transformation in wetlands

The wetlands are considered to be totally mixed each day as they are assumed to be rather small and shallow. The wlake wetland type (see Sec. 2.2.1) is thus not divided into a passive and an active part and the transformation process occurs in the entire wetland volume. For phosphorus the transformation equation is for total phosphorus only. The transformation is allowed to act on the total phosphorus concentration of the wetland and then the concentration of SRP and part-P are calculated by separating tot-P with the same

relation as before the wetland transformation. The sedimentation of tot-P in a wetland is described as:

$$Wetland\ retention = wsedp * conc\_in\_wetland * wetland\_area * 10^3$$

where wetland retention is the net retention of total phosphorus in the wetland (kg d^{-1}), *wsedp* is a calibration parameter, *conc_in_wetland* is the concentration of tot-P in the wetland (mg L^{-1}) and *wetland_area* is the wetland area (km^2).

A release of phosphorus from the wetland is modelled as an increase in the tot-P concentration. The release of phosphorus could be uptake of phosphorus by phytoplankton causing it to stay in the water phase or release of inorganic phosphorus from the sediments. It is described as:

$$Wetland\ release = wupt * inflow\_conc * \Theta^{(lake\_temp - temp\_coeff)} * wetland\_area * 10^3$$

where wetland release is the net increase in tot-P in the wetland (kg d^{-1}), *wupt* is a calibration parameter, *inflow_conc* is the concentration of tot-P in the inflow to the wetland (mg L^{-1}), Θ is a given constant (=1.2) *lake_temp* is the temperature of the lake as calculated by HBV (it should be the mean temperature of the last 30 days, this is set by the HBV parameter *lakedays*), *temp_coeff* is a given constant (=20) and *wetland_area* is the wetland area (km^2).

3 Installation

You need to have IHMS installed on your PC. Installation of IHMS is described in the IHMS Manual (Gardelin, 2006). Check for the latest HBVmodel.dll or other version you want to use, and copy it to your IHMS program directory if necessary.

The exe-version of HBV (M_start.exe) can be used without IHMS. To use this you need a file abq.ini at c:/ and a file temp.txt at the directory specified in abq.ini. See Johnell et al. (2006) for format specification for these files.

4 Input data

A lot of different input data is possible to use to run the HBV-NP model. The data necessary for different nversion of the HBV-NP model vary. In addition, not all data is necessary for every district. Some features of the model may be turned off. In Table 1, data necessary for all nversions are in bold, while data necessary for some nversions or optional is in normal font. If the models SOIL-N and ICECREAM (Johnson et al., 1987; Tattari et al., 2001) are used to produce leakage concentration from arable land for HBV-NP additional data is required for those models (Table 1).

Table 1. Data requirement of HBV-NP (adjusted from Andersson et al., 2005). Necessary data in bold.

Basic requirements	Physiographic data: **Sub-catchment divides, river courses, lakes, altitude,** slope**, soil texture and land cover distribution, lake surface area and mean depth,** river length, buffer zones along rivers. Hydroclimatic data: **Precipitation, air-temperature, time series or monthly standard values of potential evaporation, observed water discharge.** N and P data: **discharge concentrations at some site, typical soil leakage concentration for each combination of land cover, soil, and** fertilization type **at agricultural land,** with division in micro- and macropore flow for P, **standard values of leakage from other land use classes, atmospheric wet and dry deposition of N and P on water surfaces** and on forests for N**, emissions from rural households and point sources**, dates for sowing, harvesting and ploughing, phosphorus in soil, curve number and USLE numbers.
Additional requirements for SOILNDB, and ICECREAM	Relative humidity, wind, cloudiness, average soil P and organic matter, crop sequence (or non-existent combinations), crop management and yield, fertilization and application of manure, N fixation rates in ley, deposition rates, livestock density.

Most input data is introduced to the model through the input files described in Chapter 7 and in Johnell et al. (2006). Some input data are given through the parameter files. These are presented below.

4.1 P through macropores

It is possible to include phosphorus flow from arable land separate for micro- and macropores. The part of water to the soil that goes through macropores is estimated from soil type, soil moisture, and rainfall/snowmelt amount. It is calculated the same way as in the modified ICECREAM used at SLU.

*macropore part = macrate * (insoil – mactresin) / insoil*

if *insoil* > *mactresin* and *sm* > *fc* * *mactressm*. Otherwise there is no macropore flow.

The macropore part is part of water infiltrating to the soil (unit less), *macrate* is a parameter (unit less), *insoil* is the water entering the soil (mm d^{-1}), *mactresin* is a parameter for the threshold of insoil (mm d^{-1}), *sm* is soil moisture (mm), *fc* is field capacity a calibration parameter of HBV (mm), *mactressm* is a parameter for the threshold of sm (unit less). The parameters *macrate*, *mactresin* and *mactressm* are input data. Their approximate

values are given in Table 2. The parameters depend on soil type, but can only be given for subbasins. Therefore only one value can be used even if the subbasin contains several soil types.

Table 2. Parameter values for macropore routine.

Parameter	Approximate value
macrate	0.1-0.8
mactresin	7 mm
mactressm	0.65-0.7

4.2 Surface runoff and P from soil erosion

It is possible to calculate soil erosion and surface runoff in HBV-NP. The presence and size of surface runoff is calculated with a modified version of the SCS (Soil Conservation Service) Runoff method of curve numbers (CN) which depend on the current vegetation on the agricultural fields. The dimensionless curve numbers are used to estimate the potential retention of water for a storm event. Curve numbers have been empirically determined for different soil types, vegetation and other land uses (U.S. SCS, 1986; NRCS, 1972-2004).

The SCS CN equation is based on the assumption that the actual direct runoff is related to the potential runoff the same way as the actual retention of water in the catchment for a storm event is related to the potential maximum retention. Adding the assumption that the initial abstraction (including interception, depression storage, infiltration prior to runoff) is 20% of the potential retention the SCS equation can be formulated in HBV-NP terms as:

$$surfflow = \frac{(insoil - 0.2 * S)^2}{insoil + 0.8 * S} \quad \text{if } (insoil - 0.2*S)>0$$

$$S = 254 * \left(\frac{100}{CN} - 1 \right)$$

where *surfflow* is the surface flow (mm d^{-1}), *insoil* is the water entering the soil (mm d^{-1}), S is the potential maximum retention (mm d^{-1}), and *CN* is the curve number.

In HBV-NP the retention has been further modified so that the surface runoff depends on soil moisture and slope (Williams, 1995)

$$S = \left(1 - \frac{sm / fc}{ssatfc} \right) * 254 * \left(\frac{100}{CN1} - 1 \right)$$

where S is the potential maximum retention (mm d^{-1}), *sm* is soil moisture (mm), *fc* is field capacity a calibration parameter (mm), *ssatfc* is a parameter describing the quotient of saturated soil over field capacity (unit less), and *CN*1 is the curve number used by HBV-NP.

In HBV-NP, different curve numbers are given by the user for autumn and spring cultivation and for fields with crop, harvested crop and ploughed fields. Further, pasture

and ley fields have separate curve numbers. The timing of crop management determines which curve number to use. Curve numbers are calculated differently depending on the antecedent runoff conditions (ARC). Usually the three ARCs *CN1* (dry), *CN2* (medium) and *CN3* (wet) are used (Williams, 1995; Springer, 1996). The curve number *CN2* is also adjusted to slope (Williams, 1995).

$$CN3 = CN * exp\,(0.00673 * (100 - CN))$$

$$CN2 = CN + (CN3 - CN) * (1 - 2 * exp\,(-13.86 * srslope)) / 3$$

$$CN1 = 0.0001177 * CN2^3 - 0.01379 * CN2^2 + 1.348 * CN2 - 16.91$$

The curve number, *CN*, is the parameter given by the user in the parameter file and *srslope* is a parameter for the slope (%).

For frozen soil the surface runoff is increased by adjusting the CN parameter and changing the SCS equation. The CN parameters given by the user are adjusted by:

$$CN = \begin{cases} 96 & CN < 80 \\ 98 & CN \geq 80 \end{cases}$$

and the SCS equation is substituted with:

$$surfflow = \frac{(insoil - 0.005 * S)^2}{insoil + 0.8 * S} \quad \text{if } (insoil - 0.005 * S) > 0.$$

where *surfflow* is the surface flow (mm d^{-1}), *insoil* is the water entering the soil (mm d^{-1}), and *S* is the potential maximum retention (mm d^{-1}).

Soil erosion depends on surface runoff and water entering the soil. To regionalise the erositivity, USLE parameters for the present subbasin are used and compared to that of a reference site. Soil erosion is thus calculated as

$$soil\_erosion = surfflow * a * insoil^b * usle / usleref$$

where *soil_erosion* is the soil erosion (kg ha^{-1} d^{-1}), *surfflow* is the surface flow (mm d^{-1}), *insoil* is the water entering the soil (mm d^{-1}), *a* and *b* are constants (a=0.1 and b=1.71), *usle* is the USLE parameter, and *usleref* is a constant (=0.657). The *a* and *b* constants were determined for a reference site with USLE equal to *usleref*.

Different USLE parameters are used in HBV-NP for different crop management and different subbasins. These values of the USLE parameter have been determined based on crop, slope, soil and distance to water course by the universal soil loss equation (USLE). The USLE predicts the long term average annual rate of erosion (Sivertun et al., 1988).

The phosphorus load from soil erosion is calculated as

$$P\ erosion = soil\_erosion * area * pal * enrichment * (1 - buffer * buffercov)$$

where P erosion is the load of part-P to the river (kg d^{-1}), *soil_erosion* is the soil erosion (kg ha^{-1} d^{-1}), *area* is the area of the subbasin (km^2), *pal* is a parameter for the phosphorus in soil (mg P (g soil)$^{-1}$), *enrichment* is a surface runoff dependent factor that concentrate phosphorus at low flows (unit less), *buffer* is a parameter for the reduction of soil loss due to buffer cover (unit less), and *buffercov* is a parameter for the part of the river that has buffer cover (unit less).

Enrichment is calculated as:

$$enrichment = max - (max - stab) * surfflow / surfflowstab \text{ if } 0 \leq surfflow \leq surfflowstab$$

where *enrichment* is a surface runoff dependent factor that concentrate phosphorus at low flows (unit less), *max* is a constant determining the maximum enrichment (=12), *stab* is a constant for the enrichment at stabilization (=1.5), *surfflow* is the surface flow (mm d^{-1}), and *surfflowstab* is a constant determining the surface flow at which stabilization of the enrichment is reached (=4). If *surfflow* is zero the *enrichment* is zero, but if *surfflow* is larger than *surfflowstab enrichment* is equal to *stab*.

4.3 P from bank erosion in rivers

Bank erosion is a source of river phosphorus. It is calculated separately for local and main rivers, which has the parameters *berloc* and *bermain*.

$$bank\_load = (berpar / 1000000 * river\_flow^{0.6}) * river\_length * river\_depth * soildens * enrich / 1000$$

where *bank_load* is the load of particulate phosphorus from bank erosion (kg d^{-1}), *berpar* is the parameter which is called *berloc* for the local river and *bermain* for the main river, *river_flow* is the current discharge in the river (m^3 d^{-1}), *river_length* is the length of the river (m), *river_depth* is the depth of the river (m), *soildens* is a constant soil density (=1250 kg m^{-3}), and *enrich* is a parameter for phosphorus concentration in the eroded soil (g P / kg soil). The part of the equation between parentheses is the lateral erosion rate (m d^{-1}).

The *bank_load* equation comes from a GIS-based technique for estimating stream bank erosion (Evans et al., 2003). The erosion parameter values *berpar* is 10^6 times the value *erpar* calculated by a regression equation (also from Evans et al., 2003):

$$erpar = (0.00147 * PD + 0.000143 * AD - 0.000001 * CN + 0.000425 * KF + 0.000001 * MS - 0.000016) / 30.42$$

where *erpar* is the erosion parameter, *PD* is the percent of developed land in the subbasin (%), *AD* is the animal density measured in animal equivalent units per acre, *CN* is area weighted curve number for the subbasin, *KF* is the soil erodibility factor, *MS* is the mean slope (%) in the subbasin, and the constant 30.42 transforms the value to represent daily instead of monthly soil erosion. The minimum value of *erpar* is 0.000000329.

4.4 Some river calculations

The model calculates river depth, velocity, hydraulic radius, bankful flow, and other variables to be used in the model routines. For these calculations a handful of model parameters exist.

The bankful river flow (*bankful_river_flow* in Sec. 2.3.6) is the discharge in the river at bankful channel ($m^3\ d^{-1}$). It is approximated by the mean of the next to highest daily flow for the last five years.

The velocity is calculated from the discharge and a couple of parameters:

$$river\_velocity = 10^{speedx} * movavQ^{speedy} * (river\_flow/movavQ)^{speedz}$$

where *river_velocity* is the velocity of the water in the river ($m\ s^{-1}$), *movavQ* is the mean discharge for the last 365 days ($m^3\ s^{-1}$), *river_flow* is the current discharge in the river ($m^3\ s^{-1}$), and *speedx*, *speedy* and *speedz* are three parameters.

The depth of the river can be calculated as:

$$river\_depth = cross\_area / (10^{widthx} * cross\_area^{(widthy + widthz * log10(cross\_area))})$$

where $cross\_area = river\_flow / river\_velocity$.

river_depth is the depth of the river (m), *cross_area* is the cross-sectional area of the river (m^2), *widthx*, *widthy* and *widthz* are three parameters, *river_flow* is the current discharge in the river ($m^3\ s^{-1}$), and *river_velocity* is the velocity of the water in the river ($m\ s^{-1}$). If the parameter *deadvolume* is used the above calculated river depth is smoothed with the help of an average river depth and the parameter.

$$river\_depth = movavDepth * deadvolume + river\_depth * (1 - deadvolume)$$

where *movavDepth* is the mean river depth the last 365 days (m), and *deadvolume* is a calibration parameter (unit less).

The hydraulic radius of the river is calculated as:

$$radius = cross\_area / river\_depth + 2 * river\_depth$$

radius is the hydraulic radius of the river (m), *cross_area* is the cross-sectional area of the river (m^2), and *river_depth* is the depth of the river (m).

5 Model parameters

Model parameters are read by the program from the files RMOD.PAR and BMOD.PAR. The parameter values in RMOD.PAR are valid for the district. Each subbasin can have a BMOD.PAR file, and the parameter values in that file are valid for that subbasin only. Values in RMOD.PAR are used for a subbasin only if the parameter is not in BMOD.PAR.

There are many parameters in the model. The next section describes all the model parameters that are involved in the nitrogen and phosphorus model. The parameters governing the water are not explained in this manual. They can be found in for instance Johnell et al. (2006).

5.1 List of parameters for N and P routines

Below are all the model parameters that are involved in the nitrogen and phosphorus model listed alphabetically. The default value of all the parameters listed here is zero, with the exception of *lakedays* which has default value 30 when the option to use HBV-96 model version is used (hbv96 set on in INFO.PAR).

P	*berloc*	Parameter for the part-P soil erosion from local river banks. Zero turns the process off. Approximate range $0.329 \leq berloc \leq 100$.
P	*bermain*	Parameter for the part-P soil erosion from main river banks. Zero turns the process off. Approximate range $0.329 \leq bermain \leq 100$.
P	*buffer*	Parameter for the part-P soil erosion due to surface runoff. It defines the part of soil erosion that does not reach the river if there is a buffer cover. Range $0 \leq buffer \leq 1$.
P	*buffercov*	Parameter for the part-P soil erosion due to surface runoff. Part of river with buffer cover. This parameter is not calibrated. Range $0 \leq buffercov \leq 1$.
P	*cnc*	Parameter for surface runoff. Curve number for field with grown crop. This parameter is not calibrated. Range $0 < cnc \leq 100$.
P	*cnh*	Parameter for surface runoff. Curve number for harvested field. This parameter is not calibrated. Range $0 < cnc \leq 100$.
P	*cnl*	Parameter for surface runoff. Curve number for ley. This parameter is not calibrated. Range $0 < cnc \leq 100$.
P	*cnp*	Parameter for surface runoff. Curve number for ploughed field. This parameter is not calibrated. Range $0 < cnc \leq 100$.
P	*cnps*	Parameter for surface runoff. Curve number for pasture. This parameter is not calibrated. Range $0 < cnc \leq 100$.
NP	*deadvolume*	Parameter used to calculate a smoother river depth. Weight put on the average depth (in contrary to the current depth). This parameter is not to be calibrated. Range $0 \leq deadvolume \leq 1$.
NP	*deeplake*	Parameter determining the magnitude of the active volume of a lake. The value of 'deeplake' multiplied with the mean depth of the lake determines the depth for the active volume of the lake. Approximate range $0.9 \leq deeplake \leq 1.2$. *deeplake* can be assigned a high value, e.g.1000 to simulate well-mixed lakes.

NP	*depthlz*	The level (in mm) of an extra storage of the lower response reservoir of the response routine. Range $0 \leq$ *depthlz.* This parameter is not used in most applications of the HBV-NP model. However, in some applications an extra volume for mixing of water is desired to get an enlarged mixing volume and a prolonged turnover time.
P	*enrich*	Parameter for the P concentration of river bank. Used in soil erosion from river banks. Range $0 <$ *enrich.*
NP	*lakedays*	The water temperature is estimated from the air temperature during the last *lakedays* days. This parameter is not calibrated.
NP	*lakexp*	Parameter determining the relation between discharge from the active and the passive volume of the lake. Range $0 \leq$ *lakexp* ≤ 1. *lakexp* = 0 means that all discharge is from the active volume, while *lakexp* = 1 means the discharge from the different volumes is proportional to the volumes.
N	*lakeorg*	Parameter for the production of org-N in lakes. Approximate range $0 \leq$ *lakeorg* ≤ 100
P	*lakepp*	Parameter for sedimentation of part-P in lakes. Approximate range $0 \leq$ *lakepp* ≤ 0.01.
N	*lakeret*	Parameter governing the retention of inorg-N in lakes. Approximate range $0 \leq$ *lakeret* ≤ 20.
P	*lakesrp*	Parameter for the retention of SRP in lakes (positive) or release of SRP from lake bottoms (negative). Approximate range $-0.1 \leq$ *lakesrp* ≤ 0.1.
N	*locorg*	Parameter governing the production of org-N in soil and groundwater. Approximate range $0 \leq$ *locorg* ≤ 100.
N	*locret*	Parameter determining the value of the retention of inorg-N in soil and groundwater. Approximate range $0 \leq$ *locret* ≤ 20.
P	*mactresin*	Parameter for calculation of macropore flow. Threshold of inflow to soil above which macropore flow can occur. This parameter is not calibrated.
P	*mactressm*	Parameter for calculation of macropore flow. Threshold of soil moisture relative field capacity above which macropore flow can occur. This parameter is not calibrated.
P	*macrate*	Parameter for calculation of macropore flow. This parameter is not calibrated.
P	*pal*	Parameter for phosphorus in soil (mg P (g soil)$^{-1}$). This parameter is not calibrated.
P	*prodpp*	Parameter for production of part-P in lakes. Approximate range $0 \leq$ *lakepp* ≤ 1.
N	*rivorg*	Parameter for the production of org-N in main river. Approximate range $0 \leq$ *rivorg* ≤ 500.
P	*rivpp*	Parameter for the production of part-P in main river. Approximate range $0 \leq$ *rivpp* ≤ 100000.
N	*rivret*	Parameter for the local retention of inorg-N in main river. Approximate range $0 \leq$ *rivret* ≤ 1.
P	*rivsrp*	Parameter for the exchange of SRP between water and river bed. Range $0 \leq$ *rivsrp* ≤ 1.

N	*sedorg*	Parameter that determines sedimentation of org-N in lakes. Approximate range $0 \leq sedorg \leq 1$.
P	*sedrelease*	Parameter for the sedimentation and resuspension of particles, including particulate phosphorus. Approximate range $1 \leq sedrelease \leq 3$. If set to zero the process will be turned off.
P	*speedX*	Parameter for river velocity. This parameter is not calibrated. Approximate range $-0.5 \leq speedX \leq -0.2$.
P	*speedY*	Parameter for river velocity. This parameter is not calibrated. Approximate range $0.1 \leq speedY \leq 0.4$.
P	*speedZ*	Parameter for river velocity. This parameter is not calibrated. Approximate range $0.1 \leq speedZ \leq 0.3$.
P	*srpupt*	Parameter for additional SRP retention during spring in lakes. Range $0 \leq srpupt$.
P	*srslope*	Parameter for surface runoff, slope of land (%). This parameter is not calibrated.
P	*ssatfc*	Parameter for surface runoff, soil saturation above field capacity. This parameter is not calibrated. Approximate range $1 \leq ssatfc \leq 3$. *ssatfc* turn off the surface runoff routine if set to zero.
P	*uslec*	Parameter for soil erosion. USLE factor for field with crop. This parameter is not calibrated. Approximate range $0 \leq uslec \leq 1$.
P	*usleh*	Parameter for soil erosion. USLE factor for harvested field. This parameter is not calibrated. Approximate range $0 \leq usleh \leq 1$.
P	*uslel*	Parameter for soil erosion. USLE factor for ley. This parameter is not calibrated. Approximate range $0 \leq uslel \leq 1$.
P	*uslep*	Parameter for soil erosion. USLE factor for ploughed field. This parameter is not to be calibrated. Approximate range $0 \leq uslep \leq 1$.
P	*usleps*	Parameter for soil erosion. USLE factor for pasture. This parameter is not to be calibrated. Approximate range $0 \leq usleps \leq 1$.
P	*widthX*	Parameter for river depth. This parameter is not calibrated. Approximate range $-0.02 \leq widthX \leq 0.03$.
P	*widthY*	Parameter for river depth. This parameter is not calibrated. Approximate range $0.4 \leq widthY \leq 0.7$.
P	*widthZ*	Parameter for river depth. This parameter is not calibrated. Approximate range $0.4 \leq widthZ \leq 0.6$.
N	*wret*	Parameter governing the retention of inorg-N in wetlands. Approximate range $0 \leq wret \leq 20$.
P	*wsedp*	Parameter for sedimentation of tot-P in wetlands. Range $0 \leq wsedp \leq 1$.
P	*wupt*	Parameter for the tot-P production in wetlands. Range $0 \leq wupt \leq 1$.

5.2 Parameter recommendations

This section contains a few notes on what to think about when starting the task of assigning parameter values. For a calibration strategy see Sec 8.2.

In some applications only *locret* is necessary for nitrogen transformation in soil and groundwater, and *locorg* is then zero. In the TRK-project (Ejhed and Brandt, 2000) a *locret* between 1 and 4 was used for Sweden. Mostly values of 2-2.5 were used, but for Halland a lower value (1) was used and for Östgötaslätten a higher (4) was used. In this project *locorg* was not used at all. In a project for adjusting the TRK-system to regional calculations (Brandt et al., 2004) the model was calibrated for Östergötland, and also here a *locret* of 4 was used.

River retention and production is seldom used for nitrogen in applications in Sweden. Their effect often drowns in the effect of lakes. For catchment with few lakes the effect of rivers may be important though.

For lakes it is recommended to start with *deeplake* around one. If it is a small lake, or if you want high flow concentrations to be treated the same way as lower flows concentration, use a high *deeplake*. The parameter *deeplake* should only be lowered to correct too low concentrations for high flows. A minimum value that the model still can handle is around 0.2. If *deeplake* is changed *lakeret* needs to be recalibrated afterwards, while org-N concentration is not affected by *deeplake* and *lakexp*. *Lakexp* can be used to further adjust the outflow concentration by balancing how much of the outflow that comes from the active and passive lake box respectively.

For nitrogen in lakes there are three parameters to consider. A higher value of the parameter *lakeorg* gives org-N concentration a stronger seasonal variation but the parameter will not much influence the mean concentration. The parameter *lakeret* decreases inorg-N concentration in summer, giving a decrease in mean concentration and a seasonal variation to the inorganic nitrogen concentration. The parameter *sedorg* is used to decrease the level of org-N.

In the TRK-project the lake retention parameter (*lakeret*) used for Sweden were in the range 0 to 12. Lake production through *lakeorg* where used for a few lakes with values between 30 and 5000. A low value of *lakexp* was used in the TRK-project (0-0.1), while *deeplake* varied a lot (0.1-2). In the regional-TRK-project (Brandt et al., 2004) a *deeplake* of 0.8 was used for all lakes in Östergötland.

The macropore parameters *mactressm* and *macrate* should be chosen depending on main soil type of the subbasin and what parameter values have been used to generate the leakage concentrations. For typical values see Table 2 (Sec 4.1).

For calculation of surface runoff and soil erosion caused by the surface runoff, all parameters are preferably calculated before hand from maps and agricultural statistics. The *buffercov* parameter should also be set from prior knowledge, see Sec 4.2.

For bank erosion, the two parameters *berloc* and *bermain* determine the size of the erosion. These can be calibrated if you have observations of the size of bank erosion to calibrate against, otherwise they are best determined beforehand (Sec. 4.3). In the Vastra-project (Andersson et al., 2005) the two parameters varied between the minimum value (0.329) and 1.2 for Swedish Rönneå catchment. In another Swedish catchment (Motala Ström) they varied between the minimum value and 50. The enrichment parameter, *enrich*, was 0.0025 g P / kg soil in both these applications.

The parameters for calculation of river depth and river velocity are used on district level and are not be calibrated. The approximate parameter ranges are from regressions made for several regions of Sweden (Rosberg, 2003).

For phosphorus in rivers the *sedrelease* parameter determines the frequency of resuspension events. A higher value gives part-P concentration more peaks. The biological production/adhesion (*rivpp*) influences the relation between SRP and part-P, but not the total phosphorus. A higher value of *rivpp* gives a stronger seasonal variation to the phosphorus fractions. Exchange of SRP with sediment (*rivsrp*) is limited to 1. The river parameters seem to be rather insensitive. For Swedish Rönneå catchment (Andersson et al., 2005), the following values where used for the whole district: rivsrp = 0.6, rivpp = 0.06, and sedrelease = 1.6.

For phosphorus in lakes, *lakepp* is used to decrease the level of particulate and total phosphorus. If the lake is a source of phosphorus from sediment this can be simulated with negative *lakesrp*. Positive *lakesrp* on the other hand is suitable when a clear decrease in SRP during summer is seen for the lake. The parameter *srpupt* is used if the *lakesrp* lake parameters can not manage the seasonal variation and you need an additional decrease of SRP in spring. The parameter *prodpp* is used when you want another (particulate) phosphorus source to the lake. Remember that *deeplake* and *lakexp* parameters also influence the phosphorus in the lake.

The wetland parameter (*wret*, *wsedp*, *wupt*) is seldom calibrated because wetlands are in the model most often used for nutrient reduction scenarios. To calibrate wetland parameters you need to set up the model and simulate a well established wetland with good concentration observations. For Sweden *wret* has been found to be 2.3 mm d^{-1} $ºC^{-1}$ (Arheimer and Wittgren, 2002) for nitrogen, and a *wsedp* of 0.09 m d^{-1} and *wupt* of 0.1 m d^{-1} has been found for phosphorus (Tonderski et al., 2005) has been found.

6 Different model versions

The HBV-NP model has three versions, so called nversions. These are called *nversion1*, *trk* and *np*. The first two versions simulate only nitrogen, while the last one simulates both nitrogen and phosphorus.

The main differences between the model's nversion *trk* and nversion *nversion1* are:

- N load from all land use classes, except load from arable land, is added to the watercourse in nversions *trk*, while all load from land use classes is added to the groundwater in *nversion1*. There is also a seasonal variation in the leakage concentrations added to the watercourse in the *trk* version (in *nversion1* only yearly mean concentrations are used).
- It is possible to use three forest regions in *trk*, while *nversion1* has the same leakage regions for other land use classes as for arable land.
- Mire and clearcut forest are new source apportionment classes for land use in nversion *trk*, in addition to the common classes; forest, arable, pasture and other.
- Leakage from clearcut forests differs from forest leakage in *trk*. The equation governing the leakage from clearcut forest depends on atmospheric deposition, which consequently must be given as input.
- It is possible to use runoff dependent leakage concentration in *trk*.
- Wet deposition of atmospheric N is specified as a monthly N concentration in precipitation in *trk*, which is in the model multiplied with daily precipitation to give daily load. In *nversion1* seasonal load is used for atmospheric deposition.
- Dry deposition of atmospheric N is specified as monthly load in *trk*, while in *nversion1* it is seasonal load.
- In nversion *trk* rural load and point sources may be accumulated and released later if there is low water in the soil, river or lake.
- Nversion *trk* can have more wetland types. The wetland types, iwet and owet, can be used in *trk* in addition to wlake, while *nversion1* only can have wlake.

For nversion *np* the largest difference is the addition of phosphorus simulation. The N model is almost the same as for nversion *trk*. Still some differences exist.

- It is possible to use the river advection routine (Sec 2.2.2) instead of the *maxbas/maxbaz* routine for runoff delay. When used it applies to both nitrogen and phosphorus.
- The format of N input data for other land use classes has been changed. Seven forest regions may be used and leakage concentration is specified in text files instead of specified in the code and other places.
- Another region division can be used for other open land in nversion *np* compared to nversion *trk*, where the forest region division is used for other open land.

In addition to choosing nversion, there are some alternatives that can be used within one nversion; runoff dependent leakage concentration (Sec. 7.3.1.3 and 7.4.1.3), elevation dependent leakage concentration (Sec. 7.4.1.4), sedimentation and resuspension of particulate phosphorus in river courses (Sec. 2.3.6), different flow paths of phosphorus from agriculture land (Sec. 7.4.1.6).

7 HBV-NP files and file formats

In addition to the files needed to run the HBV model (see Johnell et al., 2006), some files are needed to run the nutrient model. The files for the nutrient model can not be created from the IHMS menu system. The files have to be created and edited manually. For some files the file format differs between the models' nversions. In Sec. 7.2 - 7.4, the different model versions are treated separately, and all files needed are listed and specified for each nversion. Last, in Sec. 7.5, the result files from a simulation are briefly described.

7.1 General rules for input data file formats

Common for all model versions is the identifier 'nn', found in the file names nnLEAxxx.PAR, CLASSnn.PAR and LOADnn.PAR for example. The value of 'nn' (a two-figure-number between 00 and 99) is specified in the file NSTART.PAR (se below) and must be the same as in the filenames. The pre/suffix 'nn' can preferably be used as a notation for which year the input data is valid.

General rules for the HBV-NP input data files.

- The length of the text fields is normally maximum 10 positions. Exception is made for class type and leak type which can be maximum 50 characters. Exception is also made for file directories, which often has a maximum of 80 characters including the filename.
- The length of each row is normally maximum 80 positions. For nversion np some files can have longer rows.
- All text strings is initialised and ended by a '. Note that a ' will not work.
- Each row begins with an identifier, which is followed by a number of values or text strings connected to that identifier. The format of these values is in the descriptions below identified by the letters I for integer, R for real and S for string.
- Rows with comments can be written anywhere in the file as long as it is begins with '!!'. Entries for comments are not limited by 80 positions.
- All variables are set to zero before the model simulation starts, which means that only variables which are to be assigned a value not equal to zero have to be entered in the input data files.
- The number -9999 is used for missing values

An exception from the general rules is made for the CONC.DAT file. Its rows do not begin with an identifier and consequently the file do not accept comment rows.

7.2 Input files for nversion *nversion1*

7.2.1 Input data files

The following files are necessary for *nversion1*: NSTART.PAR, CLASSnn.PAR, nnLEAxxx.PAR, and LOADnn.PAR. Each file is presented below. The dataset is included in the file names and denoted nn, while xxx stands for the leakage region. The file CONC.DAT is necessary to calibrate the model. In addition files are needed for HBV, e.g. ZON.PAR, but these are not presented in this manual (see IHMS Manual, Gardelin, 2006)).

7.2.1.1 CLASSnn.PAR

This file is created for each subbasin and stored in the directory of the subbasin. The file includes areas for all land use classes in the subbasin. The dataset is included in the file name and denoted nn. The number of classes may not exceed 250 and the name of each land use class is limited to 50 positions. Moreover, the file includes mean depths of output lakes, main river lakes and wetlands (wlake), total area of main river lakes in the subbasin, and the mean inorg-N concentration in lakes. If no concentration value is entered it is approximated in the model calculation by upstream land characteristics. The district may be further divided with the subbasins belonging to different regions. The class- file includes an identifier, 'region', for which leakage region the subbasin belongs to.

region	I	Defines which leakage region the subbasin belongs to. Governs which file with leakage concentrations that are to be read. Region is a number between 001 and 999.
arlake	R	Area (km^2) of lakes in the main river (rlake).
drlake	R	Mean depth (m) of lakes in the main river (rlake).
dolake	R	Mean depth (m) of outlet lake (olake) (the area is defined in ZON.PAR).
dwlake	R	Mean depth (m) of wetland (wlake) (the wetland area is defined as an olake area in ZON.PAR). Note: this depth must be zero (or the line omitted) if there is no wetland in the subbasin.
colake	R	Approximate yearly mean value of inorg-N in the olake/rlake/wetland (mg L^{-1}). If this concentration is not specified it is in the model approximated from load to the lake, lake volume, upstream area of the lake and specific yield (approximated by hq/2).
name of land use class	R	Area of each land use class (km^2).

Example (CLASS85.PAR):

```
'!!' Subbasin 2
'!!' Area of land classes in km2
'region'                012
'dolake'                10
'arlake'                1.2
'drlake'                11
'barley/oats'           1.2
'winter wheat'          0.5
'sugar-beets'           2.5
'ley'                   0.5
'spring oil pl. '       1.2
'pasture'               3.0
'forest'                5.5
'urban'                 1.8
```

7.2.1.2 CONC.DAT

The CONC.DAT file contains time series of measured nitrogen concentrations at the subbasin outlet. The file is stored in the subbasin directory for the subbasins with

measurements of nitrogen concentrations. To calibrate the HBV-NP model, measured concentrations are needed for at least one subbasin. For this file the general file format for input data files specified above are not valid, this file must be saved in tab-separated text format, and must have a file-header of three lines (see example below). The file should preferably include tot-N concentration, NO_x-N concentration and NH_4-N concentration. A missing measurement is entered as –9999. Inorg-N is calculated as the sum of NO_x-N and NH_4-N concentration or if NH_4-N is missing only NO_x-N. The concentration of org-N is not specified in the file but is in the model calculated as the difference between tot-N and inorg-N.

Example (CONC.DAT):

Subbasin 2.
Observed concentrations at outlet of subbasin (mg/l)

Year	Month	Day	Tot-N	NO23-N	NH4-N
1990	1	15	1.09	0.495	0.0503
1990	2	22	1.14	0.534	-9999
1990	3	08	1.25	0.601	0.0736
1990	3	18	1.25	0.570	0.0679

7.2.1.3 nnLEAxxx.PAR

The leak-file specifies the root-zone leakage concentrations of nitrogen for different land use classes. A nnLEAxxx.PAR-file is valid for one leakage region. xxx in the name of the leak-file specifies which leakage region it represents, and all subbasins in that region (specified in CLASSnn.PAR) use this leak-file. In the leak-file, a leakage concentration must be entered for each land use class with area exceeding zero in the CLASSnn.PAR files. The name of the land use class in the leak-file must agree exactly to the name in the class-file. The leak-files can be put anywhere in the file structure, and the chosen directory of the files is specified in the file NSTART.PAR (Sec. 7.2.1.5). The identifier is the HBV class (ZON.PAR) to which the land use class belongs (forest, field or glac).

The leak-file includes information of the root-zone leakage concentration of different land use classes in the following format:

name of HBVclass S1,S2,R1,R2

S1: land use class

S2: source apportionment class (arable, forest, pasture, other)

R1: root-zone leakage concentration of tot-N (mg L^{-1})

R2: percent of the tot-N leakage concentration that is inorg-N

Example (85LEA012.PAR):

'!!' Leakage region 012

'!!' HBV-class	Land use class	Source app.	Tot-N	%NO3-N
'field'	'barley/oats'	'arable'	13.71	90
'field'	'winter wheat'	'arable'	15.46	90
'field'	'potatoes'	'arable'	14.86	90
'field'	'ley'	'arable'	4.33	90
'field'	'spring oil pl. '	'arable'	22.29	90
'field'	'pasture'	'pasture'	2.76	80
'forest'	'forest'	'forest'	1.50	20
'field'	'urban'	'other'	1.50	20

7.2.1.4 LOADnn.PAR

The file is stored in the subbasin directory for each subbasin. The file specifies load from point sources, rural households and atmospheric deposition on lakes. The dataset is included in the file name and denoted nn.

urban	R1,R2	R1: load of tot-N from municipal waste water treatment plants (kg year^{-1}) R2: percent inorg-N of the urban tot-N load
rural	R1,R2	R1: load of tot-N from rural households (kg year^{-1}) R2: percent inorg-N of the rural tot-N load
industry	R1,R2	R1: load of tot-N from industry (kg year^{-1}) R2: percent inorg-N of the industrial tot-N load
stormwater	R1,R2	R1: load of tot-N from storm water (kg year^{-1}), R2: percent inorg-N of the storm water tot-N load
dep1lake	R	Deposition of inorg-N on lakes during December to February (kg km^{-2})
dep2lake	R	Deposition of inorg-N on lakes during March to May (kg km^{-2})
dep3lake	R	Deposition of inorg-N on lakes during June to August (kg km^{-2})
dep4lake	R	Deposition of inorg-N on lakes during September to November (kg km^{-2})

Example (LOAD85.PAR):

```
'!!' Subbasin 2
'!!' Load tot-N (kg/year) and % Inorg-N
'!!' Deposition of inorganic nitrogen on lakes (kg/km2)
'urban'          100    90
'rural'          200    90
'industry'       300    70
'dep1lake'       200
'dep2lake'       200
'dep3lake'       200
'dep4lake'       200
```

7.2.1.5 NSTART.PAR

The file is stored in the district directory, and includes general information for the HBV-NP model simulation. The start date for calculation of nitrogen results (e.g. R^2 values, yearly loads etc.), the directory for the files with leakage concentrations, the dataset identifier, and the HBV-NP model version are specified in this file.

ayear	I	Starting year…
amonth	I	…and starting month…
aday	I	…and starting day for saving of N-results
leakdir	S	The location of the directory with the nnLEAxxx.PAR-files
dataset	I	An integer 00 < I < 99, corresponding to 'nn' in the filenames

version	S	Specifies the file format and model version, in this case 'nversion1'

Example (NSTART.PAR)**:**

```
'ayear'    1984
'amonth'  10
'aday'     1
'leakdir'   'c:\smhi\ihms\dat\leak\'
'dataset'  85
'version'  'nversion1'
```

7.2.2 Nitrogen complements to HBV input data files

The format of these files is described in Johnell et al. (2006). Here is only commented on the HBV-NP additions.

7.2.2.1 BMOD.PAR/RMOD.PAR

The parameters of the nitrogen model are added to the hydrological parameters in the files RMOD.PAR and/or BMOD.PAR. RMOD.PAR is for parameters valid for the whole district and parameters in BMOD.PAR are valid for the subbasin in which directory the file is stored. The parameters for the nitrogen model that can be used for nversion1 are: *locorg, locret, depthlz, deeplake, lakexp, lakeorg*, *lakeret, wret*, *rivorg, rivret*. The equations and parameters are described in Chapter 2 and the parameters are summarized in Chapter 5. The parameters can be entered manually to the files, or it can be specified from the IHMS menu system.

7.2.2.2 INFO.PAR

In the INFO.PAR file it is specified that it is the HBV-NP model that is to be run. This is done by setting 'nmod' 'on' in INFO.PAR. To run the HBV model alone set 'nmod' 'off' or omit the line. Moreover, to create result files for the nitrogen computations it is required that results are saved for all subbasins, and this is ensured by editing 'map' 'on' in this file.

```
'nmod'        'on'
'map'         'on'
```

This information can be entered manually to the file INFO.PAR, or it can be specified from the IHMS menu system.

7.2.2.3 INSTATE.DAT

The initial state of the model is specified in the file INSTATE.DAT. For HBV-NP the nitrogen concentration in the upper and lower response box, in the active and passive part of the lake and the mean concentration of inorg-N in the lake can be added. If no initial values are given the HBV-NP model calculates initial values based on loads.

ncuz	I,R	N concentration in upper response box (mg L^{-1}). The range I is 202 for inorg-N and 203 for org-N. R is the value.
nclz	I,R	N concentration in lower response box (mg L^{-1}). The range I is 202 for inorg-N and 203 for org-N. R is the value.

ncepi	I,R	N concentration in upper/passive lake box (mg L^{-1}). The range I is 202 for inorg-N and 203 for org-N. R is the value.
nchypo	I,R	N concentration in lower/active lake box (mg L^{-1}). The range I is 202 for inorg-N and 203 for org-N. R is the value.
ncini	I,R	Typical inorg-N concentration in the lake (mg L^{-1}). The range I is 202 for inorg-N. R is the value. This value is used if *colake* is not specified in CLASSnn.PAR.
nqinorg	I,R	inorg-N delayed in *maxbas/maxbaz* (see Johnell et al., 2006). The range I is delay in time steps. R is the value.
nqorg	I,R	org-N delayed in *maxbas/maxbaz*. The range I is delay in time steps. R is the value.
nqinorg1	I,R	The range I is delay in time steps. R is inorg-N delayed by *lag* and/or *damp* (see Johnell et al., 2006). Last character in row identifier (1) is inflow number.
nqorg1	I,R	The range I is delay in time steps. R is org-N delayed by *lag* and/or *damp*. Last character in row identifier (1) is inflow number.
...		
nqinorg5	I,R	The range I is delay in time steps. R is inorg-N delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.
nqorg5	I,R	The range I is delay in time steps. R is org-N delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.

7.2.2.4 OUT.PAR

Specify in the file OUT.PAR which nitrogen variables that are chosen for output. Add these variables to the list of HBV-variables. The variables in OUT.PAR will end up in the files COMP.TXT and/or DOS_COMP.DAT. To get the result in the specific nutrient result file (RESULTnn.DAT) it is necessary to add the variable *qcout* and the six *nccout/ncrout* variables to OUT.PAR otherwise the output will be missing values. The output variables of the nitrogen part of HBV-NP model are:

nccout	S	computed N concentration at the outlet of the basin (**n**utrient **c**oncentration **c**omputed **out**flow) (mg L^{-1}). The range S is *totn*, *inorgn*, or *orgn*.

ncrout	S	measured N concentration at the outlet of the basin (**n**utrient **c**oncentration **r**ecorded **out**flow) (mg L^{-1}). The range S is *totn*, *inorgn*, or *orgn*.
ncuz	S	computed N concentration in upper response box (mg L^{-1}). The range S is *inorgn*, or *orgn*.
nclz	S	computed N concentration in lower response box (mg L^{-1}). The range S is *inorgn*, or *orgn*.
ncepi	S	computed N concentration in upper/passive lake box (mg L^{-1}). The range S is *inorgn*, or *orgn*.
nchypo	S	computed N concentration in lower/active lake box (mg L^{-1}). The range S is *inorgn*, or *orgn*.

Example (OUT.PAR):

```
'prec    '    'totmean '
'temp    '    'totmean '
'qcout   '    'totmean '
'nccout'      'totn'
'nccout'      'inorgn'
'nccout'      'orgn'
'ncrout'      'totn'
'ncrout'      'inorgn'
'ncrout'      'orgn'
```

7.3 Input files for nversion *trk*

7.3.1 Input data files

The following files are necessary for nversion *trk*: NSTART.PAR, CLASSnn.PAR, nnLEAxxx.PAR, and LOADnn.PAR. Each file is presented below. The dataset is included in the file names and denoted nn, while xxx stands for the leakage region. The file CONC.DAT is necessary to calibrate the model. In addition files are needed for HBV, e.g. ZON.PAR, but these are not presented in this manual (see IHMS Manual, Gardelin, 2006)).

7.3.1.1 CLASSnn.PAR

This file is created for each subbasin and stored in the directory of the subbasin. The file includes areas for all land use classes in the subbasin. The dataset is included in the file name and denoted nn. The number of classes may not exceed 250 and the name of each land use class is limited to 50 positions. The land use classes used in the *trk* model version are: 'forest', 'clearings' (i.e. clearcut forest), 'mire', 'mire in mount' (i.e. mires in the bare mountain), 'bare mountain', 'glaciar', 'other open land' (may include urban, bare limestone soil, and other open land), 'urban', 'other colonization', and a great number of combinations of arable crops and soil types. The classes 'urban' and 'other colonization' is later additions that was not available in the *trk* model version earlier. The crops and soil types used in the TRK project (Ejhed and Brandt, 2002) are shown in Table 3.

Moreover, the file includes mean depths of output lakes, main river lakes and wetlands (wlake), total area of main river lakes in the subbasin, and the mean inorg-N concentration in lakes. If no concentration value is entered it is approximated in the model calculation by upstream land characteristics. The district may be further divided with the subbasins

Table 3. Crops and soil types combined to land use classes in the TRK project.

Crop name in the HBV-NP files	**Soil type**	**Soil type abbreviation in the HBV-NP files**
Spring barley	Sand	s
Winter wheat	Loamy sand	ls
Ley	Sandy loam	sl
Sugar beets	Loam	l
Winter rape	Silt loam	sil
Green fallow	Sandy clay loam	scl
Oats	Clay loam	cl
Spring wheat	Silty clay loam	sicl
Winter rye	Silty clay	sic
Winter barley	Clay	c
Spring rape	Silt (**)	si
Potatoes	Sandy clay (**)	sc
Pasture		
Undef arable (Undefined arable land)		
Minor crops		
Wetland (*)		

(*) Wetlands with areal subsidy are counted as a 'crop', and are in the HBV-NP calculation treated as a 'crop' with root-zone leakage concentration 0 mg/l.

(**) The soil type makes up a very small part of Sweden. The leakage from these soil types have been approximated as the mean value of the leakage from the crop on the other soil types.

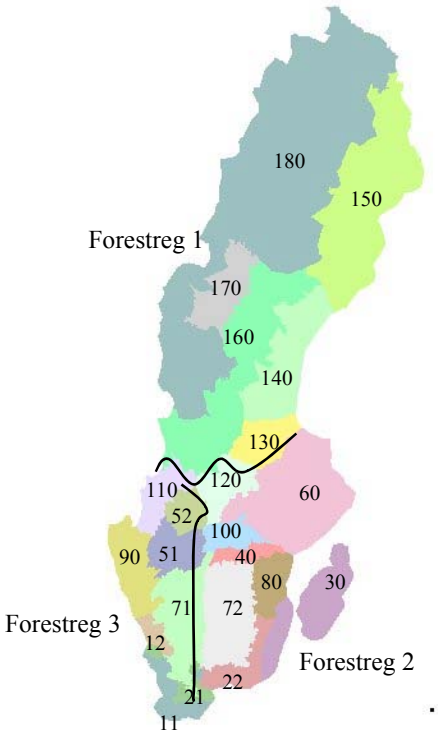

Figure 6. Division of Sweden into 22 leakage regions for arable land, and three regions for forested land. Forest region number 1 covers northern Sweden (north of leakage regions 110, 120 and 60. Forest region 2 is the region in the south draining to the east, and forest region 3 is in the south draining to the west.

belonging to different regions. The class-file includes an identifier, 'region', for which leakage region the subbasin belongs to, and an identifier 'forestreg' for which forest region the subbasin belongs to. In the TRK-project, Sweden is divided into 22 leakage regions for arable land and three leakage regions for forest (Figure 6). Subbasin mean runoff is specified in the class-file if N-leakage depending on runoff is used (Sec. 7.3.1.3).

region	I	Defines which leakage region the subbasin belongs to, and governs which file with leakage concentrations that are to be read. Region is a number between 001 and 999.
forestreg	I	Defines which forest region the subbasin belongs to. Region is a number between 1 and 3.
arlake	R	Area (km^2) of lakes in the main river (rlake).
drlake	R	Mean depth (m) of lakes in the main river (rlake).
dolake	R	Mean depth (m) of outlet lake (olake) (the area is defined in ZON.PAR).
dwlake	R	Mean depth (m) of wetland (wlake) (the wetland area is defined as an olake area in ZON.PAR). Note: this depth must be zero (or the line omitted) if there is no wlake wetland in the subbasin.
colake	R	Approximate yearly mean value of inorg-N in the olake/rlake/wetland (mg/L). If this concentration is not specified it is in the model approximated from load to the lake, lake volume, upstream area of the lake and specific yield (approximated by hq/2).
aiwet	R	Area of local wetland (iwet) (km^2)
aowet	R	Area of wetland in main channel (owet) (km^2)
caiwet	R	Catchment area of local wetland (iwet) (km^2)
diwet	R	Mean depth of local wetland (iwet) (m)
dowet	R	Mean depth of wetland in main channel (owet) (m)
nleakq	R	Mean runoff (mm) of the subbasin to be used for runoff dependent leakage. This parameter was not used in the TRK project.
name of land use class	R,(R)	Area of each land use class (km^2). Part of area that is fertilized with manure is optional. Note: If manure part of area is given, concentrations for this land use have to be given in nnLEAxxx.PAR otherwise the concentration will be zero.

Example (CLASS99.PAR):

```
'region'     11
'forestreg'  2
'forest'              3.53
'other open land'     4.70
'spring barley sl'    3.79
'winter wheat sl'     4.33
```

'green fallow sl' 1.66
'winter rye sl' 1.01
'pasture sl' 1.72
'undef arable sl' 1.84
'arlake' 0.05
'drlake' 2.10
'nleakq' 325

7.3.1.2 CONC.DAT

CONC.DAT has the same format as for *nversion1*. The CONC.DAT file contains time series of measured nitrogen concentrations at the subbasin outlet. The file is stored in the subbasin directory for the subbasins with measurements of nitrogen concentrations. To calibrate the HBV-NP model, measured concentrations are needed for at least one subbasin. For this file the general file format for input data files specified above are not valid, this file must be saved in tab-separated text format, and must have a file-header of three lines (see example below). The file should preferably include tot-N concentration, NO_x-N concentration and NH_4-N concentration. A missing measurement is entered as -9999. Inorg-N is calculated as the sum of NO_x-N and NH_4-N concentration or if NH_4-N is missing only NO_x-N. The concentration of org-N is not specified in the file but is in the model calculated as the difference between tot-N and inorg-N.

Example (CONC.DAT):

Subbasin 2.
Observed concentrations at outlet of subbasin (mg/l)

Year	Month	Day	Tot-N	NO23-N	NH4-N
1990	1	15	1.09	0.495	0.0503
1990	2	22	1.14	0.534	-9999
1990	3	08	1.25	0.601	0.0736
1990	3	18	1.25	0.570	0.0679

7.3.1.3 nnLEAxxx.PAR

The leak-file specifies the root-zone leakage concentrations of nitrogen for different land use classes. One nnLEAxxx.PAR-file is created for each leakage region, i.e. 22 files were created for the TRK-project. The xxx in the name of the leak-file specifies which leakage region it represents (specified in CLASSnn.PAR). Several subbasins can belong to the same leakage region.

In the leak-file, a leakage concentration must be entered for each land use class with area exceeding zero in the class-files. The name of the land use class in the leak-file must agree exactly to the name in the class-files. The directory of the leak-files is specified in the file NSTART.PAR (Sec. 7.3.1.5).

For all combinations of arable crops and soil types, the yearly mean root-zone leakage concentrations are listed in the nnLEAxxx.PAR files. In the TRK-project they were calculated with the SOILN model. For the other land use classes (which nutrient leakage is added to the watercourse), the yearly mean N-concentration is specified in the leak-files, and this concentration is then multiplied with seasonal factors that is in the HBV-NP code. There are some exceptions from the rule that leakage from all land use classes should be specified in nnLEAxx.PAR:

- For forest region 1 the leakage concentrations for *mire* and *clearings* are not to be specified in the leak file because they are calculated from the forest leakage.
- For forest region 2 and 3:
  For leakage region 11, 12, 21 and 22, the leakage concentrations for *forest*, *mire* and *clearings* are not specified in the leak-file (leakage from forest is specified in the HBV-NP code, and the other concentrations are calculated from the forest leakage). For leakage regions 30-120, the leakage concentrations for *forest*, *mire*, *clearings*, and *other open land* are not specified in the leak-file (leakage from forest is specified in the HBV-NP code, and the other are calculated from the forest leakage).

Normally the nnLEAxxx.PAR file includes in separate columns information of which HBV-class (forest, field or glac) that the land use class corresponds to, the name of the land use class, which class for source apportionment that the load should be assigned to (arable, forest, pasture or other), the root-zone leakage concentration of tot-N from the land use class, and percent of the tot-N concentration that is inorg-N. The format of the file is so far the same as for *nversion1*.

The file can contain information of leakage concentration from arable land that is fertilized with manure separately from leakage concentration from arable land fertilized with artificial fertilizer only. This is necessary to include in the file if the part of area that is fertilized with manure is given in the class-file, otherwise the leakage concentration will be zero for this area. The leakage concentration is given as tot-N concentration and percent inorg-N on each line after the ordinary columns with data for each class that it applies to.

Another possibility is to use runoff dependent leakage for arable land. Other land use classes can not be adjusted this way. The mean runoff of each subbasin is then given in CLASSnn.PAR. In the leak-file an extra row with the coefficients of the equation for the correction factor are given after the row with mean leakage concentration. The equation is

$$adjusted\_leak\_conc = leak\_conc0 * (R1 + R2*nqleak + R3*nqleak^2 + R4*nqleak^3),$$

where *R1-R4* are coefficients, *nqleak* is given in the class-file and *leak_conc0* is the mean leakage concentration given in this file.

name of HBVclass S1,S2,R1,R2,(R3,R4)

S1: land use class

S2: source apportionment class (arable, forest, pasture, other)

R1: root-zone leakage of tot-N (mg L^{-1})

R2: percent inorg-N of R1

R3: root-zone leakage of tot-N from manured area (mg L^{-1})

R4: percent inorg-N of R3

coeff S,R1,R2,R3,R4

S is the land use class (must already has been given in the file),

R1-R4 coefficients of the equation.

Example (Part of the 99LEA011.PAR file):

```
'field'  'other open land'   'other'      1.30  45
'field'  'spring barley sl'    'arable'  16.10  86
'field'  'winter wheat sl '   'arable'  14.10  86
'field'  'green fallow sl '    'arable'  10.10  86
'field'  'winter rye sl   '     'arable'  16.50  86
'field'  'pasture sl      '     'pasture'  1.90  86
'field'  'winter barley l'     'arable'   16.20  86
'field'  'spring rape l  '     'arable'  15.50  86
'field'  'potatoes l     '     'arable'  18.60  86
'field'  'pasture l      '     'pasture'  1.20  86
'field'  'potatoes si    '     'arable'   19.80  86
'field'  'pasture si     '     'pasture'  1.70  86
'field'  'spring barley sc'   'arable'  15.80  86
'field'  'winter rye ls'         'arable'  16.50  86
'coeff' 'winter rye ls'  1.23  -0.03  0.00002 –0.000001
```

7.3.1.4 LOADnn.PAR

The file is stored in the subbasin directory for each subbasin. The file specifies load from point sources, rural households and atmospheric deposition on lakes. The dataset is included in the file name and denoted nn. It is also possible to specify atmospheric deposition of nitrogen on forest (*atmdepfo*). This value is then used to calculate nitrogen leakage from clearings by the equations

*conc = 0.2619 * (atmdepfo * 0.01) - 1.1497 if atmdepfo>800*

conc = 0.95 if atmdepfo ≤ 800.

urban	R1,R2	R1: load of tot-N from municipal waste water treatment plants (kg $year^{-1}$), R2: percent inorg-N of the urban tot-N load.
rural	R1,R2	R1: load of tot-N from rural households (kg $year^{-1}$), R2: percent inorg-N of the rural tot-N load.
industry	R1,R2	R1: load of tot-N from industry (kg $year^{-1}$), R2: percent inorg-N of the industrial tot-N load.
stormwater	R1,R2	R1: load of tot-N from storm water (kg $year^{-1}$), R2: percent inorg-N of the storm water tot-N load.
wetdeplake	R1…R12	Monthly values of inorg-N concentration in precipitation (mg L^{-1}). Multiplied with precipitation for atmospheric wet deposition.
drydeplake	R1…R12	Dry deposition of inorg-N on lakes. Monthly values (kg km^{-2} $month^{-1}$).
atmdepfo	R	Atmospheric deposition of inorg-N (wet and dry) on forest (kg km^{-2} $year^{-1}$). Used to calculate N leakage from clearings.

Example (LOAD99.PAR):

```
'!!' 618293 134508
'urban'       14000.0        90
'industry'        0.0        70
'rural'         994.2        90
'wetdeplake'  3.27 1.63 3.20 2.42 1.27 1.45 0.94 2.01 1.11 0.73 1.61 1.17
'drydeplake'  27.5 33.3 37.4 67.5 74.5 67.7 50.9 52.6 23.2 33.5 33.2 36.5
'atmdepfo'    1527.00
```

7.3.1.5 NSTART.PAR

The file is stored in the district directory, and includes general information for the HBV-NP model simulation. The start date for calculation of nitrogen results (e.g. R^2 values, yearly loads etc.), the directory for the files with leakage concentrations, the dataset identifier, and the HBV-NP model version are specified in this file.

ayear	I	Starting year…
amonth	I	…and starting month…
aday	I	…and starting day for calculation of N-results
leakdir	S	The location of the directory with the nnLEAxxx.PAR files
dataset	I	An integer 00 < I < 99, corresponding to 'nn' in the file names. In TRK-project: 99
version	S	Specifies the file format and model version, in this case 'trk'

Example (NSTART.PAR)**:**

```
'ayear'    1987
'amonth'  09
'aday'     1
'leakdir'    'z:\model\work\leak_filer\'
'dataset'   99
'version'   'trk'
```

7.3.2 Nitrogen complements to HBV input data files

The format of these files is described in Johnell et al. (2006). Here is only commented on the HBV-NP additions.

7.3.2.1 BMOD.PAR/RMOD.PAR

The parameters of the nitrogen model are added to the hydrological parameters in the files RMOD.PAR and/or BMOD.PAR. RMOD.PAR is for parameters valid for the whole district and parameters in BMOD.PAR are valid for the subbasin in which directory the file is stored. The parameters for the nitrogen model that were used for nversion *trk* in the TRK project were: *locorg, locret, deeplake, lakexp, lakeorg*, *lakeret*. The nversion *trk* can also use parameters: *depthlz, wret*, *rivorg, rivret*. The equations and parameters are described in Chapter 2 and the parameters are summarized in Chapter 5. The parameters can be entered manually to the files, or it can be specified from the IHMS menu system.

7.3.2.2 INFO.PAR

In this file it is specified that it is the HBV-NP model that is to be run instead of the HBV model. This is done by setting 'nmod' 'on' in INFO.PAR. To run the HBV model alone, set

'nmod' 'off' or omit the line. Moreover, to create result files for the nitrogen computations it is required that results are saved for all subbasins, and this is ensured by editing 'map' 'on' in this file.

```
'nmod'          'on'
'map'           'on'
```

This information can be entered manually to the file INFO.PAR, or it can be specified from the IHMS menu system.

7.3.2.3 INSTATE.DAT

The initial state of the model is specified in the file INSTATE.DAT. For HBV-NP the nitrogen concentration in the upper and lower response box, in the active and passive part of the lake and the mean concentration of inorg-N in the lake can be added. If no initial values are given the HBV-NP model calculates initial values based on loads.

ncuz	I,R	The range I is 202 for inorg-N and 203 for org-N. R is N concentration in upper response box (mg L^{-1}).
nclz	I,R	The range I is 202 for inorg-N and 203 for org-N. R is N concentration in lower response box (mg L^{-1}).
ncepi	I,R	The range I is 202 for inorg-N and 203 for org-N. R is N concentration in upper/passive lake box (mg L^{-1}).
nchypo	I,R	The range I is 202 for inorg-N and 203 for org-N. R is N concentration in lower/active lake box (mg L^{-1}).
ncini	I,R	The range I is 202 for inorg-N. R is typical inorg-N concentration in the lake (mg L^{-1}). This value is used if *colake* is not specified in CLASSnn.PAR.
nqinorg	I,R	The range I is delay in time steps. R is inorg-N delayed in *maxbas/maxbaz* (see Johnell et al., 2006).
nqorg	I,R	The range I is delay in time steps. R is org-N delayed in *maxbas/maxbaz*.
nqinorg1	I,R	The range I is delay in time steps. R is inorg-N delayed by *lag* and/or *damp* (see Johnell et al., 2006). Last character in row identifier (1) is inflow number.
nqorg1	I,R	The range I is delay in time steps. R is org-N delayed by *lag* and/or *damp*. Last character in row identifier (1) is inflow number.
...		
nqinorg5	I,R	The range I is delay in time steps.

		R is inorg-N delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.
nqorg5	I,R	The range I is delay in time steps. R is org-N delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.

7.3.2.4 OUT.PAR

For OUT.PAR the same is valid as for *nversion1*. Specify in the file OUT.PAR which nitrogen variables that are chosen for output. Add these variables to the list of HBV-variables. The variables in OUT.PAR will end up in the files COMP.TXT and/or DOS_COMP.DAT. To get the result in the specific nutrient result file (RESULTnn.DAT) it is necessary to add the variable *qcout* and the six *nccout/ncrout* variables to OUT.PAR otherwise the output will be missing values. The output variables of the nitrogen part of HBV-NP model are:

nccout	S	computed N concentration at the outlet of the basin (**n**utrient **c**oncentration **c**omputed **out**flow) (mg L^{-1}). The range S is *totn*, *inorgn*, or *orgn*.
ncrout	S	measured N concentration at the outlet of the basin (**n**utrient **c**oncentration **r**ecorded **out**flow) (mg L^{-1}). The range S is *totn*, *inorgn*, or *orgn*.
ncuz	S	computed N concentration in upper response box (mg L^{-1}). The range S is *inorgn*, or *orgn*.
nclz	S	computed N concentration in lower response box (mg L^{-1}). The range S is *inorgn*, or *orgn*.
ncepi	S	computed N concentration in upper/passive lake box (mg L^{-1}). The range S is *inorgn*, or *orgn*.
nchypo	S	computed N concentration in lower/active lake box (mg L^{-1}). The range S is *inorgn*, or *orgn*.

Example (OUT.PAR):

```
'qcout   '   'totmean '
'qrout   '   'totmean '
'accdout '   'totmean '
'nccout'     'totn'
'nccout'     'inorgn'
'nccout'     'orgn'
'ncrout'     'totn'
'ncrout'     'inorgn'
'ncrout'     'orgn'
```

7.4 Input files for nversion *np*

7.4.1 Input data files

The following files are necessary for nversion *np*: NSTART.PAR, CLASSnn.PAR, nnLEAxxx.PAR, LOADnn.PAR, nnPLExxx.PAR, and nnFLEAyy.PAR. The files nnTIMxxx.PAR and nnOLEAzz.PAR are optional. Each file is presented below. The

dataset is included in the file names and denoted nn, while xxx stands for the leakage region, yy for the forest region and zz for the open region. The file CONC.DAT is necessary to calibrate the model. In addition files are needed for HBV, e.g. ZON.PAR, but these are not presented in this manual (see IHMS Manual, Gardelin, 2006)).

7.4.1.1 CLASSnn.PAR

This file is created for each subbasin and stored in the subbasin directory. The dataset is included in the file name and denoted nn. The file includes areas for all land use classes in the subbasin. The number of classes may not exceed 250 and the name of each land use class is limited to 50 positions. The land use classes used in the *np* model version are: 'forest', 'clearings' (i.e. clearcut forest), 'mire', 'mire in mount' (i.e. mires in the bare mountain), 'bare mountain', 'glaciar', 'other open land', 'urban', 'other colonization', and a great number of combinations of arable crops and soil types. For the case when the parameter *pflowpaths* is not used (Sec. 7.4.1.6), the arable classes can be further divided into phosphorus and slope classes depending on the phosphorus in the soil and the slope of the fields.

Moreover, the file includes mean depths of output lakes, main river lakes and wetlands (wlake), river length in meters, area of main river lakes and wetlands in the subbasin, and the mean inorg-N concentration in lakes. If no concentration value is entered it is approximated in the model calculation by upstream land characteristics. The district may be further divided with the subbasins belonging to different regions. The class-file includes an identifier, 'region', for which leakage region the subbasin belongs to, and an identifier 'forestreg' for which forest region the subbasin belongs to. The file may contain an identifier 'openreg' for which open region the subbasin belongs to. The open region identifier is used by the olea-files (see Sec. 7.4.1.5).

region	I	Defines which leakage region the subbasin belongs to, and governs which file with leakage concentrations that are to be read. Region is a number between 001 and 999.
forestreg	I	Defines which forest region the subbasin belongs to. Region is a number between 1 and 7.
openreg	I	Defines which open region the subbasin belongs to. Region is a number between 1 and 7. Optional.
arlake	R	Area (km^2) of lakes in the main river (rlake).
drlake	R	Mean depth (m) of lakes in the main river (rlake).
dolake	R	Mean depth (m) of outlet lake (olake) (the area is defined in ZON.PAR).
dwlake	R	Mean depth (m) of wetland (wlake) (the wetland area is defined as an olake area in ZON.PAR). Note: this depth must be zero (or the line omitted) if there is no wlake in the subbasin.
colake	R,R	Approximate yearly mean value of inorg-N/SRP in the olake/rlake/wetland ($mg\ L^{-1}$). If this concentration is not specified it is in the model approximated from load to the lake, lake volume, upstream area of the lake and specific yield

		(approximated by hq/2) for N but only from load for P.
prlen	R	Length of local rivers (m). Must be larger than 10.
pmlen	R	Length of main river (m). Must be larger than 0 if upstream subbasins exists.
aiwet	R	Area of local wetland (iwet) (km^2)
aowet	R	Area of wetland in main channel (owet) (km^2)
caiwet	R	Catchment area of local wetland (iwet) (km^2)
diwet	R	Mean depth of local wetland (iwet) (m)
dowet	R	Mean depth of wetland in main channel (owet) (m)
nleakq	R	Mean runoff (mm) of the subbasin to be used for runoff dependent leakage.
name of land use class	R1,R2,(I1,I2),(S)	R1: area of each land use class (km^2). R2: part of area that is fertilized with manure. For no *pflowpaths* followed by I1: slope code and I2: Phosphorus-class. S: For *pflowpaths* followed for spring cultivated crops by the string 's'. For more information on *pflowpaths* see Sec 7.4.1.6 and on spring cultivation see Sec. 7.4.1.7.

Example (CLASSnn.PAR with pflowpaths):

```
'region'            72
'forestreg'         3
'forest'            136.06
'ley sl'             11.38  0.0572
'spring barley sl'   2.51  0.0385  's'
'spring wheat sl'    0.02  0.0143  's'
'prlen     '        99920
'pmlen     '        13905
```

Example (CLASSnn.PAR with no pflowpaths):

```
'!!' Områdets utloppspunkt 640765 140278
'region'          72
'forestreg'       3
'forest'          136.06
'mire'            23.22
'other open land'    46.80
'ley sl'               11.38 0.0572 1 1
'green fallow sl'     1.29  0 2 1
'oats sl'              3.13  0.0495 2 2
'pasture sl'           5.41  0.0 2 3
'spring barley sl'    2.51  0.0385 3 2
'ley c'                2.18  0.0572 2 2
'prlen     '         99920
'pmlen     '         13905
```

7.4.1.2 CONC.DAT

The CONC.DAT file contains time series of measured nutrient concentrations at the subbasin outlet. The file is stored in the subbasin directory for the subbasins with measurements of nitrogen and/or phosphorus concentrations. To calibrate the HBV-NP model, measured concentrations are needed for at least one subbasin. For this file the general file format for input data files specified above are not valid, this file must be saved in tab-separated text format, and must have a file-header of three lines (see example below). The file should preferably include tot-N concentration, NO_x-N concentration, NH_4-N concentration, tot-P concentration, SRP concentration and part-P concentration. A missing measurement is entered as –9999. Inorg-N is calculated as the sum of NO_x-N and NH_4-N concentration or if NH_4-N is missing only NO_x-N. The concentration of org-N is not specified in the file but is in the model calculated as the difference between tot-N and inorg-N.

Example (CONC.DAT):

647412 144341 Tåkern utl Vd01 67-008
Observed concentrations at outlet of subbasin (mg/l)

Year	Month	Day	Tot-N	NO23-N	NH4-N	Tot-P	SRP	Part-P
1993	6	14	1.4000	0.0050	-9999	0.1100	-9999	-9999
1993	7	13	1.5000	0.0050	-9999	0.0560	-9999	-9999
1993	8	12	2.0000	0.0050	-9999	0.0970	-9999	-9999
1993	9	18	1.4000	0.0300	-9999	0.0500	-9999	-9999

7.4.1.3 nnLEAxxx.PAR

The leak-file specifies the root-zone leakage concentrations of nitrogen for different land use classes. It has the same format as in nversion *trk*, but contains only arable land and pasture leakage. Leakage from other land uses (e.g. forest, other open land) depends on forest region (or open region) and is specified in the nnFLEAyy.PAR file (see Sec. 7.4.1.4) or nnOLEAzz.PAR (see Sec. 7.4.1.5). One leak-file is created for each leakage region. The xxx in the name of the leak-file specifies which leakage region it represents and all subbasins in that region (specified in CLASSnn.PAR) use this leak-file. In the file a concentration must be entered for each land use class with area exceeding zero in one of the class-files. The name of the land use class in the leak-file must agree exactly with the name in the class-file. The nnLEAxxx.PAR files can be put anywhere in the file structure, and the chosen directory of the files is specified in the file NSTART.PAR (Sec. 7.4.1.9). The identifier is the HBV class (from ZON.PAR) to which the land use class belongs (field).

Normally the nnLEAxxx.PAR file includes information of which HBV-class (only field) that the land use class corresponds to, the name of the land use class, which class for source apportionment that the load should be assigned to (arable or pasture), the root-zone leakage concentration of tot-N from the land use class fertilized with artificial fertilizer, percent of that tot-N concentration that is inorg-N, the root-zone leakage concentration of tot-N from the land use class fertilized with manure, and percent of that tot-N concentration that is inorg-N. The information of leakage concentration from arable land that is fertilized with manure is necessary if part of area that is fertilized with manure is given in CLASSnn.PAR, otherwise it can be omitted.

It is possible to have runoff dependent leakage for arable land, but not for pasture. The mean runoff of each subbasin is then given in the class-file. In the leak-file an extra row

with the coefficients of the equation for the correction factor are given after the row with mean leakage concentration. The equation is

$adjusted\_leak\_conc = leak\_conc0 * (R1 + R2*nleakq + R3*nleakq^2 + R4*nleakq^3),$

where *leak_conc0* is the mean leakage concentration already given, *R1-R4* are coefficients and *nleakq* is given in the class-file.

name of HBVclass S1,S2,R1,R2,(R3,R4)

S1: land use class

S2: source apportionment class (arable, forest, pasture, other)

R1: root-zone leakage of tot-N (mg L^{-1})

R2: percent inorg-N of R1

R3: root-zone leakage of tot-N from manured area (mg L^{-1})

R4: percent inorg-N of R3

coeff S,R1,R2,R3,R4

S is the land use class (must already has been given in the file), R1-R4 coefficients of the equation.

Example (Part of the 99LEA011.PAR file):

```
'!!' HBV-klass   Markanv       Källförd   Konc  %inorg-N  Konc  %inorg-N
'field'  'spring barley sl'   'arable'  16.10  86   10.5  90
'field'  'winter wheat sl '   'arable'  14.10  86   17.2  88
'field'  'ley sl          '   'arable'   5.50  86    8.3  70
```

7.4.1.4 nnFLEAyy.PAR

The fleak-file contains the leakage concentration from other land uses than arable land and pasture. The leakage from these land uses (i.e. forest, clearings, other open land, mire, mire in mount, glaciar, bare mountain, urban and other colonization) depends on forest region. Thus nversion *np* does not depend on the concentrations and seasonal factors that for nversion *trk* are given in the programming code. The file specifies the leakage concentrations of nitrogen and phosphorus to small streams for the different land use classes. One nnFLEAyy.PAR-file is created for each forest region. The yy in the name of the fleak-file specifies which forest region it represents and all subbasins in that region (specified in CLASSnn.PAR) use this fleak-file. The fleak-files are stored in the directory specified in the file NSTART.PAR (Sec 7.4.1.9). The rows can be maximum 180 characters each.

If the *np* nversion is to be used to simulate nitrogen with the same leakage as in the TRK-project (Ejhed and Brandt, 2002) seven forest regions for Sweden are needed instead of the three used in the TRK-project. Forestreg 1 to 3 are the same as in TRK (northern, south-eastern and south-western Sweden). The parts of leakage region 120 (Figure 6) that lies in forest region 2 and 3 need their own forest region (i.e. forestreg 4 and 5). Forestreg 6 and 7 is used for the parts of leakage regions 11, 12, 21 and 22 (Figure 6) that lie in forest region

2 and 3. This division makes it possible to use the special leakage for nversion *np* that in nversion *trk* is specified in the code.

The identifier of the fleak-file is the HBV class (from ZON.PAR) to which the land use class belongs. The fleak-file includes information on the HBV-class (field, forest, and glac), the land use class, corresponding source apportionment class, the nutrient fraction and the leakage concentration of the nutrient to the river from the land use class. The concentration of the nutrient fractions 'in' – inorg-N, 'on' – org-N, 'srp' – SRP and 'pp' – part-P can be given as a yearly mean, or as a yearly mean followed by twelve monthly mean concentrations. In the latter case the monthly mean values are used. It is also possible to give the yearly mean for 'tn' – tot-N or 'tp' – tot-P together with percent inorg-N or SRP. This percent value could then be followed by monthly mean concentrations of tot-N or tot-P.

For clearings it is possible to give leakage as a factor of the forest concentration for 'in' and/or 'on' or 'tn'. This is done by writing -1 after the substance and then the factor.

For all land uses it is possible to use elevation depending leakage concentrations. The elevation in ZON.PAR is used, but it must be above one.

*adj_conc = a + b * log10(elevation).*

If *adj_conc*<0 then *adj_conc* is set to zero. The use of elevation dependent leakage is denoted by a -1 as the first number after the nutrient substance. Then the coefficients *a* and *b* are given. After the coefficients it is possible to give twelve monthly factors (percent).

name of HBVclass S1,S2,S3,R1,(R2),(R3..R14)

S1: land use class

S2: source apportionment class (arable, forest, pasture, other)

S3: the nutrient fraction (in, on, tn, sp, pp, tp)

R1: leakage concentration (mg L^{-1})

R2: percent inorg-N or SRP of R1 if R1 is tn or tp

R3..R14: monthly mean leakage concentration (mg L^{-1})

name of HBVclass S1,S2,S3,I,R1 S1: land use class (clearing)

S2: source apportionment class (forest)

S3: the nutrient fraction (in, on, tn)

I: code for special leakage type (-1)

R1: factor for clearing leakage based on forest concentration

name of HBVclass S1,S2,S3,I,R1,R2,(R3..R14)

S1: land use class

S2: source apportionment class (arable, forest, pasture, other)

S3: the nutrient fraction (in, on, tn, sp, pp, tp)

I: code for special leakage type (-1)

R1: coefficient *a* in elevation dependent equation

R2: coefficient *b* in elevation dependent equation

R3..R14: monthly variation in concentration as percent (%)

Example (Part of the 99FLEA01.PAR file):

```
'!!' forestregion 1 Northern Sweden
'field'   'other open land'   'other'   'in'  0.066  0.0858 0.132 0.132 0.132 0.033 0.033 0.033 0.033 0.033 0.033 0.0858 0.0858
'field'   'other open land'   'other'   'on'  0.264  0.2376 0.2376 0.2376 0.2376 0.2904 0.2904 0.2904 0.2904 0.2904 0.2904 0.2376 0.2376
'field'   'other open land'   'other'   'tp'  0.013  40
'forest'  'forest'            'forest'  'in'  0.066  0.0858 0.132 0.132 0.132 0.033 0.033 0.033 0.033 0.033 0.033 0.0858 0.0858
'forest'  'forest'            'forest'  'on'  0.264  0.2376 0.2376 0.2376 0.2376 0.2904 0.2904 0.2904 0.2904 0.2904 0.2904 0.2376 0.2376
'forest'  'forest'            'forest'  'tp'  0.013  40
'forest'  'clearings'         'forest'  'tn'  -1       1.25
'forest'  'clearings'         'forest'  'tp'  0.026  40
'glac'    'glaciar'           'other'   'in'  0.044
'glac'    'glaciar'           'other'   'on'  0.176
'field'   'mire in mount'     'other'   'in'  0.044  0.0572 0.088 0.088 0.088 0.0132 0.0132 0.0132 0.0132 0.0132 0.0132 0.0572 0.0572
'field'   'mire in mount'     'other'   'tn'  -1      1.265 -0.362 102  102 100 111 101 97 100 97 96 97 98 99
'field'   'urban'             'other'   'tp'  0.026  40
```

7.4.1.5 nnOLEAzz.PAR

The oleak-file is optional and used if another region division for 'other open land' than the forest region division is needed. It contains the leakage from the 'other open land' land use only. The file specifies the leakage concentrations of nitrogen and/or phosphorus to small streams for the land use class the same way as nnFLEAyy.PAR. One nnOLEAzz.PAR-file is created for each open region ('openreg' in CLASSnn.PAR) that shall have a different leakage than that given in the nnFLEAyy.PAR-file. This means that you can use the 'other open land' leakage in nnFLEAyy.PAR for the subbasins missing 'openreg' in CLASSnn.PAR and for those 'openreg' that don't have a oleak-file. The zz in the name of the oleak-file specifies which open region it represents. The oleak-files are stored in the directory specified in the file NSTART.PAR (Sec 7.4.1.9). The rows can be maximum 180 characters each.

The oleak-file has the same format as the fleak-file. It includes information on the HBV-class (field), the land use class (other open land), the source apportionment class (other), the nutrient fraction and the leakage concentration of the nutrient to the river from the land use class. The concentration of the nutrient fractions 'in' – inorg-N, 'on' – org-N, 'srp' – SRP and 'pp' – part-P can be given as a yearly mean, or as a yearly mean followed by twelve monthly mean concentrations. In the latter case the monthly mean values are used. It is also possible to give the yearly mean for 'tn' – tot-N or 'tp' – tot-P together with percent inorg-N or SRP. This percent value could then be followed by monthly mean concentrations of tot-N or tot-P.

name of HBVclass S1,S2,S3,R1,(R2),(R3..R14)

S1: land use class

S2: source apportionment class (other)

S3: the nutrient fraction (in, on, tn, sp, pp, tp)

R1: leakage concentration (mg L^{-1})

R2: percent inorg-N or SRP of R1 if tn or tp is used

R3..R14: monthly mean leakage concentration (mg L^{-1})

Example (05OLEA04.PAR file):

```
'!!' open region 4 Southern Sweden (PO12, PO12, PO21, PO22)
'!!' HBV-klass   Markanv        Källförd   Typ   Årskonc   Månadsvärden
'field'   'other open land'   'other'   'in'  0.585  0.936 0.936  0.585 0.585 0.585 0.1755 0.1755 0.1755 0.4095 0.4095 0.4095 0.936
'field'   'other open land'   'other'   'on'  0.715
```

7.4.1.6 nnPLExxx.PAR

The pleak-file contains phosphorus leakage from arable land and pasture. Phosphorus leakage from other land uses is specified in nnFLEAyy.PAR (and nnOLEAzz.PAR). The file specifies the root-zone leakage concentrations for different land use classes. One pleak-file is created for each leakage region. The xxx in the name of the pleak-file specifies which leakage region it represents (specified for each subbasin in CLASSnn.PAR). In the pleak-file, a leakage concentration must be entered for each land use class with area exceeding zero in one of the class-files. The name of the land use class in the pleak-file must agree exactly with the name in the class-file. The pleak-files are stored in the directory specified in the file NSTART.PAR (Sec 7.4.1.9). For all combinations of arable crops and soil types, the root-zone leakage concentrations are listed in the nnPLExxx.PAR files. The rows can be maximum 18000 characters.

There are currently two versions of nnPLExxx.PAR format. The choice is made in the file INFO.PAR by setting the parameter *pflowpaths* 'on' or 'off', 'off' is default.

When pflowpaths is not active, root-zone leakage concentration of SRP and part-P are given for each land use class, phosphorus class and slope class. The concentrations are given as yearly mean, but it is possible to use monthly concentrations instead. Phosphorus leakage from surface runoff and soil erosion is assumed to be included in the root-zone leakage concentrations and not treated explicitly.

On each row in nnPLExxx.PAR is given:

- the land use class
- the phosphorus class denoting phosphorus in the soil, an integer 1-3 (three classes are used)
- the slope class, an integer 1-3 (three classes are used)
- fertilizer type, 'F' for artificial fertilizer and 'F+M' for a combination of artificial fertilizer and manure.
- yearly mean part-P concentration in root-zone leakage (mg L^{-1})
- yearly mean SRP concentration in root-zone leakage (mg L^{-1})

or…

- 12 part-P concentration (mg L^{-1}), monthly mean, and then 12 SRP concentrations (mg L^{-1}), monthly mean.

Example (Part of the 99PLE040.PAR file):

'!!' Klass	Phosphorus	Lutning	Gödsel	PP(mg/L)	PO4-P(mg/L)
'spring barley s'	1	1	'F'	0.126	0.103
'spring barley s'	1	1	'F+M'	0.261	0.418
'spring barley s'	1	2	'F'	0.176	0.468
'spring barley s'	1	2	'F+M'	0.033	0.116
'spring barley s'	1	3	'F'	0.237	0.033
'spring barley s'	1	3	'F+M'	0.133	0.137
'spring barley s'	2	1	'F'	0.223	0.318
'spring barley s'	2	1	'F+M'	0.232	0.062
'spring barley s'	2	2	'F'	0.170	0.164
'spring barley s'	2	2	'F+M'	0.151	0.465
'spring barley s'	2	3	'F'	0.235	0.303
'spring barley s'	2	3	'F+M'	0.100	0.046
'spring barley s'	3	1	'F'	0.221	0.362
'spring barley s'	3	1	'F+M'	0.249	0.391
'spring barley s'	3	2	'F'	0.066	0.100
'spring barley s'	3	2	'F+M'	0.158	0.126
'spring barley s'	3	3	'F'	0.136	0.232
'spring barley s'	3	3	'F+M'	0.204	0.372
'winter wheat s'	1	1	'F'	0.176	0.444
'winter wheat s'	1	1	'F+M'	0.116	0.037
'winter wheat s'	1	2	'F'	0.053	0.204

'ley s'	1	1	'F'	0.02	0.18	0.12	0.15	0.05	0.04	0.02	0.07	0.24	0.04	0.16	0.22	0.13	0.08	0.39	0.34	0.09	0.33	0.01	0.18	0.448	0.396	0.359	0.408
'ley s'	1	1	'F+M'	0.20	0.15	0.23	0.01	0.14	0.08	0.12	0.08	0.05	0.17	0.05	0.21	0.45	0.23	0.03	0.23	0.36	0.46	0.06	0.29	0.046	0.38	0.293	0.252
'ley s'	1	2	'F'	0.03	0.12	0.17	0.22	0.16	0.10	0.13	0.26	0.06	0.14	0.03	0.09	0.25	0.15	0.01	0.02	0.31	0.17	0.31	0.37	0.398	0.048	0.256	0.227
'ley s'	1	2	'F+M'	0.16	0.19	0.24	0.17	0.17	0.03	0.02	0.13	0.16	0.10	0.14	0.24	0.28	0.09	0.25	0.17	0.02	0.43	0.29	0.13	0.245	0.114	0.149	0.012

When pflowpaths is active, root-zone leakage concentration is given for SRP in micropores, SRP in macropores, and part-P in macropores. All values are given as yearly mean, but it is possible to add monthly concentrations of part-P in macropores after the yearly mean. The given SRP concentration for macropores is assumed to apply also for modelled surface runoff. It will complement the load of particulate phosphorus from soil erosion during surface runoff (Sec. 4.2).

On each row in nnPLExxx.PAR is given:

- the land use class
- fertilizer type, 'f' for artificial fertilizer and 'm' for a combination of artificial fertilizer and manure. It can be omitted, and then the concentration is assumed valid for both fertilizer types.
- SRP concentration in micropores (mg L^{-1})
- SRP concentration in macropores (mg L^{-1})
- part-P concentration in macropores (mg L^{-1}), yearly mean
- twelve part-P concentration in macropores (mg L^{-1}), monthly means (can be omitted).

Example (Part of the 99PLE021.PAR file):

'!!'	'land use'	'SRP micro'	'SRP macro'	'PP default macro + monthly averages'													
'autumn rape cl'	'm'	0.038	0.138	0.187	0.164	0.143	0.167	0.206	0.297	0	0.49	0.246	0.46	0.407	0.17	0.15	
'autumn rape cl'	'f'	0.031	0.107	0.151	0.132	0.114	0.134	0.167	0.245	0	0.387	0.194	0.37	0.328	0.137	0.12	
'autumn rape l'	'm'	0.049	0.196	0.164	0.118	0.102	0.107	0.124	0.2	0	0.519	0.304	0.47	0.462	0.195	0.12	
'autumn rape l'	'f'	0.041	0.153	0.132	0.095	0.082	0.086	0.101	0.165	0	0.411	0.241	0.376	0.373	0.157	0.096	

```
'autumn rape sl' 'm'   0.057   0.236   0.127
'autumn rape sl' 'f'   0.048   0.184   0.103
'autumn cereal cl' 'm' 0.038   0.12    0.204
'autumn cereal cl' 'f' 0.032   0.104   0.173
```

7.4.1.7 nnTIMxxx.PAR

The time-file is only used when *pflowpaths* is active. The *pflowpaths* parameter is set in INFO.PAR. There is one time-file per leakage region (xxx) and they are found in the directory specified in NSTART.PAR. The file contains dates for sawing, harvesting and ploughing for autumn cultivation (standard) and spring cultivation (ploughing in spring). The dates are used for calculation of soil erosion and surface runoff (Sec. 4.2). The dates for spring cultivation are used for the classes with a 's'-string in the class-file. Each row begins with an identifier, 'time'.

time	I,S1,S2,S3,S4,S5,S6	I: year. Specifying the year to 9999 makes it possible to give default dates for years not otherwise specified in the file. S1: string with sawing date, autumn cultivation S2: string with harvesting date, autumn cultivation S3: string with ploughing date, autumn cultivation S4: string with ploughing date, spring cultivation S5: string with sawing date, spring cultivation S6: string with harvesting date, spring cultivation

Dates must be given for autumn cultivation for all years, but spring dates are optional. If spring dates are missing autumn dates are assumed valid for spring cultivated crops. Note that months are abbreviated to the first three letters of the English name of the month.

Example (nnTIMxxx.PAR):

```
'!!'          Date for autumn ploughing              Date for spring ploughing
'!!'    Year   sawing   harvesting  ploughing   ploughing   sawing   harvesting
'time'  9999   '28 May'  '26 Aug'    '8 Sep'     '1 Mar'    '1 May'   '15 Oct'
'time'  1983   '15 May'  '15 Aug'    '8 Sep'     '15 Mar'
'time'  1984   '28 May'  '26 Aug'    '8 Oct'
```

7.4.1.8 LOADnn.PAR

The file is stored in the subbasin directory for each subbasin. The file specifies load from point sources, rural households and atmospheric deposition on lakes. The dataset is included in the file name and denoted nn. It is also possible to specify atmospheric deposition of nitrogen on forest (*atmdepfo*). This value is then used to calculate nitrogen leakage from clearings by the equation

*conc = 0.2619 * (atmdepfo * 0.01) - 1.1497 if atmdepfo>800*

conc = 0.95 if atmdepfo ≤ 800.

urban	R1,R2,R3,R4	R1: load of tot-N from municipal waste water treatment plants (kg year^{-1}),

		R2: percent inorg-N of the urban tot-N load, R3: urban load of tot-P (kg $year^{-1}$), R4: percent SRP.
rural	R1,R2,R3,R4	R1: load of tot-N from rural households (kg $year^{-1}$), R2: percent inorg-N of the rural tot-N load, R3: rural load of tot-P (kg $year^{-1}$), R4: percent SRP.
industry	R1,R2,R3,R4	R1: load of tot-N from industry (kg $year^{-1}$), R2: percent inorg-N of the industrial tot-N load, R3: industrial load of tot-P (kg $year^{-1}$), R4: percent SRP.
stormwater	R1,R2,R3,R4	R1: load of tot-N from storm water (kg $year^{-1}$), R2: percent inorg-N of the storm water tot-N load, R3: storm water load of tot-P (kg $year^{-1}$), R4: percent SRP.
wetdeplake	R1…R12	Monthly values of inorg-N concentration in precipitation (mg L^{-1}). Multiplied with precipitation for atmospheric wet deposition.
drydeplake	R1…R12	Dry deposition of inorg-N on lakes. Monthly values (kg km^{-2} $month^{-1}$).
atmdepfo	R	Atmospheric deposition of inorg-N (wet and dry) on forest (kg km^{-2} $year^{-1}$). Can be used to calculate N leakage from clearings.
pwdeplake	R1…R12	Monthly values of SRP concentration in precipitation (mg L^{-1}). Multiplied with precipitation for atmospheric wet deposition.
pddeplake	R1…R12	Dry deposition of SRP on lakes. Monthly values (kg km^{-2} $month^{-1}$).

Example (LOADnn.PAR):

```
'!!' tot-N (kg/year), % Inorg-N of Tot-N, Tot-P (kg/year), % SRP of Tot-P
'urban'        0.0          0.0          0.0          0.0
'industry'     0.0          0.0          0.0          0.0
'rural'        327.0        90.0         46.0         70.0
'!!' Deposition on lakes.
'wetdeplake'  1.23 0.83 1.60 0.64 0.61 0.24 0.34 0.70 0.43 0.50 0.79 0.73
'pwdeplake'  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
'drydeplake'  7.4 8.3 9.1 11.9 16.7 16.1 11.3 16.6 4.7 5.7 6.6 6.2
'pddeplake'  0.33  0.33  0.33  0.33  0.33  0.33  0.33  0.33  0.33  0.33  0.33  0.33
```

7.4.1.9 NSTART.PAR

The file is stored in the district directory, and includes general information for the HBV-NP model simulation. The start date for calculation of nitrogen results (e.g. R^2 values, yearly loads etc.), the directory for the files with leakage concentrations, the dataset identifier, and the HBV-NP model version are specified in this file.

ayear	I	Starting year…
amonth	I	…and starting month…
aday	I	…and starting day for calculation of N-results
leakdir	S	The location of the directory with the nnLEAxxx.PAR-, nnFLEAyy.PAR-, nnOLEAyy.PAR-, nnPLExxx.PAR-, and nnTIMxxx.PAR-files
dataset	I	An integer 00 < I < 99, corresponding to 'nn' in the file names.
version	S	Specifies the file format and model version, in this case 'np'.

Example (NSTART.PAR)**:**

```
'ayear'     1987
'amonth'  09
'aday'      1
'leakdir'    'd:\smhi\ihms\dat\leak_filer\'
'dataset'   05
'version'   'np'
```

7.4.2 Nitrogen complements to HBV input data files

The format of these files is described in the Johnell et al. (2006). Here is only commented on the HBV-NP additions.

7.4.2.1 BMOD.PAR/RMOD.PAR

The parameters of the nitrogen model are added to the hydrological parameters in the files RMOD.PAR and/or BMOD.PAR. RMOD.PAR is for parameters valid for the whole district and parameters in BMOD.PAR are valid for the subbasin in which directory the file is stored. The parameters for the nitrogen and phosphorus model that can be used for nversion *np* are: *locorg, locret, depthlz*, *rivorg, rivret, deeplake, lakexp, lakeorg*, *lakeret, sedorg*, *wret, rivpp*, *sedrelease*, *rivsrp*, *lakesrp*, *srpupt*, *lakepp, prodpp, wsedp*, *wupt, bermain, berloc*. The following parameters also need values for river water calculations: *deadvolume, speedX, speedY, speedZ, widthX, widthY, widthZ*.

For models that use *pflowpaths*, the following parameters exists and need values: *mactresin, mactressm, macrate, cnp, cnl, cnc, cnh, cnp, cnps, uslel, uslec, usleh, uslep, usleps, ssatfc, srslope, buffercov, buffer, pal*.

The parameters are described in Chapter 2 and Chapter 5. The parameters can be entered manually to the files, or it can be specified from the IHMS menu system.

7.4.2.2 INFO.PAR

In the INFO.PAR file it is specified that it is the HBV-NP model that is to be run instead of the HBV model. This is done by setting 'nmod' 'on' in INFO.PAR. To run the HBV model set 'nmod' 'off' or omit the line. Moreover, to create result files for the nitrogen computations it is required that results are saved for all subbasins, and this is ensured by editing 'map' 'on' in this file. With parameter 'newadvec', it is possible to use the new advection routine (Sec 2.2.2) for runoff transformation of nitrogen and phosphorus instead of regular *maxbas/maxbaz* -method. The parameter 'pflowpaths' denote if phosphorus flow

should be divided into several flow paths in soil or not. If it is 'on' phosphorus root-zone leakage concentration is given for micropores and macropores and also surface runoff and soil erosion is possible to include in the model.

```
'nmod'        'on'
'map'         'on'
'newadvec'    'on'
'pflowpaths'  'off'
```

This information can be entered manually to the file INFO.PAR, or it can be specified from the IHMS menu system.

7.4.2.3 INSTATE.DAT

The initial state of the model is specified in the file INSTATE.DAT. For HBV-NP the nutrient concentration in the upper and lower response box, in the active and passive part of the lake and the mean concentration of inorg-N and SRP in the lake can be added. If no initial values are given the HBV-NP model calculates initial values based on loads.

ncuz	I,R	The range I is 202 for inorg-N, 203 for org-N, 205 for SRP and 206 for part-P. R is N concentration in upper response box (mg L^{-1}).
nclz	I,R	The range I is 202 for inorg-N, 203 for org-N, 205 for SRP and 206 for part-P. R is N concentration in lower response box (mg L^{-1}).
ncepi	I,R	The range I is 202 for inorg-N, 203 for org-N, 205 for SRP and 206 for part-P. R is N concentration in upper/passive lake box (mg L^{-1}).
nchypo	I,R	The range I is 202 for inorg-N, 203 for org-N, 205 for SRP and 206 for part-P. R is N concentration in lower/active lake box (mg L^{-1}).
ncini	I,R	The range I is 202 for inorg-N and 205 for SRP. R is the typical inorg-N concentration in the lake (mg L^{-1}). This value is used if *colake* is not specified in CLASSnn.PAR.
nqinorg	I,R	The range I is delay in time steps. R is inorg-N delayed in *maxbas/maxbaz* (see Johnell et al., 2006).
nqorg	I,R	The range I is delay in time steps. R is org-N delayed in *maxbas/maxbaz*.
pqpartp	I,R	The range I is delay in time steps. R is part-P delayed in *maxbas/maxbaz*.
pqsrp	I,R	The range I is delay in time steps. R is SRP delayed in *maxbas/maxbaz*.
nqinorg1	I,R	The range I is delay in time steps.

		R is inorg-N delayed by *lag* and/or *damp* (see Johnell et al., 2006). Last character in row identifier (1) is inflow number.
nqorg1	I,R	The range I is delay in time steps. R is org-N delayed by *lag* and/or *damp*. Last character in row identifier (1) is inflow number.
pqpartp1	I,R	The range I is delay in time steps. R is part-P delayed by *lag* and/or *damp*. Last character in row identifier (1) is inflow number.
pqsrp1	I,R	The range I is delay in time steps. R is SRP delayed by *lag* and/or *damp*. Last character in row identifier (1) is inflow number.
…		
nqinorg5	I,R	The range I is delay in time steps. R is inorg-N delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.
nqorg5	I,R	The range I is delay in time steps. R is org-N delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.
pqpartp5	I,R	The range I is delay in time steps. R is part-P delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.
pqsrp5	I,R	The range I is delay in time steps. R is SRP delayed by *lag* and/or *damp*. Last character in row identifier (5) is inflow number, maximum five.

7.4.2.4 OUT.PAR

Specify in the file OUT.PAR which variables that are saved as output. Add these variables to the list of HBV-variables. The variables in OUT.PAR will end up in the files COMP.TXT and/or DOS_COMP.DAT. To get the result in the nutrient result file (RESULTnn.DAT) it is necessary to add the variable *qcout* and the twelve *nccout/ncrout* variables to OUT.PAR otherwise the output will be missing or only show starting values. The output variables of the nitrogen and phosphorus model are:

nccout	S	computed concentration at the outlet of the basin (mg L^{-1}). The range S is *totn*, *inorgn*, *orgn*, *totp*, *srp*, or *partp*.
ncrout	S	measured concentration at the outlet of the basin (mg L^{-1}). The range S is *totn*, *inorgn*, *orgn*, *totp*, *srp*, or *partp*.
ncuz	S	computed concentration in upper response box (mg L^{-1}). The range S is *inorgn*, *orgn*, *srp*, or *partp*.

nclz	S	computed concentration in lower response box (mg L^{-1}). The range S is *inorgn*, *orgn*, *srp*, or *partp*.
ncepi	S	computed concentration in upper/passive lake box (mg L^{-1}). The range S is *inorgn*, *orgn*, *srp*, or *partp*.
nchypo	S	computed concentration in lower/active lake box (mg L^{-1}). The range S is *inorgn*, *orgn*, *srp*, or *partp*.

Example (OUT.PAR):

```
'qcout   '   'totmean '
'nccout'     'totn'
'nccout'     'totp'
```

7.5 Output files

7.5.1 Output files specific for HBV-NP

The two result files nnYRES.DAT and RESULTnn.DAT are standard output files for HBV-NP.

7.5.1.1 nnYRES.DAT

nnYRES.DAT is saved in the subbasin directory by HBV-NP. The file contains data for nutrient load and transformation within the subbasin and from upstream basins. The file includes both yearly data and a mean value for the simulated period.

At the top of the file is listed the characteristics of the subbasin, i.e. the area of the different land classes. It is followed by the nutrient balances for the subbasin. The first value in each row is the mean value for the simulated period. The values to follow are the yearly values from which the mean value has been calculated.

The nutrient balances are presented in the order from soil, via response box (shallow groundwater) through river and finally to the lake. The gross load of nutrient from the different sources within the subbasin is presented, including the load from different land uses. The nutrient pool and transformation in the response box within the subbasin are given. The load from upper subbasins and the transformation of nutrient in the river and in wetlands are included. The point sources and atmospheric deposition on the lake and the transport of nutrient from the subbasin conclude the balance. The results of load and transformation of nutrients are presented for tot-N and tot-P as well as for inorg-N, org-N, SRP and part-P. Nitrogen is given in tonnes per year, while phosphorus is given in kg per year. Figure 7 (nitrogen) and 8 (phosphorus) give a schematic overview of the different loads and transformations found in the yres-file. At the end of the file, the water balance is presented. The discharge, originating from different kinds of land use, inflow from upstream subbasin(s) and outflow to downstream subbasin, is included. The file is used in the source apportionment program (Chapter 10) to summarize gross and net loads and calculate retention of nutrients.

The rows in the yres-file differ a little between nversions, but each row has a short description. The file include a nversion identifier that tells which nversion has been used to create the file (0 = *nversion1*, 1 = *trk*, 2 = *np*). For nversion *np* is rows for total phosphorus, soluble reactive phosphorus and particulate phosphorus included.

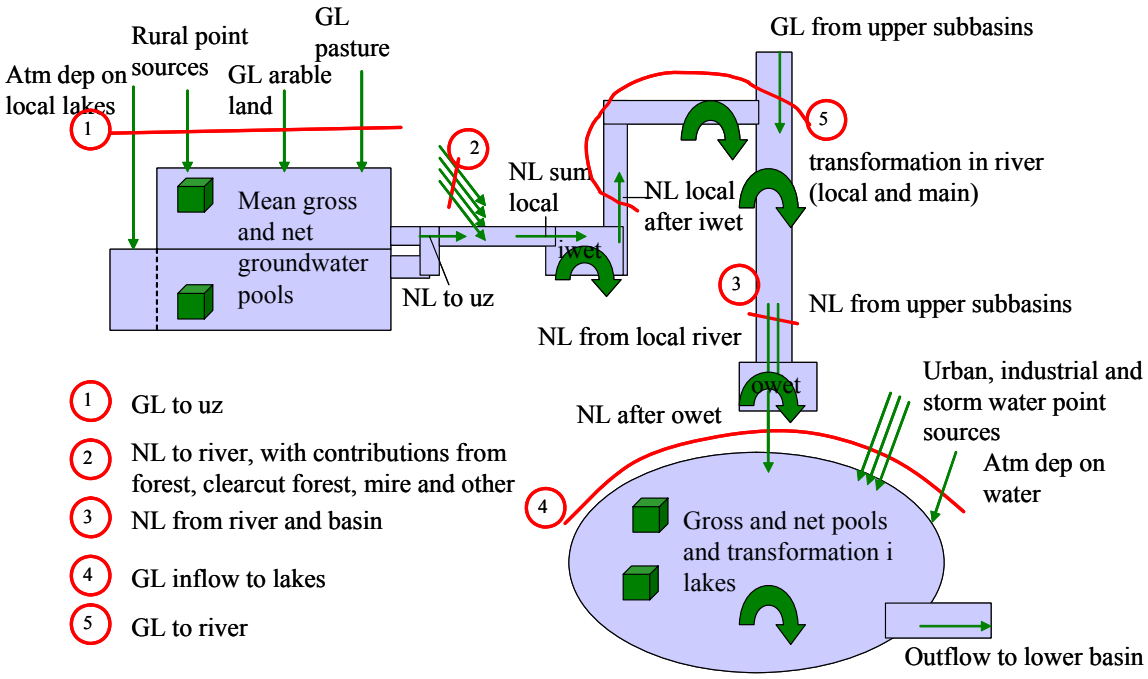

Figure 7. Overview of nnYRES.DAT loads and transformations for nitrogen. Note: for nversion1 the other land use loads (2) is included in the gross load to uz (1). Note: for nversion1 and trk not all transformations shown are included in the model.

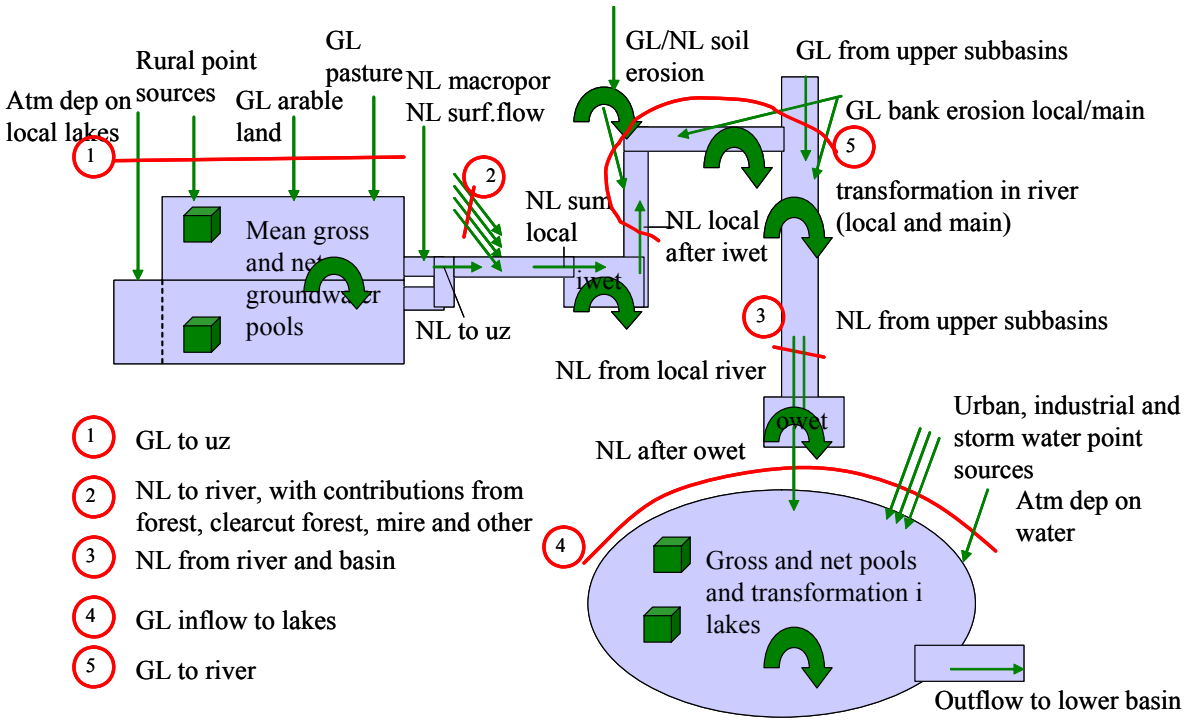

Figure 8. Overview of nnYRES.DAT loads and transformations for phosphorus.

Example (Part of nnYRES.DAT file):

```
'                                Average and yearly result file'
'                               CATCHMENT CHARACTERISTICS (km2)'
'      Total area, excluding lakes'          17.41000
'            Arable land (total)'          16.49000
...
'                                  TOTAL NITROGEN (Tonnes)'
'totN: N.L.-clearcut forest          '       0.000       0.000       0.000       0.000
'totN: G.L.-arable land              '      29.746      15.799      20.644      28.669
'totN: G.L.- arable land, plant farms'      29.746      15.799      20.644      28.669
'totN: G.L.- arable land, animal farm'       0.000       0.000       0.000       0.000
'totN: G.L. - pasture                '       0.013       0.007       0.009       0.012
'totN: N.L. - other, to River        '       0.037       0.019       0.025       0.033
'totN: N.L. - forest, to River       '       0.034       0.017       0.023       0.031
'totN: N.L. - mire, to River         '       0.000       0.000       0.000       0.000
'totN: rural point sources           '       0.693       0.694       0.692       0.692
'totN: atm. dep. on local lakes      '       0.000       0.000       0.000       0.000
'totN: G.L. to uz (arable, rural etc)  '     30.452      16.500      21.345      29.373

'totN: Mean Gross -groundwater pool'      894.763     599.041     749.406     916.354
...
```

A more complete nnYRES.DAT for nversion np can be seen in Figure 9 (Sec. 10.2).

7.5.1.2 RESULTnn.DAT

The result-file is saved in the subbasin directory by HBV-NP. The file presents time series (daily values) of discharge (computed outflow) and computed and recorded N and P (for nversion *np*) concentrations in mg L^{-1}. The columns are in the following order: computed outflow, computed tot-N concentrations, measured tot-N concentrations, computed inorg-N concentrations, measured inorg-N concentrations, computed org-N concentrations, measured org-N concentrations. If nversion *np* is used they are followed by the columns: computed tot-P concentrations, measured tot-P concentrations, computed SRP concentrations, measured SRP concentrations, computed part-P concentrations, measured part-P concentrations. For the concentrations to be presented correctly in this file they have to be included in the OUT.PAR file. If they are not, their values will not be saved by the program and only missing values or for the computed concentrations the initial value will be written to RESULTnn.DAT.

7.5.2 HBV output files used for HBV-NP

The model run is logged in the text file *HBVmodel.log*. Here are printed warning and error messages as well as the result of the simulation in form of Nash-Sutcliff (Nash and Sutcliff, 1970) explained variance criteria (R2), mean error and other criteria.

The files DOS_COMP.DAT and COMP.TXT contains the result of the simulation as specified in OUT.PAR. See Johnell et al. (2006) for more information. They can be used to save HBV-NP result as well as HBV results.

8 Running the model

This chapter describes how to set-up and calibrate the model.

8.1 Model set up

A district is set up in a special file structure with a directory for each subbasin in the district directory. Make sure you have all the input files in the appropriate file structure. There is a program at SMHI, HBVin, which can help with generating necessary files. Remember to add the nutrient parameters to the files OUT.PAR and RMOD.PAR/BMOD.PAR. Choose district in IHMS or, if you use M_start.exe, in TEMP.TXT. Use substitute from the Command prompt before you choose district if a general directory pathway is used for directories in files (e.g. 'z:\district'). Make the settings necessary in INFO.PAR to run the HBV-NP model, e.g. 'nmod' and 'map' will be set to 'on'. Set the simulation time and properties in SEQ.PAR and NSTART.PAR. If the district is simulated for the first time with this set up, start with running the HBV-NP model for at least a year to get reasonable values for internal variables, e.g. nutrient concentrations in the different storages. Preferably start the first short simulation in winter to more likely get a suitable value for the parameters *colake* and *cslake* if these are not specified in the class-file. Save the end state and use it as the starting state for coming simulations. For large lakes a spin up time of one year may be too small. For such lakes the new initial state may have to be manipulated by hand, but note that the HBV-NP model is sensitive to the concentration values given in the initial state and changing the state may cause that changes in model parameters are needed. Run the simulation and study the log-file for warnings and errors that have to be taken care of at this stage. Use 'warning' 'on' in INFO.PAR for this.

Some options in the HBV model are not to be used when running the HBV-NP model. First, the use of 'compend' instead of 'comp' as computing status in the file BASIN.PAR shall be avoided as it causes the CONC.DAT files not to be read. Second, the parameter 'cflux' that creates a capillary flow of water from the upper response routine to the soil moisture routine is not recommended to be used, since the nutrient calculation is not consistent in this case. In PATH.PAR the inflow types 'inqrec' and 'inqflex' are not supported by HBV-NP.

The IHMS system can be used to plot the variables listed in OUT.PAR. For further details of the graph possibilities, see the IHMS Manual (Gardelin, 2006). Study the result carefully for errors in input data or set up.

8.2 Calibration

Calibration is done to adjust the simulated nutrient concentrations to measured ones. This chapter describes special considerations when calibrating nutrients. For information of the automatic calibration routine and the file formats used see the IHMS Manual (Gardelin, 2006) and Johnell et al. (2006). The discharge also may need calibration. Discharge can be calibrated together with the nutrients or separate before the nutrients are added to the simulation. For information on discharge calibration, see the IHMS Manual (Gardelin, 2006). For information on the individual nutrient parameters see Sec. 5.1. HBV-NP can be calibrated manually or automatically.

8.2.1 Old calibration routine

When automatic calibration is carried out it is preferable to calibrate all parameters at the same time and not to calibrate the hydrological parameters first and then calibrate the nitrogen parameters. This is not always feasible though. When the nitrogen model is calibrated automatically using the old format of OPT.PAR and there are both hydrological and nitrogen parameters in the file, 70 % weight is given to the R2 of discharge and 30 % weight is given to the R2 of nitrogen concentrations.

Calibration weights for subbasins are for the nitrogen parameters calculated from the number of measurements in the different subbasins. The more nitrogen concentration measurements a subbasin has, the higher weight the R2 of that subbasin in the automatic calibration. Thus regional calibration is always done on available observations for computed subbasins. To save certain subbasins for validation, remove the CONC.DAT file for those subbasins during calibration.

For calibration of nitrogen it has to be specified whether it is the sum of the criteria for the inorg-N and org-N fractions or only the criterion for the inorg-N fraction that is to be maximised in the calibration. The nitrogen fraction to optimise is specified in the file OPT.PAR by adding a figure to the row that specifies *crittol*. Enter some spaces after the value for 'crittol' and then type the value:

1 for calibration on the sum of inorg-N and org-N
2 for calibration only on inorg-N.
3 for calibration on inorg-N and tot-P (only nversion *np*)

Example (The last two lines in OPTCAL.PAR for calibration on inorg-N + org-N):

```
'r2tol'      0.0001
'crittol'    0.001    1
```

When the subbasins with measurement of discharge does not coincide with the subbasins that have measurements of nutrient concentrations, care must be taken when using automatic calibration as different parameters shall be optimised at different subbasins. This is done by setting 'optweight' to '1' in the file BASIN.PAR for the subbasin with the discharge measurement that will be included. If several discharge stations is to be calibrated at once the sum of their respective optweight should be one. For nutrient all subbasins with CONC.DAT files will be included.

8.2.2 New calibration routine

There is a new format of OPTCAL.PAR available with the new file name. In this format it is possible to specify calibration variables and their weight freely. This format is used by the IHMS system. More information about automatic calibration can be found in the IHMS Manual (2006) and Johnell et al. (2006). Here is only described some special features regarding nutrient calibration.

With the new format you specify variables, subbasins, criteria and weights in OPTCAL.PAR. The following criteria is possible: R2, R2log, yearly maximum, spring maximum, autumn maximum, mean absolute spring flood error, and relative difference. A special criterion is total R2, which can only be used on outflow and inorg-N. This criterion corresponds to critlabel 1 for the old format and put 70% of the weight on discharge and 30% on the nitrogen. In addition some regional criteria are possible; R2, relative difference

and annual maximum. For these criteria the chosen subbasins values are treated as if they belonged to the same time series (see Lindström et al., 2005 for the method of regional criteria).

The format of the file can be found in Johnell et al. (2006).

Example (The last lines in OPTCAL.PAR for calibration of R2 for inorg-N in two subbasins and tot-P in one subbasin with approximately equal weight):

```
'r2tol'      0.0001
'crittol'    0.001
'wtab'       'nccout'   'ncrout'    'inorgn'   7
'wbasin'     'Storsjön'
'wbasin'     'Storälva'
'wr2'        0.5
'wtab'       'nccout'   'ncrout'    'totp'     7
'wbasin'     'Storälva'
'wr2'        0.5
```

8.2.3 Calibration strategy for nutrient simulation

For districts with a lot of measurement stations, the nutrient parameters are preferably calibrated stepwise. This means that the parameters for transformation in the shallow groundwater (response boxes) are optimised before the parameters for transformation in rivers and lakes. First subbasins without lakes are chosen and for these, all response box parameters are calibrated. This can be done one by one or regionally. These parameter values are then used in similar subbasins nearby. Second, the parameters for river transformation and transformation in lakes are calibrated while the parameters for local transformation are kept constant. Also these parameters are used in larger regions for subbasins without observed data to calibrate against. A judgement of suitable parameters for the larger region has to be done from the parameter values found for the calibrated lakes in the region.

It is a good idea to run a simulation with all parameters set to zero first. This run shows what nutrient levels we have to work with. Is there need for a large retention for this substance, or is there some loads missing? Think about if it is possible to calibrate each substance separately. This depends on what substances there exists observations for. If possible the parameters for these substances are calibrated before those whose results are compared for total nitrogen or total phosphorus.

Nitrogen and phosphorus can be calibrated separately. Except for the lake parameters *deeplake* and *lakexp* the nitrogen and phosphorus calculations are independent. When it comes to calibrating the lakes a certain amount of care should be taken to find values of these parameters that suits both nitrogen and phosphorus. See Chapter 5 for tips on specific parameters.

In addition to calibrate model parameters, the initial state of nutrients in the subbasins may have to be adjusted (Sec 7.2.2.3, 7.3.2.3, 7.4.2.3). This is necessary mostly for large lakes with a long turnover time. A suitable value of the initial value of the passive part of the lake is the concentration of the inflow, which all ends up there. A suitable value for the active lake is lower if there is retention in the lake. The outflow is composed of the water from the active part of the lake or from both parts. A value around or below the

concentration of outflow is therefore suitable. It is also possible to look at the simulation end state to find suitable starting values.

Another parameter that may have to be changed during calibration is *colake* in CLASSnn.PAR. If this value is not specified in CLASSnn.PAR the HBV-NP model will calculate a value and use that. The model does not always find a representative value on its own. The value calculated by the model (or that of *colake* if given) is saved with the state variables and will be used if that state is used as starting state in later simulations. It is possible to change the value in the initial state file if necessary. The HBV-NP calculated value may not be the best one to use for a good calibration.

8.3 A little note on adding wetlands (wlakes)

The wetlands of wlake type are treated like outlet lakes. The division of a district into subbasins has to be done so each wetland is located at the outlet point of a subbasin if wlakes are to be used. A rating table and a storage curve for the wetland can be created (see Johnell et al., 2006). If no rating curve is given, the outflow from the wetland is assumed to equal the inflow to the wetland. If no storage curve is given the wetland area is assumed to be constant. The area of the wetland is entered as an olake in ZON.PAR. The depth of the wetland is entered as *dwlake* in the file CLASSnn.PAR. The parameter *dwlake* is the key to the model to treat the olake as a wetland. For that reason it is extremely important not to have a nonzero-value of dwlake if there is no wetland in the subbasin. The retention of the wetland is specified by *wret*, *wsedp* and *wupt* in the parameter files BMOD.PAR/RMOD.PAR. However, for production of org-N in the wetland there is no unique parameter name, but is governed by the value of the lake parameter *lakeorg*. There should be no rlake in the same subbasin as the wetland.

9 Error and warning messages

Following is a list of some warnings and errors that HBV-NP can give and some hints of what is causing them.

9.1 Errors

Often the error message specifies in which file or subbasin the error occurs. Check that the file exists and that the specifications for the file format are fulfilled. Below are listed some error messages and possible causes.

- 'Define N-fraction to use for the autocal!' Or 'Crit label is missing in optcal.par'
  The old format of the file is used. Define in the file OPTCAL.PAR the nutrient fractions for which the criterion is to be maximised in the automatic calibration, see 8.2.1.
- 'Class xxx is missing in leak file'
  The area for class type "xxx" exceeds 0 in one CLASSnn.PAR, but there is no leakage concentration specified in nnLEAxxx.PAR. Check that the classes in CLASSnn.PAR and nnLEAxxx.PAR agree.
- 'inorganic load is zero' and 'organic load is zero'
  The nitrogen load from a subbasin can not consist of only organic nitrogen or only inorganic nitrogen; both the organic and inorganic fractions must be represented.
- 'Lake depth missing'
  The area of olake/wetland exceed 0 (in ZON.PAR), but there is no depth specified in CLASSnn.PAR.
- 'Forest region (1-3) is missing in class file'
  The forest region is not present in the CLASSnn.PAR file or it is outside the permitted interval (nversion *trk*).
- 'Error: Too many years in time.par'
  Too many rows in time.par, maximum 100 years may be given.
- 'Too many forestregions'
  Maximum 10 forest regions can be used at the moment.
- 'Error - leak coefficient not allowed ahead of leak concentration'
  The order of rows in nnLEAxxx.PAR is not correct. 'coeff' can only come after the corresponding nutrient concentration for the land use.
- 'Parameter deeplake must be > 0'
  The deeplake parameter must be larger than 0. Check RMOD.PAR and BMOD.PAR.
- 'Basin mean elevation is below one. Elevation dependent leaching can not be used.'
  Basin mean elevation must be above one for elevation dependent leakage. Check ZON.PAR if mean elevation is wrong.
- 'Elevation dependent leakage is only allowed for tot-N and tot-P'
  Check the format of nnFLExxx.PAR.
- 'PHCl-class in pleak-file larger than maximum'
  Check CLASSnn.PAR and nnLEAxxx.PAR for missing/mismatching phosphorus classes.

- 'slope-class in pleak-file larger than maximum'
  Check CLASSnn.PAR and nnLEAxxx.PAR for missing/mismatching slope-classes.
- 'No observation data for calibration'
  Some of the criteria specified in OPTCAL.PAR lack observations for the specified time period.

9.2 Warnings

Following is some warnings that can occur when simulating nutrients in HBV-NP.

- 'Rlake area > ilake area (in zon.par)'
  The rlake area (in CLASSnn.PAR) is subtracted from the ilake area (specified in ZON.PAR), and hence, the ilake area must exceed or equal the rlake area.
- 'Areas in CLASSnn.PAR and zon.par not in agreement. The difference is more than 0.1 %'
  Check that the areas correspond. The water balance is computed from the areas in ZON.PAR but the nitrogen leakage from the areas in CLASSnn.PAR.
- 'wvolume(n_llake,curr_basin)<0'
  The volume of the active part of the lake is negative. This is most often caused by computational reasons, and one reason can be that the lake volume is small in relation to the daily inflowing and outflowing water volumes. Check that the lake depth in CLASSnn.PAR is alright, an unrealistically small depth gives a too small lake volume. Check also that the parameter value of 'deeplake' is not too small, as this makes the active volume of the lake too small. This is a serious warning.
- 'phosphorus load is missing in LOADnn.PAR'
  For nversion *np* LOADnn.PAR is checked for lines with only N-load. Check if LOADnn.PAR if correct. To remove the warning set P-load equal to 0 in the file.
- 'number of measurements used for calibration is less than 5'
  Check used time period and CONC.DAT.
- 'river retention > river load'
  Nitrogen river retention is set to zero for that day. Parameter *rivret* may be too large if this warning is frequent.
- 'N/P rural/point load ignored, no outflow of basin'
  Point load is only added to water body if there is water. Otherwise its load is ignored (*nversion1*).
- 'N/P rural/point load postponed due to no outflow of basin/river/lake'
  Point load is only added to water body if there is water. Otherwise its addition is postponed up to a month (nversion *trk* and *np*).
- 'wetland retention > N/P pool' or 'lake retention > N/SRP/part-P pool'
  The N concentration of the wetland/lake is reduced to minimum. If this is a frequent warning the retention parameter may be too high.
- 'parameter rivsrp is set too high'
  Check RMOD.PAR/BMOD.PAR. The parameter should not be higher than 1.
- 'advection transport time in excess of xxx days. Advection time was truncated to this value'

This warning should not be allowed. It is a temporary solution only. Contact the HBV maintenance group.

- 'Curve number is missing in subbasin'
  Check RMOD.PAR/BMOD.PAR.
- 'basin retention in uz/lz > N pool'
  The N concentration of the response box is reduced to minimum. If this is a frequent warning the retention parameter may be too high.
- 'Wetland for subbasin is ignored due to zero depth'
  Area of owet/iwet has been set to zero. Check CLASSnn.PAR for depths.
- 'No atmospheric deposition in spring/winter…'
  Warning for nversion *nversion1*. Check LOADnn.PAR if it was supposed to be deposition during this period.
- 'Missing forest/other open land/… leakage concentration for subbasin'
  Check correspondence of land use classes in CLASSnn.PAR and nnFLEAyy.PAR or nnOLEAKzz.PAR.
- 'Only one of SRP and part-P has been given clearing leaching as a factor of forest'
  No clearing leakage is used. Check the clearing leakage in nnFLEAyy.PAR.

10 Source apportionment

This text is an introduction to the benefits of the source apportionment program kford_nt. The program is described in some detail in Svensson (2006).

The kford-program uses the BASIN.PAR, ZON.PAR, PATH.PAR, PATHDOWN.PAR and nnYRES.DAT files from a HBV-NP district. The pathdown-file is created specially for the kford-program. The kford-program has some demands on the district and subbasin file structure. All directories must be numbers, and the subbasin numbers consist of three digits and may not normally exceed 700. A governing file, KFORD.KEY, can be used to determine what the program will do or input can be given to the program during the run. Several options are available for what the program can do. The most common task is 'KE', i.e. the source apportionment calculation. Other uses are compilation of different discharges and extraction of data to a file suitable for generating maps.

10.1 Description of files

10.1.1 Input files

KFORD.KEY governs what the kford-program will do. The file should be stored by the kford_nt.exe file. Information about operative system, district directory, data set, time period are given in the file. The directory for writing the results must exist before the program is run. The information must be given in the following order and format.

os	S	Operative system: use *dos* for PC
basindir	S1,S2	S1: operative system: *dos* for PC. S2: full path to the district directory.
dataset	S	Dataset used in NSTART.PAR and for naming the result files.
period	S1,S2	Simulation period. Years with four digits. S1: first year written in yres-file, S2: last year written in yres-file.
yresfile	S	Used name of the yres-files.
newpath	S	Tells if the path given in basindir above is to be used instead of the paths given in BASIN.PAR to find the subbasins. Default is no, a Y or a J will turn it on. Optional.
rutin	S	Chosen routine: 'KF' (all routines), 'KE' (only source apportionment), 'KK' (extraction to map plot), 'MQ' (merge discharge files), 'BQ' (local discharge), and 'EQ' (outlet results).
tsaro	S	Number of subbasin for which the routine is to be calculated. Doesn't have to be the last subbasin even though PATHDOWN.PAR describes the path down to the last subbasin. The results are written to the kford//*tsaro* directory in the district directory. Only possible to use for nversion *np*.
writedir	S1,S2	S1: Operative system: *dos* for PC.

		S2: full path to the directory were the result files are to be saved. Optional.

Example (KFORD.KEY):

```
'OS'         'dos'
'basindir'   'dos'       'D:\Vastra\Ronnea\96\'
'dataset'    '99'
'period'     '1986'      '1988'
'yresfile'   'yres99.dat'
'rutin'      'KF'
'tsaro'      '048'
```

PATHDOWN.PAR describes the downstream subbasins of a subbasin. There is one file for each subbasin except the last one, the catchment outlet. There is one record group for each downstream subbasin.

group	S	Empty string
type	S	Type of inflow: always *in*.
pathdir	S1,S2,(S3)	S1: operating system (*dos* for PC). S2: full directory path to next subbasin (for main flow). S3: full directory path to branching subbasin. In case the two branches' path down are uneven use an empty string (") for the shorter branch.

It is possible to calculate the source apportionment for some district with bifurcations. Note that the routine 'BQ' is not working in this case though. Retention will be calculated for both branches and weighted together with the yearly mean flow in each branch as the weight. If the bifurcation divides the flow into two different districts the HBV-NP calculations will best handled if the common subbasins are modelled in both districts. For the source apportionment program the paths does not have to be in the same districts.

For description of BASIN.PAR, ZON.PAR and PATH.PAR see Johnell et al. (2006). For description of nnYRES.DAT see Sec. 7.5.1.1 above.

In addition, several of the files generated by the program are used as input files for other tasks of the program.

10.1.2 Result files

All result files are ASCII text files. Below the content of the files are summarized. The content files of the SAnnddd.DAT and TSnnddd.DAT are described in more detail in Sec. 10.2 and KFORD_EXTRnn.DAT in Sec. 10.3. 'nn' denotes the dataset and ddd the subbasin number.

Sa-files: One for each subbasin. These files give retention of nutrient loads in the subbasin and to the district outlet. Also some loads of the subbasin are included, e.g. gross load from point sources, total gross and net load of the subbasin.

Ts-file: This file gives the total gross load and net load of the district (tonnes for N, kg for P) divided between different source types, e.g. total gross load forest, total net load industrial.

Kford_extr-file: Retentions and loads for all subbasins in a format suitable for mapping. Most of the values are collected directly from the sa-files. The subbasins have one row each, and the columns contains retentions and load for all substances, i.e. total nitrogen, inorganic nitrogen, organic nitrogen, soluble reactive phosphorus, particulate phosphorus and total phosphorus.

TQMnn.DAT, *TQSnn.DAT* and *TQYnn.DAT*: Files that gives the subbasins' total discharge for each subbasin. They give the mean discharge for the subbasin averaged over month (*M*), season (*S*) or year (*Y*).

Q.DAT, IORGN.DAT, ORGN.DAT, PARTP.DAT, SRP.DAT, TOTN.DAT, and *TOTP.DAT*: These files give district number, outlet co-ordinates, mean value for all years and for every year. The value is discharge (m^3 yr^{-1}) and total net load (tonnes for N, kg for P) for the district outlet.

10.2 Calculations for source apportionment and total loads

The kford-program calculates the retention for different sources and also some loads for the subbasin (sa-files). It also calculates the total gross loads and net loads for different sources for the district (ts-file). In Sec. 10.2.1 – 10.2.4 is the equations for these calculation compiled for nversion *np*. For the other nversions fewer sources are used. To understand the equations the rows in the yres-files are given identification numbers (Figure 9).

Figure 7 and 8 can be used for identifying some of the loads in the yres-file. Some other are described here. Note that nitrogen is given in tonnes and phosphorus in kg in the yres-file, and that the rows are not the same for the different phosphorus fractions. In 'GL.-arable' and 'GL -pasture' is only micropore flow included if pflowpaths is on. The macropore flow has its own row and is added to the outflow of the upper response box. It is thus a part of 'NL to uz', but not of 'GL to uz'. In parenthesis on rows 511-514 it should read 'part of NL to uz', but there was not enough room on the rows for the print out. Net load to the river by erosion is given by 'NL from erosion (total)', and it includes both soil erosion and bank erosion. Together with 'GL from upper basin' the net load to the river by erosion form the 'GL to river'. For SRP the surface flow, 'NL from surface flow', is added to the outflow from the upper response box (outuz) and is thus included in 'NL to uz'. 'NL to river and basin' is divided into the contribution from the local river and the main river: 'NL from local river' and 'NL from upper subbasin'. In Figure 9 below follow part of an yres-file where only the simulation period mean load is printed.

```
        ' Average and yearly result file'
        ' CATCHMENT CHARACTERISTICS (km2)'
1       ' Total area, excluding lakes'            59.71999
2       ' Arable land'                            32.51000
3       ' Arable land manure'                      6.33635
4       ' Forest,  Clearcut forest'                9.74000          0.34000
6       ' Pasture'                                 8.45000
7       ' Other land'                              5.27000
8       ' Mire'                                    3.00000
9       ' Lakes (not ilakes)'                      0.00000
10      ' nversion identifier'  2

        '                       NITROGEN BALANCE'
```

```
        '                        TOTAL NITROGEN (tonnes)'
100     'totN: N.L.-clearcut forest          '            0.000
101     'totN: G.L.-arable land              '          614.500
102     'totN: G.L.- arable land, plant farms'          550.000
103     'totN: G.L.- arable land, animal farm'           64.500
104     'totN: G.L. - pasture                '           41.707
105     'totN: N.L. - other, to River        '           12.275
106     'totN: N.L. - forest, to River       '            0.493
107     'totN: N.L. - mire, to River         '            0.000
108     'totN: rural point sources           '          146.760
109     'totN: atm. dep. on local lakes      '            0.000
110     'totN: G.L. to uz (arable, rural etc)'          802.967

        'totN: Mean Gross -groundwater pool  '
        'totN: transform. - local            '
        'totN: % transform. – local          '
        'totN: Mean Net -groundwater pool    '

115     'totN: N.L. to uz (arable, rural etc)'          907.315
116     'totN: N.L. - to river (forest et c) '           12.768
117     'totN: N.L.- sum local               '          920.083
118     'totN: N.L. local after iwetland     '          920.083
126     'totN: G.L. from upper subbasin      '        39995.438
127     'totN: G.L. to river                 '            0.000
128     'totN: transformation in river       '            0.000
129     'totN: N.L. from rivers and basin    '        39995.438
130     'totN: N.L. from local river         '        39995.438
131     'totN: N.L. from upper subbasin      '        40122.066
132     'totN: N.L. after owetland           '        41396.754
133     'totN: atm. dep. on water            '            0.000
134     'totN: urban point sources           '            0.000
135     'totN: industrial p.sources          '            0.000
136     'totN: storm water p.sources         '            0.000
137     'totN: G.L. -inflow to lakes         '        41396.754

        'totN: Gross pool in lakes           '            0.000
        'totN: transform in lakes            '            0.000
        'totN: %transform in lakes           '            0.000
        'totN: Net pool in lakes             '            0.000

138     'totN: Outflow to lower basin        '        41396.750

        '                        INORG. NITROGEN (Tonnes)'
200     'NO3: N.L.-clearcut forest           '            0.000
201     'NO3: G.L.-arable land               '          614.500
202     'NO3: G.L.- arable land, plant farms '          550.000
203     'NO3: G.L.- arable land, animal farms'           64.500
204     'NO3: G.L. - pasture                 '           41.707
205     'NO3: N.L. - other land, to River    '            4.910
206     'NO3: N.L. - forest, to River        '            0.197
207     'NO3: N.L. - mire, to River          '            0.000
208     'NO3: rural point sources            '           17.900
209     'NO3: atm. dep. on local lakes       '            0.000
210     'NO3: G.L. to uz (arable, rural etc) '          674.107

        'NO3: Mean Gross -groundwater pool   '
        'NO3: transform. - local             '
        'NO3: % transform. - local           '
        'NO3: Mean Net -groundwater pool     '

215     'NO3: N.L. to uz (arable, rural etc) '          737.176
216     'NO3: N.L. - to river (forest et c)  '            5.107
217     'NO3: N.L.- sum local                '          742.283
218     'NO3: N.L. local after iwetland      '          742.283
226     'NO3: G.L. from upper subbasin       '        20176.158
227     'NO3: G.L. to river                  '            0.000
228     'NO3: transformation in river        '            0.000
229     'NO3: N.L. from rivers and basin     '        39995.438
230     'NO3: N.L. from local river          '        39995.438
231     'NO3: N.L. from upper subbasin       '        20085.510
232     'NO3: N.L. after owetland            '        21025.566
233     'NO3: atm. dep. on water             '            0.000
234     'NO3: urban point sources            '            0.000
235     'NO3: industrial p.sources           '            0.000
236     'NO3: storm water p.sources          '            0.000
```

```
237     'NO3: G.L. -inflow to lakes          '        21025.566

        'NO3: Gross pool in lakes            '            0.000
        'NO3: transform in lakes             '            0.000
        'NO3: %transform in lakes            '            0.000
        'NO3: Net pool in lakes              '            0.000

238     'NO3: Outflow to lower basin         '        21025.566

        '                       ORGANIC NITROGEN (Tonnes)'
300     'OrgN: N.L.-clearcut forest          '            0.000
301     'OrgN: G.L.-arable land              '            0.000
302     'OrgN: G.L.- arable land, plant farms'          550.000
303     'OrgN: G.L.- arable land, animal farm'           64.500
304     'OrgN: G.L. - pasture                '            0.000
305     'OrgN: N.L. - other land, to River   '            7.365
306     'OrgN: N.L. - forest, to River       '            0.296
307     'OrgN: N.L. - mire, to River         '            0.000
308     'OrgN: rural point sources           '          128.860
309     'OrgN: atm. dep. on local lakes      '            0.000
310     'OrgN: G.L. to uz (arable, rural etc)'          128.860

        'OrgN: Mean Gross -groundwater pool  '
        'OrgN: transform. - local            '
        'OrgN: % transform. - local          '
        'OrgN: Mean Net -groundwater pool    '

315     'OrgN: N.L. to uz (arable, rural etc)'          170.139
316     'OrgN: N.L. - to river (forest et c) '            7.661
317     'OrgN: N.L.- sum local               '          177.800
318     'OrgN: N.L. local after iwetland     '          177.800
326     'OrgN: G.L. from upper subbasin      '        19819.277
327     'OrgN: G.L. to river                 '            0.000
328     'OrgN: transformation in river       '            0.000
329     'OrgN: N.L. from rivers and basin    '        39995.438
330     'OrgN: N.L. from local river         '        39995.438
331     'OrgN: N.L. from upper subbasin      '        20036.553
332     'OrgN: N.L. after owetland           '        20371.182
333     'OrgN: atm. dep. on water            '            0.000
334     'OrgN: urban point sources           '            0.000
335     'OrgN: industrial p.sources          '            0.000
336     'OrgN: storm water p.sources         '            0.000
337     'OrgN: G.L. -inflow to lakes         '        20371.182

        'OrgN: Gross pool in lakes           '            0.000
        'OrgN: transform in lakes            '            0.000
        'OrgN: %transform in lakes           '            0.000
        'OrgN: Net pool in lakes             '            0.000

338     'OrgN: Outflow to lower basin        '        20371.182
        '                       PHOSPHORUS BALANCE'
        '                       TOTAL PHOSPHORUS (kg)'
400     'totP: N.L.-clearcut forest          '            0.000
401     'totP: G.L.-arable land              '          614.500
402     'totP: G.L.- arable land, plant farms'          550.000
403     'totP: G.L.- arable land, animal farm'           64.500
404     'totP: G.L. - pasture                '           41.707
405     'totP: N.L. - other, to River        '           12.275
406     'totP: N.L. - forest, to River       '            0.493
407     'totP: N.L. - mire, to River         '            0.000
408     'totP: rural point sources           '          146.760
409     'totP: atm. dep. on local lakes      '            0.000
410     'totP: G.L. to uz (arable, rural etc)'          802.967

        'totP: Mean Gross -groundwater pool  '
        'totP: transform. - local            '
        'totP: % transform. - local          '
        'totP: Mean Net -groundwater pool    '

411     'totP: N.L. from surface flow arable '            0.003
412     'totP: N.L. from surface flow pasture'            0.001
413     'totP: N.L. macropor arable (part of '          103.159
414     'totP: N.L. macropor pasture (part of'          103.159
415     'totP: N.L. to uz (arable, rural etc)'          907.315
416     'totP: N.L. - to river (forest et c) '           12.768
```

```
417     'totP: N.L.- sum local               '          920.083
418     'totP: N.L. local after iwetland     '          920.083
419     'totP: G.L. from soil erosion arable '           87.925
420     'totP: G.L. from soil erosion pasture'           87.925
421     'totP: N.L. from soil erosion arable '           87.925
422     'totP: N.L. from soil erosion pasture'           87.925
423     'totP: G.L. from erosion local river '            3.032
424     'totP: G.L. from erosion main river  '           32.717
425     'totP: N.L. from erosion (total)     '            0.000
426     'totP: G.L. from upper subbasin      '        39995.438
427     'totP: G.L. to river                 '        41039.192
428     'totP: transformation in river       '          357.555
429     'totP: N.L. from rivers and basin    '        41396.754
430     'totP: N.L. from local river         '         1274.686
431     'totP: N.L. from upper subbasin      '        40122.066
432     'totP: N.L. after owetland           '        41396.754
433     'totP: atm. dep. on water            '            0.000
434     'totP: urban point sources           '            0.000
435     'totP: industrial p.sources          '            0.000
436     'totP: storm water p.sources         '            0.000
437     'totP: G.L. -inflow to lakes         '        41396.754

        'totP: Gross pool in lakes           '            0.000
        'totP: transform. in lakes           '            0.000
        'totP: %transform. in lakes          '            0.000
        'totP: Net pool in lakes             '            0.000

438     'totP: Outflow to lower basin        '        41396.750

        '                      S. R. PHOSPHORUS (kg)'
500     'SRP: N.L.-clearcut forest           '            0.000
501     'SRP: G.L.-arable land               '          614.500
502     'SRP: G.L.- arable land, plant farms '          550.000
503     'SRP: G.L.- arable land, animal farms'           64.500
504     'SRP: G.L. - pasture                 '           41.707
505     'SRP: N.L. - other land, to River    '            4.910
506     'SRP: N.L. - forest, to River        '            0.197
507     'SRP: N.L. - mire, to River          '            0.000
508     'SRP: rural point sources            '           17.900
509     'SRP: atm. dep. on local lakes       '            0.000
510     'SRP: G.L. to uz (arable, rural etc) '          674.107

        'SRP: Mean Gross -groundwater pool   '
        'SRP: transform. - local             '
        'SRP: % transform. - local           '
        'SRP: Mean Net -groundwater pool     '

511     'SRP: N.L. from surface flow arable  '            0.003
512     'SRP: N.L. from surface flow pasture '            0.003
513     'SRP: N.L. macropor arable (part of N'           51.580
514     'SRP: N.L. macropor pasture (part of '           51.580
515     'SRP: N.L. to uz (arable, rural etc) '          737.176
516     'SRP: N.L. - to river (forest et c)  '            5.107
517     'SRP: N.L.- sum local                '          742.283
518     'SRP: N.L. local after iwetland      '          742.283
526     'SRP: G.L. from upper subbasin       '        20176.158
527     'SRP: G.L. to river                  '        20918.443
528     'SRP: transformation in river        '          107.122
529     'SRP: N.L. from rivers and basin     '        21025.566
530     'SRP: N.L. from local river          '          940.058
531     'SRP: N.L. from upper subbasin       '        20085.510
532     'SRP: N.L. after owetland            '        21025.566
533     'SRP: atm. dep. on water             '            0.000
534     'SRP: urban point sources            '            0.000
535     'SRP: industrial p.sources           '            0.000
536     'SRP: storm water p.sources          '
537     'SRP: G.L. -inflow to lakes          '        21025.566

        'SRP: Gross pool in lakes            '            0.000
        'SRP: transform. in lakes            '            0.000
        'SRP: %transform. in lakes           '            0.000
        'SRP: Net pool in lakes              '            0.000

538     'SRP: Outflow to lower basin         '        21025.566
```

```
        '                       PART. PHOSPHORUS (kg)'
600     'ParP: N.L.-clearcut forest          '            0.000
601     'ParP: G.L.-arable land              '            0.000
602     'ParP: G.L.- arable land, plant farms'            0.000
603     'ParP: G.L.- arable land, animal farm'            0.000
604     'ParP: G.L. - pasture                '            0.000
605     'ParP: N.L. - other land, to River   '            7.365
606     'ParP: N.L. - forest, to River       '            0.296
607     'ParP: N.L. - mire, to River         '            0.000
608     'ParP: rural point sources           '          128.860
609     'ParP: atm. dep. on local lakes      '            0.000
610     'ParP: G.L. to uz (arable, rural etc)'          128.860

        'ParP: Mean Gross -groundwater pool  '
        'ParP: transform. - local            '
        'ParP: % transform. - local          '
        'ParP: Mean Net -groundwater pool    '

613     'ParP: N.L. macropor arable (part of '           51.580
614     'ParP: N.L. macropor pasture (part of'           51.580
615     'ParP: N.L. to uz (arable, rural etc)'          170.139
616     'ParP: N.L. - to river (forest et c) '            7.661
617     'ParP: N.L.- sum local               '          177.800
618     'ParP: N.L. local after iwetland     '          177.800
619     'ParP: G.L. from soil erosion arable '           87.925
620     'ParP: G.L. from soil erosion pasture'           87.925
621     'ParP: N.L. from soil erosion arable '           87.925
622     'ParP: N.L. from soil erosion pasture'           87.925
623     'ParP: G.L. from erosion local river '            3.032
624     'ParP: G.L. from erosion main river  '           32.717
625     'ParP: N.L. from erosion (total)     '            0.000
626     'ParP: G.L. from upper subbasin      '        19819.277
627     'ParP: G.L. to river                 '        20120.752
628     'ParP: transformation in river       '          250.430
629     'ParP: N.L. from rivers and basin    '        20371.182
630     'ParP: N.L. from local river         '          334.628
631     'ParP: N.L. from upper subbasin      '        20036.553
632     'ParP: N.L. after owetland           '        20371.182
633     'ParP: atm. dep. on water            '            0.000
634     'ParP: urban point sources           '            0.000
635     'ParP: industrial p.sources          '            0.000
636     'ParP: storm water p.sources         '            0.000
637     'ParP: G.L. -inflow to lakes         '        20371.182

        'ParP: Gross pool in lakes           '            0.000
        'ParP: transform. in lakes           '            0.000
        'ParP: %transform. in lakes          '            0.000
        'ParP: Net pool in lakes             '            0.000

638     'ParP: Outflow to lower basin        '        20371.182
```

Figure 9. Part of a nnYRES.DAT for nversion np with identification numbers added to the left to identify the loads. The identification numbers are 1-9 for areas, 100-199 for tot-N, 200-299 for inorg-N, 300-399 for org-N, 400-499 for tot-P, 500-599 for SRP, and 600-699 for part-P.

10.2.1 Source apportionment for nitrogen

The following calculations are made for the source apportionment of nitrogen which are printed in the sa-files. The calculations are made for each subbasin. In the equations below [1]-[9] are used for the catchment characteristics with identification 1-9 in Figure 9, while [00]-[38] are used for loads with identification 100-138, 200-238 and 300-338. Some equations include have comments on what they are used for. The signs >0 and ≥0 mean that the expression is limited to be positive.

Ret local = 1. - [15] / [10]
Ret iwet = 1. - [18] / [17]

Ret river = 1- [29] / [27] (local and main river)

Ret owet = 1. - [32] / [29]

Ret lakes = 1. - [38] / [37]

Ret owet and lakes = 1. - [32] / [29] * [38] / [37] ≥0 (for production in river)

Ret lakes and river usb = 1- [31] / [26] * [32] / [29] * [38] / [37] ≥0 (for load from upper subbasin)

OutLoad lake+river = 1- Ret lakes and river usb

Ret lake+river 2 = 1- [18] / [17] * [30] / [18] * [32] / [29] * [38] / [37] ≥0 (for land use leakage to the river)

Ret lakes+river 3 = 1- [30] / [18] * [32] / [29] * [38] / [37] ≥0 (for production in iwet)

Ret basin = 1- [15] / [10] * [18] / [17] * [30] / [18] * [32] / [29] * [38] / [37] ≥0 (for sources to uz/lz)

The product of OutLoad lake+river for all downstream subbasins (Π (OutLoad lake+river) all downstream subbasins) is limited to ≥0.

Ret lakes+river pathdown iwetload = 1- (1-Ret lakes+river 3)* Π (OutLoad lake+river) all downstream subbasins (for production in iwet)

Ret owet and lake pathdown = 1- (1-Ret owet and lakes) * Π (OutLoad lake+river) all downstream subbasins (for production in river)

Ret lakes+river pathdown riverload = 1- (1-Ret lakes+river 2)* Π (OutLoad lake+river) all downstream subbasins (for loads 00 and 05-07)

Ret lakes+river pathdown lakeload = 1- (1-(Ret lakes≥0)) * Π (OutLoad lake+river) all downstream subbasins (for loads 33-35)

Ret total to sea = 1- (1 - Ret basin) * Π (OutLoad lake+river) all downstream subbasins (for loads 01-04 and 08-09)

Ret load average to sea = ([10] * Ret total to sea + [16] * Ret lakes+river pathdown riverload + ([33] + [34] + [35] + [36]) * Ret lakes+river pathdown lakeload) / ([10] + [16] + [33] + [34] + [35] + [36])

RiverLoad /total area = ([17] - ([08] + [09]) * (1 - Ret_local)) / [1]

GL point sources = [34] + [35] + [36]

GL arable_area = [01] / [2]

NL arable_area = [01] * (1 - Ret total to sea) / [2]

Ret lakes/lakearea = ([38] - [37]) / [9]

Local GL = [10] / [1]

Local NL = [15] / [1]

Total GL = ([10] + [16] + [34] + [35] + [36]) / [1]

Total NL = ([38] - [26] * OutLoad lake+river - ([38]-[37])>0 - ([32] – [29])>0) * (1-Ret lakes>0) – [33]) * Π (OutLoad lake+river) all downstream subbasins / [1]

NL diffuse = (([29] – [31]) * (1 - Ret owet and lake pathdown)) / [1]

GL lake source = [33] + ([38]-[37])>0 + ([32] – [29])>0

NL lake source = (([38] - [37])>0 + [33] * (1-Ret lakes>0) + ([32] – [29])>0) * (1-Ret lakes>0)) * Π (OutLoad lake+river) all downstream subbasins

10.2.2 Total loads for nitrogen

The following calculations are made for total load of the district. The results are printed in the ts-file. In the equations below [00]-[38] are used for identification numbers 100-138,

200-238 and 300-338 in Figure 9. The signs >0 and ≥0 mean that the expression is limited to be positive.

Total Gross Load arable plant farm= Σ [02]
Total Gross Load arable animal farm= Σ [03] + Σ [04]
Total Gross Load forest = Σ [06] + Σ [00]
Total Gross Load mire = Σ [07]
Total Gross Load other = Σ [05]
Total Gross Load atmdep = Σ [09] + Σ [33]
Total Gross Load rural = Σ [08]
Total Gross Load urban = Σ [34]
Total Gross Load industry = Σ [35]
Total Gross Load stormwater = Σ [36]
Total Gross Load internal iwet = Σ ([18] - [17]) >0
Total Gross Load internal owet = Σ ([32] - [29]) >0
Total Gross Load internal natural = Σ (([15] - [10]) >0 + Σ ([31]-[26]) >0 + Σ ([30]-[18]) >0 + Σ ([38] - [37]) >0)
Total Net Load arable plant farm = Σ [02] * (1 - Ret total to sea)
Total Net Load arable animal farm = Σ ([03] + [04]) * (1 - Ret total to sea)
Total Net Load forest = Σ ([06] + [00]) * (1 - Ret lakes+river pathdown riverload)
Total Net Load mire = Σ [07] * (1 - Ret lakes+river pathdown riverload)
Total Net Load other = Σ [05] * (1 - Ret lakes+river pathdown riverload)
Total Net Load atmdep = Σ [09] * (1 - Ret total to sea) + [33] * (1 - Ret lake+river pathdown lakeload)
Total Net Load rural = Σ [08] * (1 - Ret total to sea)
Total Net Load urban = Σ [34] * (1 - Ret lake+river pathdown lakeload)
Total Net Load industry = Σ [35] * (1 - Ret lake+river pathdown lakeload)
Total Net Load stormwater = Σ [36] * (1 - Ret lake+river pathdown lakeload)
Total Net Load internal = Outflow to lower basin (tsaro) - Σ Total Net Load (the ten above)

10.2.3 Source apportionment for phosphorus

The following calculations are made for the source apportionment of phosphorus which are printed in the sa-files. The calculations are made for each subbasin. In the equations below [1]-[9] are used for the catchment characteristics with identification 1-9 in Figure 9, while [00]-[38] are used for loads with identification 400-438, 500-538 and 600-638. Some equations have comments on what they are used for. The signs >0 and ≥0 mean that the expression is limited to be positive.

Ret local = 1. – ([15] – ([11] + [12] + [13] + [14]))/[10]
Ret iwet = 1. - [18] / [17]
Ret river = 1- [29] / [27] (local and main river)
Ret buffer = 1. - ([21] + [22]) / ([19] + [20])
Ret owet = 1. - [32] / [29]
Ret lakes = 1- [38] / [37]

Ret lakes and river usb = 1- ([31] / ([24] + [26])) * [32] / [29] * [38] / [37] ≥0 (for main river bank erosion and for loads from upper subbasin)

OutLoad lake+river = 1- Ret lakes and river usb

Ret lakes and river local river = 1- ([30] / ([18] + [21] + [22] + [23])) * [32] / [29] * [38] / [37] ≥0 (for local river bank erosion)

Ret lakes and river local = 1- ([21] + [22]) / ([19] + [20]) * ([30] / ([18] + [21] + [22] + [23])) * [32] / [29] * [38] / [37] ≥0 (for soil erosion)

Ret lakes and river 3 riverload = 1- [18] / [17] ([30] / ([18] + [21] + [22] + [23])) * [32] / [29] * [38] / [37] ≥0 (for land use leakage to the river)

Ret basin = 1- ([15] – ([11]+[12]+[13]+[14]))/[10] * [18] / [17] * ([30] / ([18]+[21]+[22]+[23])) * [32] / [29] * [38] / [37] ≥0 (for sources to uz/lz)

Ret owet lake = 1. - [32] / [29] * [38] / [37] ≥0 (for production in river)

OutLoad basin = 1 - Ret basin

The product of OutLoad lake+river for all downstream subbasins (Π (OutLoad lake+river) all downstream subbasins) is limited to ≥0.

Ret lakes+river pathdown riverload = 1- (1 - Ret lakes and river usb) * Π (OutLoad lake+river) all downstream subbasins (for load 24)

Ret lakes+river pathdown riverload 4 = 1- (1 - Ret lakes and river local river) * Π (OutLoad lake+river) all downstream subbasins (for load 23 and production in iwet)

Ret lakes+river pathdown riverload 2 = 1- (1 - Ret lakes and river local)* Π (OutLoad lake+river) all downstream subbasins (for loads 19-20)

Ret lakes+river pathdown lakeload = 1- (1-Ret lakes≥0) * Π (OutLoad lake+river) all downstream subbasins (for loads 33-36)

Ret lakes+river pathdown riverload 3 = 1- (1- Ret lakes and river 3 riverload) * Π (OutLoad lake+river) all downstream subbasins (for loads 00, 05-07 and 11-14)

Ret total to sea = 1- OutLoad basin * Π (OutLoad lake+river) all downstream subbasins (for loads 01-04 and 08-09)

Ret owet lake pathdown = 1- (1-Ret owet lake) * Π (OutLoad lake+river) all downstream subbasins (for diffuse load)

Ret load average to sea = ([10] * Ret total to sea + ([11]+[12]+[13]+[14]+[16]) * Ret lakes+river pathdown riverload 3 + ([19] + [20]) * Ret lakes+river pathdown riverload 2 + [23] * Ret lakes+river pathdown riverload 4 + [24] * Ret lakes+river pathdown riverload + ([33] + [34] + [35] + [36]) * Ret lakes+river pathdown lakeload) / ([17] + [19] + [20] + [23] + [24] + [33] + [34] + [35] + [36])

RiverLoad /total area = ([17] - ([08] + [09])*(1- Ret local)) / [1]

GL point sources = [34] + [35] + [36]

GL arable_area = ([01] + [13]) / [2] (through soil and macropores)

NL arable_area = ([01] * (1 - Ret total to sea) + [13] * (1 – Ret lake+river pathdown riverload 3)) / [2]

Ret lakes/lakearea = ([38] - [37]) / [9]

Local GL = [10] / [1] (micropores, atm. deposition ilake and rural)

Local NL = [15] / [1] (micro- and macropores, atm. deposition ilake, rural, and surface flow. Note: more sources than Local GL)

Total GL = ([10] + [11] + [12] + [13] + [14] + [16] + [19] + [20] + [23] + [24] + [34] + [35] + [36]) / [1] (atm.dep. olake not included)

Total NL = ([38] - [26] * OutLoad lake+river - ([38]-[37])>0 - ([32] – [29])>0) * (1-Ret lakes>0) – [33]) * Π (OutLoad lake+river) all downstream subbasins / [1]

NL diffuse = ([30] * (1 - Ret owet lake pathdown)) / [1]

GL lake source = [33] + ([38]-[37])>0 + ([32] – [29])>0

NL lake source = (([38] - [37])>0 + [33] * (1-Ret lakes>0) + ([32] – [29])>0) * (1-Ret lakes>0)) * Π (OutLoad lake+river) all downstream subbasins

10.2.4 Total loads for phosphorus

The following calculations are made for total load of the district. The results are printed in the ts-file. In the equations below [00]-[38] are used for identification numbers 400-438, 500-538 and 600-638 in Figure 9. The signs >0 and ≥0 mean that the expression is limited to be positive.

Total Gross Load arable plant farm = Σ [02] + Σ ([11] + [13] + [19]) * ([2] - [3]) / [2]

Total Gross Load arable animal farm = Σ [03] + Σ [04] + Σ [12] + Σ [14] + Σ [20] + Σ ([11] + [13] + [19]) * [3] / [2]

Total Gross Load forest = Σ [06] + Σ [00]

Total Gross Load mire = Σ [07]

Total Gross Load other = Σ [05]

Total Gross Load atmdep = Σ [09] + Σ [33]

Total Gross Load rural = Σ [08]

Total Gross Load urban = Σ [34]

Total Gross Load industry = Σ [35]

Total Gross Load stormwater = Σ [36]

Total Gross Load internal iwet = Σ ([18] - [17]) >0

Total Gross Load internal owet = Σ ([32] - [29]) >0

Total Gross Load internal natural = Σ (([15] - [10] – [11] – [12] – [13] – [14]) >0 + ([23] + [24]) >0 + ([31] – [26] – [24]) >0 + ([30] - [18] – [21] – [22] – [23]) >0 + ([38] - [37]) >0)

Total Net Load arable plant farm = Σ [02] * (1. - Ret total to sea) + ([11] + [13]) * ([2] - [3]) / [2] * (1. - Ret lake+river pathdown riverload 3) + Σ [19] * ([2] - [3]) / [2] * (1. - Ret lakes+river pathdown riverload 2)

Total Net Load arable animal farm = Σ ([03] + [04]) * (1. - Ret total to sea) + Σ ([11] + [13]) * [3] / [2] * (1. - Ret lakes+river pathdown riverload 3) + Σ ([12] + [14]) * (1 – Ret lakes+river pathdown riverload 3) + Σ [20] * (1. - Ret lakes+river pathdown riverload 2) + Σ [19] * [3] / [2] * (1. - Ret lakes+river pathdown riverload 2)

Total Net Load rural = Σ [08] * (1 - Ret total to sea)

Total Net Load forest = Σ [06] * (1 - Ret lakes+river pathdown riverload 3) + Σ [00] * (1 - Ret lakes+river pathdown riverload 3)

Total Net Load mire = Σ [07] * (1 - Ret lakes+river pathdown riverload 3)

Total Net Load other = Σ [05] * (1 - Ret lakes+river pathdown riverload 3)

Total Net Load urban = Σ [34] * (1 - Ret lake+river pathdown lakeload)

Total Net Load industry = Σ [35] * (1 - Ret lake+river pathdown lakeload)

Total Net Load stormwater = Σ [36] * (1 - Ret lake+river pathdown lakeload)

Total Net Load atmdep = Σ [09] * (1 - Ret total to sea) + [33] * (1 - Ret lake+river pathdown lakeload)

Total Net Load internal = Outflow to lower basin (tsaro) - Σ Total Net Load (the ten above)

10.3 Calculations for the extraction files

Extraction files contain retentions and loads in a format suitable for mapping. The file KFORD_EXTRnn.DAT contains nitrogen result and KFORD_EXTRPnn.DAT contains phosphorus results. Most of the values are collected directly from the sa-files. The first column contains the subbasin number. The following 16 columns contain values for tot-N, the next 16 inorg-N, and the 16 for org-N (Table 4) for KFORD_EXTRnn.DAT. In KFORD_EXTRPnn.DAT the subbasin number column is followed by 16 columns of tot-P, 16 of SRP and 16 of part-P (Table 4).

Table 4. Content of the 16 columns for each substance in the extraction files.

Column	Name	Corresponding variable in sa-file	Description
1	Rlocal	Ret local	Retention in the response boxes for the subbasin
2	Rlake_river_pd	Ret lakes+river pathdown lakeload	Retention in the lake of the subbasin and in rivers and lakes all the way to the sea
3	Rtot_sea	Ret total to sea	Retention in response boxes, wetlands, river and lake in the subbasin and in rivers and lakes all the way to the sea
4	RivL_tot_area	River Load /Total area	Gross load from all land uses in the subbasin divided by the land area of the subbasin (tonnes km^{-2} for N, kg km^{-2} for P)
5	GL_point	GL Point sources	Gross load from urban (waste water treatment plants), industry and storm water for the subbasin (tonnes for N, kg for P)
6	GL_arable	GL arable_area	Gross load from arable land for the subbasin divided by the arable area (tonnes km^{-2} for N, kg km^{-2} for P)
7	NL_arable	NL arable_area	Net load (after retention all the way to the sea) from arable land for the subbasin divided by the arable area (tonnes km^{-2} for N, kg km^{-2} for P)
8	Local_GL	Local GL	Gross load to the response box (arable land, rural household and atmospheric deposition on ilakes) for the subbasin divided by the land area (tonnes km^{-2} for N, kg km^{-2} for P)
9	Local_NL	Local NL	Net load from the response box (arable land, rural household and atmospheric deposition on ilakes) after retention in the response box for the subbasin divided by the land area (tonnes km^{-2} for N, kg km^{-2} for P). Note: For phosphorus the Local NL may also include macropores and surface flow and thus more sources than the Local GL.
10	TGL	Total GL	Gross load for all external sources except atmospheric deposition on olake (i.e. land use, atmospheric deposition on ilake, rural households, bank erosion, point sources) for the subbasin divided by the land area (tonnes km^{-2} for N, kg km^{-2} for P)
11	TNL	Total NL	Net load after retention all the way to the sea for all external sources except atmospheric deposition on olake (i.e. land use, atmospheric deposition on ilake, rural households, bank erosion, point sources) for the subbasin divided by the land area (tonnes km^{-2} for N, kg km^{-2} for P)
12	NL_aro	Not in sa-file	Net load after retention all the way to the sea for all land uses in the subbasin divided by the land area (tonnes km^{-2} for N, kg km^{-2} for P). Calculated as River Load /Total area * (1- Ret lakes+river pathdown riverload) (Ret lakes+river pathdown riverload 3 is used for P)
13	NL_point	Not in sa-file	Net load after retention all the way to the sea from urban (waste water treatment plants), industry and storm water for the subbasin (tonnes for N, kg for P). Calculated as GL Point sources * (1- Ret lakes+river pathdown lakeload).
14	NL_diffuse_area	NL diffuse	Net load after retention all the way to the sea for all diffuse sources (i.e. land use, atmospheric deposition on ilake, rural households, bank erosion) for the subbasin divided by the land area (tonnes km^{-2} for N, kg km^{-2} for P)
15	GL_lake_source	GL lake source	Gross load of the lake (i.e. atmospheric deposition on olake, production in owet and olake) for the subbasin (tonnes for N, kg for P)
16	NL_lake_source	NL lake source	Net load after retention all the way to the sea of the lake (i.e. atmospheric deposition on olake, production in owet and olake) for the subbasin (tonnes for N, kg for P)

11 References

Andersson, L., Rosberg, J., Pers, B.C., Olsson, J. and B. Arheimer, 2005. Estimating catchment nutrient flow with the HBV-NP model – sensitivity to input data. Ambio, 34(7):521-532.

Arheimer, B. and M. Brandt, 1998. Modelling nitrogen transport and retention in the catchments of southern Sweden. Ambio, 27(6):471-480.

Arheimer, B. and H. B. Wittgren, 1994. Modelling the effects of wetlands on regional nitrogen transport. Ambio, 23(6):378-386.

Arheimer, B. and H. B. Wittgren, 2002. Modelling nitrogen removal in potential wetlands at the catchment scale. Ecological Engineering, 19:63-80.

Arheimer, B., Brandt, M., Grahn, G., Roos, E., and A. Sjöö, 1997. Modellerad kvävetransport, retention och källfördelning för södra Sverige (Modelled nitrogen transport, retention and source apportionment for the south of Sweden). Report RH No. 13, Swedish Meteorological and Hydrological Institute, Norrköping (In Swedish with English summary)

Bergström, S., 1995. The HBV model. In Singh, V. (Ed.) Computer Models of Watershed Hydrology. Water Resources Publications, Littleton, Colorado.

Gardelin, M., 2006. IHMS 5.8 – Kortfattad manual med exempel, Swedish meteorological and Hydrological Institute, Norrköping.

Bergström, S., Brandt, M. and A. Gustafson, 1987. Simulation of runoff and nitrogen leaching from two fields in southern Sweden. Hydrological Science Journal, 32(2-6):191-205.

Brandt, M., 1990. Simulation of runoff and nitrogen transport from mixed basins in Sweden. Nordic Hydrology, 21:13-34.

Brandt, M., Grahn, G., Årnfelt, E., and N. Bäckman, 2004. Anpassning av TRK-systemet från nationell till regional nivå samt scenarioberäkningar för kväve – Tester för Motala Ström (Adjustment of the TRK-system from national to regional level and scenario calculations for nitrogen – tests for River Motala Ström). Hydrologi No. 94, Swedish Meteorological and Hydrological Institute, Norrköping (In Swedish)

Ejhed, H., and M. Brandt, 2002. TRK, Transport – Retention – Källfördelning, Belastning på havet (TRK, Transport – Retention – Source Apportionment, Load to the sea). Report 5247, Swedish Environmental Protection Agency, Stockholm (In Swedish).

Evans, B.M, S.A. Sheeder, and D.W. Lehning, 2003. A spatial technique for estimating streambank erosion based on watershed characteristics. Journal of Spatial Hydrology, 3(1) (www.spatialhydrology.com).

Johnell, A., B. Johansson, C. Pers and M. Persson, 2006. Beskrivning av HBV-modellens program. Version 7.0. (Documentation of the HBV-model program). The document can

be found at Winfs/data/prod/Hydrologisk_Produktion/Install/HBV/Version_7_0/ Beskrivning av HBV-modellens program.doc, Swedish meteorological and Hydrological Institute, Norrköping. (Partly in Swedish).

Johnsson, H., Bergström, L. and P.-E. Jansson, 1987. Simulated nitrogen dynamics and losses in a layered agricultural soil. Agriculture, Ecosystems and Environment, 18:333-356.

Lindström, G., Johansson, B., Persson, M., Gardelin, M. and S. Bergström, 1997. Development and test of the distributed HBV-96 hydrological model. Journal of Hydrology, 201: 272-288.

Lindström, G., Rosberg, J. and B. Arheimer, 2005. Parameter precision in the HBV-NP model and impacts on nitrogen scenario simulations in the Rönneå River, Southern Sweden. Ambio, 34(7):533-537.

Nash, J.E., and J.V. Sutcliffe, 1970. River flow forecasting through conceptual models Part I – A discussion of principles. Journal of Hydrology, 10: 282-290.

NRCS, 1972-2004. NRCS National Engineering Handbook, Part 630 Hydrology, Ch. 7-10. Available on the web http://www.wcc.nrcs.usda.gov/hydro/hydro-techref-neh-630.html.

Pettersson, A., B. Arheimer and B. Johansson, 2001. Nitrogen Concentrations Simulated with HBV-N: New Response Function and Calibration Strategy. Nordic Hydrology, 32(3):227-248.

Sivertun, Å., L.E. Reinelt, and R. Castensson. 1988. A GIS method to aid in non-point source critical area analysis. Int. J. of Geographical Information Systems, 2:365-378.

Springer, E.P., 1996. Surface water and erosion calculations to support the MDA G performance assessment. Los Alamos Report LA-UR-96-4894, Los Alamos National Laboratory, University of California, Los Alamos.

Svensson, P., 2006. Systembeskrivning: KFORD (Description of the KFORD system). The document (Beskrivning_kford.doc) can be received from the HBV maintenance group, Swedish meteorological and Hydrological Institute, Norrköping (In Swedish).

Rosberg, J., 2003. Modeling phosphorus transport and retention in river networks. Undergraduate Thesis in Hydrology, Dept. Earth Sciences, Uppsala University, Uppsala, 44 pp.

Tattari, S., Bärlund, I., Rekolainen, S., Posch, M., Siimes, K., Tuhkanen, H.-R. and M. Yli-Halla, 2001. Modeling sediment yield and phosphorus transport in Finnish clayey soils. Trans. ASAE (Am. Soc. Agric. Eng.), 44:297-307.

Tonderski, K.S., Arheimer, B., and B.C. Pers, 2005. Modelling the impact of potential wetlands on phosphorus retention in a Swedish catchment. Ambio, 34(7):544-551.

U.S. Soil Conservation Service, 1986. Technical Release 55: Urban Hydrology for Small Watersheds. USDA (U.S. Department of Agriculture). June 1986. Available on the web at ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf .

Williams, J.R., 1995. The EPIC Model. In: Computer Models of Watershed Hydrology, Ed: V.P. Singh, Water Resource Publications, 909-1000.

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