# How to improve the simulation of low flow discharges ? (Use of the knowledge of low flow processes in a model)

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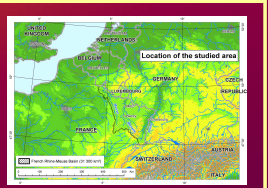
## I. BACKGROUND: PREVIOUS WORKS & OBJECTIVES

This research was first investigated for an applied project: the development of a daily model for low flow forecasting. The studied area is located in the East of France and 60 basins are concerned. Our objective was to use our knowledge about low flow processes in the model. In a previous work, we have showed that the results of the model can be improved especially in forecast by using recession coefficients. These were calculated from an hydrological analysis and directly put in the model to calibrate base flow coming out from the groundwater storage of the model (Lang & al., EGU 2006). The main difficulties of this stage were related to the recession parameter variability, and the way of introducing it into the model:




First the recession parameter variability (see fig.1) was palliated by using a statistical analysis to determine the "mean" recession coefficient.

Secondly the mean recession coefficient was put directly in the model to calibrate base flow coming out from the groundwater st

*Fig. 1: Illustration of the recession coefficient variability*

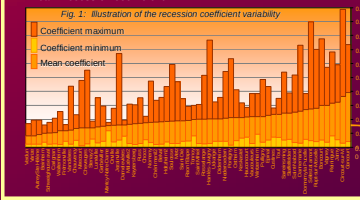
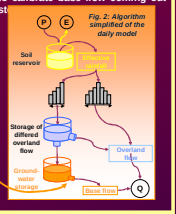



*Fig. 2: Algorithm simplified of the daily model*




**AT THE END OF THIS WORK WE HAVE FOCUSED ON TWO MAIN ASPECTS WHICH ARE THE OBJECT OF THIS POSTER**

**1. The variability of the recession coefficients has not been explained:**

*Fig. 3a: Correlation between recession coefficients and evapotranspirations: Period 1971-2003*

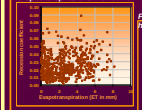
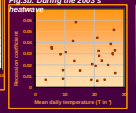



*Fig.3b: During the 2003's heatwave*



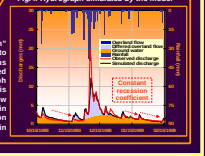

No relation between recession coefficients & ET or T.

The factors used classically to explain this variability did not give satisfaction.

In the model the "mean" recession coefficient is used to simulate base flow; thus recession coefficients calculated from the simulated hydrograph are necessarily constant if there is no influence of overland flow (anyway it is the condition to be in a recession period and recession coefficients are only calculated in this case).

**2. We have not taken into account this variability in the model:**

*Fig.4: Hydrograph simulated by the model*

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Reference:
LANG C., FREYERMUTH A., GILLE E., FRANCOIS D. (2006) : « PRESAGES : a tool for low flow forecasting », EGU General Assembly 2006, Session HS5-NP0262, Vienna, 2-7 April 2006.

## II. RELATION BETWEEN OBSERVED PROCESSES & MODELING

### PARTICULARITY IN THE RECESSION ANALYSIS

Among factors which could explain the variability of the recession coefficient (evapotranspiration, etc.) we analyzed the choice of $Q_0$, i.e. the first discharge of a recession phase. Indeed, if this first discharge is badly chosen it can influence the recession coefficient value. If the first discharge chosen is too high (during recession flood) the obtained coefficient will not be representative of a recession situation (base flow has not to be mixed up with overland flow). In this case, $Q_0$ would be highly correlated to the recession parameter. However the choice of recession phases has been made by rigorous criteria and systematically checked. For this reason we are almost sure that the selected phases correspond only to recession periods which are not influenced by rainfall. Nevertheless relationships between $Q_0$ and the recession coefficients are interesting.

### PARTICULARITY IN THE MODELING

The input of the "mean" recession parameter in the model gives satisfactory results. The model's efficiency is evaluated by the Nash criterion (Nash is always superior to 70% and reached for certain basins 90%).
However both the analysis of the hydrograph and of the relation between simulated and observed discharges watch of the bad results for the most low flow discharges. The correlations between simulated and observed discharges have been realized and analyzed for all basins. It is interesting to note that a classification can be operated because the bad results do not concern all the basins:

-the permeable basins do never show a relation between $Q_0$ and the recession coefficients (fig. 5).

-for certain impermeable basins a relationship can be established between these two values (fig.7).

**PHYSICAL FEATURES**

-the permeable basins show a bias in the correlation (fig. 6).

-the impermeable basins do not show a bias (fig. 8).

High recession coefficients correspond to high $Q_0$ discharges.

**RELATION**

*Fig. 5: The recession coefficients vs. $Q_0$ (River Meuse at Goncourt)*


*Fig. 6: Observed daily discharges vs. simulated (River Orne at Boncourt)*

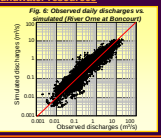
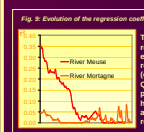



*Fig. 9: Evolution of the regression coefficient according to $Q_0$*




These curves represent the evolution of the regression coefficient (calculated between Q0 and the recession parameter) when the highest values of $Q_0$ are progressively removed.

- The red curve shows a significant decrease. It means that the highest values of $Q_0$ are strongly correlated with the recession parameter. When these values are progressively removed the regression coefficient becomes less significant.
- The orange curve shows at once a regression coefficient non significant. The highest recession coefficients are not related to highest $Q_0$ values.

**Basins without groundwater resources**

The Nash criterion is high: 83%. The graph shows a good correlation.

**NO BIAS**

The model shows deficiency in the simulations for permeable basins during severe low water. Simulated base flow discharges continue to decrease when observed discharges decrease slower.

**BIAS**

**SIMILAR CLASSIFICATION BETWEEN PARTICULARITY LINKED TO THE RECESSION ANALYSIS AND PARTICULARITY LINKED TO THE MODELING**

**Basins with groundwater resources**

*Fig. 7: The recession coefficients vs. $Q_0$ (River Mortagne at Autrey Sh)*

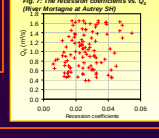
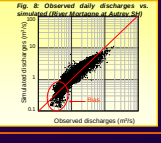



*Fig. 8: Observed daily discharges vs. simulated (River Mortagne at Autrey Sh)*




High recession coefficients do not correspond necessarily to high $Q_0$ discharges.

**NO RELATION**

The Nash criterion is high too: 83%. But the correlation is bad.

**Recession analysis conclusion:**

A relation between physical features of the basins and the recession parameters has been established:
High recession rates are observed in impermeable basins. Actually during recession period the river discharges correspond only to base flow. For an impermeable basin with no groundwater reservoir what do we quantify during recession period? Indeed obtained values seem more to correspond to recession flood coefficients than to recession coefficients.

**There are similar observations between the recession analysis and results of the low flow modeling:**
**The low flow modeling can be improved by using these aspects (see part III).**

**Modeling conclusion:**

Nash is a global criterion. To evaluate low flow simulation we have to use other criteria more specific at low flow discharges.

The algorithm of the model has to be improved to correct the bad simulations for low flow discharges of permeable basins.

## III. HOW TO IMPROVE SIMULATIONS ?

To improve the simulations of low flow discharges we have to understand the origin of the biases to correct them. We also have to use other criteria than the only Nash criterion because this one is too global. A high value of Nash can mask important defects.

### 1. SIMILAR OBSERVATIONS BETWEEN MODELING & RECESSION ANALYSIS

| MODELING | RECESSION ANALYSIS |
|---|---|
| BIAS: OBSERVED DISCHARGES DECREASE LESS QUICKLY THAN SIMULATED | VARIABILITY OF THE RECESSION COEFFICIENT: THIS ONE CAN SHOW VERY SLOW RHYTHMS OF RECESSION |
| SITUATION OBSERVED ONLY FOR THE LOWEST DISCHARGES | SITUATION OBSERVED DURING LONGEST AND MOST SEVERE LOW WATER |

BOTH OBSERVATIONS AND MODELING SEEM TO CONCLUDE THAT
THE RECESSION RATE IS MORE SLOWER DURING SEVERE LOW WATER

### 2. HYPOTHESES OF PHYSICAL EXPLANATIONS

The recession coefficient is variable because several groundwater storages are present in a basin.

In our climate long dry-spell are not frequent and in much cases the recession discharges do not represent the depletion rate of the only deep groundwater storage. It is a sum of various types of depletion (unsaturated zone, perched aquifer, deep groundwater storage, etc.).

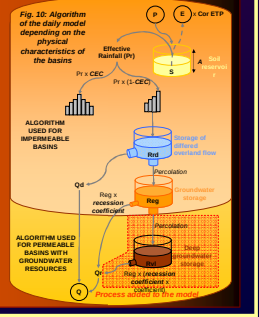
A long time without rainfall is thus necessary before emptying every soil compartments and of reaching the "real" deep groundwater storage which has a slow recession rate.

These considerations can explain:
-the variability of the recession rate: there are a sum of various depletions;
- bad simulations during severe low flows: in our model the recession parameter is constant but it should be variable as in the reality; during severe low water it must be slower to avoid a too fast decrease of discharges.

### 3: MODIFICATION OF THE MODEL TO TAKE INTO ACCOUNT THE PREVIOUS CONCLUSIONS

We add in the model a second groundwater storage called "deep groundwater storage". It must have a slower recession rate than the groundwater reservoir. During severe low flow only the deep groundwater reservoir is not empty and it produce base flow. The adding of this second groundwater reservoir must allow to reproduce the variability of the recession coefficient and to correct the bias because base flow decreases more slowly.

*Fig. 10: Algorithm of the daily model depending on the physical characteristics of the basins*




## IV. RESULTS AND VALIDATION

### CHOICE OF CRITERIA TO EVALUATE THE PERFORMANCE OF THE MODEL:

Criteria to evaluate the performance of the model have to focus on the deficiency of the model. The Nash criterion must be completed by other criteria especially adapted to low flow. We propose different criteria:

- Nash calculated from the logarithm of the values;
-Comparison of observed vs. simulated flow duration curves;
-Correlation of observed vs. simulated discharges;
-Correlation of observed vs. simulated $MAM_{10}$;
-Comparison of observed base flow index vs. simulated;
-Comparison of observed recession coefficients vs. simulated.

These criteria are more adapted to evaluate the low flow. The optimization of the model can be realized from certain of these criteria instead of using Nash.

### VALIDATION:

First we observe that the adding of a second groundwater reservoir correct the bias previously observed (fig. 11). Indeed the deep groundwater storage avoid a too fast decrease of discharges during severe low flow. The correlation of $MAM_{10}$ (fig. 12) also shows good results ($MAM_{10}$ is a severe criterion which can be difficult to reproduce by a model). The using of two reservoirs allows also to reproduce the variability of the recession coefficient (fig. 13).

*Fig. 11: Daily observed discharges vs. simulated*

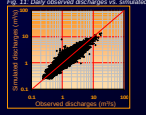



*Fig. 12: Observed MAM$_{10}$ vs. simulated*

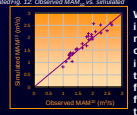
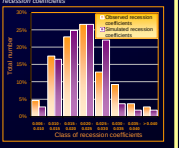



*Fig. 13: Histograms of observed and simulated recession coefficients*




We have tested this model for impermeable basins: simulations are not improved and discharges coming out from the deep reservoir are insignificant. It is a proof of the role of the physical characteristics because for impermeable basins there is not or few groundwater resources. There is thus no reason of adding a second reservoir.

**CONCLUSION:** The unexplained variability of the recession coefficients has been resolved and the modeling has been improved by using the knowledge of physical processes generating the low flow.