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FEWS-Rhine

Definition Study

Version 1.2

Report

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FEWS-Rhine

Definition Study

Version 1.2

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CLIENT:	RIZA, Landeshydrologie und -geologie Switzerland
TITLE:	FEWS-Rhine Definition Study

ABSTRACT:

This report presents the results of a Definition Study to a Flood Forecasting System of the River Rhine. Principals for the study are the Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA) from the Netherlands and Landeshydrologie und -geologie from Switzerland.

The two organisations LHG and RIZA asked a consortium of the Swedish Meteorological and Hydrological Institute (SMHI), and WL | Delft Hydraulics to carry out this Definition Study.

The objective of the Definition Study is to determine the overall conceptual structure of a River Rhine Flood Forecasting System meeting the requirements of LHG and RIZA and indicate the path towards the development of such forecasting systems.

The following method was used to define a Rhine Basin Flood Forecasting System for the Netherlands and for Switzerland:

A. Organise a series of meetings, workshops and interviews with both representatives of LHG and RIZA
B. The objective of the interviews was to investigate in detail the wishes, or more formally, the user requirements of the clients.
C. The objective of the workshop was to present the findings of the SMHI and WL | Delft Hydraulics on the interviews and to check whether the interpretation of both contractors of the user requirements was consistent with the wishes of the clients.
D. Reports on the meetings and findings of the interviews were sent to the clients for review. The comments were used to arrive at final versions of the reports.

Based on the results, the report describes the required models, adaptations of models as well as the functional design of such a FEWS. It indicates the activities to be undertaken to implement a FEWS in the Netherlands as well as in Switzerland. A confidential appendix is added which estimates the cost of such implementation.

REFERENCES: RI-2945
FE/99/09

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0.1	Arjen Markus and others		26 March 2000		J. Kwadijk		J. Stout	
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1 Introduction

1.1 References

This report presents the results of a Definition Study to a Flood Forecasting System of the River Rhine. Principals for the study are the Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbewerking (RIZA), from the Netherlands and Landeshydrologie und -geologie, LHG, from Switzerland. The work is defined in the contracts and attachments with reference number RI-2945 sent with the letter ZWS4145/99, dated December 9, 1999 between WL | Delft Hydraulics and RIZA and in the contracts and attachments LHG no. FE/99/09 (SMHI registration no 1999/1043/190), November 1999, between SMHI and LHG.

1.2 Motivation for the study

Discussions between principals of LHG (Switzerland), and RIZA (The Netherlands), have led to the joint opinion that the existing Flood Forecasting Systems for the river Rhine for the Netherlands and for the LHG are to be improved and/or extended. In addition it was considered that improvements and/or extensions of an existing Flood Forecasting System done by a specific country might be of interest to other riparian countries as well. As LHG and RIZA recognised extension and/or improvements of their own systems as being most urgent, the organisations initiated a Definition Study that should determine the overall structure of a flood forecasting system for the Dutch or Swiss part of the River Rhine. The two organisations LHG and RIZA asked a consortium of the Swedish Meteorological and Hydrological Institute (SMHI), and WL | Delft Hydraulics to carry out this Definition Study.

1.3 Set-up of the report

The final report consists of the chapters below:

- Chapter 2 presents the objectives of this Definition Study
- Chapter 3 describes the current systems used in the Netherlands and Switzerland.
- Chapter 4 describes the functionality and layout of the new system based on the investigation of the user requirements.
- Chapter 5 contains the results of an analysis that was carried out with SOBEK and HBV to examine the effects of an hourly and a daily timestep respectively and the possibilities of the re-use of existing HBV models in the German sub-basins.
- The next chapters deal with:
  - — Required improvements and adaptations (Chapters 6 and 7).
  - — Time schedule for implementation (Chapter 8).
  - — Resources requirements, hardware and operating system (Chapters 9 and 10).

An estimation of the investment of building the new system has been added separately.

2 Objectives of the Definition Study

2.1 Objective

The objective of the Definition Study is to determine the overall conceptual structure of a flood forecasting system that is dedicated to the respective parts of the river basin, that meets the requirements of LHG or RIZA and to indicate the path towards the development of such forecasting systems.

2.2 Constraints

The clients made the following general constraints in advance:

The new system for RIZA should be designed in such a way that reliable forecasts with a lead time of *four days* can be made at the Lobith gauging station located at the border between Germany and the Netherlands. In practice this means that the upstream boundary station for the system is the gauging station Maxau .

The new system for LHG should cover all the functionality of the current Swiss forecasting system but the system should make the technical forecast procedures for this system more transparent. In Switzerland the basins upstream of the lakes should be included in the system.

The new systems should make use of the models and software currently used by the clients for their flood forecasting, e.g. HBV, FLORIJN, SOBEK.

3 Methodology

The following method was used to define a Rhine Basin Flood Forecasting System for The Netherlands and for Switzerland:

- Organise a series of meetings, workshops and interviews with both representatives of LHG and RIZA.
- The objective of the interviews was to investigate in detail the wishes, or more formally, the user requirements of the clients.
- The objective of the workshop was to present the findings of the SMHI and WL | Delft Hydraulics on the interviews and to check whether the interpretation of both contractors of the user requirements was consistent with the wishes of the clients.
- Reports on the meetings and findings of the interviews were sent to the clients for review. The comments were used to arrive at final versions of the reports.

The following meetings with the clients were held:

Date	*Location*	*Type*	*Objective*	*Result*
2/6/1999	Arnhem	Workshop	Pre-investigate wishes clients	Report, proposal
13-14/12/1999	Bern	Interview	Investigate wishes LHG	Report
17/1/2000	Arnhem	Interview	Investigate wishes RIZA	Report
14-15/2/2000	Delft	Workshop	Present results, confirm User requirements	Report, final list of user requirements
6/3/2000	Bern	Interview	Fact finding & discussions	Minutes of the meeting

The reports of the meetings were collected and stored in digital format on a diskette. The final list of user requirements is added in appendix A to this final report.

3.1 Definitions

For a good understanding of this report we define the following names:

FloRIJN:	The system currently used at RIZA to forecast discharges at Lobith. The upstream boundary is the Andernach gauging station
The current Swiss forecasting system:	The system that is currently used at the LHG in Bern, which includes the ETH-HBV model developed by Braun and Jensen.
HBV/IMHS	The version of the HBV model including the user interface developed by SMHI
SOBEK:	The 1-D hydraulic model maintained by WL | Delft Hydraulics, RIZA and DHV

4 Description of the current flood forecasting systems

The purpose of this chapter is to outline the existing forecasting systems, so that the sketch of the new overall system may be related to these. Besides the method of working with the system some details are provided on the data requirements and the limitations of the systems. Furthermore, the strong points of each system are listed, so that the good things may be kept and the unsatisfactory ones replaced or revised.

4.1 The RIZA system FloRIJN

Currently, RIZA uses a suite of simulation models, together called FloRIJN. A statistical model is used for daily water level forecasts. During floods this statistical model is used parallel with FloRIJN. Both systems have fairly simple data requirements:

- The (measured) water levels or discharge at Andernach for a period of eight days prior to the present.
- The measured and predicted water levels, recalculated to discharges of some six stations on the Rhine in Germany and the water levels for several tributaries that flow into the River Rhine between Andernach and Lobith. (Figure 4.1 shows the Rhine basin)
- The measured precipitation data of several stations for the past eight days and the forecasted precipitation for the coming two days in the northern German part of Rhine basin.

The discharge data and the forecasts for the station at Andernach are provided by the WSD in Mainz. For the river Ruhr the discharge forecasts are provided by the Ruhrverband whereas the meteorological data are provided by the Dutch KNMI.

The hydrological data arrive at the forecasting systems through the monitoring system of Rijkswaterstaat (MSW) into the central database of RIZA BC2000. The meteorological data are sent to the RIZA central database by KNMI via a modem connection.

During floods the FloRIJN system is used on a daily basis by a group of specialists and only they are allowed to operate the system. During normal conditions, when the water level at Lobith is below the flood criteria, the forecast is made once a day by the staff of the "Berichtencentrum". When water levels at the Lobith gauging station exceed the flood threshold, forecasts are made twice a day. The results are distributed by standard reports to all clients.

The structure of FloRIJN is based on the idea of interdependent tasks that need to be carried out successively:

- First all relevant data are retrieved from the central database.
- These are then checked for quality and validity and, if required, corrected manually.
- In the third step the hydrological modelling is carried out. The prediction for the lateral inflow from two tributaries between Andernach and Lobith (namely Sieg and Lippe) to the main river is made by a fairly simple precipitation-runoff model.
- The exchange between groundwater and river is simulated by a separate groundwater model. This model provides input for the SOBEK model.
- The flow in the main channel is simulated using the SOBEK model.
- The *final results* are the prediction of the water level and flow rate at Lobith for the next four days.

Because users have to select the task themselves, they are very much in control of what is happening. At various stages in the forecasting process the results can be checked. The system allows the users to go back to an earlier procedure and start the forecast from there. The input data and the results are stored locally, so that hindcasting can be done.

Shortcomings

The current system is simple to use, but does have a few important drawbacks:

- Reliable predictions can be made for three days in advance only.
- The *simulation* models do not have the required accuracy yet, so that the *statistical* model is used in critical situations. Research has shown that this model can not be adapted to a version that is capable to forecast with a lead time of 4 days.
- The role of the groundwater model in the simulation is unclear, though it was introduced to overcome substantial inaccuracies.[1]
- The way the data checks are organised is only useable when the amount of input data is limited (as it is in the current system).

Properties that should be preserved

The following properties that are present in the current system should be preserved:

- The task-driven approach which puts the user in control.
- The ease of use, especially the fact that all parameters in the system can be reviewed.
- The local storage facilities that make hindcasting easy to do.
- The connection to RIZA's central database.

Because BfG have invested quite some work in the calibration of the HBV-models for the whole of the German Rhine basin, RIZA want to use their results.

[1] *Recently, the question has come whether the groundwater model should be run only 8 days of history or with a much longer period. Though answering this question is not a part of this Definition Study, the answer may influence the implementation of parts of the new system.*

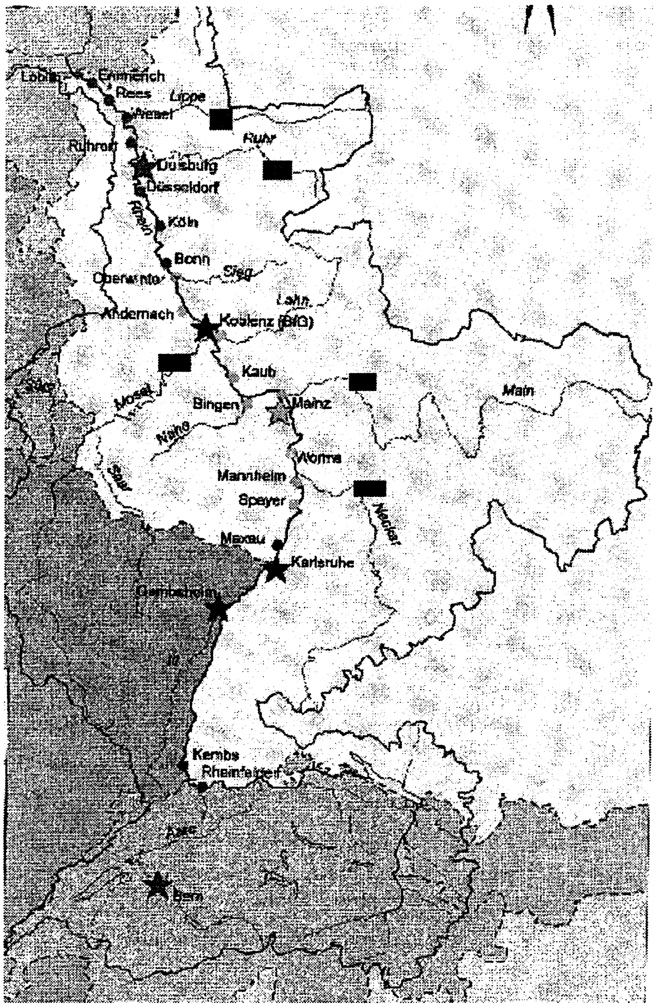

Figure 4.1 Overview of Rhine basin

4.2 LHG's system

4.2.1 General

LHG is the organisation responsible for Flood Forecasting in the Swiss parts of river Rhine and operational hydrological forecasts have long since been calculated for several points in the Swiss part of the river Rhine, among them the main point at Rheinfelden. Interested parties are e.g. river navigation authorities, Hydropower companies and Rescue Services.

The flooding problem in wintertime is most acute during warm fronts with rain falling on snow. Normally only minor flooding problems occur during ordinary springtime snowmelt conditions. There may be extreme, however local, flooding in all seasons as a result of heavy rainfall. The most dangerous floods occur in small and fast responding rivers originating at medium and high altitude.

Despite some troublesome drawbacks in the existing forecasting system at LHG, several of the functions and scientific methods are considered to be valuable and established and should, if feasible, be included in the new system to be developed. Examples of such functions are the interpolation (Kriging) of input data, the general methods for data validation and completion, the Swiss-specific snow melt modelling in HBV and the possibilities to simulate lake management.

4.2.2 Input data

Meteorological data is collected by SMA every 10 minutes from 80 fully automatic meteorological stations, the ANETZ stations. Hourly data (precipitation, temperature, wind-speed and water vapour pressure) are sent via FTP to the central FTP-server of the Swiss administration.

Acquisition of information from about 160 automatic hydrological stations operated by LHG is done by an Automatic Data Acquisition System (MAC-server). The data are stored to the MAC-server, and are can be accessed from different user applications at LHG, such as the forecasting system. Some 40 of these stations are used in the existing hydrological model.

The meteorological data from the central FTP-server are retrieved automatically several times a day with an automatic UNIX-script. Normally hydrological data retrieval from the MAC-data acquisition systems takes place once a day. This is done by an automatic procedure based on a UNIX-script, which uses order-files to retrieve the input data from the regular data acquisition systems. A robust and sophisticated data analysing procedure then follows to prepare the data for the calculations. The input data are thoroughly checked using statistical rules regarding the input-data. Data are interpolated in space and time using a version of the optimal interpolation method. The result is a 2D grid for precipitation and a 3D grid for temperature from which the values are averaged for each sub-basin. The existing system offers very limited possibilities for the user to display and review the input data, e.g. as tables or graphs, before the forecasts are calculated.

For every hour the raw (not yet checked and validated) data are stored in separate folder for every station and calendar day. An almost identical/parallel set of information is built for the checked data, only difference is that for each hour values for all station are stored. Measured values that are processed are temperature, precipitation, wind, and humidity, however wind and humidity information is not used at the moment.

4.2.3 Hydrological Modelling

The current hydrological model covers the middle and lower parts of the river Rhine catchment, downstream of the larger lakes. Most of the lakes are regulated although Bodensee and Walensee are not influenced by regulations. Also the inflows to the larger lakes should be modelled in the new system. In order to allow HBV-simulation of the tributaries originating in Austria and Germany it must also be possible to import the data from Germany (Karlsruhe forecasting office) and Austria that are needed. The alpine reservoirs are mainly of interest during low flow situations.

The map "Swiss Run off Forecasting Basin" shows the LHG first choice of hydrological forecasting points as green dots. There may be a need for additional sub-division, in order not to use very large basins and in order to create the reservoir outlet points in the model.

4.2.4 Forecasts and Forecasting

Every twelve hours LHG receives a two-day meteorological forecast (Swiss model) on hourly basis from SMA. Additionally, once a day the 5-day-forecast (Europe model) is received, which is used for the third forecasting day or in case the Swiss model results are missing. The meteorological forecast is interpolated in way similar to the one described above, but starting from the grid (14 km * 14 km) of the meteorological model instead of station data.

Hydrological forecasts are made at one-hour timestep three days ahead for the discharge at all measuring points, and for water-levels at a chosen number of points. The model is run every working day except in flooding situations when forecasts are made several times a day, as such situations last only a few days. Starting-values (state conditions) are saved for approximately one month.

4.2.5 Hardware

The current system runs on a SUN workstation with mirrored backup hard disc. Computer time needed to produce a forecast is approximately 20 minutes. One major drawback is the lack of support from the computer department at LHG.

5 Functionality and layout of the future FEWS system

From the discussions with LHG and RIZA a clear picture has arisen about the required functionality of the two organisations for two new, flood forecasting systems. The required functionality was illustrated in the form of a demonstration program during the workshop. The details of that picture are presented in this chapter.

5.1 Identification of user requirements

5.1.1 General

The detailed user requirements were identified during the meetings with LHG and RIZA and have been discussed in detail during the common workshop. The resulting list of the requirements was sent around after the workshop and reviewed and returned by LHG and RIZA. This reviewed detailed list of requirements has been added as appendix A. We describe these wishes in detail, as we strongly believe that this is the best way to clearly define the requirements the new system will have to meet

From the comparison of the lists of requirements from both RIZA and LHG, it is clear that most requirements are very similar and that differences mainly have to do with the differences in hydrology and some organisational aspects.

In the next lines the general requirements are briefly described. There are six categories of requirements:

- *Daily routine:*
  The new systems should help LHG and RIZA in their daily forecasting routine, which means that learning and understanding the system should not take too much effort. The systems should as far as practically possible, protect the user against making mistakes. A user manual and/or on-line help should give easy guidance to the user. Also, the time it takes to make a prediction must be within certain limits.
- *Hydrology:*
  The new systems should of course adequately describe the hydrology of the Rhine basin in Switzerland and the downstream Rhine basin between Maxau and Lobith in Germany, including it's tributaries. In both cases there is the need to come from meteorological predictions to predictions of the water levels by interpolation techniques and hydrological modelling. With respect to this, extra functionality in pre-processing procedures (data checks, interpolation, data editing) may be needed in the case of RIZA as the amount of input data needed to make a forecast will increase significantly.
- *Catering to clients:*
  Both organisations have external clients that have particular needs for the forecasting results. For RIZA the situation is simple: all clients get the same type of

report. LHG on the other hand need to produce several types of reports, (e.g. printed documents, pdf-files, ascii-files), adapted to the clients' purposes, also depending on forecasted runoff for a different number of stations.
In any case, due attention should be paid to the possibility of using Internet as a medium for disseminating the reports, even though there is no direct need to implement such a facility.

- *Robustness*
  When the available measured data and the various meteorological and hydrological forecasts have been imported, the systems will have to check both *completeness* and *quality* of the data. The systems should warn the user when data are missing or are out of range. The user should be allowed to fill in any gaps that may arise or to instruct the system to do this automatically, because the systems must work at all times, even when the data are faulty or missing altogether. This requires a series of checking algorithms and interpolation or estimation techniques. Both LHG and RIZA put great emphasis on the ability to *visualise* the incoming data as well as the results of these pre-processing steps before they are used in the hydrological calculations.
  In conjunction to this, *hindcasts and alternative predictions* must be possible, if the need should be.
  Fall back procedures must be defined that take over if the meteorological or hydrological input data fail to arrive.
- *Transparency*
  As the workflow involves a fairly large number of steps that each transforms the data, it is of utmost importance that the user is able to get insight in the processes. This is achieved by:
  1. Clearly defining the different procedures needed to arrive at the final forecast
  2. Obliging the user to carry out these procedures in a fixed succession.
  3. Making the process and especially the results *visible.*

  The user should be able to trace the origin of the intermediate results, should be able to *understand* and perhaps influence the transformations, for instance by setting different maximum levels for a parameter or overriding the decision of the system to accept or reject certain data.
  The systems should keep track of the quality (performance) of the hydrological forecasts.
- *Extensibility*
  Whereas transparency applies to the systems in their "present" state, extensibility applies to the ease with which new sources of information or new techniques, such as radar observations or new meteorological models can be incorporated. It also applies to tasks of rearranging the sub-basins, adding a monitoring station and so on. The systems documentation must indicate the procedures for such changes and at least for the simpler ones the expert-user should be able to do this him or herself.
- *Maintenance*
  The systems must be an integral part of the computer infrastructure of LHG and RIZA. This limits the choices for the operating system and possibly third-party software, but also necessitates mobilising the computer departments. They will also be responsible for back-up and restore procedures.

The most important overall requirements are that the system is fast and robust and that at all times the user is *in control.*

5.2 Summary of important decisions

During the final workshop at which the user requirements were presented, several decisions were made that will influence the implementation of the future system:

- *Changes to HBV snow melt routines*
  It was recognised that some changes should be made to the standard HBV/IHMS model to incorporate the treatment of snow melt as is done in the current Swiss system.

- *Timestep of one hour*
  In stead of the timestep of one day normally used in the HBV/IHMS, the HBV model in the future system will use a timestep of one hour. Due to the timescale of flooding in Switzerland (it only takes several hours for the rainwater to reach the main rivers in critical situation) it is necessary to have the same high time resolution as in the present system. For the rest of the Rhine basin, this might be less critical, but a uniform timestep makes the system easier to build, use and maintain.

- *Extension of the hydraulic model up to Maxau*
  The hydraulic model Sobek that is used in the FloRIJN system runs from Andernach to the Dutch coast. To extend the lead-time to four days it is necessary to extend the model upstream to Maxau (this work is currently being carried out and will be completed by the end of 2000). The upstream boundary conditions can then be obtained from the water level *measurements* by the WSD in Mainz.

- *Treatment of the Mosel tributary and others*
  Just as it is the case now, the hydraulic model will *not* include the Mosel tributary in full nor several of the larger tributaries within Germany. The Mosel tributary will be modelled from Cochem to the junction with the main channel. All tributaries that are not explicitly modelled by SOBEK will be treated as boundary conditions: the flows will come from the HBV models for these upstream basins.

- *Role of the groundwater model*
  In the present FloRIJN system a groundwater model is used in conjunction with Sobek. At the workshop it was decided that the groundwater model would not be extended up to Maxau as will be the case for the hydraulic model. Recently, however, some questions have been raised about the accuracy of the present set-up in FloRIJN. There is some ongoing research to improve the situation and depending on the results, the groundwater model may be extended after all or the period over which the model is run will be extended.

- *Storage procedures*
  All participants of the workshop agreed that proper storage procedures are important for hindcasts. The details of these procedures however were less evident. Should one store *all* incoming data, the *corrected* data and the *results* of the forecasts at all stages? What amounts of storage will be involved? Is it necessary to store a copy of the *system's parameters* along with it, so that in the event of changes to the system (either updates of the software or updates in the calibration parameters) one could always go back and redo the calculations? For what period of time should the data be held? Should one be selective about it or simply make back-ups routinely?
  The following principal decisions were made:
  — It is not necessary to store the system's parameters along with the calculation, as long as a unique version number is stored with each calculation. This simplifies the back-up procedure.
  — Unless the analyses would reveal that there is too much data to be stored, each forecast together with its input will be stored for a certain period of time. No attempt will be made to only store the forecasts during "interesting" situations.
  The procedure for storing the data for later retrieval still has to be described in detail and some strategic decisions still need to be made. To aid the discussion, however, the next chapter contains an estimate of the amount of data involved.

The system should be open to possibilities of additional weather forecasts, such as ensemble technique forecasts or forecasts made using alternative methods, e.g. short term forecasts based on weather radar information.

5.3 Layout of the system

The explicit wish of both LHG and RIZA to have a forecasting system in which the user is in control at every moment is best satisfied when the system is process-based, that is, the procedure of making a forecast from the imported measurements and weather forecasts is presented by separate steps. The user then moves from one step to the next, each time approving the intermediate results.

The demonstration version that was prepared for the workshop is based on the same principle (*cf.* Appendix C). The schematic representation from this demo has been refined somewhat by making a few tasks more explicit (see Figure 5.1). The tasks in the diagram are described further in Appendix B, here we give a summary:

Task	Results
Import data	Set of raw input data (measurements and weather forecast)
Pre-processing	Set of validated input data
Interpolation	Set of input files, ready for hydrological calculations
Lake management	Actual operation of the lakes and reservoirs
Calculate current discharges and water levels	Simulated present and last x-days water levels and discharges from results for the period up to the present.
Update the models	Updated model input (initial conditions and inputs), ready for actual hydrological and hydraulic forecast calculations
Predict water levels and discharges for next few days	Forecasted water levels and discharges
Formulate alternatives	Alternative input data, for alternative forecasts
Prepare reports	Report ready for distribution to clients.

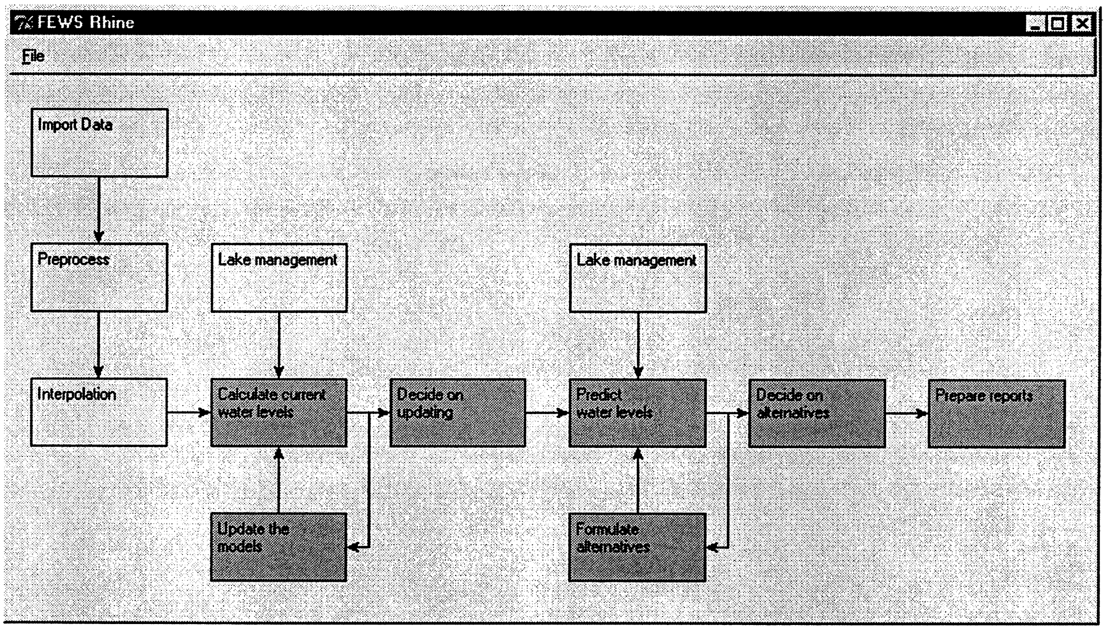

Figure 5.1 - Framework of tasks within the future system

5.4 Presenting the input and output

A major issue regarding the new forecasting systems will be to adequately present the input and output data. As long as the input data for a particular station are to be visualised, a tabular display of the actual data or a graph of the input over time will suffice. However, the present Swiss system already comprises in the order of one hundred stations, and it is likely that the number of stations will increase significantly for the Dutch system when the FloRIJN system has been extended to Maxau and covers a large part of Germany. This includes both real stations (hydrological, discharge/water level, as well as meteorological with several variables, temperature and precipitation among others) and virtual stations that are used for calculated or forecasted averages for each sub-basin.

Visualising such an amount of data can only be done with a combination of methods: traditional graphs and tables for particular stations and an overview for the whole area (see figure 5.1). Depending on the type of data the following methods are proposed:

- *Meteorological input data:*
  As the parameters comprise temperature, precipitation, wind speed and humidity measured for one or more stations, one could show graphs but also a map indicating the initial meteorological situation as categories:
  — Dry, stable weather in *green*
  — Moderate precipitation in *yellow*
  — Heavy precipitation in *red*
  Other parameters include the accumulated precipitation or the snow cover.
  The map should actually be an "interactive" display, so that when you click on any sub-basin, you get to see the timeseries in detail as table or graph.
- *Hydrological input data:*
  The data associated with the hydrological stations are very similar in character to the meteorological measurements. In this case the overview could show a sort of *hydrological classification* per sub-basin, for example: the forecast for today combined with the latest available discharge measurements in order to give an indication of the current hydrological conditions.
- *Inspection of the data quality:*
  The results of the data checking procedures can be expressed in similar categories as the above. The map of these categories will give a quick indication of the relative number of gaps and spurious values in the input data.
- *Lake management data:*
  To obtain a quick overview of the lake management situation, one could map the remaining capacity (in cm) or the percentage of volume currently fixed. Together with an indication of the type of management rules (normal or flood rules - if one can speak of such rule sets), this would give a useful map to judge whether the capacity of the lakes is sufficient or not.
- *Weather forecast and satellite/radar images:*
  The vast amount of data coming from these sources makes it necessary to display them as a movie that is run continuously or stepwise. Alternatively one can sum the totals for next one, two or three and show these as numbers or isolines on a map.
- *Predicted water levels and discharges:*
  Again for obtaining an overview, the categorical colouring method can be employed. On the other hand, most clients want detailed reports for a limited number of stations and these reports will be the primary product that is to be dispatched.
- *Presentation of intermediate results:*
  Various types of intermediate data (the input data for the HBV model per sub-basin or the modelling results per sub-basin for instance) can be viewed in similar ways. The emphasis will be on displaying them by graphs. Clicking in the sub-basin on the map will then bring the corresponding graphs.

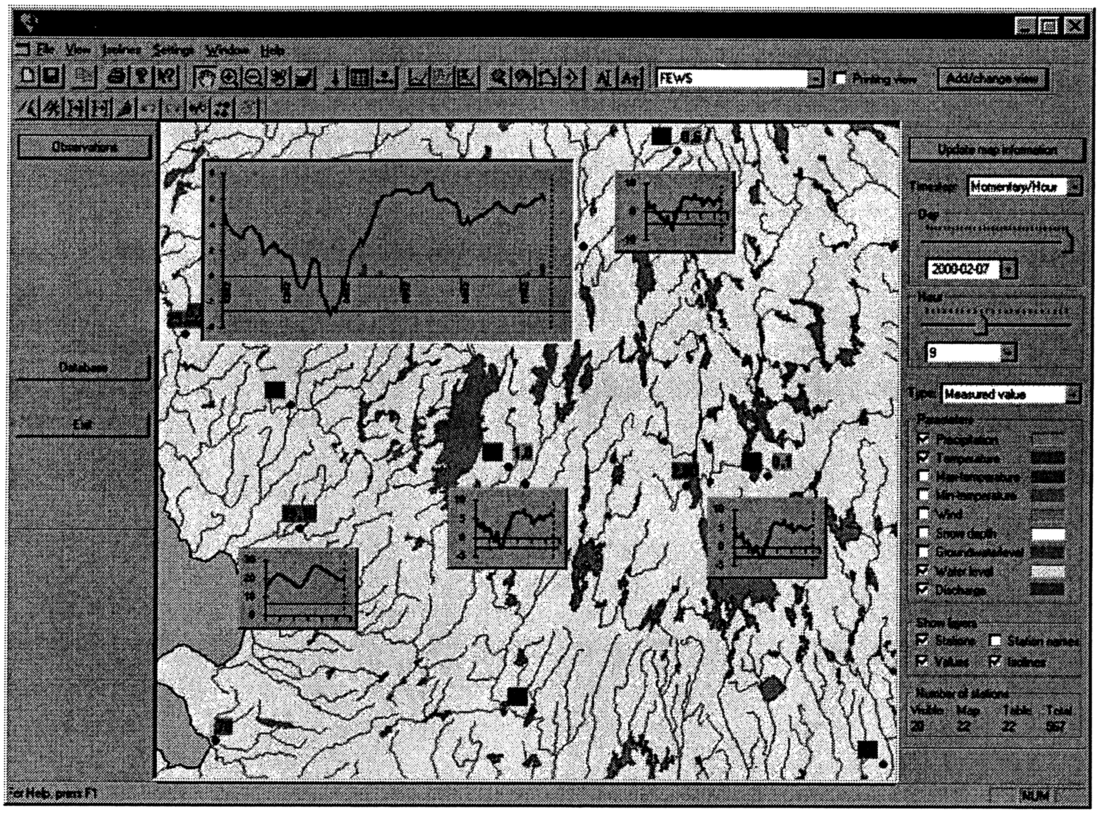

Figure 5.2 Preliminary design outline of Graphical User Interface for defining and changing lake & reservoir operation rules

6 Results of tests within the Definition Study

6.1 HBV-model

Within this Definition Study SMHI has made test-calibrations in two catchments in Switzerland, Sihl and Linth for which data and additional information have been furnished by LHG. Only limited time reserved for the tests, furthermore was the runoff to be simulated influenced by diversion of water to neighbouring catchment and short-term regulations. Consequently those preliminary calibration results have been far from satisfactory, nevertheless valuable experience in data handling, parameter assessment, etc., was gained.

SMHI has also made a test in order to investigate if the parameters derived from HBV-calibration of catchments in the German part of the Rhine, done by BfG, using a daily timestep could be used for simulations using a shorter (1 hour) time-step. For the Prims basin (727 km^2) encouraging results where obtained. The test showed that the only manual modification necessary to change from daily to hourly timestep was an adjustment of the Maxbas-parameter in the response routine in the model. It can therefore be concluded that the daily-timestep calibration already made for substantial part of the German part of the river Rhine can be used in the FEWS-Rhine without time-consuming re-calibration.

In order to illustrate the sensitivity of the hydrological model to different amounts of precipitation SMHI have made an analysis of the Rhine tributary Lippe (gauging station Schermbeck) during a flood event in 1993/94. An increase of the measured precipitation over a five-day period by a total of 40 mm gave as a result an increase in HBV-simulated discharge from 310 to 539 m^3/s. The 14 day history was approximately 100 mm of precipitation and measured total over the 5 days was approximately 44 mm. This clearly demonstrates the importance of reliable weather forecast for the accuracy of the hydrological forecasts.

6.2 SOBEK

Because of the discussion regarding the timestep (one hour, 6 hours or day) that should be used with the HBV model (given the response time of the Swiss hydrological system) we made some preliminary tests with a simple SOBEK schematisation to decide whether there would be significant influences of the time resolution used by the hydrological model.

It has been decided, that the HBV-model will be used with a one-hour timestep. The consequences for SOBEK will be evaluated in some detail at a later date. As the smaller timestep for the hydrological forcing means that the hydraulic model is fed more detailed information, it can be expected to lead to some improvement in the hydraulic forecasts.

6.3 Estimate of storage requirements

To try to estimate the amount of data involved in a single forecast (both input and output), we assume that the current Swiss system has a similar size. The table below summarises the most important figures (it has been assumed that all data are provided for a period of 48 hours at hourly intervals, when such information was not readily available).

Input data	*Number of stations/grid data*	*Number of parameters*	*Number of timesteps*
Meteorological stations (hourly data for precipitation, temperature, wind speed and humidity)	80	4	48
Hydrological stations (hourly data of water level and calculated flow rate)	40	2	48
Temperature forecasts (SM, 48h, 20x29 grid; EM120h, 5x8 grid)	580 40	1	2x48 1x120
Precipitation forecast (Swiss model, 48h, 20x29 grid; European model, 120h, 5x8 grid)	580 40	1 1	2x48 1x120

Output data	*Number of stations/grid data*	*Number of parameters*	*Number of timesteps*
Results from HBV sub-models (for each sub-basin)[2]	order of 60	10	72
Downstream monitoring stations (output of model)	order of 100	2	72

When these numbers at least indicate the order of magnitude, the single major contribution comes from the meteorological forecasts (which are delivered twice a day). Roughly three thousand numbers are involved per timestep (50% of which come from the meteorological forecast). The total number of data per forecast amounts to 200 thousand.

In this figure we have not included the intermediate results from the interpolation procedures nor the checked and corrected version of the input data. This would approximately lead to a multiplication by three.

[2] *In this estimate, the results from the HBV models which take variables like snow, sun, moisture, etc. The number is estimated to be 10.*

To summarise:

- Per forecast the original input and final output results will comprise of approximately 200,000 numbers.
- The full set of data, including the intermediate results, would comprise approximately 0.6 Million numbers.

When we compare this to the - nowadays - ordinary disk size of 4 GB for a hard disk or 600 MB of storage on a CD-ROM, we get the following estimates for the calendar period that can be stored in each combination (assuming an average of less than 1.3 forecasts a day):

Storage medium	*Minimum amount of data*	*Maximum amount of data*
CD-ROM (600 MB)	1.5 years	half a year
4 GB hard disk	ten years	at least three years

These estimates indicate that the storage requirements are not exceptionally large and that the envisaged scheme of *storing all forecasts* does not burden the back-up system extraordinarily.

7 Required amendments to the HBV/IHMS-model

7.1 General

The following sections describes the amendments to the existing HBV/IHMS-model needed to fulfil the requirements for hydrological modelling in the Swiss part of the river Rhine (and other alpine condition rivers). Some test calibration has been accomplished during the Definition Study to gather experience from calibration the HBV/IHMS-model in alpine rivers. However there has been little opportunity to test, in a scientific way, which of the routines in the HBV model, i.e. the snow routine in HBV-ETH that is needed to arrive at a satisfactory forecasting performance. The decisions concerning amendments of the hydrological model are therefore based on discussions, LHG experience and reports describing the development of the presently used HBV-ETH model.

To ensure a trouble-free adaptation of the calibration already made by BfG for significant parts of the Rhine tributaries in Germany, amendments will be made to the HBV/IHMS software in order to make model parameters, for the most part, independent of the timestep used. This may also facilitate the calibration of the HBV/IHMS version in Switzerland as initial calibration can be made using a daily timestep, while fine-tuning is done on an hourly timestep.

7.2 Additional input data, alteration of data handling

The standard HBV/IHMS reads input timeseries (temperature and precipitation) from the binary-file PTQW. Modifications needed to allow the model to handle wind speed and humidity as input data are considered relatively small as some preparations has been within recent R&D projects.

The handling of input data for the HBV model has to be modified in several ways compared to the presently used standard procedures. As temperature inversions are quite frequent in the Alps, especially during wintertime, the traditional temperature lapse rate approach is not sufficient. Temperature should therefore be considered as elevation dependent, and one value computed for each elevation zone in each sub-basin. This task will be accomplished within the interpolation module and the output should then be read by the HBV-model. This implies the need for modification in the routines for handling sub-basin and elevation zone meteorological data (measured as well s forecasted) instead of station data. Among other changes probably required the need to handle hourly-value time-series longer than 3.5 years can be pointed out.

7.3 Snowmelt calculations

In order to arrive at best possible snow melt calculations in the middle elevation range of the Alps it is, as earlier mentioned, considered necessary to use a more sophisticated modelling of the snowmelt than the standard day-degree method in HBV/IHMS. The model to be included in the FEWS-Rhine shall utilise the snow routine developed in Switzerland, and take into consideration not only temperature, but also wind and humidity. Furthermore shall the approach of a day-degree factor varying over the season be used. Details regarding the specific Swiss-ETH snowmelt computations are described in the report by Braun (ref. 2).

As concern interpolation of wind, Jensen (ref. 3) has found no correlation. For the humidity no significant correlation can be expected nor has been found. It's probably better to calculate relative humidity from Water Vapour Pressure, make the interpolation using the relative humidity, and then convert back to Water Vapour Pressure. In situations when the influence from wind is important - wind is blowing in wide areas - wind-data should be taken in a general way, and not as exact values for the individual stations. A rather simple interpolation method is probably good enough for those values, on the other hand it's an advantage if all values are treated the same way in the pre-processing module.

7.4 Handling of reservoirs

The standard SMHI HBV model routes generated runoff along a river by combining e.g. Muskingum routing with an additional lag-function. Routing through unmanaged lakes is done by level-pole routing. In case of regulated reservoirs or lakes, reservoir operation strategies in very complex systems of reservoirs can be taken into account.

For the future FEWS-Rhine the larger managed lakes and important reservoirs shall be modelled, reservoirs either separately or lumped together. Based on the established management rules the standard reservoir operation rules will be implemented in the "regulation tables". Also important diversions from one sub-basin to another will be taken into account.

For occasions where special circumstances calls for application of non-standard operations there will be a possibility to manually enter data on expected reservoir outflow during a forecast. For reservoirs and regulated lakes this manually estimated forecast must be entered for 3 days ahead and 24 values per day. This temporary information will then be used instead of the outlet discharge computed from the predefined rules.

It will be possible to utilise recorded streamflow as input to the next sub-basin as long as such data are available. During a forecast the system shall have the capability to switch from observed discharge/streamflow to simulated when no discharge data are available.

To facilitate the calibration and forecasting in those Swiss sub-basins that are influenced by short-term regulation in hydropower plants it is planned to use synthetic time-series with an hourly variation over the working day in the range from 0 to turbining capacity (TC). If necessary, this time-series will then be added to, or subtracted from, the observed hydrograph to compensate for the man-made fluctuations caused by peak power generation.

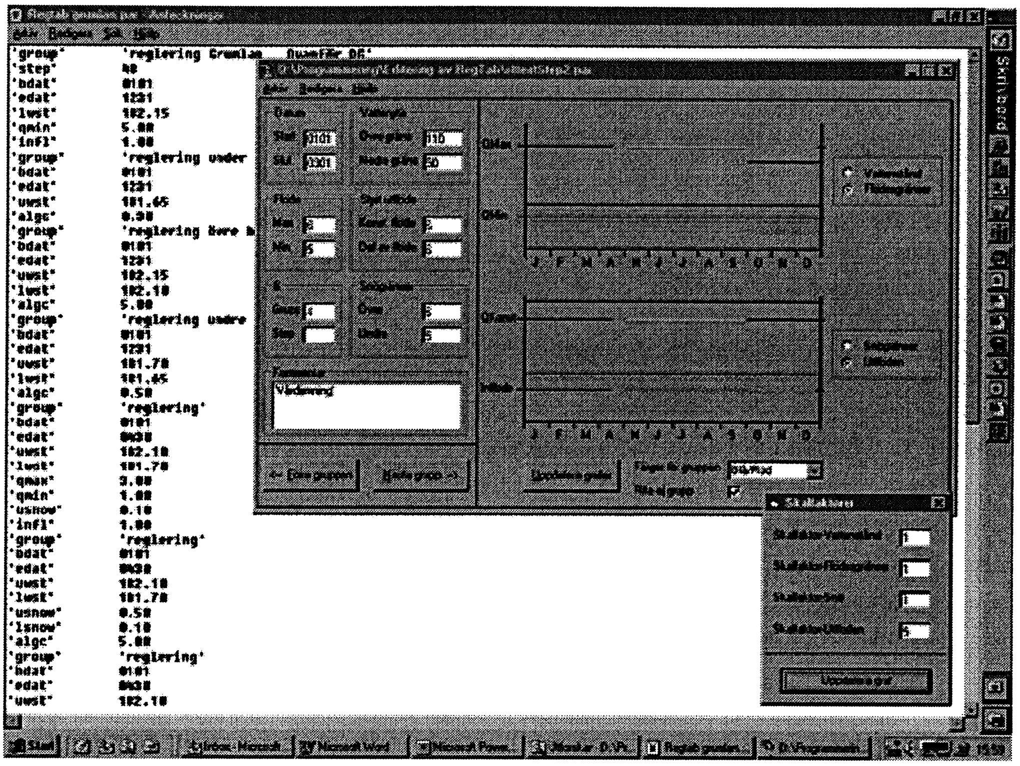

Figure7.4 Preliminary design outline of Graphical User Interface for defining and changing lake & reservoir operation rules

7.5 Updating procedures

Today's HBV/IHMS uses the method of updating the input (e.g. increase temperature, decrease precipitation) for the last few timesteps to make the simulated hydrograph fit with the measured values (also referred to as updating the hydrograph). The updating is guided by a number of business-rules, e.g. if snow is available; start by changing the temperature or maximum increase of precipitation is 2 mm per day.

As a result of discussions within the project, especially at the workshop in Delft, it has been decided to use a combination of updating of the simulated hydrograph after comparison with the measured values and an uncomplicated version of auto-regressive updating of the forecast (LHG presently uses an auto-regressive method). The system will also be capable of giving the user a warning when the updating method does not do a good job. This method will be developed and implemented for both the Swiss FEWS-Rhine and the HBV-modelling input to the hydrodynamic model in the RIZA FEWS-Rhine. The only difference may be the choice of rules to govern updating of the hydrograph.

7.6 The user interface

In order to make the new system user-friendlier and also to obtain a similar look and feel within the different modules in the FEWS-Rhine some amendments to the existing HBV/IHMS user interface are needed. It is foreseen that for the daily forecasting routine the FEWS-RHINE GUI will be used. However when a user wants to use specific procedures necessary for the HBV-model, use will be made of the HBV-IHMS. This refers primarily to the parts of the GUI that govern the input of reservoir operation rules and the defining of updating procedures in single sub-catchments. Obviously calibration and validation procedures of the HBV model, to be carried out before implementing the FEWS-RHINE system, will make use the HBV-IHMS environment as well.

8 Required adaptations

The forecasting systems, the Swiss part of the Rhine basin and the German and Dutch parts, are very much alike even though significant differences exist in the hydrology of the two regions. These differences may not influence the architecture of the system, however, they do have consequences. It is the purpose of this chapter to indicate these consequences.

There are roughly three categories in which the systems differ for each client:

- Data collection and pre-processing
- Model calculations
- Reporting

The aim is to clarify the *character* of the difference and the way we can solve them without creating two separate systems. This is important from the points of view of development and maintenance:

- *Development:*
  If certain components of the system need to exist in different versions, then the development of these components takes more time than when only one is necessary.
- *Maintenance:*
  Having several versions of components within the system makes the correction of errors or extensions to the system much more expensive - probably at least two programs will have to adapted, instead of just one.

8.1 Adaptations in data collection and pre-processing

The most obvious source of differences will be the *format* in which the data are delivered by the various meteorological and hydrological services. The system will have to cope with such differences, but once the data have been read, they can be stored in a unified format that is independent of the input sources.

(It is more worrisome that these formats may change from time to time. That means that the import procedure must be flexible enough to deal with fairly disparate formats, for example the line at which the data begin may vary because the header lines are not always the same. This situation, however, can probably be ameliorated by employing scripting languages like Perl or Tcl that are capable of dealing with such input.)

As for a second source of differences, the *business rules* for checking the data quality that apply to the two groups will be different. As long as the business rules can be fully *parameterised* and therefore can be read from a configuration file, there is no need to have different *executable programs* that do the checks.

In the current Swiss system, a 3D Kriging interpolation method is used to get spatially continuous temperature data. For several other parameters a 2D method is used. The use of this Kriging interpolation need not be limited to the Swiss part of the system: the method may well be employed for the German and Dutch region as well. The main qualitative difference would be that in the latter region, the vertical variation of temperature is not that important, because the area has much smaller differences in height.

There are of course some quantitative differences as well, but they will most probably be different weighing coefficients, they will not mean a fundamentally different interpolation formula.

8.2 Adaptations for model calculations

In the current Swiss system only the hydrological model HBV is used and a routing procedure to interconnect the various sub-basins, whereas in FloRIJN a simple precipitation-runoff model, a groundwater model and the hydraulic model SOBEK are used. These apparently different approaches do not lead to significant differences in this new system however:

- For the Swiss part the routing procedures are quite sufficient
- For the Dutch and German part the routing procedures are effectively replaced by the groundwater model and the SOBEK model.
- These different set-ups can be arranged by using a different sequence of processes, as all are separate programs.

The only important difference is that the set of input files that needs to be prepared differs, but this is a matter of different *data*, not of different *versions of programs*.

8.3 Adaptations for reporting

Finally, the reporting facilities that are requested by the two principals differ. The LHG have a need for customised reports, as each client have their own wishes, whereas RIZA have opted for a single standard report that will be sent to each client.

The fact that the LHG requires a flexible reporting facility, means that the facility must be able to make all kinds of reports; the standard report required by RIZA is just one possibility. RIZA will therefore also get a flexible facility whose features will not be used to the full, but this will not be noticeable to RIZA (for example, it will simply offer but one layout, instead of several).

9 Time schedule for development and implementation

9.1 Time schedule

The following table shows a tentative time schedule with starting date, end date and duration of the main activities necessary to implement the two FEWS systems at RIZA and LHG respectively. The duration of tasks refers to the period the activity lasts and not necessarily to the required person-days to carry out the task.

This table assumes a starting date in June 2000. The schedule is very tight when we want to meet the end date of the project in December 2001. One of the main constraints is the collection by the BfG of the database on hourly values needed to model the German sub-basins. This database should be completed rather soon as the modelling of the German sub-basins is expected to take a lot of time. To meet a timely installation of the first version of the FEWS, the modelling activities should be finished not later than March/April, 2001.

Activity	start-date	end-date
Detailed functional design	june-00	july-00
Progress meetings	july-00	october-01
Development UI	october-00	september-01
Data entry procedures	september-00	november-00
Validation and editing procedures	october-00	november-00
Interpolation procedures	august-00	november-00
Database development for cal/val HBV in Germany	september-00	october-00
Updating procedures	september-00	december-00
Adaptation HBV	september-00	december-00
Hydrological modelling Germany	october-00	march-01
Hydrological modelling Switzerland	october-00	april-01
Link HBV-SOBEK	january-01	january-01
Hydraulic modelling	july-00	january-01
Presentation procedures	october-00	february-01
Installation FEWS, including training and delivery of documentation	september-01	january-01

9.2 HBV calibration

The consultants would like to point out that this section should be regarded as preliminary suggestions. The amount and planning of work as described below will affect the time-schedule for development and implementation of the FEWS-Rhine project.

9.2.1 Calibration of HBV for RIZA/Germany and Holland, suggested working approach

Preparations for using a combination of a recently developed rain-fall runoff generator and hydrological modelling simulation as a basis for statistical estimation of design flow in the river Rhine has been initiated by RIZA. On behalf of RIZA, BfG/Koblenz have carried through a calibration of the HBV/IHMS model for a major part of the river Rhine in Germany. Altogether some 92000 km^2 have been calibrated, in most cases down to and including the main discharge station in each important tributary. The meteorological input used for the calibration (daily timestep) was precipitation and temperature calculated as average per sub-basin. The work accomplished by BfG is based on the period 1976-1995 for calibration and verification. The work is described in Ref. 8. It includes a description of the performance criteria used to evaluate the result. Established target criteria were met in most of the catchments, only in a few sub-basins affected by regulations or other unusual conditions/circumstances results were below expectations. The calibration covers approximately 55 basins.

In order to arrive at a complete hydrological model for the Rhine downstream of Maxau, calibration and verification for the remaining part of the tributaries, and the relatively small intermediate sub-basing along the main reach of the river must be completed. It's estimated that some 15 new sub-basins have to be calibrated due the need to complete the hydrological model.

We suggest that work needed is planned and carried through according to the following tentative guidelines:
To begin with the earlier calibration made by BfG shall be checked, and possibly adjusted, especially shall simulation of high peaks be checked. Furthermore shall simulation of the period from 1995 and onwards be completed in order to get a continuous data record in the FEWS-Rhine.

It would probably be advantageous if the HBV-calibration for new system could cover a historical record as long as possible. However have test within the Definition study shown that it's possible to use parameter-sets established as a result of the calibration already made. The period for which an hourly timestep database must be built, and model calibration and validation must be made, can therefore be reduced.

Consequently it is suggested to use the historical period used for calibration to app 5-8 years, e.g. starting from a date prior to the flooding in 1993-94 (or prior to the 1995 flood). As an hourly time-step will be used, sufficient number of flood events will be included in the calibration period, furthermore will the major flooding events in the mid 90ies be used. Tentatively the years 1993-98 will be used for calibration and the remaining period for validation. The final decision about length of calibration and verification periods can be taken during the project inception phase.

As the time and resources needed to establish the hourly value database may be afflicted with restrictions, it's important to start this work as soon as possible. The geographical information needed (land-use, area per elevation zone etc) will be possible to derive from existing GIS databases in Germany (BfG planned to be responsible for this work) and (if needed) from similar sources in the Netherlands. Should any problems occur, related to for example expected inhomogeneity in timeseries, e.g. due to the shift from data for individual stations to basin averages, the adjustment of model calibration shall be done in connection with the adjustment for change of timestep (and model version used).

It is planned that BfG in Koblenz shall accomplish a substantial part of the tasks related to the continued calibration of the hydrological model for the RIZA FEWS-Rhine. Despite the fact that BfG staff are experienced HBV users, additional support from SMHI to calibration/validation, linking of sub-catchments etc is considered necessary to secure work progress in terms of results and project time-schedule limitations.

9.2.2 Calibration of HBV for LHG/Switzerland, suggested working approach

For the Swiss FEWS-Rhine it's suggested to use existing, checked data, the meteorological as well as the hydrological time-series as input. These shall be retrieved from the standard national databases at SMA and LHG respectively.

For the planned new system it would probably be advantageous if the database to be built consists of a historical record period as long as possible, as this would enable model validation and flood event evaluation over a long period. However the major cause for development of the new system is the need for an up-to date, easy maintainable operational forecasting system. Therefore it is suggested to limit the length of the historical period used for calibration to app 5-8 years, e.g. starting from 1995. This will reduce the effort needed to build the database as well as the time needed for calibration and validation of the hydrological model. As an hourly time-step will be used, sufficient number of flood events will be included in the calibration period, furthermore will the major flooding events in May 1999 be used. Tentatively the years 1995-1999 will be used for calibration and the remaining period for validation.

It can be expected that this process of setting up and calibrating the hydrological model will be facilitated using experience and knowledge from the existing system (such as the existing parameter sets for the existing sub-basins). The existing system at LHG includes some 55 basins already calibrated with old model. It is estimated that approximately 15-20 new sub-basins has to be set-up and calibrated due to a need for finer spatial resolution, extension of the modelled area, implementation of lakes and reservoirs etc

The work shall start off with defining the hydrological schematisation with respect to existing sub-division, foreseen changes in location of discharge measurement stations and the need to simulate the lake and reservoir outflow and variations due to short-term regulation in run-off the river hydropower plants etc. After an initial HBV/IHMS course and on the job-training it's expected that LHG can carry trough a substantial part of the model set-up, especially establishing the initial basin-information and parameter files for each sub-basin. The main part of the geographical information needed could, as already shown during tests in connection with the Definition study, be retrieved from the GIS database at LHG.

9.3 Training

For training of the operational use of the systems two levels are recommended (additional training for set-up and calibration of the hydrological model is needed if clients shall take in the hydrological development phase).

The basic level

This is meant for those who use the systems only for their forecasting routine. They should be trained how to start their system, look into and interpret the (intermediate) results, how to make use of scenarios, update procedures and how to collect the final results from the system. Required knowledge includes basic Microsoft-Windows experience (Windows95, Windows98 or Windows-NT) and knowledge about the common flood forecasting procedures at RIZA or LHG. As both systems should be easy to handle, the length of the training is a few days. The training will be provided when the first version of the systems will be installed at LHG and RIZA.

The advanced level

This level is for those who use their system not only for the daily forecasting routine but also to analyse previous forecasts (Hindcasts) and those who are permitted to adapt the system (e.g. by adding an extra meteorological or gauging station). With respect to the last comment, the exact adaptations that advanced-level users are allowed to make should be defined during the implementation phase. In addition to the basic level, these advanced users should learn about the structure of the particular system and the way data are handled before they are used in the models, (e.g. data base structure, sequence of procedures, knowledge about the interpolation procedures). We would also recommend that the training includes basic knowledge about the models HBV and (in case of RIZA) Sobek. Previous knowledge should be the basic level knowledge of either system and a fairly extended experience with flood forecasting. Some knowledge about computer programming could be useful. The length of the training could be 5-10 days or more, depending on the clients wishes to make adaptations. This advanced-level training can be provided after the final version of the systems is installed at the clients offices. It could be part of a service/maintenance contract.

9.4 Service and Support

As for training also for service and support two levels are recommended. The exact agreements on the contents of the respective support levels should be made during the implementation phase. The following brief descriptions are intended to illustrate the different levels.

Level 1 Maintenance of the systems for the daily routine.

The first level is to support the clients to do the daily routine forecasts. For routine questions this includes a quick and answering of questions by e-mail or telephone. The desired way for emergency support, e.g. when the system goes down, depends on the computer management rules of the different organisations. An option is an on-line service, which is only possible if the organisations allow others to use and change their computer systems. Another possibility is transferring (parts of) the system through FTP. If the problems cannot be solved by such actions, it also could include an agreement for support on sight within 24 hours. This type of service should be included during the first operational year of the systems. After the first year this could be organised in form of a service contract.

Level 2. Adaptations of the systems

Adaptations of the systems other than those that can be carried out by the users are not part of a service contract. When necessary these should be commissioned in a separate project.

10 Resources requirements

The planning of work and estimation of cost for development and implementation of the FEWS-Rhine hydrological forecasting systems described in this report (and the financial supplement) is based on the following prerequisites and assumptions:

10.1 Geographical information

For the Swiss system it has been concluded that the best way forward will be to retrieve the geographical information needed for all sub-basin from the existing GIS system information at LHG. For the not yet calibrated catchments upstream of the lakes at the verge of the Alps that will be included in the new system the geographical information must be compiled anyway, and in this way all information will be updated and homogenous. Calibration can to some extent be facilitated by means of using information about parameters values etc the existing system.

LHG are responsible for providing the information required.

10.2 HBV-calibration in Germany

For the German part of the river Rhine RIZA plans to enter into an agreement with BfG in Koblenz. A contract will define the need for time-series of daily/hourly meteorological data needed for calibration and model validation of sub-basins not yet calibrated as well as for the already calibrated sub-basins that will be modified for simulations using an hourly timestep. Furthermore will the support from BfG to the planned calibration work be defined.

The consultants expect that the input data compilation and calibration/modifications of the HBV/IHMS model for the German part of the river can be planned and accomplished according to a time-schedule for the FEWS-Rhine project to be specified in detail at a later stage.

10.3 Meteorological data and forecasts

For Switzerland the meteorological data and forecasts needed are well defined and already delivered to LHG on an operational basis. However, there is a need for additional data from Germany and Austria. SMA announced that the resolution (and hence format) of the meteorological model will change. For the future RIZA FEWS-Rhine data and forecasts from several counties must be furnished from a number of agencies and co-operation partners.

The consultants trust that all necessary agreements for co-operation concerning supply of data and forecasts will be the responsibility of RIZA. Furthermore, delivery of the information must start in due time, to allow establishment of the database, according to a time-schedule for the FEWS-Rhine project to be specified in detail at a later stage

11 Hardware and operating system

The implementation of the systems must be such that:

- The users work in an environment that is familiar to them and to their computer department (*cf.* user requirements 7.1, 7.9 and 7.12 in appendix A).
- Third-party software, of which GIS is an example (user requirement 7.6), agrees with this environment

Given these constraints and others the hardware on which the forecasting systems will run is a standard, moderately fast PC, running MS Windows NT 4.0 or Windows 95/98.

This PC will have to be connected to the appropriate network in order to receive the input data from the various sources. Apart from this it will not rely on anything else *during the forecast procedure*, such as central storage facilities and so on. The transfer of data to a central storage facility is done when the forecast has been completed, so that the data become available for others.

When the forecasting systems are updated or revised, the installation on the PC will be refreshed and duly logged.

This set-up enables the systems to meet all the requirements that are described under the section *Maintenance*, especially the requirement that the systems must be operational at all times: using a standard PC configuration and connections to central storage facilities that are needed only at designated times guarantees that in case of eventualities a back-up system can be used.

12 Estimation of time and cost (confidential)

An indicative estimate is available as a separate (confidential) attachment.

12.1 Risk handling

The consultants trust that all needed agreements for co-operation concerning supply of data and forecasts will be on the responsibility of RIZA and LHG. Furthermore the consultants expect that if the results of third parties are used, e.g. the work by the BfG, the supply of these results, in a form that can be accepted by the consultants, will be on the responsibility of RIZA and LHG. Also must delivery of the information start in due time to allow establishing of the database according to a time-schedule for the FEWS-Rhine project to be specified in detail at a later stage

A User requirements list

Introduction

This is a revised note produced in February 2000 that describes in detail the requirements and wishes of the LHG and RIZA with regard to the flood early warning systems for the Rhine (FEWS Rhine). It is based on the meetings that took place respectively in December 1999 in Berne and the meeting that took place in January 2000 in Arnhem and updated in accordance to the discussions between LHG, RIZA, BfG, SMHI and WL | Delft Hydraulics in the Workshop in Delft 14-15 February.

The purpose of detailing the requirements is that it become clear what the outline of the new systems should be, what information sources it should deal with, how it can be used to help the RIZA, LHG and their clients.

User requirements RIZA

The requirements and wishes can be divided into the following categories:

- *Daily routine:*
  The new system should support the workflow in such a way that the steps are clear to any one with a reasonable amount of training.
- *Hydrology:*
  The new system should adequately model the hydrological system of the Rhine basin. Proper attention must be given to the regulation of the lakes and reservoirs.
- *Catering to RIZA's clients:*
  RIZA have a number of external clients that are delivered standard reports. Currently there is no need to customise the reports.

- *Robustness:*
  The current system uses a variety of sources and algorithms to take care of any missing information. This capability should be present in the new system as well.
- *Transparency:*
  The current system, FloRIJN, allows the user to look at the incoming data, even allowing him to change the data, and to look at the various results. This "openness" should be maintained and, if possible, be further enhanced (the new, extended, system will import more data and will import them automatically).
- *Extensibility:*
  The system should be easy to adapt:
  — New insights in the hydrology of the Rhine basin (dividing sub-basins or joining them)
  — New sources of information (different monitoring stations, different sources of meteorological forecasts)
- *Maintenance:*
  The hardware on which the new system should run has to be properly maintained, as does the software. Incorporating this in the mainstream followed by Rijkswaterstaat as a whole is an essential condition.

Each of these categories is described in detail below. The tables have been adapted from the requirements document for the flood early warning system envisaged for the LHG. Empty records show those requirements from the LHG which have no match for the RIZA system and requirements marked with an asterisk (*) indicate which requirements are slightly different.

User requirements of LHG

The requirements and wishes can be divided into the following categories:

- *Daily routine:*
  The new system should support the workflow in such a way that the steps are clear to any one with a reasonable amount of training.
- *Hydrology:*
  The new system should adequately model the hydrological system of the Rhine basin. Proper attention must be given to the regulation of the lakes and reservoirs.

- *Catering to LHG's clients:*
  The LHG have a number of external clients that have specific needs. The system should be flexible enough to produce reports for them.

- *Robustness:*
  The current system uses a variety of sources and algorithms (hard and soft limits, maximum difference between adjacent data) to check the input data. This capability should be present in the new system as well.
- *Transparency:*
  An important and almost fatal shortcoming of the present system is the fact that nobody but the developer has insight in what is going on. For both every-day circumstances and post-mortem analyses it is vital that the steps taken by the system can be inspected. This puts a certain pressure on the "openness" of the system.
- *Extensibility:*
  The system should be easy to adapt:
  — New insights in the hydrology of the Rhine basin (dividing sub-basins or joining them)
  — New sources of information (usage of radar data for instance or the addition of monitoring stations)
- *Maintenance:*
  The hardware on which the new system should run has to be properly maintained, as does the software. Incorporating this in the maintenance of all computer systems at LHG would be beneficial.

Each of these categories is described in detail below.

Daily routine

The system will be used on a daily basis in normal circumstances, providing a report on the hydrology for RIZA's and LHG's clients and several times a day in potential flooding situations. The system will be used by trained personnel only, but the response time must be quick enough.

No.	User requirements RIZA	User requirements LHG
UR1.1	The user should be able to make a prediction within a reasonable[3] time, to cater for extreme conditions.	The user should be able to make a prediction within a reasonable[4] time, to cater for extreme conditions.
UR1.2	The user should be able to use the system when he or she has taken a reasonable amount of training.	The user should be able to use the system when he or she has taken a reasonable amount of training.
UR1.3	The system should support the user in a manner that he/she will make as little errors as possible.	The system should support the user in a manner that he/she will make as little errors as possible.
UR1.4	Importing the data from external sources should be automatic.	Importing the data from external sources should be automatic.
UR1.5	Examining the data should be possible, both if the data have a dubious quality and if the user simply wishes to see the data.	Examining the data should be possible, both if the data have a dubious quality and if the user simply wishes to see the data.
UR1.6	--	The user must be able to examine and change the management rules for the lakes and reservoirs.
UR1.7	It should be possible to compare the predictions with measurement data.	It should be possible to compare the last predictions (runoff/precipitation) with the actual and up-to-date measurement data.
UR1.8	The system should use measurement data whenever available.	The system should use measurement data whenever available.
UR1.9	The system should always be operational, that is, it may be necessary to use a mirrored system or two parallel systems.	The system should always be operational, that is, it may be necessary to use a mirrored system or two parallel systems.
UR1.10	The system must make predictions for the next four days. The extension of the system to forecasts up to 6 days should be easily possible and well documented (e.g. by using the existing forecast at Maxau).	The system must make predictions for the next three days.
UR1.11	--	The system should use the measurement data from all pre-defined hydrological stations.

[3] *RIZA have indicated that half an hour is a reasonable period. Much longer would be unacceptable. Aim is that the system should be ready to carry out 4 forecasts per day*
[4] *15-30 minutes, 1 forecasts per 2 hours should be possible.*

No.	User requirements RIZA	User requirements LHG
UR1.12	--	Skipped
UR1.13	--	The system should use the measurement data from all meteorological stations.
UR1.14	The system should use the forecasts from "a" meteorological service.	The system should use the forecasts from the Swiss meteorological service, as provided two times a day (for a two-day period). In the near future the frequency will be four times a day.
UR1.15	--	The system should use the forecasts from the European service for the third day (this has a different resolution though) and also if the Swiss forecast is not available
UR 1.16	The system should allow the following updating procedures If the measured and computed discharge differ: 1. The HBV sub-basins are updated by automatically varying the precipitation input until the error in discharge is smaller that a pre-defined limit. 2. The simulated forecast is then adjusted with 100% of the remaining error at t=0. This adjustment decreases gradually to 0% adjustment until t = x. At t = x, the forecast is equal to the simulated discharge. If, after step 1 and 2, SOBEK- simulated water levels in the main stream differ significantly from measured water levels the following updating should be possible: 3. The user is able to vary the lateral inflow to SOBEK by tuning the groundwater model in the same manner as in the current system.[5] 4. It should be possible to adapt the computations (which include the forecast period) to the measurements by shifting horizontally (in time) or vertically (in water level or flow rate).	The system should allow the following updating procedures If the measured and computed discharge differ: 1. The HBV sub-basins are updated by automatically varying the precipitation and/or temperature input until the error in discharge is smaller that a pre-defined limit. 2. The simulated forecast is then adjusted with 100% of the remaining error at t=0. This adjustment decreases gradually to 0% adjustment until t = x. At t = x, the forecast is equal to the simulated discharge. 3. Manual updating of computed discharge by changing precipitation and temperature should also be possible.
UR1.17	The system must predict water levels and flow rates for pre-defined stations, most importantly Lobith.	--
UR1.18	Skipped	--
UR1.19	The system should be able to retrieve all relevant measured data as well as weather forecast data from the BC2000 database system at RIZA's headquarter.	--

[5] *The current groundwater model apparently uses too short a history to give results that are accurate enough. Its role should be inspected more carefully.*

No.	User requirements RIZA	User requirements LHG
UR1.20	Automatic predictions are an attractive feature, but then proper logging must take place.	--
UR1.21	Data management should be kept roughly the way it is now, with edit, check, store and clean up procedures.	--
UR1.22	Skipped	--
UR 1.23	The multiple user problem should be taken care of	The multiple user problem should be taken care of
UR 1.24	The system should allow to view a film of the weather forecast and (interpolated) meteorological data.	The system should allow to view a film of the weather forecast. It should be possible to display it at any time during or after the forecast.
UR 1.25	--	The system should allow for an automatic start of the forecast. However, the user should always be forced to look at intermediate results (yet to be defined) before sending out a forecast report.
UR 1.26	Default is that all predictions are stored	Default is that all predictions are stored

Hydrology

It may seem obvious that the system has to adequately describe the hydrology of the Rhine basin, but there are a few details that need some care.

No.	User requirements RIZA	User requirements LHG
UR2.1	--	The system should take into account that the Bodensee and the Walensee are not managed.
UR2.2	--	The system should take into account that all other large lakes are managed. The precise rules vary and are only partially formalised.
UR2.3	--	The system should "know" that the three lakes Lac du Neufchatel, Bielersee and Murtensee are connected directly.
UR2.4	--	The inflow to the lakes should be modelled. (Now modelling starts at the outflow)

No.	User requirements RIZA	User requirements LHG
UR2.5	--	The HBV model[6] should properly take into account the snow melt, especially during rainfall.
UR2.6	--	The system should recognise the importance of the midland area in flood situations. In this area the system should be ready if the location of future operational hydrological stations is known.
UR2.7	--	The system should not incorporate a hydraulic model, as studies have shown that such an approach does not increase the accuracy of the results.[7]
UR2.8	--	It should be noted that measurements of snow depth are not used, because their reliability is not larger than the modelling values (the measurements are highly influenced by local circumstances and do not represent a regional average).
UR2.9	At regular intervals (but only during stable periods) the model state must be reset based on measurements.	At regular intervals (but only during stable periods) the model state must be reset based on measurements.
UR2.10	The discharge forecasts for the Ruhr from the Ruhrverband in Essen should be taken into account.	--
UR2.12	Default will be that HBV will make a forecast. This forecast will be replaced by the Ruhrverband for the first x hours when this Ruhrverband forecast is available.	--
UR2.12	Skipped	--
UR2.13	For the stretch Andernach-Lobith groundwater inflow must be taken care of in the proper way (that is, the groundwater sub-model of FloRIJN should be an integral part of the system). It remains to be seen if a groundwater sub-model should be applied for the stretch Maxau-Andernach or not.	--
UR2.14	The new system must be accurate enough in the prediction of the water levels during floods (cf. E. Sprokkereef and H. Buiteveld, personal communication, January 2000).	--
UR2.15	Use should be made of the experience of the BfG in the modelling of the hydrology of the Rhine basin (e.g. their HBV models).	--

[6] *We refer to the HBV model as currently used and maintained by SMHI. The specific changes that have been made by the ETH should be taken as guidelines rather than requirements.*
[7] *This refers to independent studies by Jensen and Electricité de France.*

No.	User requirements RIZA	User requirements LHG
UR2.16	The main input data to the model, the measured water levels and discharges at Maxau, will be delivered by the WSD in Mainz.	--
UR2.17	It will be possible to use the forecasts by the WSD as a back-up.	--
UR2.18	Meteorological forecasts for the relevant part of Germany should be retrieved (the form and frequency, for example gridded data instead of timeseries for individual stations, as well as the institution that will deliver them) still have to be determined).	--
UR2.19	Replace by UR2.27.	--
UR2.20	The results from the HBV models for the tributaries will be fed to the SOBEK model for the main river.	--
UR2.21	The system must be able to use the runoff from tributaries outside the modelled area which are retrieved from the respective forecasting centres.	--
UR2.22	Replaced by UR1.16	--
UR 2.23	The regulation rules of the retention basins should be put into the system	--
UR 2.24	--	The system should warn the user if the hydrological forecast is such that Q Murgental is expected to raise above 850 m3/s. Default in the system should be that the Murgentaler station has a Q-max of 850 m3/s. But it should still be possible to change Q-max manually if necessary (similar to the lake management).
UR 2.25	--	The system should be able to estimate the water level in the Bodensee
UR 2.26		The system must be able to deal with runoff from tributaries of the Swiss Rhine flowing from adjacent countries to Switzerland.
UR2.27	The timestep of the hydrological system will be one hour	The timestep of the system will be one hour

Catering to RIZA's and LHG's clients

RIZA currently have no special requirements regarding the support of their clients, in contrast to the LHG. Hence this table remains almost empty for the RIZA system.
LHG currently has the following clients:

- *River authorities in Basel*
- *Hydroelectric power plants on the river Rhine:*
  They use the information provided by the LHG for automatic operation up to certain run-off levels and planning the human resources from 12 hours t o two or three days in advance.
- *Local authorities:*
  Their concern is the protection against floods along the rivers Aare, Rhine and Thur.

No.	User requirements RIZA	User requirements LHG
UR3.1	--	The system should provide standard reports depending on the runoff conditions of yet-to-be-defined content (the current reports are adequate though and can be used as an example).
UR3.2	--	The system should provide at least some flexibility in making customised reports.
UR3.3	--	Skipped
UR3.4	--	Skipped
UR3.5	--	The system should predict the water stage at designated locations, e.g. along the rivers Aare, Rhine and Thur (Stage/discharge relations should be stored in the system).
UR3.6	--	Presenting the reports via Internet must be possible.
UR3.7	--	In future, external clients must be able to log in and get the reports themselves.
UR3.8	RIZA's clients do not need customised reports.	--
UR 3.9	The system should be able to send a report to RIZA's presentation tool in a yet to be defined lay-out	--
UR 3.10	The system should create a report in the same or similar lay-out as the current Vorhersage bulletin for the LHG system	--

Robustness

One very important aspect of the system is that in case one or more external sources fail to produce the required information, the system must still come up with predictions. If necessary the user must be able to provide missing information manually.

A related issue is that the data that are available often require some form of processing, like spatial interpolation, before they can be used in the predictions. The algorithms in the present system can be adopted or should at least be used as guidelines.[8]

No.	User requirements RIZA	User requirements LHG
UR4.1	The quality of the incoming data should be properly checked.	The quality of the incoming data should be properly checked.
UR4.2	It should be possible to change the data, if this is deemed necessary, for instance in case of outliners.	It should be possible to change the data, if this is deemed necessary, for instance in case of outliners.
UR4.3	--	The interpolation algorithm should take the effect of inversions into account, for example by using the current 3D Kriging method. This applies to temperature only.
UR4.4	The system must be capable of handling missing data within a timeseries.	The system must be capable of handling missing data within a timeseries.
UR4.5	The system must be capable of handling a missing station	The system must be capable of handling a missing station
UR4.6	The system must take care of the situation that all data are missing	The system must take care of the situation that all data are missing (within some reasonable limit)
UR4.7	It must be possible to analyse the input data for a prediction	It must be possible to analyse and visualise the input data before making a prediction or at any other time.
UR4.8	It must be possible to analyse the predictions after the fact: • All input and changes to the input must be preserved • The predictions must be preserved	It must be possible to analyse the predictions after the fact: • All input and changes to the input must be preserved • The predictions must be preserved
UR4.9	The user must be able to manually input meteorological forecasts, if the forecasts can not be obtained automatically.	The user must be able to manually input meteorological forecasts, if the forecasts can not be obtained automatically.
UR4.10	The current statistical model for water level forecasting should be useable with or within the new system	--

[8] *LHG have made clear that it is by no means necessary (or even desirable) to adopt parts of the source code of the present system.*

Transparency

The new system for RIZA will receive much more data than the current system and from quite different sources. This makes it necessary that all processing steps be clear and well documented and that it be possible to monitor the intermediate results.

Past experience has shown that from time to time problems within the LHG system occur and they must be solved as soon as possible. Therefore all processing steps must be clear and well documented and it should be possible to monitor the intermediate results.

No.	User requirements RIZA	User requirements LHG
UR5.1	All steps in the procedure used by the system must be clearly documented.	All steps in the procedure used by the system must be clearly documented.
UR5.2	All intermediate steps must be accessible, that is, the origin of the data that are used as input in a particular step must be clear and the input data must be accessible.	All intermediate steps must be accessible, that is, the origin of the data that are used as input in a particular step must be clear and the input data must be accessible.
UR5.3	The results of intermediate steps must be accessible	The results of intermediate steps must be accessible
UR5.4	The (expert) user must be able to view and change the quality checks.	The (expert) user must be able to view and change the quality checks.
UR5.5	Transferred to maintenance	Transferred to maintenance
UR5.6	The definition of the sub-basins must be clear and uniquely defined.	The definition of the sub-basins must be clear and uniquely defined.
UR5.7	Skipped	--
UR5.8	Skipped	--
UR 5.9	The system should keep track of the quality (performance) of the hydrological forecast (Statistics)	The system should keep track of the quality (performance) of the hydrological forecast (Statistics)

Extensibility

Given the fact that measurement stations change, regulation rules are adapted and there will be new technological developments, the system must be extensible. Small extensions, such as the addition or the removal of a measurement station, can be done by RIZA themselves. Larger extensions or adaptations will probably require intervention from the developer but should still be possible with a minimum of effort.

No.	User requirements RIZA	User requirements LHG
UR6.1	The procedure for adding a new measurement station should be clear-cut.	The procedure for adding a new measurement station should be clear-cut.
UR6.2	The procedure for deleting a measurement station should be clear-cut.	The procedure for deleting a measurement station should be clear-cut.
UR6.3	The procedure for changing the set of data that can be retrieved from a measurement station should be clear-cut	The procedure for changing the set of data that can be retrieved from a measurement station should be clear-cut
UR6.4	The procedure for changing the division in sub-basins should be clear-cut.	The procedure for changing the division in sub-basins should be clear-cut.
UR6.5	The procedure for changing the source of meteorological forecasts should be well documented (this is one of the items that would probably require support from the developer).	The procedure for changing the source of meteorological forecasts as well as for the reduction of the meteorological forecast grid should be well documented (this is one of the items that would probably require support from the developer). Several options should be discussed
UR6.6	The procedure for adding new sources of information, such as radar data, should be well documented.	Two additional procedures for adding new sources of information should be well documented. 1. improvement of spatial interpolation of point measurements using measured radar data 2. replace the first 0-3 hours of the numerical weather forecast by radar now-casting data
UR6.7	The procedure for adapting the system to other river basins than that of the Rhine should be well documented (This item will require developers support).	The procedure for adapting the system to other river basins than that of the Rhine should be well documented. (This item will require developers support)

Maintenance

The RIZA computer system should, just like the current one, be embedded in the rest of the organisation at RIZA. This means that certain third-party software must be used, if that particular type of software is part of the system and that the software must run on certain hardware and use the central infrastructure at RIZA's headquarters in Lelystad.

The LHG computer system should be embedded in the rest of the organisation at LHG. This means that certain third-party software must be used, if that particular type of software is part of the system and that the software must run on certain hardware and use the central infrastructure at LHG.

No.	User requirements RIZA	User requirements LHG
UR7.1	Maintenance should be taken care of by the computer department.	The maintenance should be taken care of by the computer department.
UR7.2	Care must be taken that the system is operational at all times. This may require a mirrored system (as is the case now) or a parallel installation.	Care must be taken that the system is operational at all times. This may require a mirrored system (as is the case now) or a parallel installation.
UR7.3	Enough data storage on-line and off-line must be provided, so that post hoc analyses are possible for a yet-to-be-specified number of years.	Enough data storage on-line and off-line must be provided, so that post hoc analyses are possible for a yet-to-be-specified number of years (off-line storage may in principle provide an unlimited period).
UR 7.4	It must be possible to run the system at RIZA's headquarter.	--
UR 7.5	It must be possible for members of the flood forecasting group to run the system at local workstations, as long as the workstation can access the RIZA network.	--
UR 7.6	If a GIS should be used, it must be ArcInfo or ArcView.	If a GIS should be used it must be ARC-Info or Arc-View
UR 7.7	2 user levels are required : 1. forecaster 2. system manager	2 user levels are required : 1. forecaster 2. system manager
UR 7.8	Predictions are to be computed on local facilities, while data will be stored on a central facility.	Predictions are to be computed on local facilities, while data will be stored on a central facility.
UR 7.9	The system should run under Windows NT 4.0, Windows95 and Windows98.	The system should run under Windows NT 4.0 (or Windows 2000, depending on the requirements of the computer department)
UR7.10	The (expert) user must be able to view and change the parameters for the HBV models for the various sub-basins.	The (expert) user must be able to view and change the parameters for the HBV models for the various sub-basins.

No.	User requirements RIZA	User requirements LHG
UR7.11	The (expert) user must be able to view and change the parameters for the underlying SOBEK model, so as to include new structural developments in the Rhine basin	--
UR7.12	Agreements with local IT sections should be made on back-up procedures and detailed system requirements	Agreements with local IT sections should be made on back-up procedures and detailed system requirements
UR7.13	Both a forecasting system and a developers system should be made	Both a forecasting system and a developers system should be made
UR7.14	The language used in the forecasting system is Dutch	The language used in the forecasting system is yet to be defined

B Description of the FEWS system

This appendix describes in some detail the tasks of the FEWS system, as illustrated in the demonstration version that accompanies this report. Though there will undoubtedly be some need to change the order of processes or the tasks that are to be performed, once the implementation is undertaken, the main layout or the philosophy will not change.

General

The set-up of the system is such that the user moves from one task to the next and the tasks will be implemented by one or more individual *processes*. In other words: the flood forecasting system is process-driven, as opposed to a system based on geographic maps.

This approach has a number of advantages:

- The user is always aware what task should be done next
- The user can monitor the progress of the whole forecast by simply comparing the number of completed tasks to the total of tasks.
- The user can backtrack his analysis by restarting a previous task or by reviewing the intermediate results of that task.

Within the demo, a colouring scheme is used to monitor the progress:

- Each task is represented by a box whose colour indicates the state.
- *Yellow* means: this task can be run and represents the next step or is one of the next steps.
- *Red* means : this task requires others to be completed first (most probably because it needs input from these other tasks).
- *Green* means: this task has been completed successfully. (You are, however, allowed to redo the step)

Each task will be presented in the same format:

- A short description of what is to be done
- In detail: what should be available before the task can run (the *preconditions*)
- In detail: what will be done (the *actions*)
- In detail: what is the result (the *post-conditions*)

Task: Import data

The first and perhaps most essential step is the import of all relevant data into the system. This is where the flood forecasting system starts.

Preconditions:	None
Actions:	1. Send request to data providers 2. Import data: • forecasted meteorological data • measured meteorological data • measured hydrological data 3. Produce report: Completeness of imported data
Post-conditions:	Report available for checking by user Raw data can be visualised by the user Input for task *Pre-processing*

Task: Pre-processing

Before the calculation can start, the raw data must be checked and transformed into input for the hydrological and hydraulic models.

Preconditions:	Task *Import data* has been completed
Actions:	1. Carry out data validation 2. Edit the imported data, if necessary 3. Produce report on the quality of the data 4. Produce a set of "authorised" input data
Post-conditions:	Report on quality check available for the user Pre-processed data can be visualised by the user Input for task *Interpolation*, consisting of "authorised" input data

The users have the following responsibilities and options:

- They are always able to visualise the pre-processed data and edit them.
- They should give their consent for automatic or manual editing of the data, if they are "suspicious":
  - — There are no data at all for one or more stations (which station should be used in stead?)
  - — There are no meteorological forecasts (use a substitute in stead or use rough manual predictions?)
  - — Data are out of prescribed range
  - — Adjacent data are too far apart

Whatever the choices of the users, the following is true:

- The system will always produce warnings, if data are missing or data are out of range.
- The system will report the choices made by the users.

The quality checks are guided by *business rules* that describe what to do, for example:

- If forecasts are missing => editing is necessary (user is forced to edit)
- If more than x stations are missing => editing is necessary (user is forced to edit)
- If less than x stations are missing => only progress with available stations
- If more than x stations have data out of range => editing is necessary (user is forced to edit)
- If less than x stations have data out of range, progress with reliable data

Task: Interpolation

After the raw imported data have been checked and edited, there is a set of "authorised" input data that can be transformed into input files. Perhaps it is necessary to interpolate within timeseries and certainly the meteorological data will have to be allocated to the various sub-basins. For Switzerland this means using a 3D Kriging method to interpolate the temperature field.

Preconditions:	Task *Preparation* has been completed (set of "authorised" input data available).
Actions:	1. Measured station data are interpolated to grid 2. Forecasted data are interpolated to grid 3. Forecasted grid data are interpolated to grid 4. Grid data are interpolated to HBV sub-basins
Post-conditions:	Input files ready for the HBV models

The users have the following options:

- View the grid data (spatial variation in precipitation and temperature)
- View the input data for the sub-basins
- Edit the input data for the sub-basins

Task: Lake management

The management rules for the lakes in Switzerland and the reservoirs along the river Rhine in Germany are not standard input available from measurements or forecasts. Rather they form a separate set of input data that can be varied independently of the first task. It is, however, important that the users can view the rules that will be used and edit them for the particular forecast.

Preconditions:	None
Actions:	1. Present the standard rules per lake or reservoir 2. Edit the rule, if the user wants to 3. Transfer the new information to the database for the current calculation.
Post-conditions:	Authorised rules for the lake management

Task: Calculate current water levels

The next step is to run the HBV and SOBEK models for a short period that runs up to the present moment to see if updating is required.

Preconditions:	Input files ready for the HBV models Authorised rules for the lake management up to present.
Actions:	1. Run HBV models, calculate current discharges 2. Run SOBEK model with HBV results, calculate current discharge and water levels 3. Compare measured and simulated discharges 4. Produce warnings, if the differences are too large
Post-conditions:	Simulated current discharges and water levels Decision whether updating is required or not

The users have the following options and obligations:

- Visualise the results of both the HBV and the SOBEK model (in combination with measurements up to present)
- Decide if it is necessary to update the parts or all of the modelling

Task: Update the models

Updating the models may be necessary, and for this several options are available. Through the relevant business rules the system advises to apply updating (see the task *Calculate current water levels*) and the user can select any one of these options:

- Automatic updating of the whole modelling system
- Updating the HBV models per sub-basin
- Updating the information about the water levels in the lakes and reservoirs
- Updating the groundwater model (for the RIZA part)
- etc.

Preconditions:	Simulation results for present situation available.
Actions:	1. Have the user select any one of the options. 2. Run the updating procedures. 3. Store the updated state variables 4. Log the updating option that was chosen.
Post-conditions:	New initial conditions and (possibly) input files for redoing the calculation of the current water levels.

The users have the following options and obligations:

- Redo the calculation with the updated input files (this is required!)

Task: Predict water levels for next few days

When the initial state of the models has been tuned via the previous calculation step, it is time to make the actual prediction. This is in fact a repetition of that step, except that the period that is to be simulated runs into the future. Most input will be the same.

Preconditions:	Input files ready for the HBV models. HBV and SOBEK models have been properly updated. Authorised rules for the lake management for the next few days.
Actions:	1. Run HBV models, calculate discharges 2. Run SOBEK model with HBV results, calculate discharge and water levels 3. Log all decisions on input: • Standard or alternative input • Alternative management rules
Post-conditions:	Predicted discharges and water levels

The users have the following options and obligations:

- Visualise the results of both the HBV and the SOBEK model (in combination with measurements up to present)
- Decide to re-run the models to see if changing the management rules or if it is necessary to update the parts or all of the modelling
- Decide if the forecast is ready to be sent to the clients.

Task: Formulate alternatives

To determine the likelihood of the forecasts, it will be possible to formulate alternative input for the models. Such alternatives will be simple:

- Reduce the precipitation by 50%
- Increase the precipitation by 50%
- Increase the overall temperature by 2 °C
- etc.

When this is done, the user can make an alternative prediction and combine the results in the report.

Preconditions:	Standard forecast is available.
Actions:	1. Let the user formulate an alternative set of input 2. Prepare the input for a forecast 3. Log the parameters of the alternative set
Post-conditions:	Alternative set of input for the forecasts.

Task: Prepare reports

Once the forecast has been approved, the reports can be created and sent off to the clients. Automatically sending the reports to clients is possible in electronic form via Internet. Documents can be disseminated in a suitable format like HTML, plain text or PDF. This may be customised: only when certain criteria are met, will the clients automatically receive the reports.

The system will not include a facility to automatically fax the reports to the clients.

For the moment, the products will simply be a set of documents and graphs that can be printed.

Preconditions:	Approved forecast available.
Actions:	1. Prepare the reports, filling in the results from the forecast 2. Make the reports available via Internet 3. If wanted and available, include alternative forecasts.
Post-conditions:	Printable reports

The users have the following options and obligations:

- Prepare customised reports for selected clients.
- Preview the report before it will be printed.
- Combine the standard forecast with possible alternative (to indicate the likelihood of the conclusions).

C Diskette with all intermediate project reports

D DEMO - new version

E Reference reports

Ref. 1

Räumliche Interpolaton der Stundenwerte von Niederslag, Temperatur und Schneehöhe
Holger Jensen ETH, Zurich, (1989)

Ref.2

Simulation of Snowmelt-Runoff in Lowland and Lower Alpine Regions of Switzerland
Ludwig N. Braun;ETH, Zurich, (1985)

Ref.3

Influence of water vapour pressure and wind velocity,
in: Investigations on Short-Range Forecasts for Rhein at Reinfelden,
Report 100.35 ETH Zürich

Ref. 4

Parameter Values for Snowmelt Runoff Modelling,
J. Martinec and A. Rango, in Journal of Hydrology, 84 (1986)

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