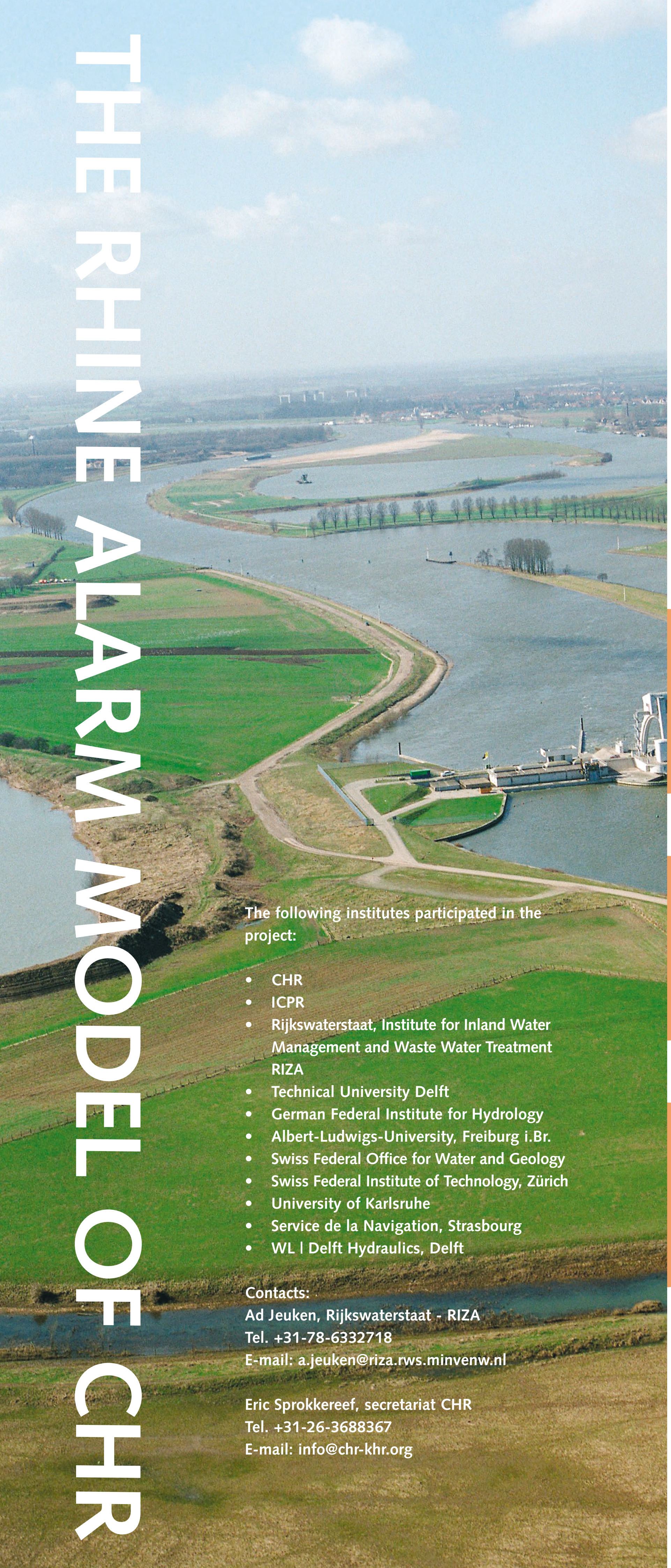

THE RHINE ALARM MODEL OF CHR

The following institutes participated in the project:

- CHR
- ICPR
- Rijkswaterstaat, Institute for Inland Water Management and Waste Water Treatment RIZA
- Technical University Delft
- German Federal Institute for Hydrology
- Albert-Ludwigs-University, Freiburg i.Br.
- Swiss Federal Office for Water and Geology
- Swiss Federal Institute of Technology, Zürich
- University of Karlsruhe
- Service de la Navigation, Strasbourg
- WL | Delft Hydraulics, Delft

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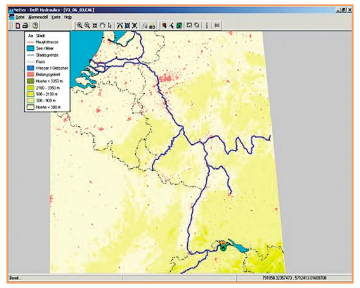
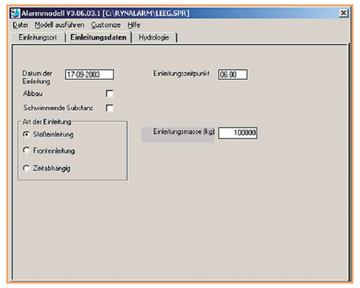
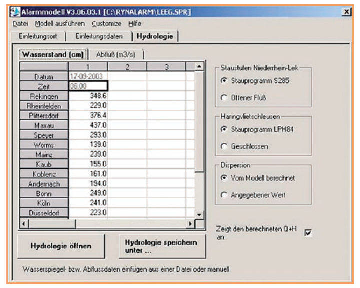


Fig. 9 Geographically based user interface.



Datum der Einleitung: 17-09-2003
Einleitungszeitpunkt: 06:00
Abbau ☐
Schwimmende Substanz ☐
Art der Einleitung
● Stoßeinleitung
○ Fronteinleitung
○ Zeitabhängig
Einleitungsmasse (kg): 100000

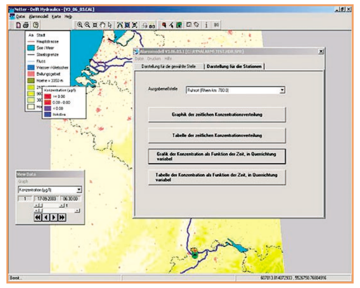
Fig. 10 Input mask for the spill data.



	1	2	3
Datum	17-09-2003		
Zeit	06:00		
Rekingen	348.6		
Rheinfelden	229.0		
Plittersdorf	376.4		
Maxau	437.0		
Speyer	293.0		
Worms	139.0		
Mainz	239.0		
Kaub	155.0		
Koblenz	161.0		
Andernach	194.0		
Bonn	249.0		
Köln	241.0		
Düsseldorf	223.0		

Staustufen Niederrhein-Lek
● Stauprogramm S285
○ Offener Fluß
Haringvlietschleusen
● Stauprogramm LPH84
○ Geschlossen
Dispersion
● Vom Modell berechnet
○ Angegebener Wert
Zeigt den berechneten Q+H an. ☑
Wasserspiegel- bzw. Abflussdaten einfügen aus einer Datei oder manuell

Fig. 11 Input mask for the hydrology data.



Ausgabemeßstelle: Ruhrort (Rhein km: 780.8)
Konzentration (µg/l)
1 17-09-2003 06:30:00

Fig. 12 Geographically based output mask.

and possibly the river bank from which the pollutant has been discharged (2-D option). Furthermore, hydrological data, i.e. water levels and/or discharges measured at certain gauges as well as certain discharge control options, such as a regulated or free-flowing river, can be entered (fig. 11).

OUTPUT

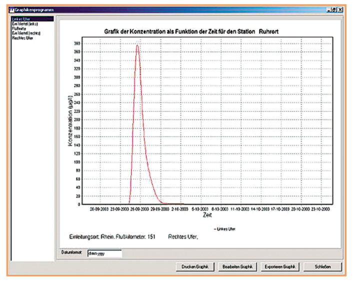
The output of the model includes:

- the geographical presentation of the progress and dispersion of a pollutant cloud (fig. 12)
- the course of concentration at a gauge (graphically and tabularly, fig. 13)
- the maximum concentration and travel times to the concentration maximum along the river (graphically and tabularly)
- the course of concentration in the cross-section of the river (graphically and tabularly).

Based on the calibration and verification, it is known that the Rhine alarm model can forecast the arrival time of a pollution wave, if the prevailing course of discharge applies, with a deviation of, on average, less than 5%.

EXAMPLE

Figure 14 shows the result of observations made of the accidental spill in June 1993 when, at Rhine kilometer 433.2, approximately 3 tons of degradable nitrobenzene were discharged into the Rhine from the left bank. The measurements entered in figure 14 were taken of composite samples, which means that, in principle, the course of concentration was measured only approximately. The comparison is therefore only indicative. As the Rhine alarm model does not take into account the slower flow velocity of the zones near the banks of the river, for short distances from the spill location the calculated arrival time of pollution wave is too early when the substances are discharged from the river bank (see fig. 14, Mainz observation station, 65 km downstream of the spill location. The cross-sectional distribution of the substance discharged was taken into account for these comparisons. Furthermore, a degradation coefficient of 0.25 per day for the substance was given. The accuracy of the measurements for the observation stations at Lobith on the right bank and Bimmen on the left bank, which are only about 2.5 river kilometres apart, is shown in figure 14. The results show that an accurate forecast of the arrival time at each observation station requires the beginning and duration of the pollution discharge as well as the quantity discharged and the degradation coefficient to be given exactly. Because these requirements cannot usually be fulfilled, the model is used primarily for determining the time the pollution wave takes to pass.



Einleitungsort: Rhein, Flußkilometer: 151 Rechtes Ufer,
Datumformat: dd-mm-yyyy

Fig. 13 Output mask with the course of concentration at a specific observation point in the cross-section of the river.

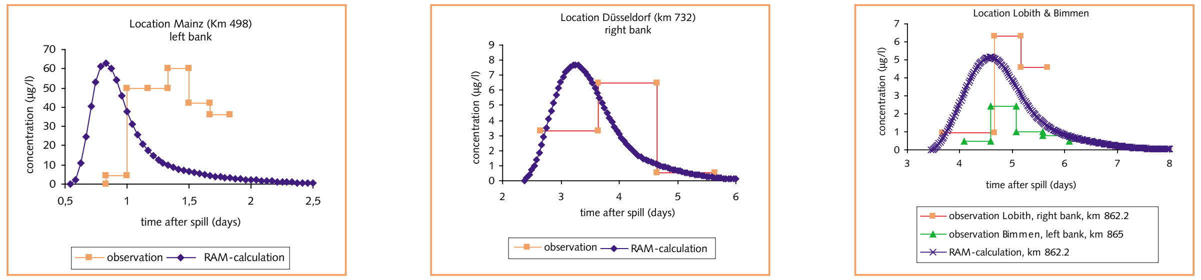


Fig. 14 Comparison of the forecast with the Rhine alarm model and those actually measured (accidental spill June 1993).

KHR
CHR

THE RHINE ALARM MODEL OF CHR

Background

Operation

Application

THE RHINE ALARM MODEL OF CHR

- **Alarm model to predict the arrival time and dispersion of harmful substances in the river Rhine.**
- **Operational deployment in case of accidental pollutions.**
- **As fixed part of the Rhine early warning system, the model supports the monitoring of an accidental pollution.**

MOTIVE AND OBJECTIVE

Following the fire disaster at the Sandoz chemical factory in Basel in 1986, during which large quantities of chemically-polluted water flowed into the Rhine, the ministers of the Rhine riparian countries commissioned the International Commission for the Protection of the Rhine (ICPR) and the International Commission for the Hydrology of the Rhine Basin (CHR) to develop an alarm model.

Fig. 1 Alarm and warning system on the Rhine.

BOUNDARY CONDITIONS

- In the case of an accidental pollution the model can be applied operationally, i.e. results have to be available without delay.
- The model is based on real-time input data giving information about the incident as well as water levels and/or discharges, which can be retrieved from the main warning stations via remote transmission from the gauging sites.
- The design of the model is simple and operable on PCs so that it can be used easily at all warning stations.

1988: VERSION 1.0

The first uncalibrated version 1.0 of the Rhine alarm model was completed in 1988. In 1990 the calibrated and verified version 2.0 followed, which took into account the impact of so-called stagnant water zones on the transport of substances. Stagnant water zones are areas of almost standing water or areas without any net flow. They are randomly distributed on the bed and along the banks of a river and can occur naturally (meandering of the river, vegetation, etc.) or anthropogenically (e.g. groynes, fig. 2).

Fig. 2 Groyne fields in the river Waal (Netherlands)

1990: VERSION 2.0

Version 2.0 was extended to include the Swiss stretch of the Rhine from Stein am Rhein. The river Aare downstream of Lake Biel was also added. The provisional inclusion of the river Moselle in the alarm model was replaced by a new part of the model applicable for the German stretch of the Moselle (fig. 4). In addition, as from version 2.0, it can be specified whether the substance released is floating matter such as oil. On the basis of travel time calculations the provisional inclusion of the river Aare was replaced in version 2.1 by a part of the model applicable for the river stretch from the outflow of Lake Biel to the confluence with the Rhine (fig. 4). Versions 2.0 and 2.1 are operated under MS-DOS.

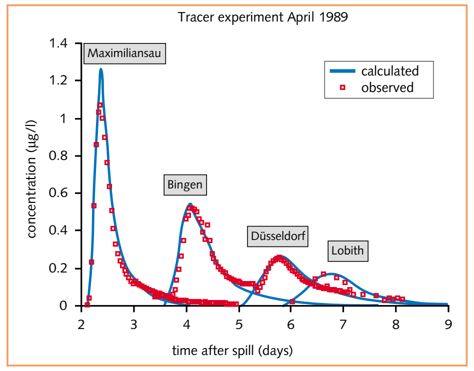


Fig. 3 Comparison of observed and calculated concentrations, tracer experiment 1989 from Basel to The Netherlands.

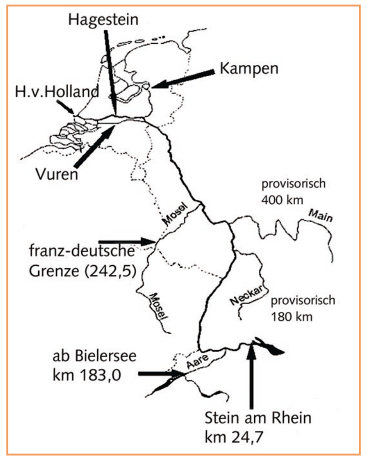


Fig. 4 Network of the Rhine alarm model.

1998: WINDOWS VERSION 3.0

In 1998 the WINDOWS version 3.0 was developed. This version includes two-dimensional modules that also calculate the transport of substances across the width of the river (fig. 5 and 6) and, in addition, in the tributaries of the delta area in the Netherlands between Hagestein and Hoek van Holland (fig. 4).

For easy updating of discharge data up to ten discharge situations can be entered in the WINDOWS version. The model calculates for every time step, usually one day, the position in the river of the pollution wave and uses the locally applicable discharge situation for the calculation of the transport.

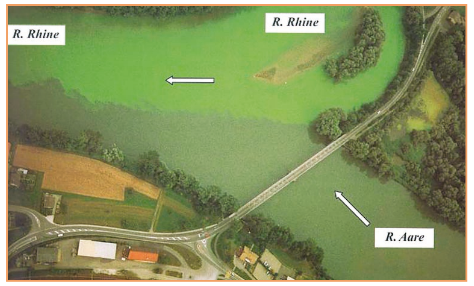


Fig. 5 Confluence of the rivers Aare and Rhine during the tracer experiment in the Rhine (tracer input Rheinau).

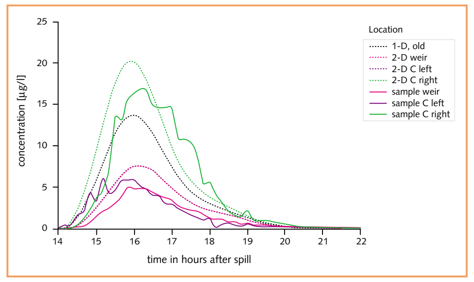


Fig. 6 Concentrations at various reference locations in the cross-section of the river immediately upstream of the Albbruck weir.

The WINDOWS version offers the possibility of saving discharge data. This means that, instead of the actual discharge data, discharge scenarios can also be used to obtain a first estimation of the arrival time of a pollution wave. As the actual discharge routing in the Rhine changes very slowly, indication of the mean channel flow is a fairly exact forecast. However, because of the discharge dynamics of the river Moselle, discharge scenarios give even more reliable information on the earliest and latest arrival time of a pollution wave relative to the observed discharge situation at the time of the announcement of the incident (fig. 7).

In order to improve the accuracy of the forecast, especially when there is low flow and the river is regulated with weirs, the Dutch stretch of the Rhine downstream from Arnhem has been included in greater detail in the WINDOWS version. As there is no significant relation between discharge and water level in this area due to backwater, not only discharge can be entered but also water levels.

For gauges which are hard to reach, relations to other neighbouring gauges regarding discharge were made (Q-Q relations). Examples of this are the gauges Neuhausen-Flurlingen (Rhine km 45.8) and Reckingen (Rhine km 90.7) on the upper Rhine between Lake Constance and Basel.

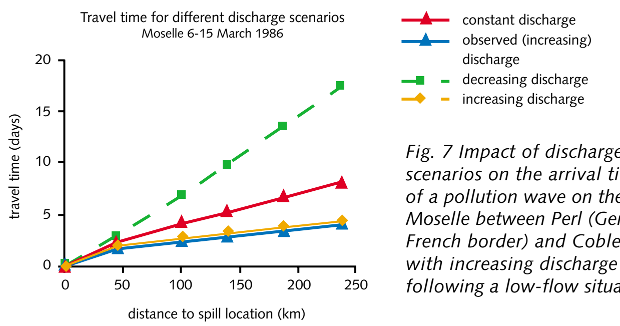


Fig. 7 Impact of discharge scenarios on the arrival time of a pollution wave on the Moselle between Perl (German-French border) and Coblence with increasing discharge following a low-flow situation.

Fig. 8 The Low Rhine with the weir at Amerongen (Netherlands).

APPLICATION

The current WINDOWS version 3.06.03.1 is very user-friendly and applicable for every river and/or canal system. The model was developed for the operational use within an early warning system and has two components:

a) a geographically-based user interface with input masks for the accidental spill and for the hydrology as well as output masks for the presentation of calculation results
b) calculation modules

The source codes are independent of the area concerned.

On the geographically-based user interface (fig. 9) the user can select the location of the incident on a map and likewise the location for which a calculation is required. Further input data relate to the time of the incident, the amount of pollutant discharged (fig. 10)