# MODELLING OF THE FORECASTS OF DISCHARGES IN THE CATCHMENTS OF THE SVRATKA AND THE SVITAVA

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***Abstract:*** In the CHMI Brno Regional Office ( Morava River Basin) was in 1999 installed by the HYSOFT firm the HYDROG-S simulation and forecast model of the Svratka catchment, which was in 2000 supplemented with the adjoining Svitava catchment. The model is set up in the Svratka catchment down to the Veverská Bitýška station, which is situated above the Brno reservoir. The forecast of the inflow into the reservoir represents a prized information for the following regulations of the outflow, facilitated by the Morava Catchment company. In the Svitava catchment the model is set up down to the closing gauging station of Bílovice nad Svitavou. In 2002 the model was enlarged to the station of Židlochovice on the Svratka, which is below the confluence of the Svratka and Svitava.
***Keywords:*** hydrological simulation and forecast model, catchment, discharge, rainfall-runoff process, calibration, watergauging station, precipitation station, transmisision of data

# VORHERSAGE VON DURCHFLÜSSEN IN DEN EINZUGSGEBIETEN VON SVRATKA UND SVITAVA

***Zusammenfassung:*** In dem Tschechischen Hydrometeorologischen Institut wurde im Jahr 1999 das Simulations - und Vohersagemodell für Einzugsgebiet Svratka installiert. Das Modell wurde im Jahr 2000 um das nebenliegende Einzugsgebiet von Svitava erweitert. Das Modell wird im Einzugsgebiet der Svratka bis zur Pegelstation Veverská Bitýška eingesetzt, die oberhalb von Brno-Stausee liegt. Die Vorhersage von Zufluss in den Brno-Stausee ist eine sehr preiswerte Information für die weitere Manipulation von Abflüssen. Diese werden von der Morava Fluss Direktion durgeführt. Im Einzugsgebiet der Svitava wird das Modell bis Endstation Bilovice eingesetzt. Im Jahr 2002 wurde das Modell bis zur Pegelstation Židlochovice an der Svratka erweitert, die unterhalb von Zusammenfluss von Svratka und Svitava liegt.
***Schlüsselworte:*** Hydrologisches Simulations-und Vorhersagemodell, Einzugsgebiet, Durchfluss, Niederschlag - Abfluss Modell, Kalibrierung, Pegelstation, Niederschlagsmesser, Datenübertragung

## 1. Introduction

Significant floods from the end of nineties – especially the July 1997, which with its extent and subsequence were the largest in the whole of last century, accelerated processing of hydrological forecasting in the Regional Forecasting Offices (RFO) of CHMI as well. An expert search of forecasting models for purposes of finding a proper modelling technique was prepared and subsequently a tender was opened for implementation of functional forecasting models for selected basins where calibration was requested in co-operation with CHMI experts. The activities of contractual parties selected from this competition were financed by grant project „Extreme hydrological phenomena in river basins“. A partner for co-operation in implementation of forecasting models in the Morava river basin was the Hysoft Company. We defined some main goals in the beginning of work on this project. Besides selection, calibration and testing suitable hydrological forecasting models, it was necessary to install automatic rain gauges in pilot basins and verify gradually the forecasting methods using actual data and put it into a daily use.

## 2. Svratka and Svitava Basins

The Svratka catchment is situated on the north of the Moravian part of the Czech-Moravian Highlands and from here it continues in the south-easterly direction over the Boskovice Furrow, the Brno Massif and the Moravian Kras to the Dyje-Svratka Valley. The shape of the catchment is approximately an oblong with the longer axis in the direction of north-west south east. The length of the catchment is approximately 115 km, the width 60 km. The Svratka originates on the slopes of the Žákova hora in an elevation of over 700 m A.S.L. in the region of the crystallinics of the Czech-Moravian Highlands. In the upper and middle part the Svratka creates a narrow, deep-cut valley, which is at places interrupted by wider hollows. In the upper part of the stream is situated the Vír reservoir (56,2 million $m^3$). The Brno reservoir is the second biggest reservoir in the Svratka catchment (21 million $m^3$). The Svitava originates between Javorník and Moravský Lačnov in the region of the Eastern-Bohemian chalk. It has on average lesser slope than the upper and middle Svratka. It flows in a direction which is almost southerly. The catchment has an elongated shape and its total area is 1160,24 $km^2$. It joins the Svratka below Brno. The total stream length from the spring to the confluence with the Svratka is 97,7 km. Bigger reservoirs in the catchment are Letovice (Křetínka) (11,6 million $m^3$) and Boskovická Bělá (7,3 mil. $m^3$). The slope of the Svitava is not gradual, especially in the middle part there are more solid reefs. The catchment consists predominantly of arable land 66% and forests 24%. From the geological point of view the Svitava catchment is very varied, because there are a number of geological formations here with a great many minerals. The catchment is depleted by a permanent offtake by a so called Březovský watermain for the city of Brno. It is a permanent offtake of around 1 $m^3 \cdot s^{-1}$.

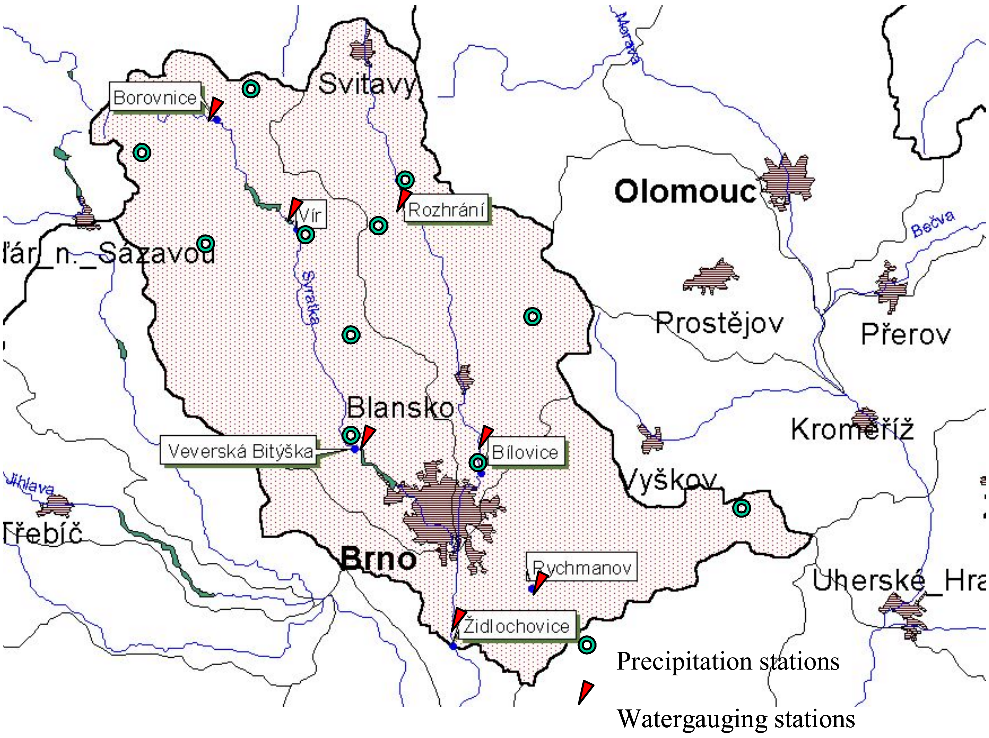


*Figure1. Plan of the catchments*

***Forecasting procedure***

The HYDROG program system is designed for the simulation or operative forecasts of water runoff from the catchment caused by a torrential rainfall. During the simulation it is possible to choose from two possibilities:

- The hydrodynamic properties of the system are not changing, that is the regulation valves of reservoirs are unchangeably set.

- Outflow from chosen reservoirs may be directed. The user can then prescribe own directed outflows and the program controls whether they are possible, or it is possible to import real outflows from the reservoirs.

When using for operative forecasts, these are determined in mutually shifted time points, on the basis of an immediate state of the system and forecast of rainfall in rainfall measuring stations. The immediate state of the system supposes either simply stabilised flow of water in the river network, or it is possible to estimate it by simulation in the preceeding period. In this case we come back in time to the time point, when it is possible to suppose stabilised flow. In chosen gauging stations, in which discharge is measured, it is then possible to make correction of the calculated values by the measured ones. Then follows the calculation of the forecast discharges itself.

### *3.1. The rainfall-runoff process*

The calculation itself is being made on a schematized catchment, when the real catchment is replaced by an orientated evaluated graph. This consists of stream sections, areas hanged onto them, surface reservoirs and an underground reservoir.

During the course of the rainfall-runoff process, the rain fallen on the catchment flows through such a graph. During this, two kinds of routing are considered:

- hydrological,
- hydraulic.

During hydrological routing, from the total intensity of the rainfall falling on the areas are gradually subtracted hydrological losses (the model respects these losses by a universal loss curve, in which the loss of infiltrations according to Horton dominates, in relation to the rainfall sum in the preceeding week).

During the hydraulic routing, the simulation of areal runoff takes place on the areas of the graph and concentrated runoff in the stream channels, reservoir routing, down to the closing cross section of the catchment. The hydraulic routing represents a common solution of the initial and side problem.

The movement of water on areas and through edges of the graph is generally described by Saint-Venant equations for non-stabilised flow. These are in the used mathematical model simplified as follows. First equation - the equation of continuity is left in the differential form, the second equation (movement) is then replaced by Manning's equation. This simplification is called the kinematic wave approximation. It is possible to use this procedure everywhere where for Froude number it holds that $Fr < 2$. In places of stream confluences only the continuity of discharges is kept. The solution of the quoted equations is performed with the help of the explicit differential method. The routing of water through reservoirs stems from the basic reservoir equation. For the solution, the Runge-Kutta explicit differential method is used.

Underground runoff is at the beginning and during the simulation designated for individual sections by the distribution of the underground runoff in the closing cross section in relation to the size of the hanged areas. Its change in time is solved with the help of a conceptual regression model. For very small catchments it may be given as a constant.

### *3.2. Calibration*

The program system is adjusted for the calibration of the model. It is possible to make subjective calibration, by a mere change of calibration coefficients (multiplies properties as roughness, hydraulic conductivity etc.) and by the comparison of simulated and measured courses of discharges in chosen cross sections. Apart from this it enables to make semiautomatic and automatic calibration. This makes the choice of values of these coefficients and ensuing activity automatically.

### *3.3. Input data*

The current reporting watergauging network of the CHMI and River Basin companies is sufficient for the flood forecasting on the main streams, only in some regions it will need supplementing. A problem is the assurance of the stabilisation of rating cross-sections and the function of the stations during extreme floods. Rating curves of discharges during high stages are verified, and under complicated hydraulic conditions extended with the utilisation of hydraulic models.

3.3.1. Hydrological data

The automatic collection of data from watergauging stations is at the moment being made by several transmission systems both on the forecast workplaces of the CHMI and on the water management executives of the River Basin Companies. The arrived-at agreements on co-operation between the CHMI and the River Basin Companies enable the stations of the other side to be used. With the on-going of automation the duplicity of data collection is gradually growing, which of course during extreme situations leads to a greater reliability of the system. Despite this, in future a uniform system of data collection should be adhered to for all stations important for the flood service.

The HYDROG modelling system works in a one hour time step. The processing scheme is on the figure 2. The input data for everyday routine operation of the model in the Svitava catchment are hydrological data from the gauging station Bílovice nad Svitavou, the directed outflow from the reservoir Letovice on the Křetínka river, and elevation data about the movement of the water surface from the Letovice reservoir. In the Svratka catchment, discharges are gained from the Borovnice, Veverská Bitýška and Židlochovice stations, directed outflow from the Vír dam and elevation data about the movement of water surface in the Vír reservoir.

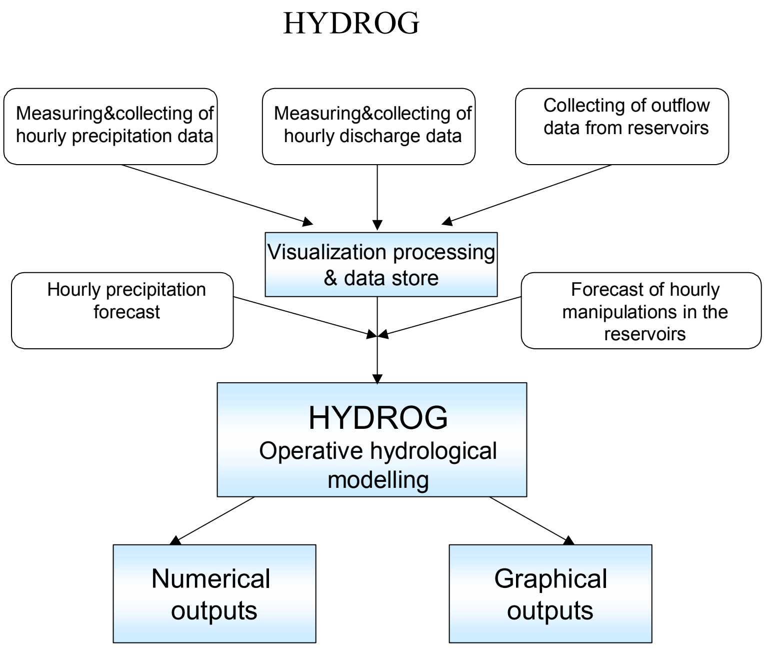


*Figure 2. Processing of hydrometeorological data*

3.3.2. Precipitation sums

Hourly data on precipitation sums are gained in the Svitava catchment from 5 CHMI precipitation measurement stations with automatic transmission of data (Polička, Rozhrání, Synalov, Sloup, Bílovice) and 2 Morava Basin Company precipitation stations (Letovice reservoir, Brno reservoir) situated either directly in the catchment or in its immediate vicinity. The precipitation sums in the Svratka catchment are relayed from 6 CHMI stations (Polička, Kadov, Dolní Rožínka, Synalov, Dolní Loučky, Nemochovice) and 2 Morava Catchment stations (Vír reservoir and Brno reservoir).

3.3.3. Precipitation forecast

For the precipitation forecast, the CHMI uses the outputs of numerical models operated by the meteorological services in some European countries, and the ALADIN regional model. The outputs of the models are systematically compared and evaluated, and the meteorologist on duty makes the final decision about the quantified precipitation forecast. Hourly precipitation forecasts are given, for 24 or 48 hours ahead.

### *3.4. Calculation*

The menu offers the values of forecast of discharges, simulation and volume of flood. The value of forecast of discharges triggers off an algorithm designated for forecasts of discharge of water in chosen cross sections of the river network. Forecasts for designated gauging stations are calculated every morning from 8:30 till 9 am. It is possible to calculate the forecast for any time start up to 48 hours, which is limited by the quantified precipitation forecast. It is possible to choose one or more gauging stations from the given division of the river network to sections. After starting the program asks for the numbers of sections, in which discharges are measured, and the numbers of sections, in which results will be given for both writing out and graphical representation. After giving these data, the simulation of performance of the system in the past period is started. It requires the giving of actual courses of precipitation in the precipitation measurement stations and the giving of courses of the directed outflows from reservoirs in this period. As an initial condition, it is suitable for streams to consider stabilised flow (the program will find the division of discharges in stream sections, according to the given discharge in the closing gauging stations). The simulation is finished in the present, i.e. in an actual time point. In this moment, the course of discharges in all sections of the system and the surface elevation in all reservoirs are known. The operator can in this moment make a correction of these data according to the actual measurement in all reservoirs and measured cross sections. By doing this, he or she may largely eliminate mistakes, which to this moment influenced the accuracy of the solution.

After performing the correction, or the confirmation of the data, the calculation of the_forecast discharges is started. The calculation takes place in a future period, for which the course of forecast precipitation must be given (e.g. ALADIN). It is presumed, that the positions of the closing valves will not change to the next deciding time point (or it is possible to directly feed in the course of the directed outflows). Every reservoir has therefore its dynamic properties unambiguously determined. The outflows from reservoirs in the future period are in the first case therefore a function of only their filling,

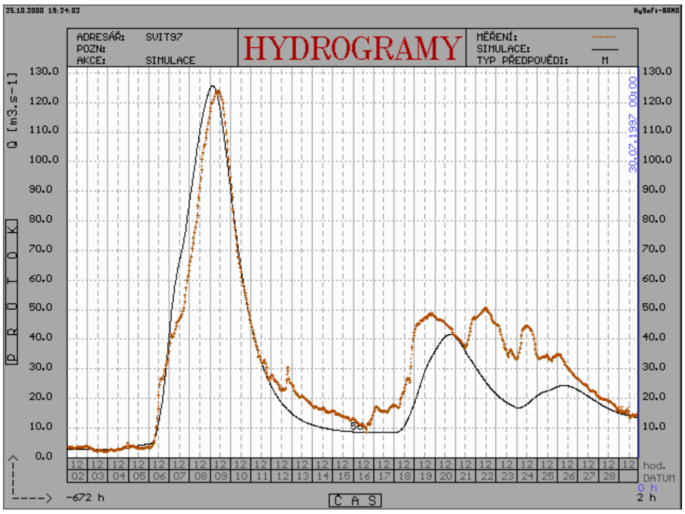


*Figure 3. Calibration of the model, July 1997*
*Svratka river Catchment*

and generally change with time in dependence on the size of inflows. After the lapse of certain time (e.g. 24 hours) it is possible to repeat the whole procedure. The starting time point for simulation in the last period will be kept as in the preceeding step. The course of the fed-in directed outflows will be prolonged by this time period (correction of the last course), they will have a real course. Also the precipitation will be in the last period by this time period made more accurate according to the measured reality. In the future period they will be again made more accurate by a new forecast.

When calculating the volume of the flood, the calculation will be made for the first given section and above the given level of discharge. In question is the total volume of the flood for the overall given duration of the simulation. On the figure 3 there is the calibration of the model for the gauging station Veverská Bitýška during the flood in 1997.

### *3.5. Evaluation of hydrological forecasts*

A significant influence on the shape and size of the flood hydrograph computed by the hydrological model has precipitation, be they data measured or forecast. That was one of the reasons why already last year the evaluation of quantified precipitation forecast was additionally added to this task. Operative station network with daily reporting was used for comparison, for the years 1999 and 2000. This year the sums of forecast daily sums 24 and 48 hours were compared with the whole precipitation measurement network, for a chosen summer period from the year 2000. The given out forecasts show relatively good agreement with reality and their use is suitable in the present form with the risk, that for higher values of forecast precipitation an error larger than 15 mm will occur for less than 10 % of the cases and an error >20 mm for less than 5 %. With this in mind we must then approach when expecting the results from the hydrological model, where the errors in forecast then multiply.

## 4. Conclusion

Legislative basis of forecasting and reporting flood service is given for CHMI in the new water act. At present time the HYDROG model is experimentally half-running in the Regional Office in Brno. The forecasting discharges are handed on to the dispatching of Morava Basin Company. For better and faster giving out of forecasts, automation of further stations planned in the CHMI and radar information on precipitations depths will help.

At the same time, on the Internet are published actual stages in a chosen network of reporting gauging stations, and we also consider the publishing of hydrological forecasts. The system will shortly be tied with the Telephone book of flood service on the Internet.

## 5. References


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