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Extended Abstracts

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Global Water Quality and Quantity Data Monitoring Activities of the United Nations GEMS/Water Programme

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Abstract

Global Environment Monitoring System (GEMS/Water), the United Nations global programme of freshwater quality monitoring was established under the sponsorship of the United Nations Environment Programme (UNEP), World Health Organization (WHO), World Meteorological Organization (WMO), and the United Nations Educational Scientific and Cultural Organization (UNESCO). Over the last 20 years the programme has grown to encompass global representation within 70 countries and consists of approximately 600 sampling stations and a database of 1,150,000 data points for water quality. Operating jointly with GEMS/Water are the activities of the Global Runoff Data Centre (GRDC) which operates a network of over 3.600 stations in 45 countries. Both, GRDC and GEMS/Water participated in the 1996/97 Global Freshwater Assessment excercise as requested by the UN Commission for Sustainable Development. It has become apparent in this task that water resources assessment and management has to be undertaken on an equal consideration of both: Quantity and quality issues. GRDC therefore extended its collaborative ties with GEMS/Water to link water quantity and quality information. A particular GRDC emphasis has been the calculation of freshwater from continents into the oceans which is the basis for load calculations of suspended matter and pollutants from major rivers into coastal areas and the world oceans. Phase three of the GEMS/Water programme calls for the tighter co-ordination and interplay between the quantity and quality components of the work. Specific activities within the two programme areas will be harmonized including monitoring station selection criteria, location, parameter selection, sampling frequency, sampling date, etc. Station identification catalogues for the two networks have been merged and joint managerial considerations for common linked operations are under development. Results of the harmonization of the quality and quantity aspects of water resources management will lead to improved estimates of material fluxes to the oceans from major global river basins and a clearer identification of problem areas related to water supply and water quality contamination in participating countries.

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Integrative Management of Data and Information at the Global Runoff Data Centre (GRDC)

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Abstract

The paper discusses in an integrative manner the conference themes on the example of the day-to-day and strategic operation of the Global Runoff Data Centre. The paper thus provides insight in the linkage of problems and pragmatic solutions arising from data acquisition, access to data, data quality, use of the data and managerial aspects on the technical (database) and programmatic (links and cooperative efforts) aspects. The principal message of the paper is, that the participatory approach to data acquisition, quality approach, the use and the associated management of information is a key for the derivation of added value for the understanding of water and climate related processes and derived benefits for national economies. Perhaps the most important rational for the transfer of hydrological information on a regional and global scale is that no institution is able to bear alone the cost of a global observing system from which national economies can derive added value. The cost - benefit ratio for various uses of data such as water resource development projects, storage design, flood forecast varies between 1:1.50 and 1:21.20 (WMO, UNESCO 1997). Even under the most conservative estimates therefore, the benefit equals or exceeds the costs for data collection analysis and use by at least 50%. However, there is a lack of recognition of the crucial link between water-related investments and the support of these investments and management decisions with high quality data and science-based information (Grabs 1996).

The Global Runoff Data Centre (GRDC) operates under the auspices of the World Meteorological Organization (WMO) and acts as clearing house for global hydrological data and the supply of research and information products for climatological and hydrological programmes and projects. The principal objective of the GRDC is to facilitate and optimize the information exchange in surface water hydrology. Another important objective is to provide decision-makers with hydrological information needed to resolve hydrological problems, i.e. in the assessment of impacts of surface water availability on regional scales. This requires an end-to-end management of data and information with in-built feed-back to data providers. Discharge date are sought inter alia from:

- Large basins which drain into the oceans with stations close to the mouth of the rivers into the world oceans;

- Gauging stations from near pristine areas which serve as reference station against the impact of anthropogenic changes and the assessment of possible climate change impacts;

- River basins which have a high socio-economic importance; i.e. large cities, high population growth, single source for water supply etc.

The latter are important for the global assessment of trends and dynamics of river basin development and the criticality of surface water availability in selected river basins of the world. In addition, data are sought for stations with very long, high quality time series of discharge for statistical assessments and as trend indicators for changes, being natural or anthropogenic.

National hydrological services transfer selected, quality controlled data to the GRDC. In this process, the data providers maintain ownership rights over their data and also take the role as custodians of these data: The national services are responsible for the quality of their data, as well as the consistency of the discharge time-series which are transferred to the GRDC.

The actual accuracy of the data cannot be fully assessed at the Centre, however, the data is screened for plausibility to eliminate obvious errors about which the data providers are informed. Problems with data accuracy do occur in terms of different measurement practices and most of all in the way hydrological services control the conduct of measurements and the entry of data in the national database. Deviations from measured discharge from "true" discharge depend also on the type of river and the location of stations (i.e. in turbulent headwaters or near the mouth of tide-influenced rivers) and the volume of discharge during the time of measurement. Typically, errors are larger during floodflow measurements compared with measurements done during mean flow conditions. The final assessment of the quality of data however depends on the actual use of these data and therfore is ultimately defined by the user.

The data are archieved in an INFORMIX relational database system which is designed for delivering prompt services for data users and the continuous update of the time-series of presently over 3600 gauging stations. About two person-months are required per year to update the database with newly received data from countries. The core investment for the database system has been approximately U.S. $ 90.000 and about $ 20.000 are required per annum for hardware updates and inhouse development of database software applications. This guarantees fast response times which typically are below one minute for database operations such as queries for a specific datum, import/export a 20-year daily discharge time series and updating time series under the condition that the data have been pre-formatted. The database is indexed for rapid access and daily discharge data are organized in a single table with a combined key consiting of the GRDC-reference number, the year and month of data.

The access to data and information is regulated by a well defined data policy under which the GRDC operates. This data policy balances the interests of users with the interests of the data providers. Inadequate access to data is based on a few major reasons: Insufficient communication between national hydrological services and national data users as well as between different national agencies dealing with water; non-user friendly data archives which hamper access to data and, on the regional and global scale, economic and security considerations of the data owners. It has to be recognized, that the sharing of water data is subject to political decisions in many countries of the world.

The integrative management of data and information at the GRDC has a wide scope which comprises of the following aspects:

- Target-oriented acquisition of hydrological data on a global scale;
- Transparent and consistent storage of the data;
- User services including the answering of data requests, assistance in data selection for research purposes and the provision of an array of general data products;
- Provision of high level products for research and as contributions for international programmes;

- Establishment and maintenance of feed-back links with hydrological services which allow the backflow of information from projects using a multitude of national datasets to the original data providers;

- Linkage and active participation in other regional and global observing networks such as UNESCO's project: Flow Regime of International and Experimental Network Data (FRIEND); the World Hydrological Cycle Observing System (WHYCOS) of WMO and the Global Climate and Terrestrial Observing Systems. A particular high priority has the cooperation with the Global Environment Monitoring system - Water (GEMS/Water) of UNEP/WHO with respect to the linkage of water quantity and quality issues;

  Networking of researchers and experts in integrated water resources management on regional scales such as in the joint contribution of GRDC, Federal Institute of Hydrology (BfG) and the German Technical Agency (GTZ) to the Global Water Partnership (GWP).

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Management and analysis of precipitation data on global scale

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1 Background (with regard to GPCP and GPCC)

The objective of this paper is to describe the problems of management of precipitation data on global scale, based on the experience gained at the Global Precipitation Climatology Centre (GPCC). The Centre is operated by Deutscher Wetterdienst (National Meteorological Service of Germany) as German contribution to the international programmes of global climate research and observation. International framework is the World Climate Research Programme and its Global Energy and Water Cycle Experiment (GEWEX). GPCC is represented in the GEWEX Hydrometeorology Panel, and it participates in the planning of WCP-Water and in the development of the Global Climate Observing System (GCOS).

The WMO/ICSU Joint Scientific Committee for the World Climate Research Programme established, at its Seventh Session, Lisbon, March 1986, the Global Precipitation Climatology Project (GPCP), to provide climate researchers with conveniently accessible global precipitation analyses based on observational data for use in:

- Verification and initialization of global climate models.
- Investigation of climate anomalies, variability and specific phenomena (e.g. El Niño/Southern Oscillation).
- Determination of the earth's water balance.

The Global Precipitation Climatology Centre (GPCC), a component of GPCP, is specialized for terrestrial precipitation and in-situ observations. Its functions comprise (WCRP 1990):

- Collection of precipitation data worldwide under auspice of WMO.
- Quality-control and correction of the conventionally measured data.
- Calculation of gridded area-mean monthly precipitation totals from conventionally measured data for the earth's landsurface.
- Error assessment on the grid with regard to systematic measuring errors, stochastic errors of the in-situ data, sampling error in area-mean.
- Combination of raingauge-observed data and satellite-based estimates (in cooperation with other GPCP participants).
- Dissemination of the gridded products.

In a first step, GPCC produces gridded area-mean precipitation datasets for the global landsurface using conventionally measured data. The data processing system is generally described by Rudolf (1993). In a second step, GPCC's gridded results are combined with satellite-based precipitation estimates to a nearly global dataset covering land and ocean. The combination is jointly realized by various participants of GPCP (Huffman et al. 1995). The combination technique adjusts the satellite-based estimates to the gridded raingauge data. Subsequently, availability and quality of raingauge data are critical for the accuracy of both, the raingauge-based and the combined product.

A requirement to apply the observational product for verification of climate models is that its accuracy or error is estimated for each individual gridcell. Errors are caused by systematic undercatchment using conventional rain-gauges, individual erroneous data in the database (which are not discovered by quality-control) and sampling errors from calculation of area-means from point-data.

2 Availability of precipitation data

Conventionally measured data from raingauge networks are still the most reliable information to obtain area-averaged precipitation for the landsurface. Satellite-based estimates are subject to larger biases and stochastic errors and need to be adjusted to in-situ observations (Barrett et al. 1995, Rudolf et al. 1996).

A first meteorological database for precipitation can be obtained from (at least daily) synoptically observed weather reports and monthly climatic data, which are distributed worldwide as "SYNOP" and CLIMAT reports via the World Weather Watch Global Telecommunication System (GTS). GPCC regularly collects monthly precipitation totals from this source for nearly 7,000 stations worldwide.

Recognizing the high spatial and temporal variability of precipitation, station networks of high density are necessary also for global scale analyses. In order to derive monthly area-mean precipitation on a grid of 2.5° latitude by longitude with an error of most probably less than 10%, observed data from a number of 2 to 10 raingauges per area of 10,000 km² are required, dependent on the regional variability of precipitation. A number of 2 stations per 10,000 km² already results in the need of data from 40,000 stations for the total global landsurface (Rudolf et al. 1994).

In order to achieve the desired database for GPCC's analyses, WMO has sent out requests for additional data by letters to all Members in 1992 and 1994. The Executive Council of WMO "reaffirmed the importance of the task undertaken by the GPCC to collect raingauge data worldwide and produce a global monthly-mean climatology of precipitation. The Council urged the Members to assist the Centre and make available precipitation records in a timely fashion." (WMO 1993).

So far, institutes from more than 140 countries have supplied additional data on a voluntary basis, following the WMO requests and bilateral negotiation with GPCC. The entire GPCC database includes now monthly precipitation totals of about 48,000 stations. The data period begins with 1986, the time series are largely complemented by climatological means for the normal period 1961-1990. GPCC's best data-covered year is still 1987 with monthly precipitation data for about 37,500 stations. A gradual decrease of the number of stations after 1987 down to 7,000 stations for 1997 is caused by the delay of the delivery of additional data and by the time required by the national agencies and subsequently by GPCC for data processing and quality-control (Rudolf et al. 1997). Also the spatial distribution of the data shows large data poor areas. The database still needs spatial and temporal completions as well as the continuation of data delivery to GPCC in future. Co-operation of all countries is required!

3 Quality-control

Data which arrived at GPCC are partly affected by reading or coding errors and other modifications happening during the transmission from the originator to the archive. In many questionable cases it is not possible to get replies from the data originator. The following problems occur:

- Important meta data (station identifications, format descriptions) are missing and have to be procured.
- Delivered datasets are irregularly formatted.
- Delivered station coordinates are erroneous (occurs frequently).
- Doublettes of stations have to be eliminated.
- Missing precipitation is not clearly indicated in the data.
- Recorded precipitation depths are affected by coding/decoding errors.
- Temporal misplacement of data in time-series.

A fully automatic quality-control would eliminate all questionable data and, with regard to the high variability of precipitation, also remove a large amount of true data, in particular extreme values. These data, however, are very important to describe the real structure of the spatial distribution and the variablity within the gridded analysis results. In order to keep the true extreme data in and also to remove obviously wrong data from the analysis system, a visual check of questionable data - although very time-consuming - seems to be inalienable (cf. Rudolf and Schneider, same issue).

4 Treatment of errors

Area-means of precipitation derived from raingauge data are contaminated by errors being of different origin:

- Systematic measuring errors depend on the characteristics of the instrument type, size and exposition and on the meteorological condititions during the individual event. Any correction will not result in the true individual local precipitation amount, but will put the data closer to the truth in a statistical sense. Corrected data are still contaminated by stochastic errors from approximative corrections.
- Erroneous individual data which are not discovered by quality-control cause a stochastic error of a data collective.
- The sampling error is area-related and depends on the number of observations per area and the regional precipitation variability.
- The methodical error represents approximations of the used interpolation scheme or the method for calculation of area-mean precipitation.

These errors types must be treated and quantified separately, and the results need to be merged to an total error of the area-mean precipitation (cf. Rudolf and Schneider, same issue).

5 Conclusions

Data disseminated via telecommunication facilities, e.g. GTS, support a quick response on special situations (e.g. flood forecasts resp. analyses). On global scale, daily precipitation is near-realtime available from about 4,000 observing stations, and monthly precipitation from 7,000 stations. Spatial analyses based on this dataset (e.g. the monthly "Monitoring Product" of GPCC) provide the community with a first guess of global precipitation amounts and anomalies (deviation from and percentage of climatic mean).

In order to obtain more reliable gridded precipitation, as it is required for validation of remotely sensed data and models or for determination of water budgets, a larger number of observations would be required. Most countries operate large networks for national purposes, and also supply - mostly with restrictions - additional data to international projects. The dilemma is that with additional data from networks of a lower order a larger number of erroneous data will enter the database. Without any quality-control, however, outliers can strongly affect gridded results and cause errors which may exceed the other error components.

Requirements concerning the improvement of global and continental scale precipitation analyses are: Enhancement of international data exchange, a more active participation of more countries in international projects, and the preparation of catalogues of data being available including meta-data on the station location, the observation method and performance of quality-control.

References

Barrett, E.C., J. Doodge, M. Goodman, J. Janowiak, E. Smith & C. Kidd (1994): The First WetNet Precipitation Intercomparison Project (PIP-1). Remote Sensing Review, Vol. 11 (1-4), 49 - 60.

Huffman, G.J., Adler, R.F., Rudolf, B., Schneider, U., Keehn, P.R. (1995): Global precipitation estimates based on a technique for combining satellite-based estimates, raingage analyses, and NWP model precipitation information. J. of Climate 8(5), 1284-1295.

Rudolf, B. (1993): Management and Analysis of Precipitation Data on a Routine Basis. Proceedings Int. Symp. on Precipitation and Evaporation (Ed. B. Sevruk and M. Lapin), ETH Zuerich, Vol. 1, p. 69 - 76.

Rudolf, B., H. Hauschild, W. Rueth, U. Schneider (1994): Terrestrial Precipitation Analysis: Operational Method and Required Density of Point Measurements. NATO ASI I/26, Global Precipitations and Climate Change (Ed. M. Desbois and F. Desalmand), Springer Verlag Berlin, p. 173 - 186.

Rudolf, B., H. Hauschild, W. Rueth, U. Schneider (1996): Comparison of Raingauge Analyses, Satellite-Based Precipitation Estimates and Forecast Model Results. Advances in Space Research, 18(7), p. (7)53 - (7)62.

Rudolf, B., T. Fuchs, W. Rueth, U. Schneider (1997): Precipitation Data for Verification of NWP Model Re-Analyses: The Accuracy of Observational Results. Proceedings WCRP International Conference on Reanalyses, Washington, DC, 27-31 Oct 1997, to be published.

WCRP (1990): The Global Precipitation Climatology Project - Implementation and Data Management Plan. WMO/TD-No. 367.

WMO (1993): Forty-Fifth Session of the Executive Council, Geneva, 8-18 June 1993, Abbridged Report with Resolutions. General Summary No. 4.5.8, WMO-No. 794.

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Quality control and error assessment of precipitation data with regard to global analysis

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1 Background

Global data sets of area-average and time-integrated precipitation provide the basis for investiga-tions of the global hydrological cycle and assessment of climate change. The purpose of the GEWEX Global Precipitation Climatology Project (GPCP) is the operational evaluation of global data sets of monthly precipitation for the period from 1986 onwards for climate research and model verification (for a detailed description of GPCP centers and functions see WCRP 1990). The Global Precipitation Climatology Centre (GPCC) of the GPCP routinely provides gridded global data sets of monthly precipitation derived from in-situ measurements for the land-surface. These analyses are combined with satellite-based precipitation estimates into a data set covering both land and oceans by using a quality-dependant weighting scheme (Huffman et al. 1995). For using such an optimum estimation technique and for a reliable verification of climate models error estimates have to be determined for each individual data set and each grid.

Error estimates for the satellite-based data sets are provided by the GPCP satellite data processing centres. The error range for the raingauge analyses is estimated by the GPCC by empirically quantifying the different sources of uncertainty of conventional raingauge measurements. The different error types can be classified into two categories:

1) errors in obtaining area-average precipitation from point measurements depending on the analysis method (Bussieres and Hogg 1989), on the spatial density of the station network (Rudolf et al. 1994) and its spatial distribution (Willmott et al. 1994; Morrissey et al. 1995) and on the spatial variability of the precipitation field and
2) inaccuracies of the point precipitation measurements themselfes, which consist of two parts, a systematic error in raingauge measurements and a random component.

Sources of random error are especially errors in the course of data processing and transmission (e.g. typing and coding/decoding errors). To minimize the effects of this latter error component a careful quality-control of the monthly precipitation data is performed in the operational data processing at the GPCC.

2 Data processing and quality-control

Monthly precipitation depths are received via the Global Telecommunication System (GTS) of the WMO World Weather Watch in monthly surface (CLIMAT) reports for ca. 1,600 stations, or can be calculated from surface synoptic (SYNOP) reports exchanged via the GTS. Monthly precipitation totals are calculated at the GPCC for ca. 4,600 stations from the SYNOP reports received at the DWD, Offenbach after passing the quality-control for the synoptic reports (Schneider et al. 1992; Schneider 1993). Monthly precipitation totals estimated by the NOAA Climate Prediction Center (CPC), Washington D.C., for about 6,100 stations from the SYNOP reports received there are also provided to the GPCC.

Since the spatial density of the combined GTS data sets (nearly 7,000 stations each month after removal of the redundant stations) is still insufficient for a reliable analysis of monthly precipitation over many parts of the continents the GPCC is continuing its efforts, with support of the WMO, to increase its station data base (see Rudolf et al. 1998 for details).

A central part of the GPCC operational data processing system, which is described in Rudolf (1993), is the precipitation point data bank (PDB) consisting of 3 major parts:

1) the continuous monthly precipitation data of the different sources (for each station data from up to 5 sources are stored separately, as there are monthly precipitation totals from CLIMAT reports, totals calculated from synoptic reports at the CPC and the GPCC, and additional regional as well as national data sets),
2) the climatological normals for different base periods and
3) a station catalogue containing the station-related information, such as geographical coor-dinates, elevation above mean sea level, station name and WMO and/or national station number.

Another important part of the data processing system is the quality-control of the gauge-measured monthly precipitation data and station meta data. First of all the station meta data (identification, geographical location) have to be checked, corrected (geogr. coordinates are partly erroneous) or complemented. If monthly precipitation data at a station are available from more than one source, then an "optimal" value is selected automatically based on statistically predefined random errors of the data from the different sources and intercomparisons between them. The quality-control of the precipitation data at the GPCC is semi-automatic. In the automatic check of the full raingauge data set the precipitation data at a station are checked against the climatological normal and for spatial homogeneity and questionable data are flagged.

Data marked as questionable in the automatic quality-control process subsequently can be manually reviewed by a trained expert using an interactive programme on a graphics workstation. This software is showing all relevant information of the station being checked, as well as the precipitation data of the neighbouring stations and background fields such as gridded climatologies or a 3d-orography (the data source is displayed by symbol, stations with data flagged as questionable are marked by colour). Obvious errors in the precipitation data are corrected, if possible. Otherwise incorrect data are set to the code for missing values or, if available, the monthly precipitation from another source can be selected for the analysis. If a station is misplaced, its geographical location can also be corrected. All these corrections are then archived in the PDB.

The automatic part of the control-procedure has not been designed to correct data, but to reduce the number of data for which a visual control is necessary. A fully automatic quality-control would eliminate all questionable data and, with regard to the high variability of precipitation, also remove a large amount of true data, in particular extreme values. These data, however, are very important to describe the real structure of the spatial distribution and the variability within the gridded precipitation analysis. In order to keep the true extreme data and also to remove obviously wrong data from the analysis system, a visual check of the questionable data, although very time-consuming, seems to be inalienable.

The final analysis of gridded area-average precipitation is performed on the basis of the quality-controlled data by using the objective analysis method SPHEREMAP (Shepard 1968; Willmott et al. 1985), which is based on an inverse distance and directional weighting scheme.

3 Error assessment for global-scale analyses

GPCC tries to minimize the error resulting from erroneous input data by a full quality-control of all data used in the raingauge analysis as described above. The remaining error is assumed to have a stochastic distribution. It is separately quantified for different regions (WMO blocks or countries) and different data sources (network types, originators), based on statistical inter-comparisons of the different datasets with carefully checked data from CLIMAT reports for the same stations.

Systematic measuring errors are trendentiously compensated using long-term mean correction factors, which were derived by Legates (1987), who corrected the monthly long-term-mean precipitation for about 25,000 stations, using Sevruk's correction formulas and approximated meta data. The monthly mean correction factors, which are mostly in the range of 1.0 to 3.0, describe the mean annual cycle but not the year-to-year variation. From this and from the limited accuracy of the correction in principle results, that after the correction with regard to systematic measuring errors a stochastic error component is remaining. The GPCC quantifies this error component by 40% of the systematic correction term. This method is not yet sufficient, since the systematic error strongly depends on the meteorological conditions during the individual rain- or snowfall event. GPCC is working on an advanced method using wind-speed and precipitation-type data from synoptic data for correction on a daily basis.

The sampling error is of random type and has been investigated by GPCC using data from dense networks of Australia, Canada, Finland, Germany and USA. Based on statistical experiments performed for 322 test cases, relations were derived between the sampling error and the number of observations and spatial variability of precipitation in these regions. The relative sampling error with a number of 5 raingauges per gridcell is between 7% and 40% of the true area-mean of monthly precipitation, with 10 stations an error between 5% and 20% can be expected (Rudolf et al. 1994).

Intercomparison studies performed at GPCC for various analysis methods have shown, that the methodical error is much smaller than the sampling errors and can be neglected for large-scale analyses.

The station-related stochastic errors are transferred to the grid-area, and on the grid they are combined with the sampling error using error progression theory. The size of the resulting total error of the calculated gridded precipitation ranges from a few up to some tens in percent of the assumed true area-mean. Errors resulting from an insuffient correction of systematic measuring errors dominate in regions with snowfall and high windspeeds, the sampling errors are major for data-poor regions, especially where precipitation is highly variable.

4 Conclusions

The sampling error in grid interpolation of point-data and calculation of area-average pre-cipitation can be reduced by the use of a larger database. The dilemma is that with additional data from networks of a lower order a larger number of erroneous data will enter the database. An automatic-only quality-control using statistically derived thresholds removes all outliers, both erroneous data or true extreme values. The error resulting for the gridded product is expected to be large but cannot be quantified exactly. To keep the true extreme data in the analysis system and to gain reliable gridded results, a visual check of the questionable data, although very time-consuming, is inalienable. With the full control, the errors remaining from undiscovered erroneous data are mostly negligible. Without any quality-control, however, outliers can strongly affect gridded results and cause errors which may exceed the other error components.

References:

Bussieres, N. and W.D. Hogg (1989): The objective analysis of daily rainfall by distance weighting schemes on a mesoscale grid. Atmosphere-Ocean **27**, 521-541.

Huffman, G.J., R.F. Adler, B. Rudolf, U. Schneider and P.R. Keehn (1995): Global precipitation estimates based on a technique for combining satellite-based estimates, raingage analyses, and NWP model precipitation information. J. Climate **8**, 1284-1295.

Legates, D.R. (1987): A climatology of global precipitation. Publ. in Climatology **40** (1), Newark, Delaware, 85 pp.

Morrissey, M.L., J.A. Maliekal, J.S. Greene and J. Wang (1995): The uncertainty of simple spatial averages using rain gauge networks. Water Resources Res. **31**, 2011-2017.

Rudolf, B. (1993): Management and analysis of precipitation data on a routine basis. Proc. Int. Symp. on Precipitation and Evaporation (Eds. B. Sevruk and M. Lapin), ETH Zuerich, Vol. 1, 69-76.

Rudolf, B., H. Hauschild, W. Rueth and U. Schneider (1994): Terrestrial precipitation analysis: Operational method and required density of point measurements. NATO ASI I/26, Global Precipitations and Climate Change (Eds. M. Desbois and F. Desalmand), Springer Verlag Berlin, 173-186.

Rudolf, B., T. Fuchs and U. Schneider (1998): Management and analysis of precipitation data on global scale. This issue.

Schneider, U. (1993): The GPCC quality-control system for gauge-measured precipitation data. Report of a GEWEX workshop on Analysis Methods of Precipitation on a Global Scale, Koblenz, 14-17 Sept. 1992, WCRP-81, WMO/TD-No. **558**, A5-A7.

Schneider, U., D. Henning, H. Hauschild, M. Reiss and B. Rudolf (1992): Zur Berechnung monatlicher Niederschlagshöhen aus synoptischen Meldungen. Meteorol. Zeitschr.N.F. **1**, 22-31.

Shepard, D. (1968): A two-dimensional interpolation function for irregularly spaced data. Proc. 23rd ACM Nat. Conf., Brandon/Systems Press, Princeton, NJ, 517-524.

WCRP (1990): The Global Precipitation Climatology Project - Implementation and Data Management Plan. WMO/TD-No. **367**.

Willmott, C.J., C.M. Rowe and W.D. Philpot (1985): Small-scale climate maps: A sensitivity analysis of some common assumptions associated with grid-point interpolation and contouring. American Cartographer **12**, 5-16.

Willmott, C.J., S.M. Robeson and J.J. Feddema (1994): Estimating continental and terrestrial precipitation averages from rain-gauge networks. Int. J. Climatol. **14**, 403-414.

Need for hydrological and related data

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The need for hydrological and related data

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1. Introduction

During the 1970's and 80's the main aim of hydrological data collection programs was to provide the basic information required for development of water resources to meet identified needs and for the protection of life and reduction of property damage in flood events. The 1990's have seen a significant shift in emphasis from development of the resource to the management of the resource under the guiding principle of ecologically sustainable development. Also, expanding populations and increased use of floodplains in many countries have seen an increase in the number of people and properties at risk in flood events. At the same time, there has been a shift in economic thinking towards a user pays-cost recovery philosophy and this has resulted in commercialisation of elements of the water industry in many countries. It has followed that there has been a change in emphasis from collecting hydrological data with long-term objectives in mind to one of collecting data for short-term goals. The net result has been a global decrease in long-term basic hydrological data collection networks. Also, hydrological networks have in the recent past been judged more in terms of economic theories (identifiable benefits), than in terms of their contribution to environmental management.

Shiklomanov (1997) details the extreme difficulty in preparing a global assessment of water resources because of the lack of sufficient and reliable information on water availability, quality and use in many areas of the world. The WMO/UNESCO (1991) report on Water Resources Assessment shows an increase in hydrological networks globally during the period 1977 to 1987. However, between 1987 and 1989 a general decrease occurred in the number of precipitation stations, a levelling off in the number of discharge stations and both increases and decreases in the number of water quality stations.

The International Conference on Water and Sustainable Development, Paris, March 1998 identified a "Programme of Priority Actions" which included as the first action, "Improving Knowledge of Water Resources and Uses". This action area recommended:

- Establishment and improvement of integrated monitoring systems;
- Strengthening of regional, national and international programmes for acquiring fundamental knowledge; and
- Promoting the networking of interlinked and widely disseminated systems for exchanging documentation on water.

2. Changing uses of hydrological and related data

The 1970's and 1980's saw the focus for hydrological data collection to be development of and protection from water. With respect to the information necessary to assess the resource, major issues have included availability of the resource, quality of the resource, ease of access, cost, operational infrastructure and to a limited extent, environmental impact. The main needs have been domestic water supplies, water for agricultural purposes, water for industrial purposes, including mining and other extractive industries and in some cases, navigation. Increasing development of flood plain areas has resulted in flood warning and forecasting needs also increasing in importance. Information has been used for the design and operation of the developed systems. However, not only has the water resource been used as a source, but it has also been used as a convenient sink for the disposal of waste.

The 1990's have also seen significant changes in the principles associated with the management of water resources. These principles have been identified and highlighted by a number of International meetings, including the International Conference on Water and the Environment, Dublin, 1992 (ACC/ISGWR, 1992) and the UNCED-Agenda 21 (1992) process and include:

- the identification of water as an economic good with an associated economic value in all of its competing uses;
- the importance of water within the principle of ecologically sustainable development;
- the multi-disciplinary nature of water resources management; and
- the recognition of freshwater as scarce, vulnerable resource, essential to the preservation of all forms of life.

The net result has been increased awareness of the need to collect important information required for the management of water resources under the principle of ecologically sustainable development, but a reduction in the budgets allocated to those groups charged with this responsibility; that is, the "do more with less" approach. As practicing hydrologists, I believe that it is time we went back to basics in assessing the hydrological and water resources data we collect. This requires us to re-define the requirements for hydrological data in terms of the types of data we collect; the accuracy requirements of this data; and the classification of data quality for various applications (including the integration of data collection neworks). That is, in terms of the Guide to Hydrological Practices (WMO, 1994), to revisit data collection, processing and dissemination.

3. The types of data we collect

3.1 Activities using hydrological data

Accurate information on the quantity, variability and quality of any nation's water resources is important, as water is vital to present and future sustainable development. Rainfall is often variable in nature and as a result, streamflow can also be variable with long droughts or large and devastating floods. In most countries, water resources are under increasing demand and threat from competing users and uses. Generally, they are variable in quality and quantity, unpredictable in occurrence and frequently remote from centres of demand.

Due to the temporal and spatial variability of hydrological and climatic data, many tens of years of record at numerous sites and a quantitative understanding of the hydrology of each region are necessary to meet the important needs for surface water information. This requirement to collect data many years in advance of its eventual use emphasises the importance of developing and continuously reviewing well-designed and integrated networks that are in balance with existing and future needs for information. The general fields of application of hydrological/water resources data remain:

- Water Resources Management
- Land Resources Management
- Environmental Management
- Primary Industries
- Power Supply
- Water Supply
- Transport
- Flood Mitigation
- Defence
- Insurance
- Research/education
- Recreation

However, as indicated above the change in emphasis has been from development to sustainable management of the resource, that is a shift towards management issues. This has resulted in expansions to the types of data we collect and also the recognition that we are developing integrated information systems and not just collecting data.

3.2 Types of hydrological data

The types of hydrological data required for the uses identified above include:

- Meteorological
  - Rainfall (daily and continuous, including snow and ice)
  - Evaporation
  - Air Temperature
  - Wind Speed
  - Solar Radiation
  - Sunshine Duration
- Surface Water
  - Catchment Characteristics (soil types) and Land Use
  - History of changes (eg land and water use)
  - Water levels and Runoff
  - Yield (and associated probabilities of failure)
  - Flood History (areas at risk and response plans)
  - Soil moisture
  - Rainfall-Runoff relationships (annual and event)
  - Relationships with Groundwater
- Groundwater
  - Location
  - Stratigraphy
  - Yield
  - Behaviour
  - Relationships with Surface Water
- Water Quality (for surface water, groundwater and water-use, existing quality and required quality)
  - Chemical
  - Biological
  - Sediment
- Water use and demand
  - Water use by category
  - Water demand (existing and future demands)
  - Water conservation activities
  - Pollution sources
  - Water re-use
  - Economic data on returns for water use

Recent years has seen a growing requirement for data/information relevant to the sustainable management of the resource, that increased emphasis on the implications of water use in terms of water quality, water use and demand and integrated relationships between land and water resources (both groundwater and surface water). One Australian example of this shift in emphasis has been the National Land and Water Resources Audit recently established by the Australian Government (National Land and Water Resources Audit, 1998).

4. Accuracy requirements of hydrological data

The Guide to Hydrological Practices (WMO, 1994) provides recommended accuracy (uncertainty levels) expressed at the 95% confidence interval for a range of hydrological and hydrometeorological parameters. However, no indication as to the relationship between the accuracy of the information and its potential use is provided. It may be assumed that this is the most stringent of recommendations and that data collected to this accuracy can be used for any purpose. However, with hydrological data being used for many additional purposes and decision making based on this data taking on increased importance, the required accuracy of data should be established with its purpose in mind. This is also relevant when considering the method for collecting hydrological data. For example, point rainfall data can be collected to a specific level of accuracy, however the estimation of areal rainfall data can be improved through the use of radar information. The accuracy of the derived rainfall field will determine what purpose this information can be put to. That is, is it sufficiently accurate to use as input in complex hydrological models.

5. Classification of data quality for various applications

Hydrological data are being collected for a range of purposes and there is increasing pressure for hydrological data collection systems to be cost effective. The quality of data collected has a direct bearing on the cost of establishing and maintaining a data collection system. Also, most eater agencies now require at least one benefit (if not more) to be obtained from the operation of a data collection site. Therefore, it will become increasingly important for hydrologists to be able to identify the specific types of data required for a particular purpose and the required accuracy of data for that purpose. Networks an then be proposed and evaluated on the basis of their ability to provide data and information to meet the identified purposes.

6. References

ACC/ISGWR, 1992: *International Conference on Water and the Environment.* The Dublin Statement and Report on the Conference, WMO 55pp.

Shiklomanov, I.A. (Editor), 1997: *Assessment of water Resources and water Availability in the World*, Background Document for the *Comprehensive Assessment of Freshwater Resources on the World*, WMO, Geneva, Switzerland, 90pp.

WMO (1994) *Guide to Hydrological Practices.* WMO No. 168.

WMO/UNESCO, 1991: *Report on Water Resources Assessment. Progress in the Implementation of the Mar del Plata Action Plan and a Strategy for the 1990s*, WMO/UNESCO, 65pp.

UNCED, 1992: Agenda 21 - *Chapter 18 - Freshwater.*

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Assessment of the sensitivity of catchment models to imperfect rainfall input estimation

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Introduction

This paper investigates the sensitivity of several catchment models to imperfect rainfall input estimation. This topic is of interest for modellers and also for water ressources managers, to assess the size and characteristics of raingauge networks needed in rainfall-runoff modelling studies. The study presented here is built on an original approach developed by *Andréassian and Michel* [Impact of imperfect rainfall knowledge on catchment model efficiency, submitted to *Water Resources Research*, 1998; hereinafter referred to as *Andréassian and Michel*, submitted manuscript, 1998] where real rainfall and runoff data are used in conjunction with a catchment model, GR3J. This paper investigates the comparative sensitivity of the parameters of GR3J and modified versions of IHACRES and TOPMODEL : random raingauge subsets of an existing network are produced to feed the catchment models, and the sensitivity of model efficiency and calibrated parameter values to the level of rainfall information available is studied.

Relevant Literature

O'Connell [1982] reviewed the existing literature on methods of raingauge network design. After describing approaches based on the sole analysis of rainfall fields, he identified two categories of approaches based on rainfall-runoff modelling:

(i) a first approach where synthetic rainfall is generated and fed through a catchment model: the synthetic rainfall field is sampled at discrete points to simulate an actual raingauge network, and the catchment model is used with the total rainfall field to generate synthetic streamflow. The impact of limited rainfall information on modelling results is then assessed through a comparison between "actual" synthetic streamflow and streamflow generated using sampled rainfall fields.

(ii) a second approach where actual rainfall and runoff data are used in conjunction with a catchment model: the reference streamflow is an actual streamflow data set, and the existing raingauge network is sampled to feed the catchment model.

O'Connell [1982] gave his preference to the first approach, stating that this approach allows to study the effect of any number of sampling point, since the "true" rainfall field is known. But *Sugawara* [1993] stresses that observing the actual mean areal rainfall over a basin is impossible. Why should we then base our analysis on such a concept, knowing that none of the catchment models we use can be run with it ? In this paper, we follow *Sugawara* [1993] and rely on (ii) to assess the impact of our limited rainfall knowledge on catchment modelling,

Presentation of the Catchment Rainfall Spatial index

A Catchment Rainfall Spatial (CRS) index was proposed by *Andréassian and Michel* [submitted manuscript, 1998] to quantify the quality of rainfall information available to model the rainfall-runoff relationship on a catchment. This CRS index is used in the following study to quantify the quality of a particular raingauge network for a rainfall-runoff modelling objective. Mathematical details of CRS index calculation are presented in Appendix.

Presentation of the Catchment Models

Three reliable simple structures of daily continuous catchment models were used in this study :

- GR3J is an empirical three-parameter model. It belongs to a family of models developed at Cemagref since the early 1980s. [*Nascimento,* 1995 ; *Edijatno et al.,* 1998].
- a modified version of IHACRES model structure. IHACRES is a six-parameter model with a theoretical (linear systems/unit hydrograph) basis [*Jakeman et al.,* 1990 ; *Littlewood and Jakeman,* 1994].
- a five-parameter modified version of TOPMODEL, which uses a parameterised analytical expression of the soil-topographic index distribution. [*Beven and Kirkby,* 1979 ; *Beven et al.,* 1995].

In the present study, the three model structures were used as lumped models, all using the same amount of data, i.e. rainfall-runoff time-series and potential evapotranspiration estimates.

Study Area

Ten years (1980-1989) of daily rainfall-runoff data were used for the Yonne River catchment near Courlon (10,200 km²), France. The Yonne River is a tributary to the Seine River and a major contributor to flood events that cause damages in the greater Paris area. Daily rainfall data sets were calculated as the arithmetic mean of rainfall records of subsamples of the 33 raingauges available for both catchments over the whole period of study. Catchment models were calibrated and controlled on two periods of 5 years, 1980-1984 and 1985-1989.

Sensitivity of the models to catchment raingauge network quality

To study the relationship between a given raingauge network quality, as measured by the CRS index, and the efficiency of models in simulating daily flows, we randomly generated 2000 subsets of the 33 raingauges.

Models were run with each of the 2000 rainfall data sets using a split-sample test procedure with calibration-validation tests on both periods of study (1980-1984 and 1985-1989). Fig. 1 presents the results of the 2000x2 control runs performed using GR3J, plotted against the Nash and Sutcliffe goodness-of-fit criterion value for the simulation runs.

The relationship between raingauge network quality, as measured by the CRS index, and calibrated parameters of the models

In this section, we use the same randomly generated raingauge subsamples as above. On the basis of the three models used in this study, it was possible to identify four different types of parameter behaviour, with respect to the CRS index (Fig. 2) :

1. convergence towards a single value, independent from the calibration period,
2. convergence towards a value, dependent from the calibration period,
3. stability of the parameter value, for the range of CRS index values,
4. no identifiable trend.

Discussion and conclusion

The present study showed, as it could be expected, a clear influence of rainfall information quality - as estimated by the CRS index - on the efficiency of rainfall-runoff models. Low-information raingauge networks cause lower and more variable model performance. Similarly, these networks may cause a high variance in the calibrated value of model parameters, but these parameters show different reactions to an increase of available rainfall information. Some parameters (such as all GR3J parameters and the modulation temperature factor of IHACRES) converge towards a single optimum, showing the model ability to make an efficient and consistent use of increasing information. Other parameters (such as some of TOPMODEL parameters), exhibit a stronger dependence on the calibration period, and have more than one optimum values. Although this may not affect model efficiency in validation (as distinct parameter sets may provide the same efficiency level), this behaviour may be a drawback for many applications, such as regionalisation. Behaviour 3, shown for example by the pure time delay of IHACRES, proves the good identifiability of such parameters. Last, behaviour 4 shows the low identifiability of some parameters. The three routing parameters of IHACRES (the flow separation coefficient and the quick and slow flow routing constants) belong to this category. This can be explained in our case : when one part of the flow becomes small, the corresponding routing constant loses its identifiability.

We believe that these results will be helpful to gain a better understanding of the importance of the size and characteristics of rainfall networks used in rainfall-runoff modelling, and provides some highlightson the robustness of some catchment model structuresand on the sensitivity of their parameters on the input data.

References

Beven, K.J. and Wood, E.F. (1983). Catchment geomorphology and the dynamics of runoff contributing areas. *Journal of Hydrology*, **65**, 139-158.

Beven, K.J., Lamb, R., Quinn, P., Romanowicz, R. and Freer, J. (1995). TOPMODEL. In *Computer models of watershed hydrology, V.P. Singh (Ed.),* Water Resources Publications, 627-668.

Edijatno, Nascimento, N., Yang, X., Makhlouf, Z. and Michel, C. (1998). GR3J : a daily watershed model with three free parameters. *Hydrological Sciences Journal, in press.*

Jakeman, A.J., Littlewood, I.G. and Whitehead, P.G. (1990). Computation of the instantaneous unit hydrograph and identifiable component flows with application to two small upland catchments. *Journal of Hydrology,* **117**, 275-300.

Littlewood, I.G. and Jakeman, A.J. (1993). Characterisation of quick and slow streamflow components by unit hydrographs for single- and multi-basin studies. *Methods of hydrological basin comparison, M. Robinson (Ed.),* Institute of Hydrology, Report 120, 94-105.

O'Connell, P.E. (1982). Raingauge network design - a review. In *Modeling components of hydrologic cycle, V.P. Singh (Ed.)*, pp.13-50, Water Resources Publications, Littleton.

Nascimento, N.O. (1995). Appréciation à l'aide d'un modèle empirique des effets d'actions anthropiques sur la relation pluie-débit à l'échelle du bassin versant. Ph.D. dissertation. CERGRENE / ENPC, 550 pp.

Sugawara, M. (1993). On the weights of precipitation stations. In *Advances in theoretical hydrology, J.P. O'Kane (Ed.)*, pp. 59-74, Elsevier, Amsterdam.

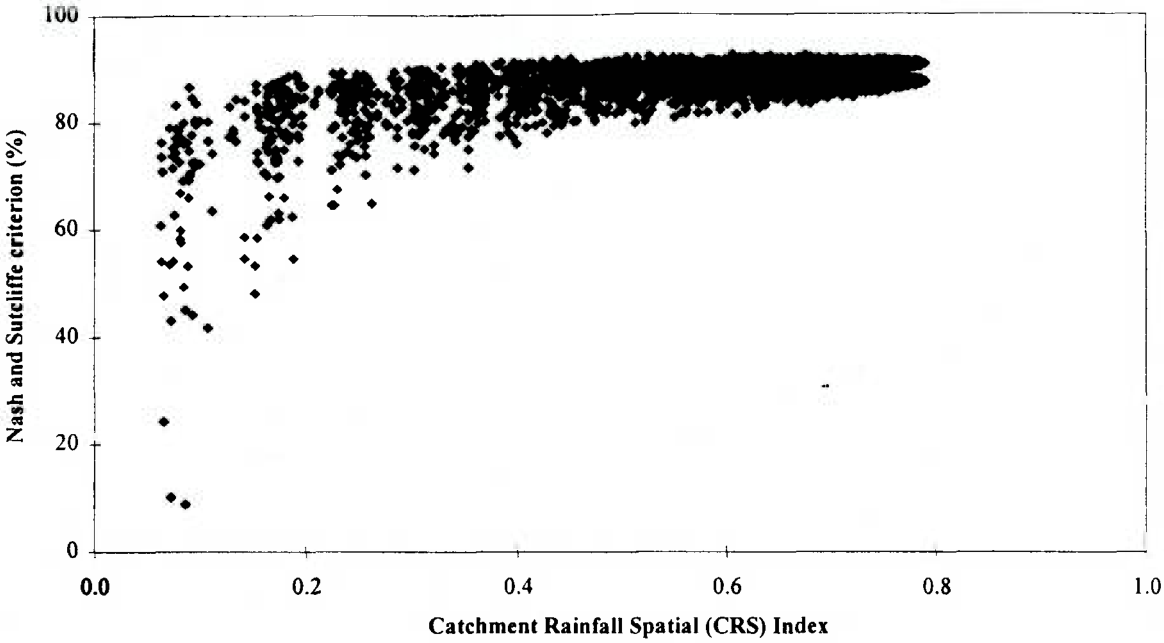
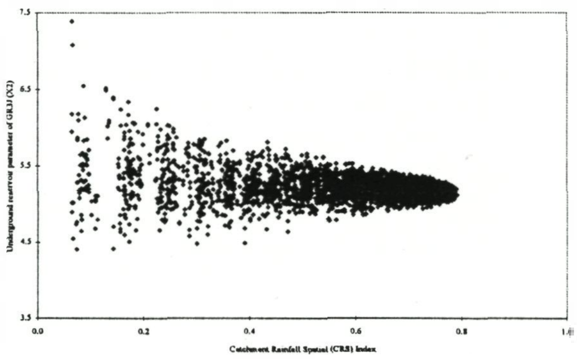
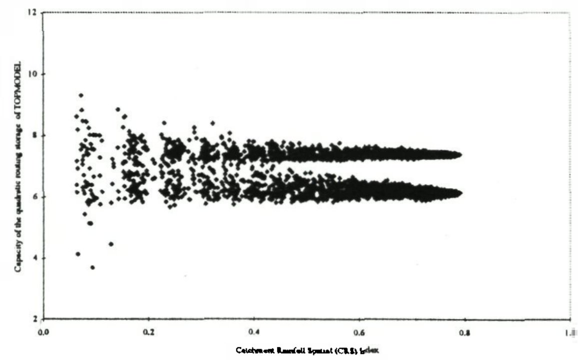


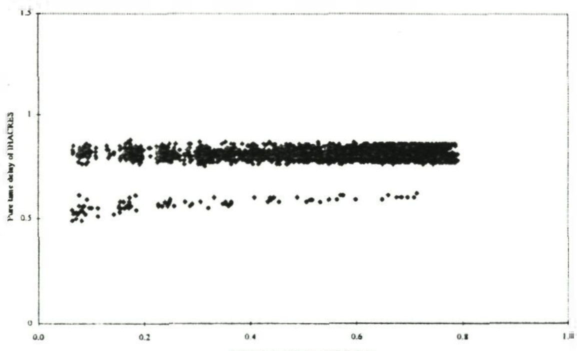
Figure 1 : GR3J efficiency in validation vs quality of raingauge network subsets



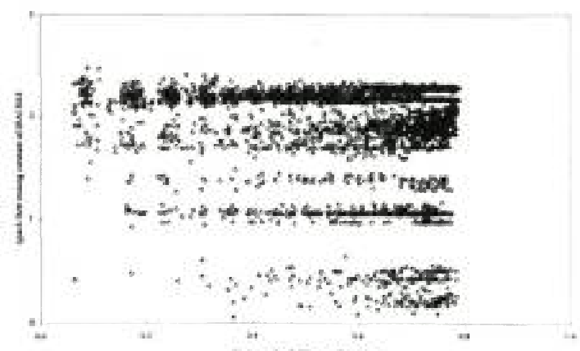
(1)



(2)



(3)



(4)

Figure 2 : the four different types of parameter behaviour, with respect to the CRS index

Appendix 1

The Catchment Rainfall Spatial index is computed as follows:

$$CRSindex = \sqrt{TIndZ * TIndXY} \quad , \qquad 0 < CRSindex < 1 \qquad (1)$$

$$TIndZ = \frac{1}{1 + \dfrac{k_z}{\sqrt{IndZ}}} \quad , \qquad 0 < TIndZ < 1 \qquad (2)$$

$$TIndXY = \frac{1}{1 + \dfrac{k_{xy}}{\sqrt{IndXY}}} \quad , \qquad 0 < TIndXY < 1 \qquad (3)$$

$$IndZ = \frac{1}{2} * \left[\sum_{i=1}^{n} \frac{1}{1 + \left(\dfrac{z_i - z_g}{\left(\dfrac{z_x - z_n}{2} \right)} \right)^2} \right]^2 + \sum_{i<j} \frac{\left(\dfrac{z_i - z_j}{z_x - z_n} \right)^2}{\dfrac{1}{8} + \left(\dfrac{z_i - z_g}{\left(\dfrac{z_x - z_n}{2} \right)} \right)^4 + \left(\dfrac{z_j - z_g}{\left(\dfrac{z_x - z_n}{2} \right)} \right)^4} \qquad (4)$$

$$IndXY = \frac{1}{2} * \left[\sum_{i=1}^{n} \frac{1}{1 + \left(\dfrac{x_i - x_g}{\sqrt{\dfrac{S}{4}}} \right)^2 + \left(\dfrac{y_i - y_g}{\sqrt{\dfrac{S}{4}}} \right)^2} \right]^2 + \qquad (5)$$

$$\sum_{i<j} \frac{\left(\dfrac{x_i - x_j}{\sqrt{S}} \right)^2 + \left(\dfrac{y_i - y_j}{\sqrt{S}} \right)^2}{\dfrac{1}{8} + \left(\dfrac{x_i - x_g}{\sqrt{\dfrac{S}{4}}} \right)^4 + \left(\dfrac{y_i - y_g}{\sqrt{\dfrac{S}{4}}} \right)^4 + \left(\dfrac{x_j - x_g}{\sqrt{\dfrac{S}{4}}} \right)^4 + \left(\dfrac{y_j - y_g}{\sqrt{\dfrac{S}{4}}} \right)^4}$$

Notations :

(x_i, y_i, z_i)	*cartesian space coordinates of the i-th raingage P_i (i = 1, 2, ... n)*
(x_g, y_g)	*(x,y) coordinates of the centroid of the catchment area*
z_g	*mean elevation of the catchment*
z_x and z_n	*maximal and minimal elevation of the catchment*
S	*catchment area*

k_z , k_{xy} *scaling coefficients*

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Missing water related multidisciplinary data hinder the sustainable management of the groundwater resources in developing countries (examples, needs, possibilities and experiences from Argentine)

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1. Introduction

Sustainable management of the freshwater resources means an appropriate exploitation and protection of water against overexploitation and pollution, so that they remain unchanged in that way that they will fulfil the basic needs of the present societies and that they will be available for further generations. This is the guiding vision of sustainable development like it was adopted during the conference of the United Nations for Environment and Development in 1992 in Rio de Janeiro by more than 170 heads of governments: life shall be designed world-wide in a way that the basic needs of the present generations can be satisfied without destroying the life bases of future generations. Using the water management policy as a principle test, it can be recognised that nowadays - 7 years later - especially the developing countries have not yet accepted the resulting commitments and hence hinder the sustainable development of their societies. The water resources are misused, overexploited and irreversibly contaminated.

Reasons are manifold. Due to the high water availability in the case study Argentine and many other developing countries water was considered in the past as unlimitied available, as free and hence of low value. The rapid increase of the water demand within the last decade requires that more and more water must be exploited (especially more and more groundwater). Primary reasons are the direct and indirect consumption by the growing urban population and the excessive water demand (from user and supplier side). On the other side decreases the water availability continuously. Reasons are the increasing contamination, the overexploitation, the decreasing recharge due to climate change, etc. Both processes are related to numerous social-economic, political-institutional, environmental and scientific-technical aspects. An integrated approach of all these aspects with their complex interrelations is necessary instead of selective parameters which do not describe the real situation which is required for a sustainable water resources management. But not even the classical water related data like (natural) scientific and technical data are collected and monitored in developing countries with the necessary extent. The supplying institutions often adapt their supply only on the increasing demand and drill more and more wells without any sustainable planning or consideration of the aquifer system. Necessary changes or rehabilitations of the supply systems, etc. remain unconsidered. Collecting water related data seems not to be of importance. Very little money is being spent on this issue. In opposite, most developing countries spent large amounts for ineffective water management and the therefrom resulting negative consequences. Not considered remains that a regular and comprehensive data collection and a good data management require only very few financial resources compared with the money that must be spend for the consequences resulting from bad management (less than 1 % of the total costs for the water management/supply).

2. Case studies - Problems

The fundamental water related parameter and necessary data for their description were analysed for the largest cities of Argentine (Buenos Aires, Rosario, Cordoba, La Plata, Tucumán, Santa Fe, Salta, Mar del Plata). Aim was to investigate the social-economic, financial, environmental, scientific-technical and political-institutional water related problems, their reasons, parameters and data to describe them and their complex interrelations (Tab. 1).

With different extent, all investigated cities show many of the worst symptoms of the regions underdevelopment: vast areas, great numbers of poor people, high concentrations of contamination and traffic congestion. Many of these problems affect the environment and the water resources within and outside of the urban areas e.g. by increasing sources and intensities of contamination, increasing quantities of exploited water (due to: increase of industrial production, sewage, domestic waste). The uncontrolled increase in population and the directly related decrease of living conditions cause an increase of environmental impacts which are directly related to health problems which again require more and more public finances. They, as do the aggravating social conditions require more and more public finances to be spent, a requirement that often can not be met due to the limited financial resources. Living conditions are interrelated with political and institutional problems, e.g. missing programmes to increase the social conditions by corresponding programs due to: political instability and unpredictability, missing programmes to improve the quality of life in rural areas, missing programmes to increase living standard, missing agreements between different institutions, and missing interdisciplinary and inter-institutional co-operation. Missing or insufficient programs for environmental education and information (formal and non-formal) lead to an increase of environmental contamination and results in an excessive water consumption. Excessive water consumption together with leakages in the water supply system cause an excessive water demand. Excessive demand and insufficient supply result in a unsatisfied water demand. The uncontrolled, ineffective and inefficient water resources management, including water supply and sewage services led to numerous consequences. Especially those on the groundwater resources are - due to the lack of data - often unknown. (1.) Extensive uncontrolled groundwater exploitation has lead to continuously decreasing groundwater levels (Buenos Aires (parts), La Plata, Santa Fe, Cordoba, Rosario, Tucumán, Salta). Due to missing recharge data, it is unknown whether the aquifer systems are overexploited or not. (2.) Extensive uncontrolled groundwater exploitation from deeper aquifers within or near to the urban areas of most cities resulted locally in their contamination by vertical inflowing highly contaminated shallow groundwater (due to the hydraulic potential difference created by the exploitation), (3.) At various sites at the coast mostly between Buenos Aires and Mar de Plata the extensive groundwater exploitation has lead to a progressive salinisation of the aquifers towards the continent. (4.) In various of the investigated cities drinking water may be contaminated within the red of the supply system, especially during cuttings of the supply, where sewage can enter by fissures.

3. Rising questions

Looking on the evaluated case studies some questions rise: What is necessary for solving the described problems? What can the policy and decision makers do? How can they act in the appropriate form if they do not have the necessary background information and knowledge about available resources, contamination hazards, existing sources of contamination, the interrelation between the social-economic conditions? How can they formulate environmental laws without including important components as the polluter pays principle as one of the most powerful tools to prevent or minimise pollution at its source? How can they establish programmes to diminish contamination, if they do not know about the priorities of the cases, if they do not know to which extent the particular contamination sources affect the water resources, if they do not know which contaminated site must be completely sanitated and which ones can be treated by cheaper measures, e.g. by sealing and if they do not know about effective and economical treatment methods, e.g. for industrial effluents? How can they decide whether a polluting industrial plant must be closed immediately or if it is sufficient to oblige them special protection measures that they must introduce within a certain time (proper treatment plants, cleaner production methods, relocation to more appropriate places)? How can they plan the future demand for the capacity of the water supply, the capacity of water treatment plants and municipal waste deposits if they do not have demographic studies and forecasts of the future demand? How can they know up to which quantity of water they may exploit without overexploiting the aquifers if they do not have hydrogeological information? How can they know which measures are necessary to protect the water resources if they do not have corresponding studies (vulnerability maps, etc.)? How can they optimise the water supply system if they are not metering the water, if they have no knowledge about performance indicators and benchmarking? How can they decide which are the most needed short-term actions and which can remain for middle and long-term consideration. How can they satisfy the concern of the population whose environmental awareness is continuously increasing and how can they answer their questions if they do not have necessary data and information? How can they prevent or minimise disasters if they do not consider warnings from international warning systems? Why for example did they not attach importance to the information by the National Weather Service of the United States that successfully predicted the start and scope of the "El Niño" half a year before it started?

4. Prerequisite for solutions are multidisciplinary water related data

Water as central part for sustainable development is strongly related to numerous scientific-technical, environmental, social-economic and political-institutional aspects which are interconnected in a very complex way (Tab. 1). This requires a corresponding comprehensive interdisciplinary and inter-institutional approach, where all aspects must be considered in a well-balanced form. A prerequisite therefor is that all water related data referred to the problems and aspects compiled in Table 1 must be collected and the timely changing parameters must be monitored. A requisite which is missing especially in developing countries.

Only these data allow a long-term sustainable water resources management where the most relevant water related scientific-technical, environmental, socio-economic and political-institutional parameters (driving forces) are considered in an integrated approach. Only that allows that their development in the past can be analysed and that the interrelations between the different parameters can be quantitatively determined (e.g. by network analysis). For the future decades, the developments of the parameters can be described and quantified (e.g. by possibility functions). Water supply and water demand can be forecasted (e.g. expressed as possibility functions) by superposition of all particular forecasts of all influencing water related parameters. These forecasts of water supply and water demand form the base for decisions in the area of water resources management. Balancing the forecasts for water supply and water demand, quantifies the possibility for a future water crisis and allows an early initiation of counter-measures. The resulting shifts of the development can be quantitatively forecasted. Expressing the future developments in economic (financial) values, the real, the total economic value of water, that includes all environmental and social values, can be considered. That gives the base to develop sustainable ecological and economic well directed alternatives and allows to evaluate them by a long-term ecological and economic cost benefit analysis. The most important parameters, which can be used most effectively to increase the sustainability in water resources management can be determined and corresponding procedures and economic/financial incentives and political instruments can be developed.

Interdisciplinary water related problems, their interrelations, the high financial costs and social-economic and environmental consequences of not applying multidisciplinary data collection and analysis as base for an integrated sustainable water resources management, possibilities how to introduce the first steps on the way for data collection and data management on municipal, provincial and national level, possibilities of education, training and international co-operation programmes are given for above case studies. Here missing multidisciplinary water related data have already resulted in severe problems which will end in local water crises if not immediately the basis for a sustainable introduced.

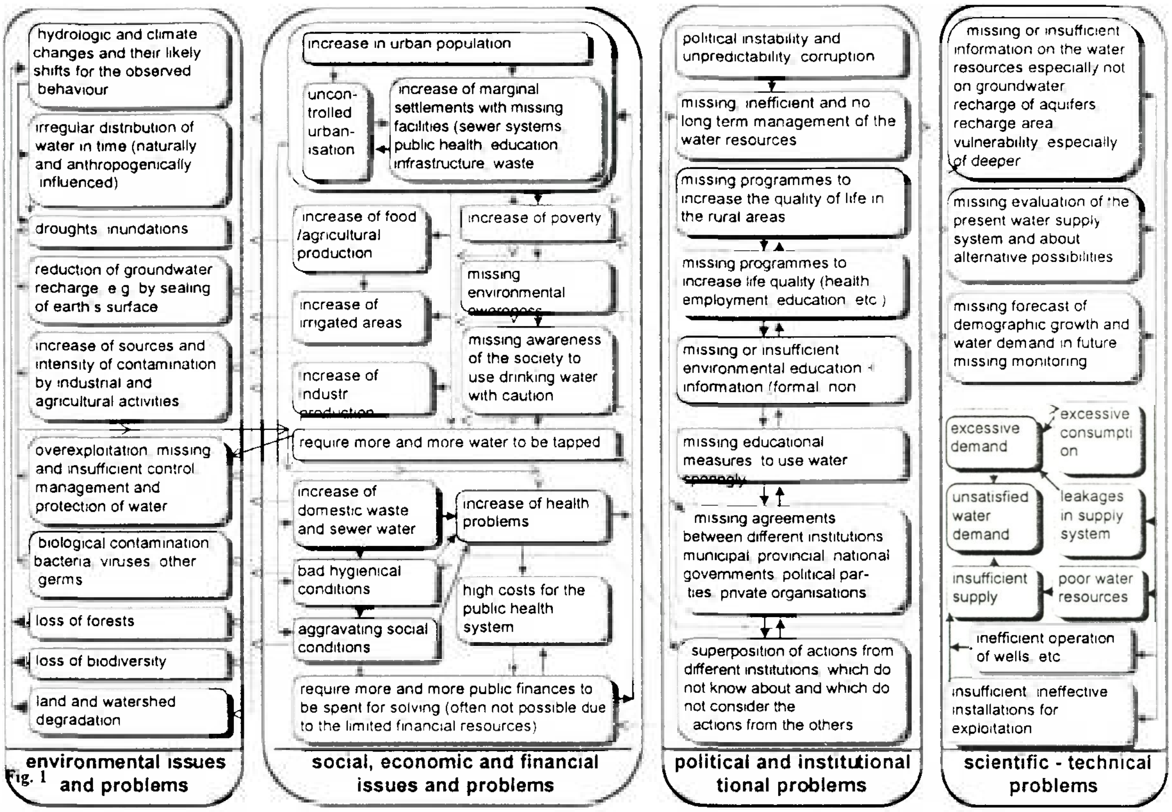
hydrologic and climate changes and their likely shifts for the observed behaviour
irregular distribution of water in time (naturally and anthropogenically influenced)
droughts inundations
reduction of groundwater recharge e g by sealing of earth s surface
increase of sources and intensity of contamination by industrial and agricultural activities
overexploitation missing and insufficient control management and protection of water
biological contamination bacteria viruses other germs
loss of forests
loss of biodiversity
land and watershed degradation
environmental issues and problems
increase in urban population
uncon-trolled urban-isation
increase of marginal settlements with missing facilities (sewer systems public health education infrastructure waste
increase of food /agricultural production
increase of poverty
missing environmental
increase of irrigated areas
missing awareness of the society to use drinking water with caution
increase of industr
require more and more water to be tapped
increase of domestic waste and sewer water
increase of health problems
bad hygienical conditions
high costs for the public health system
aggravating social conditions
require more and more public finances to be spent for solving (often not possible due to the limited financial resources)
social, economic and financial issues and problems
political instability and unpredictability corruption
missing inefficient and no long term management of the water resources
missing programmes to increase the quality of life in the rural areas
missing programmes to increase life quality (health employment education etc)
missing or insufficient environmental education information (formal non
missing educational measures to use water
missing agreements between different institutions municipal provincial national governments political parties private organisations
superposition of actions from different institutions which do not know about and which do not consider the actions from the others
political and institutional problems
missing or insufficient information on the water resources especially not on groundwater recharge of aquifers recharge area vulnerability especially of deeper
missing evaluation of the present water supply system and about alternative possibilities
missing forecast of demographic growth and water demand in future missing monitoring
excessive demand
excessive consumption
unsatisfied water demand
leakages in supply system
insufficient supply
poor water resources
inefficient operation of wells etc
insufficient ineffective installations for exploitation
scientific - technical problems

Fig. 1

Tab. 1

International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management

Koblenz, Federal Republic of Germany
22 - 26 March 1999

A semi-empirical model to simulate soil water storage within the root zone at regional scale

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To assess water resources of the Dyle watershed (440 km^2), in Belgium, an extended research project has been developed since 1978. As a result an extensive data set was obtained and used in many studies. Recently, using the above mentioned data a detail analysis of the factors affecting the rainfall-runoff relationships has been carried out for some soils in the Dyle basin (El Idrissi, 1996; Assouline et al., 1997). In this study the time evolution of the soil water storage and the determination of soil water saturated areas contribute in the better knowledge of the runoff processes. But soil water content assessment on a regional basis using direct measurements represents a large effort because it is time consuming and expensive. The use of computer simulation for such purposes has the potential to minimise the number of soil moisture measurements, allow interpolation between measurements, accumulate and integrate all processes involved in the soil water balance, and develop the potential for regional analysis and projections (Saxton et al., 1988).

The elaboration of the HUTA-30 model as a comprehensive simulation model, enables to integrate climatic, soil and crop factors to compute daily water storage changes for unknown locations within the watershed. Data set from 9 sites located upstream of the watershed were analysed for three different soils classified by De Backer et al. (1982) as follows: (1) silt and sandy-silt from plateau and slopes; (2) sand and silty sand from plateau and slopes along the sides and (3) silt and sandy-silt from valleys and depressions. One access tube for gamma neutron probe extensive soil moisture data set spread over 30 months from the Dyle basin was coupled with a computer simulation method to test a combined approach for assessment of soil water for the mention region. Neutron probe was placed in each place to determine water moisture content at 30 cm depth. The Rainfall data were collected by 4 rain gauges equipped with tipping bucket. All the measurements of soil moisture content have been performed on sites with herbal cover.

The studied physical properties of the 9 sites are presented in table 1. Dry bulk density, ρ_m, was determined by gamma-neutron scattering method (NAE type) at 30 cm depht; pores mean diameter, D_m, with a mercury porosimeter; water storage at saturation, θ_{sat}, as well as residual water storage; θ_r, by means of a pressure plate.

* Corresponding author

Site	SDA	VLV	AbJ	CYL	ChG	TNG	GNt	GNP	CNt
θ_{sat} (cm³/cm³)	40.67	39.33	28.33	43.67	30.33	31.00	38.33	37.33	36.67
θ_r (cm³/cm³)	8.00	10.33	3.33	5.33	5.00	5.33	14.67	7.00	8.00
K_{sat} (mm/day)	15.5	47.52	19.98	22.40	35	18.24	17.23	16.44	62
ρ_m (g/cm³)	1.60	0.98	1.23	1.49	1.03	1.46	1.24	1.55	1.17
D_m (μm)	2.37	6.19	12.39	3.09	5.25	4.67	2.46	3.38	8.02

Table 1: Physical and hydrodynamic properties of the 9 study sites

The proposed model is based on the following assumptions: (i) the soil is an isotropic, homogeneous, and continuos medium, (ii) in the top layer (0-30 cm), the soil moisture content is uniform; (iii) water fluxes occur in the vertical down flow direction; (iv) daily precipitation are assumed to be uniform along the day. The model is based on the mass balance equation:

$$DS_j = (W_{inputs} - W_{outputs}).\ dt \quad (1)$$

where DS_J is the daily difference in water storage; W_{inputs} the precipitation (rainfall + snow); Ia_j, effective infiltration in the soil; $W_{outputs}$ the sum of water losses by evapotranspiration, ETR_j and by redistribution, Rd_j. All parameters are in mm and in daily basis.

The soil infiltration is described by Philip's equations (1957a, b). These equations relate the sorptivity, S [mm/day$^{-1/2}$], and A is the infiltration velocity [mm/day]. The empirical model proposed by Gosh and Maity (1976) has been chosen to compute $S(\theta)$:

$$S = a(\theta_{sat} - \theta_a)^b \quad (2)$$

a is the first unknown parameter required by the model and b was considered equal to 0.5.
The model proposed by Van Genuchten (1980) was used to determine the water distribution in the downward vertical direction:

$$RD_j = K_{sat}.(S_{e_j}^{0.5}).[1-(1-S_{e_j}^{(1/m)})^{m})^{2}] \quad (3)$$

The m shape parameter of this model, can take any value between 0 and 1, being $m = 1-(1/n)$. n is the second unknown parameter of the proposed model.
Crop evapotranspiration ETR can be calculated indirectly from $ET0$, which is the reference evapotranspiration, using the relation proposed by Doorenbos and Pruit (1977):

$$ETR = Kc.ETo.(\frac{\theta_a}{\theta_{max}}) \quad (4)$$

Kc is the crop coefficient and can be calculated as the ratio between maximum evapotranspiration and the reference evapotranspiration $ET0$ when the crop is growing in optimal conditions. Kc is the third unknown parameter of the proposed model.

The model parameters were optimised by the standard error estimation SEE. This objective function has to be minimised by means of the simplex algorithm (Nelder and Mead, 1965). When SEE is minimised (SEE_{op}) a, m and Kc became a_{op}, m_{op}, and Kc_{op}. Results from each experimental site are presented in table 2. The highest value of ESE_0 never exceeds 10 mm, which is more or less 8% of the storage at saturation.

Site	SDA	VLV	AbJ	CYL	ChG	TNG	GNt	GNP	CNt
SEE_{op}(mm)	8.14	9.51	5.76	9.93	8.27	7.46	7.39	7.16	8.84
a_{op} (x100)	24.82	3.22	9.18	8.42	0.41	9.53	0.22	14.33	23.06
m_{op} (x100)	22.97	16.03	52.54	14.14	29.85	46.48	9.27	31.81	36.61
Kc_{op} (x100)	46.58	48.92	21.00	61.39	34.59	47.55	39.08	51.00	26.49

Table2: Optimal results of model parameters

Measured and simulated soil water storages were compared: correlations between simulated and observed data were computed for three sites corresponding to the three soil types. Results showed that significant correlations were obtained. All simulated soil water storages were graphed with the measured values for all the studied sites. Figures 1, 2, 3 shows the good accuracy of the model for the three selected sites. The graphs show the significant soil water variation within the locations due to major soil differences.

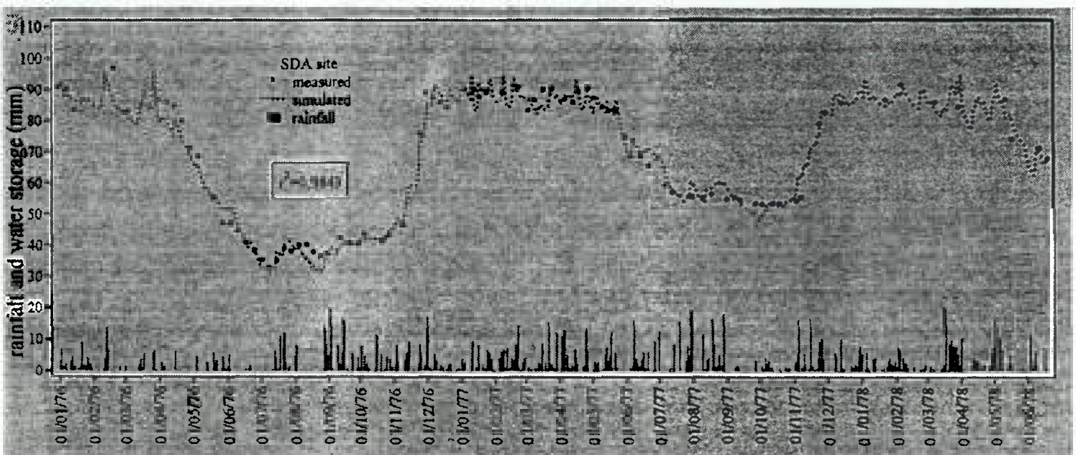

Figure 1: Time evolution of measured and simulated water storages at SDA site

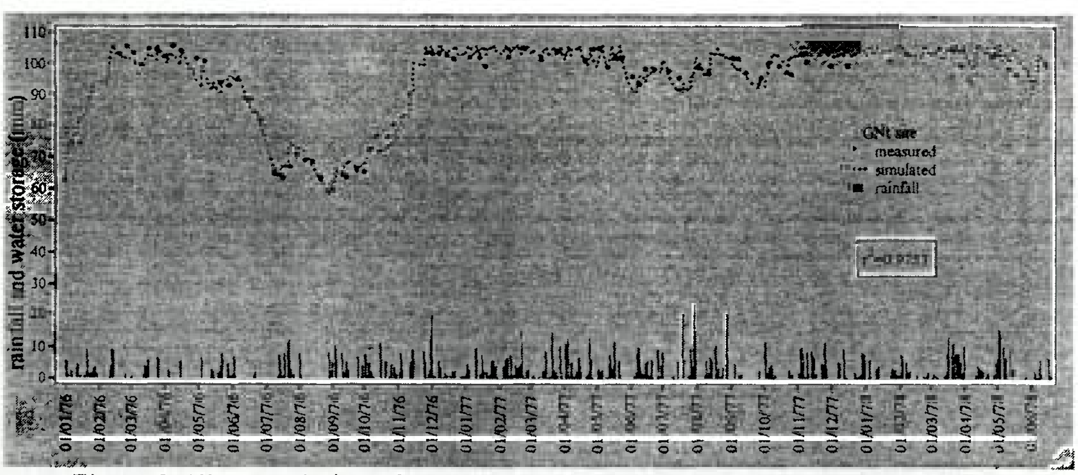

Figure 2: Time evolution of measured and simulated water storages at GNt site

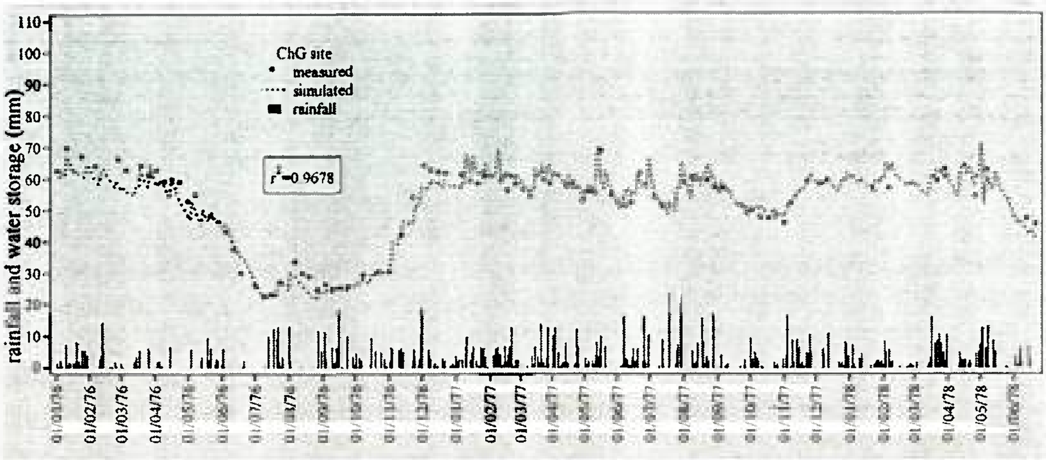

Figure 3: Time evolution of measured and simulated water storages at ChG site

The spatial variability of the soil water storage among other hydraulic parameters has been studied by Villagra et al. (1995). The variability of this parameter confers a variation coefficient of the order of 40% to estimates using water balance equation.

To examine the impact of parameter uncertainties, a sensitivity analysis was carried out. It consisted in adding a perturbation to the optimised parameter and then quantifying the corresponding output variability by means of relative error. The sensitivity graph is presented in figure 4. It reveals that K_c is the most sensitive parameter whereas a has the lowest influence on the output.

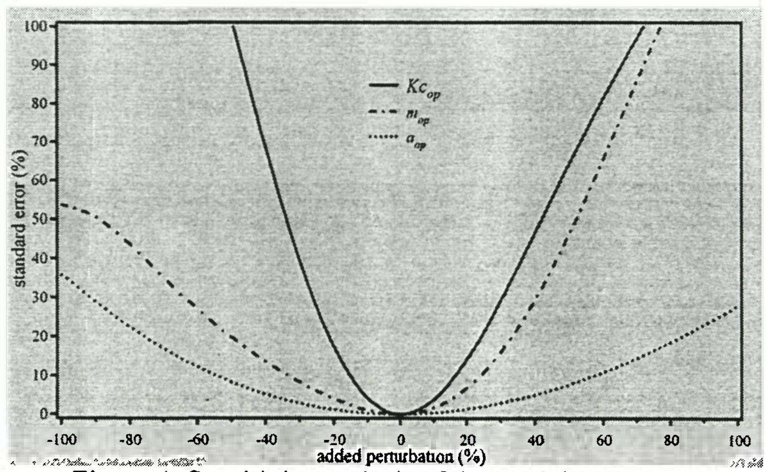

Figure 4: Sensitivity analysis of the model parameters

References

- ASSOULINE, S.; A., EL IDRISSI and E., PERSOONS; 1997. Modelling the physical characteristics of simulated rainfall: a comparison with natural rainfall. Journal of Hydrology, 196, 336-347
- DE BACKER, L.W.; O., COGELS; J., BATARDY et M., DEHON; 1982. Sélection humidimétrique et porosimétrique de sites. Bulletin du G.F.H.N., 11, 22-37.
- DOORENBOS, J. and W.O., PRUITT; 1977. Guidelines for predicting crop water requirements. FAO, Irrigation and drainage paper , n°: 24.
- EL IDRISSI, A.; 1996. Effet de l'humidité initiale du sol sur le processus de ruissellement à l'échelle de la parcelle et du bassin versant. Thèse de doctorat, Université Catholique de Louvain, 120 pp.
- GHOSH, R.K. and S.P., MAITY; 1976. Influence of antecedent moisture on infiltration of water into soils (in situ). Soil Science, 122 (2), 124-125.
- NELDER, J. and R., MEAD; 1965. A simplex method for functional minimisation. Computer Journal, 7 (4), 308-313.
- PHILIP, J.R.; 1957-a. The theory of infiltration, Part 1. Soil Science, 83, 153-157.

- PHILIP, J.R.; 1957-b. The theory of infiltration: Part 2, Sorptivity and algebraic infiltration equations, part 4. Soil Science, 84, 257-264.
- SAXTON, K.E; C.O., STOCKLE; M.W., MEYER and O.W., BAUMER; 1988. Soil Water Assessment by Simulation for Dry-land Agricultural Hydrology. in Proceedings of the 1988 International Symposium 'Modelling Agricultural, Forest, and Range-land Hydrology'. ASAE publication 07-08, pp 33-40.
- VAN GENUCHTEN, M.Th.; 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J., 44, 892-898.
- VILLAGRA, M.M.; O.O.S., BACCHI; R.L., TUON and K., REICHARDT; 1995. Difficulties of estimating evapotranspiration from the water balance equation. Agricultural and Forest Meteorology, 72, 317-325.

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Groundwater quality monitoring - data use and access in Austria

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Introduction

In the last decades the protection of groundwater has gained more and more importance. One reason for this development is the growing awareness that groundwater quality is endangered by various substances. Nitrate is one of the most well-known substances detected in groundwater, but also numerous other substances or groups of substances such as pesticides, chlorinated hydrocarbons, heavy metals etc. were detected during groundwater investigations.

Groundwater is an important natural resource and groundwater quality monitoring has become an essential part of water management. In Austria e.g. more than 99% of the drinking water is abstracted from groundwater. In the late eighties the Austrian Water Quality Monitoring System (AWQMS) was developed for both groundwater and running waters. The Austrian Water Quality Monitoring System was installed by the Federal Ministry of Agriculture and Forestry in close co-operation with the Federal Environment Agency and the provincial authorities.

At the European level several activities concerning groundwater monitoring have been initiated since the early nineties. Groundwater is recognised as an important resource and hence the protection of groundwater has become an essential target of water management. This was documented very clearly by the Council Resolution of 25 February 1992 on the future Community groundwater policy (Official Journal of the European Communities No C 59/2). Based on this Council Resolution the draft "Action Programme for integrated Groundwater Protection and Management" (Commission of the European Union, 1996) has recently been developed. The spirit of this action programme is incorporated in the Amended proposal for a Council Directive establishing a framework for a Community action in the field of water policy (Document 9265/98 ENV 258 PRO-COOP 91). In future this Council Directive will be the legal basis for the protection of inland surface waters, transitional waters, coastal waters and groundwaters within the European Union.

Furthermore the European Environment Agency (EEA, Copenhagen) carried out several studies referring to groundwater quality monitoring activities in the EEA countries (EU15, Norway, Liechtenstein and Iceland) and monitoring and information needs at the European level (Koreimann et al., 1996; Scheidleder et al., 1997). The main duty of the EEA is to provide objective, reliable and comparable information at the European level (EEC/1210/90).

Goals of the AWQMS and use of the data

Main goals of the AWQMS are:

1. To provide reliable and comparable groundwater quality data for defined groundwater bodies in Austria.

Information is required to be in compliance with the legal obligations concerning the assessment of groundwater quality as laid down in the Ordinance on Groundwater Threshold Levels (Federal legal gazette No. 502/91 and 213/97). If a certain groundwater body does not meet the requirements as laid down in this ordinance remediation measures have to be taken by the competent provincial authority. This legal instrument has been developed to reduce impacts of diffuse sources. The Austrian monitoring network is not especially designed to detect impacts of point sources.

2. To meet the needs of the customers. These needs can be summarised as follows:

- information for decision makers, planning organs, the general public
- description of the current state of groundwater quality
- detection of development tendencies (trends)
- establishment of preventive or remediation measures
- efficiency assessment (of the above mentioned measures)

Brief description of the monitoring system

To meet the above mentioned requirements a system was developed comprising:

- a monitoring network which is based on uniform principles (site selection, site distribution, ...)
- investigation parameters which are comparable and in general based on uniform criteria
- regular sampling cycles and
- comparable methods for sampling and analyses

The groundwater quality monitoring network comprises about 2000 sampling sites. These sampling sites are situated in groundwater regions in porous media (about 1800)- mostly quaternary sediments - and in regions with karst and crevice groundwater (about 200). The unequal distribution of sampling sites is due to the different conditions of these main aquifers. Whereas karst and crevice groundwater is primarily located in Austria's alpine regions with little anthropogenic impact, groundwater in porous media is situated in the valleys and basins along rivers. In these regions most land use activities and a high population density are situated as well as industrial plants and traffic infrastructure (roads, railway lines etc). The sampling sites for groundwater in porous media are distributed in about 150 groundwater regions which comprise an area of about 33 000 km^2. Within the groundwater areas sampling sites are distributed in a regular pattern due to the requirement to detect diffuse sources of pollution.

The monitoring network comprises monitoring wells, drinking water wells, wells for industrial use and wells for other uses. To avoid a bias towards better quality, the proportion of drinking water wells was kept low and furthermore only wells of small supply plants are used for the monitoring. As a rule large drinking water supply plants are situated in regions with better groundwater quality.

All basic requirements of this monitoring system are laid down in a law. Details and definitions e.g. of sampling sites, groundwater bodies, number of sampling sites, parameters, frequency of observations, analytical methods etc. are laid down in the ordinance on "Water Quality monitoring" (Federal legal gazette No 338/91). Since the criteria for the assessment of groundwater quality are also laid down in an ordinance (Federal legal gazette No 502/91 and 213/97) these legal obligations can be regarded as "protocols" for the monitoring systems as defined by Ward (1997): "A standardised set of procedures for preparing data, analysing data, interpreting results, and reporting information". Details about analysis, sampling techniques and quality assurance are laid down in the public call for tender (every two years) which is part of the contract for laboratories undertaking sampling and analysis.

Data access

WATER QUALITY DATA ON THE WORLD WIDE WEB

World Wide Web facilities within the Information System of the Federal Environment Agency are used for data administration, evaluation, analysis, reporting and the provision of information and data to the general public. For this purpose Internet (public access) and Intranet, an internal facility only accessible to a defined user group, are available.

Special tools for the day to day work and the production of reports have been developed in the Intranet. At present these facilities are only accessible for members of the Federal Environment Agency and the Federal Ministry for Agriculture and Forestry but it is planned to include the provincial authorities in the near future.
The water homepage of the Federal Environment Agency provides information and data of the Austrian Water Quality Monitoring System (http://www.ubavie.gv):

- the annual report
- the possibility to query the data base of water quality data

The annual report combines data evaluation and interpretation. Each article of the report is put on the Internet as soon as it is finalised. The report contains summarised information, maps, analysis of state and trends, assessments with regard to legal rules and regulations, action needed (e.g. remediation measures) etc.

For inquiries to the data base of the water quality data by the general public direct access was installed. As soon as water quality data are sent to the Federal Environment Agency and loaded into the national data base, public access is possible. Among the information provided are the most important parameters (about 30 for the time being) and, in addition, a brief description of the location of the sampling sites.

To get information first the type of sampling site has to be selected (groundwater in porous media, karstic groundwater or running water). Next, on a map of Austria showing provinces and municipalities the region of interest can be selected by mouse-click. A list of sampling sites located near the selected point will then be provided giving the number of the sampling sites and their location (name of the river, municipality, distance from the point which was selected on the map). The next step is to select a sampling site from the list and, on the next web page, the parameters of interest. As result of the query a graph showing the concentration of the chosen parameter from the beginning of the monitoring up to the recent data and a list of the measured values per sampling date are obtained.

In the near future more detailed maps of the provinces showing groundwater areas or running water sampling sites will be provided allowing for a more precise selection of sampling sites or groundwater areas (a WebGIS is also being developed).
The broad acceptance of data and information presented by this medium is documented by 15900 external hits on the water pages at the above mentioned homepage in the year 1997.

Apart from data access via Internet printed annual reports (e.g. Grath & Kralik (1997)), working papers for those who are involved in the monitoring programme, scientific papers are available (see e.g. Grath et al. (1993), Schwaiger et al. (1994), Grath & Halbwirt (1993), Vogel et al. (1996)) as well as brief statements for various information media.

INFORMATION REQUESTS TO THE FEDERAL ENVIRONMENT AGENCY
In 1996 and the first half of 1997 about 150 inquiries to the Federal Environment Agency referring to the AWQMS were documented (see Vogel, 1997), not including information requests to the other institutions involved in AWQMS. The user groups which were interested in the information of the AWQMS and the percentage of information requests are presented in Table 1.

Table 1: Groups using the information of the AWQMS

User group	%
Planning engineers, Consultants, Industrial Companies, ...	21
Private Persons	19
Journalists	14
Public Administration	11
Universities and other Scientific Institutions	11
Environmental Groups	11
Interest Groups	6
Political Parties	6
Real Estate Agents	1

Table 1 gives an overview of the very different user groups interested in information on groundwater quality. This interest might be due to the fact that more than 99% of drinking water in Austria is abstracted from groundwater (to equal parts from wells in groundwater in porous media and springs in karst and crevice groundwater.

Conclusions

The successful functioning of the Austrian Water Quality Monitoring System is guaranteed by the fact that all basic requirements - including financing - are laid down in legal regulations. The acceptance of the different possibilities for data access is demonstrated by e.g. about 15900 hits per year on the web-server and the great number of written or oral requests to the Federal Environment Agency. Furthermore data are in permanent use by the provincial authorities. Available data are also often used for the assessment of contaminated sites as a source of information on the status of groundwater in the surrounding area.

Since the information needs at the European level become increasingly important data should also meet the needs of the European Commission in compliance with the proposed Water Framework Directive as well as for the proposed water monitoring network design by the EEA.

References

Commission of the European Union (1996): Commission Proposal for an Action Programme for integrated groundwater protection and management Com (96) fin. - 96/0181 (COD), Official Journal of the European Communities No C355/1

Grath J., Halbwirt H. (1993): Ergebnisse aus dem Österreichischen Grundwasserkataster, ÖWAV-Seminar Spurenstoffe: Geogen oder anthropogen - spezielle Aspekte von Wassergüteerhebungen (in German) ÖWAV-Seminar 16/17. Nov. 1993, Wien (Proceedings)

Grath J., Kralik M. (1997): Wassergüte in Österreich - Jahresbericht 1996, Teil B (in German), Federal Ministry for Agriculture and Forestry, Vienna and Internet: http://www ubavie.gv.at

Grath J., Schwaiger K., Chovanec A., Nagy W., Schicho-Schreier I. (1993): Halogenated hydrocarbons in Austrian groundwater - first results of a new water quality monitoring system, in: Organohalogen compounds, Vol. 14 Dioxin '93 13th International Symposium on Chlorinated Dioxins and Related Compounds, Vienna, September 1993, Federal Environmental Agency, Austria p 295-298

Koreimann, C., Grath J., Winkler G., Nagy W., Vogel W.R. (1996): Groundwater monitoring in Europe, European Topic Centre on Inland Waters, Topic Report 14 Inland Waters, European Environment Agency

Scheidleder, A., Grath J., Winkler G., Stärk U., Koreimann C., Gmeiner C. (1997): Groundwater quality and quantity in Europe, European Topic Centre on Inland Waters, Draft Report under contract of the European Environment Agency

Schwaiger K., Grath J., Chovanec A. (1994): The Austrian context for information needs for water quality, Technical Report in Hydrology and Water Resources No.402 WMO/TD 612 p 105-118

The Council of the European Union (1990): Directive of the European Council EEC/1210/90 on the Establishment of the European Environment Agency and the European Environment Information and Observation Network

The Council of the European Union (1992): Council Resolution of 25 February 1992 on the future Community groundwater policy, Official Journal of the European Communities No C 59/2

The Council of the European Union (1998): Amended proposal for a Council Directive establishing a framework for Community action in the field of water policy, Interinstitutional File No 97/9967 (SYN) addendum to document 9265/98 ENV 258 PRO-COOP 91

Vincze G. (1998): The Austrian Water Quality Monitoring System, Information System on the World Wide Web; Intranet - Internet; Presentation held at the GEF/UNDP Danube River Basin Information System Workshop 23-25 March 1998 in Baden (Austria)

Vogel W.R. (1997): The Austrian Water Quality Monitoring System - How to Put Information to Work, Information and Communication in Environmental and Health Issues, Eco-Informa '97 Volume 12 p 220-225

Vogel W.R., Grath J., Winkler G., Chovanec A. (1996): The Austrian Water Quality Monitoring System - Information for Different Levels of the Decision Making Processes, Monitoring Tailor Made II, Proceedings, Information Strategies in Water Management, p 147 - p 153

Ward R.C.(1997): Data Analysis Protocols in Water Quality Monitoring; Water Quality Monitoring Short Course held at VKI, Denmark August 11-15, 1997

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Needs and constraints for the calculation of the regional annual runoff in Denmark

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Introduction

One important monitoring task of the National Environmental Research Institute (NERI) involves the estimation of diffuse nutrient pollution of both inland water courses, lakes and coastal areas (Kronvang et al., 1995). Diffuse nutrient pollution associated with different land use practises such as e.g. agricultural production and forestry is particularly important when assessing the eutrophication of aquatic ecosystems. The aquatic environment is monitored at 130 monitoring stations which covering approx. 60 % of the total Danish land surface of approx 43.000 km^2 (Kronvang et al., 1993). The diffuse nutrient losses from unmeasured areas have hitherto been calculated by regional authorities applying different methodologies. A new simple empirical loading model has been developed based on 8 years of data from about 70 small catchments which are not affected by effluents from point sources. The model suggests that the diffuse annual nutrient losses from catchments can be estimated by proportion of both arable land, sandy soils and organic soils and wetlands in the catchment. The only model parameter which explicitly reflects local climate dynamics and variations is the specific annual runoff.

There are some problems related to this parameter particularly due to the geomorphologic conditions in Denmark. Firstly, the discharge in many streams along the Danish coasts cannot be measured directly, mainly because of the fact that they are exposed to tidal processes. Secondly, within vast areas subsurface drainage networks severely transform and affect natural runoff patterns. Moreover, there is a remarkable difference between the topographic and surface related watershed boundaries on the one hand and the groundwater divide on the other, particularly within headwater catchments.

Objectives

Due to the problems mentioned above as well as the lack of nationally standardised methods, there is a need for a simple regional calculation of the specific annual runoff in Denmark, especially for those areas where measurements are not available.

To this end we developed an empirical equation for the calculation of annual runoff accounting for variations in climate, land use, soil conditions as well as the difference between the topographic boundary and the groundwater catchment boundary and for the time delay in the hydrological response according to the values of climatic parameters during the two previous years. The model is based on runoff measurements at national monitoring stations, while the climatic information was derived from daily data on precipitation and potential evaporation for the period 1989 to 1996 (in accordance with the time interval for which runoff data from the national monitoring programme is available). The study aims at providing the basis for an improved and harmonised estimation of diffuse nutrient export from catchments to rivers and the sea.

The availability of hydrologically relevant data on the regional scale

As part of the Ministry of Environment, NERI is responsible for the annual national reports on the environmental status of surface water resources and nutrient transport via rivers to sea. The basic time series on both discharge and water qualities are provided by the counties and include some 350 national monitoring stations on water quality located in various parts of the country.

The water assessment on the national scale requires the availability and integrated use of geographical information on stream networks, lakes and wetlands as well as specific catchment parameters such as soil properties and land use / land cover schemes. So far the crucial constraints have been related to the lack of common databases which could be used for catchment based water quality studies in an integrated manner.

Currently there is only one complete set of high resolution digital maps on water courses in Denmark which is available at the Geological Survey. Unfortunately, there is no official description available of how these data sets have been generated. Comparison tests between these maps and official maps (scale 1:25.000) provided by the National Survey and Cadastre of Denmark indicate however, that it provides slightly less detailed information than the paper maps.

The present official data base on catchment boundaries provided by the Geological Survey (GEUS) contains catchment boundaries up to 4th grade for the entire country stored as line or polygon features. The digital maps can be used for visualisation purposes. The catchments are defined starting at river junction rather than according to the location of the monitoring stations, which causes problems as monitoring stations are often located somewhere up- or downstream of a river junction. Hence there is a mismatch between maps of catchments related to monitoring stations on the one hand and maps of water course / river junction catchments on the other. In 1996 many of the monitoring station catchments have been digitised in addition at NERI. However, in 1998, the Ministry of Environment and the environmental departments of the counties of Denmark have agreed to revise and extend the national network monitoring stations. Consequently, there is an increasing need to establish an official geographical catchment database comprising all of the water quality and hydrometric monitoring stations of national concern.

Various climate data (different parameters, daily measurements) can be ordered from the National Weather service both for single gauging stations or as an spatial average for larger areas. So far, there is no agreement between and within the different ministries regarding the free data exchange between different public and governmental institutions. Hence it would be to expensive to operationally use data from all national climate stations for NERI's annual water quality assessment. Consequently, we used the spatially averaged data (fig. 1), where regional daily weather in Denmark is currently represented by 44 single pixels, each of which covers an area of 40 x 40 km^2.

Currently, there are no complete and updated versions of national digital maps on land use and land cover data available apart from those within the European CORINE database which however are comparably imprecise and suffer from their low spatial resolution.

With respect to soil conditions there is different information sources on subsurface physical properties available which potentially may be used for regional hydrological studies in Denmark. However, the only polygon soil data bases providing deep soil information either do not cover the whole area of Denmark or they are only digitally available in a scale 1:500.000. Moreover, the spatially more detailed maps and data bases cannot be accessed free of charge.

Methods and results of the runoff estimation study

Among the national monitoring stations we chose 90 stations, with catchment areas between 5 km^2 and 25 km^2 and for which both spatially distributed land use (CORINE) and spatially detailed soil information (scale 1:25000, down to 20 cm below surface) have been available on a catchment scale. This size restriction was meant to ensure that the model can be used even for small catchments, which are known to be hydrologically more complicated. For each of the catchments climate data have been derived and weighted according to the absolute location of the catchment within the regional climate pixel scheme. Next, we used the commercial statistical software SAS to determine the dependency of annual runoff on climate conditions, land use and soil properties.

The square of the correlation coefficient (R^2) achieved was never higher than 0.44, which indicated that we did not properly account for the local geomorphological and water storage conditions. Thus we decided to introduce a coefficient which compares the difference between the local long-term average in measured annual runoff and a potential uncorrected water balance index (precipitation minus potential evapotranspiration) with the maximum of the 90 values of this long-term difference occurring in one of the 90 catchments investigated. Moreover, the annual runoff in the catchments indicated that we had to account for the hydrological status of the previous years in order to enable the estimation of the current runoff for a given year. Accordingly, climate information for the previous 2 years and the daily means for the period 1961-1989 have been included in the model to account for the long-term hydrological preconditions. Finally summer precipitation (1May to 31October) has been introduced as another variable. After the introduction of the new parameters in the model and exclusion of soils types and land use from the model the square of the correlation coefficient (R^2) increased to 0.8.

Next, we compiled a geographical database consisting of a digital map of the catchments monitored joined with the digital map of the coastal zone administrative units of Denmark. Finally, this new digital map was discretised by an overlay procedure using a mesh-polygon map (25 km^2 rectangles) of Denmark so that in the resulting map no units larger than 25 km^2 remained. This map potentially enables the GIS-based calculation of both runoff (see fig. 2) and nutrient loads to the coastal areas. Some of the intermediate maps mentioned will be used directly in an Area Information System (AIS), a project which enables and ensures a harmonised establishment of compatible digital maps and associated data sets on land use, geology and various hydrological features which enable and enhance integrated environmental assessment on the national scale. That project will be presented at this conference in a parallel paper (Mielby et al.)

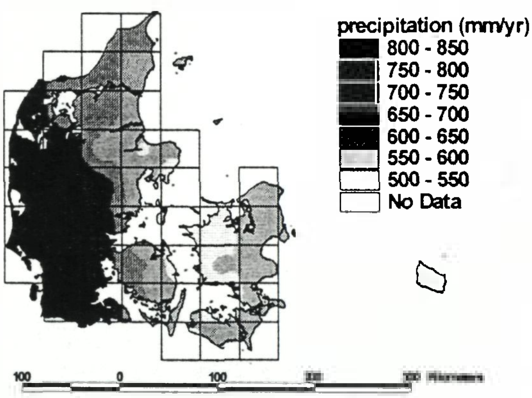

Figure 1. Mean annual precipitation 1989-1996

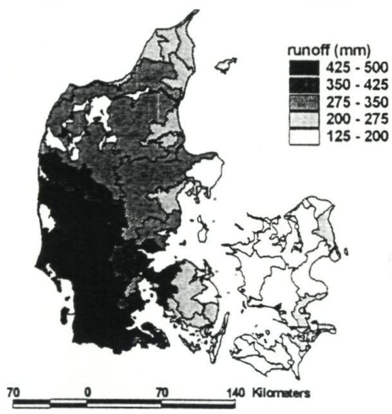

Figure 2. Model estimated runoff 1994

Outlook

The next steps of the project involve the test of the influence of the discharge estimation (rather than measured discharge) on the nutrient loss calculation using the empirical equation.

Generally, water balances in headwater catchments reflect the fact that seepage water is exported through the lateral subsurface flow to the downstream areas. Accordingly we will include other, larger catchments in our statistical analyses. Subsequently, the geographical database will be extended by 2 more variables to enable and justify the model use in different catchments and subcatchments irrespective of their relative location / position within the hierarchical catchment structure. One important variable to be included is the drainage network density, and another "a hierarchical position variable" according to the "Strahler-order".

Likewise, we will try to perform monthly rather than annual calculations based on a more sophisticated time series analysis. Finally we will seek to be able to distinguish low flow from flow events without using an estimated base flow index (or based on the soil type related base flow index developed at the Institute of Hydrology / Wallingford) which is not available for ungauged catchments.

The new extended studies will be based on data that will be available as a result of the AIS project.

References

Kronvang, B., R. Grant, S.E. Larsen, L.M. Svendsen and P. Kristensen, 1995. Non point-source nutrient losses to the aquatic environment in Denmark: impact of agriculture. Marine and Freshwater Research, 46 (19), 167-177

Kronvang, B., G. Ærtebjerg, R. Grant, P. Kristensen, M. Hovmand and J. Kirkegaard, 1993. Nationwide monitoring of nutrients and their ecological effects: state of the Danish aquatic environment. AMBIO, 22 (4), 176-187

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A concept of monitoring objectives and its application to the Finnish National Hydrometric Network

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Introduction

The national hydrometric monitoring network is the basic system for surface water level and river discharge observations in Finland. The network is coordinated by the National Hydrological Service located at the Finnish Environment Institute. Three other hydrometric monitoring systems are operated in the country: (1) regional networks of the environmental administration, (2) sectoral networks of various fields of industry, and (3) the network of small hydrological basins, coordinated by the National Hydrological Service.

The extent of the national hydrometric network had been continuously increased since its establishment in the beginning of this century till the late 1980s. At that time it was recognised, that there was a need to evaluate the network and reconsider its extent and structure. The background factors were the lack of clear network profile, new and developing user needs, possibilities for using other hydrometric monitoring systems, and growing economic restrictions in the public sector.

The National Hydrological Service decided to carry out a development programme in order to restructure the national hydrometric network. Two main objectives were defined for the programme: (1) clarification of monitoring objectives and network structure, and (2) improvement of cost-efficiency. The actual programme comprised three steps. During the first step, the future role of the network was defined so that there would be a balance and a logical division of labour between the national network and other hydrometric monitoring systems. The second step comprised individual classification and evaluation of the stations. The principles that had been determined during the first step formed the bases of this work. The third step was focused on spatial estimation. The ability to spatial estimation was studied in general and the role of individual stations was evaluated in statistical tests.

This report is a summary of the first programme step. The main result, the developed network concept, was considered to be interesting as a general principle of network management. In the case of the Finnish national network the further application of this concept resulted in considerable cost savings.

User needs and monitoring objectives

Hydrometric networks have often been analysed by preparing station classifications that are based on the purposes of monitoring. Reports on network design in hydrology include numerous examples of such groupings. Sometimes the classifications are focused on detailed user requirements, and in some cases the categories reflect more general goals for the produced information. Very often both of these elements are represented simultaneously.

The basic idea of the present study was the use of two separate concepts: user needs and monitoring objectives. The user needs are the end-users' specified requirements, such as data for bridge design, legal supervision of lake regulation, or trend research of hydrological time series. The monitoring objectives describe the type of information that is produced; in fact they form the network coordinator's technical tools to fulfil the users' requirements. The linkage between the two concepts is also recognised in the latest edition of the Guide to Hydrological Practices (WMO 1994): "based on the purpose of the network, an objective or a set of objectives can be established in terms of information required".

From the point of view of an individual station, user needs and monitoring objectives play a different role. One station can serve many user needs. This is always the case in main rivers and large lakes, but it is very general in small river basins as well. When a network is classified by monitoring objectives, one monitoring station typically represents one category. This is the result of the fact that objectives describe merely the type of information which is produced - not the purposes for which the data are used.

Classification of monitoring objectives

The classification of monitoring objectives was based on a uniform system, which has been used in the five Nordic countries (Denmark, Finland, Iceland, Norway, Sweden) for the characterisation of discharge stations (Puupponen 1996). The classification was developed in the Finnish application so that it also covered water level monitoring, and thus it could be applied to each hydrometric station. The following five categories of monitoring purposes were defined.

Water balance stations that are used for the monitoring of hydrometric characteristics in large lakes and river basins; the duration of monitoring is long-term and the quality of maintenance is high.

Spatial estimation stations that are used for the transfer of discharge data to other catchments; the duration is long-term and the quality of maintenance is high.

Operational stations that are used for the daily operation of water resources projects; the duration is the project lifetime and the quality of maintenance depends on the project requirements.

Planning and inventory stations that are used for the planning of projects or inventory of hydrometric characteristics in small lakes and river basins; the duration is limited and the quality of maintenance depends of the project requirements.

Research stations that are used for specific research projects (often integrated research in small catchments); the duration is limited in most cases and the quality of maintenance is high.

User needs were also defined during the programme. They were divided into 14 categories that represented three main fields of activity: operational use and planning, monitoring and research, and protection of waters. It was recognised that user needs can be presented in many different ways. They change clearly more often than the monitoring objectives. The classification of user needs was not utilised directly in this context.

The classification of monitoring objectives turned out to be very important. In addition to the evaluation of individual stations it was found to be suitable for the characterisation of different hydrometric networks. The point was that the defined categories were clearly network related. At the general level, the monitoring objectives represented the structural characteristics that were considered to be important in the future operation of the networks.

Role of the national hydrometric network and other monitoring systems

It was decided that the future role of the national hydrometric network should be based on two main characteristics. Firstly, there was a clear need to include water level and discharge observations in large lakes and rivers in this network. These stations had already formed the core of the network during its operation. In terms of monitoring objectives, these measurements can be carried out by using either water balance stations or operational stations, depending on the role of regulation.

Secondly, it was recognised that spatial estimation is a very fundamental need, and it requires a subnetwork that has continuous operation and a high quality of maintenance. These requirements can be fulfilled in the best way within the national hydrometric network. By objective, these station are spatial estimation stations.

According to the above lines, operational stations in small lakes and rivers were left outside the national hydrometric network. A decision was made to include these stations only in regional or sectoral hydrometric networks, depending on the organisation responsible for monitoring. It was stated, that the role and responsibilities of planning and inventory stations should be similar. This was a logical decision, because regional and sectoral networks are flexible and they are focused on local data needs.

The network of small hydrological basins had a strong research tradition. All actual research stations were considered to belong to this network in the future as well. So far, the sectoral networks have had very few actual research stations, but they may become a noteworthy group in the future.

The result was, that the network characteristics that were considered to be important in the future had a clear linkage with the defined monitoring objectives. This principle could be applied further to individual stations. Four of the five monitoring objectives could be connected directly to a single network, and only the category of operational stations had to be divided between two different networks. The table below summarises the connections between the monitoring objectives and the networks.

Table 1. Connections between hydrometric monitoring objectives and networks.

Station according to monitoring objective	Network
Water balance station	National hydrometric network
Spatial estimation station	National hydrometric network
Operational station (large lake/river)	National hydrometric network
Operational station (small lake/river)	Regional/sectoral network
Planning and inventory station	Regional/sectoral network
Research station	Network of small hydrological basins

Application of the network concept

The network concept was applied so, that decision rules were first developed in order to classify the stations of the national hydrometric network by objective. After this formal classification, the future contribution of each station was evaluated individually, which resulted in some reconsiderations.

The starting point was the reduction of the original network (national hydrometric network in 1990). This approach could be adopted, because all of the station types that were considered to be important in the future were well represented. It was also known that the network had stations of secondary importance. Economic considerations favoured the reduction policy as well.

The result of the whole programme was, that the number of station was reduced from 721 to 398. According to the categories of monitoring objective the structure of the network developed as follows:

- water balance stations from 186 to 171
- spatial estimation stations from 91 to 71
- operational stations from 403 to 156
- planning and inventory stations from 41 to 0
- the network did not have any actual research stations.

The total annual costs of the own field of administration were estimated to decrease from FIM 7.7 to 5.2 million during 1991-1996 (price level of 1996). The areal coverage of water level monitoring decreased only some 2.5%. In discharge monitoring the decrease of coverage was some 2%.

References

Puupponen M. (ed.). 1996. Hydrometric monitoring and its development in the Nordic countries. NHP Report no. 42, The Nordic Coordination Committee for Hydrology, Helsinki, 108 pp.

WMO. 1994. Guide to Hydrological practices. Fifth edition. WMO no. 168, World Meteorological Organization, Geneva, 735 pp.

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Specificities of the hydrology of karst accumulation Ričica on the river Ričina in Croatia

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1. Geological and hydrogeological data

The drainage area of the river Ričina in the Dinaric karst in Croatia is built of Permian-Triassic clastic beds, Cretaceous and Early Paleogene carbonate beds and Late Paleogene, Neogene and Quaternary clastic deposits [1].

The oldest deposits are Permian-Triassic rocks (P, T) exposed in a very small area northeast of Posušje (Fig. 1). They consist of sandstone, carbonate slate and occasional inclusions of gypsum. The permeability is in the whole low.

Lower Cretaceous (K_1) is represented by well-stratified limestones with occasional dolomite intercalations. The high permeability of these rocks enables the loss of water to underground.

Transition beds between Lower and Upper Cretaceous ($K_{1,2}$) consist of weathered, poorly stratified, low permeable dolomite with thin limestone interbeds which laterally alternates with dolomitic limestone or poor dolomite.

Upper Cretaceous carbonate beds (K_2) are most widespread in the Ričina basin (Fig. 1). They have been continuously deposited on earlier Albian-Cenomanian sediments. Due to the intensely tectonic broken, karstified and high permeable limestones, which represents this geologic age, the loss of water over the area of these deposits is high. The river Ričina with its upper stream runs across the area of these deposits and the loss of water from its channel is also large.

The carbonate sediments of Paleocene and Lower/Middle Eocene age (Pc, $E_{1,2}$) lie unconformably over Senonian limestones. The beginning of the Paleogene sea transgression is represented by "Liburnian beds" composed of the limestones. At first they have been deposited in brackish and later in marine environments. With the transgression progress, alveolina-numulitic limestones have been conformably deposited over Liburnian beds, where the latter are missing, the limestone lies unconformably over Cretaceous limestone. In Fig. 1 these two units are shown together. Due to their high permeability, the loss of water is large from both drainage area and a downstream channel of the river Ričina.

The Eocene flysch beds ($E_{2,3}$) are deposited unconformably over the Paleogene or Cretaceous sediments. It is a typical flysch, impermeable in the hydrogeological sense, with a rhythmic alternation of turbidity sequences which are composed of conglomerates, carbonate sandstones and marls.

The youngest clastic deposits of Paleogene age (E, Ol) are Promina beds [2]. They consist of irregular alternating thick bedded conglomerate, sandstone and marl. They are conformably deposited over the flysch or unconformably deposited over the older Paleogene and Cretaceous sediments. The spring area of the river Ričina is placed in these secondary porous rocks.

Neogene deposits (N) through which the middle stream of the river Ričina runs (Fig. 1), lie unconformably on the Upper Cretaceous sediments. The unit is built of clay, marl and sandstone with coal in its lower part and of marl and marly limestone in its upper part. As a whole, the unit is impermeable.
Quaternary deposits (Q) are exposed in a small area southeast of Rastovača (Fig. 1). They are represented by alluvial deposits of sand, gravels and clays. The permeability depends on clay ingredients.
Forcible tectonic in this area resulted in fold structures in the Dinaric direction (NW-SE). Fold structures (reverse fold, nappes) were moved one over another with tangential tectonic stress during the Pyrenean tectonic phase.

2. Hydrological characteristics
The drainage basin of the river Ričina to the dam Ričica is shown in Fig. 2 and its full acreage is about 290 km^2. The shape of the basin is elongated and the relation between the width and length of the basin is approximately 1 : 2.5.
The hydrological regime of the Ričina is markedly torrent-like. Very often the long lasting bed of the streamflow is also dry, on an average more than nine months per year, and in occasional precipitation of high intensity sudden occurrences of water waves are possible.
The heights of annual precipitation on the drainage basin of Ričina range from 1000 to 1800 mm; on an average annually about 1400 mm. However, the essential characteristics of the drainage basin and the bed of Ričina are such karst forms which enable great losses of water from the surface into the underground. Because of that, the quantities of water flowing by Ričina are on an average very low - for the whole drainage basin to the dam Ričica even surprisingly low. In general, in the Dinaric karst in 80 percent of cases the runoff coefficients range from c = 0.50 to even more than c = 0.80 (in small drainage basins in overgrown karst) [3]. In the Ričina drainage basin the runoff coefficients are on an average lower than 10 percent, so this characteristics makes Ričina one of the rivers of the Dinaric karst the poorest in water.
As a background for dimensioning the reservoir Ričica the data from hydrological stations on Ričica from the period of 1953 to 1977 were used [4]. At that time in the upper part of the drainage basin of Ričina on the tributary Topola there was only the retention Rastovača. In Figure 3 the hydrograph of mean monthly discharges in the period (1953-1977) is shown and the mean discharge in this period is Q = 1.17 m^3/s. The volume of Ričica reservoir is 80,000,000 m^3 and it is anticipated that water from the reservoir is to be used for water supply and irrigation.
The reservoir Ričica has been used since 1989 and at the same time in the farthest upstream part of Ričina drainage basin a reservoir Tribistovo of the volume of 15,000.000 m^3 was realized.
After building these reservoirs the discharges of water in Ričina have suddenly been reduced. In Figure 3, together with the discharges of the earlier period according to which the Ričica reservoir was dimensioned, the mean monthly discharges of Ričica in the profile of the dam Ričica in the period of the work of the reservoir from 1989 to 1995 are given [5]. The mean discharge of Ričina in the period from 1989 to 1995 is Q = 0.300 m^3/s and almost four times smaller than the mean discharge for the period from 1953 to 1977, which data have been relevant for determining the size of the Ričica reservoir.
The main reason for such great reduction of the available inflow of water from the Ričina drainage basin is the building of Tribistovo reservoir where water from the basin of 30 km^2 of size flows in. Although, more than 200 km^2 of the drainage basin is still left till reaching the Ričica reservoir, where the possibilities of losing water into a subsurface area remain the same as before. Thus, water flowing on the surface should first fill all the precipices in the drainage basin and in the bed of Ričina and its tributaries and only that which is left reaches the Ričica reservoir. It should be mentioned that closing the precipices in Dinaric karst is a very expensive job and often unpayable due to the large number of precipices and the possibilities of opening the new ones after the existing ones have been reclaimed.
Besides the described losses from the bed and the drainage basin of Ričina there are also losses of water into a subsurface area from Ričica reservoir. The losses of water into the subsurface area depend mostly on the levels of water in a reservoir and on the state of underground saturation with water. For calculating the daily water losses into the underground Q_e the equation of the water balance

was used in the following form:

$$Q_e = Q_R + Q_V + Q_P + \Delta Q - Q_S - Q_F - Q_E \qquad (m^3/s) \qquad (1)$$

where Q_R is the discharge of Ričina; Q_V - the discharge of Vrbica; Q_P - precipitation to the surface of the reservoir; ΔQ - the change of the volume of the reservoir; Q_S - the discharge over the spillway; Q_F - the discharge through the sluiceway and Q_E - evaporation from the water surface.

By way of illustration, in Figure 4 the mean daily losses of water from Ričica reservoir into the underground during 1990 are shown. Due to the dependence of the losses on the state of subsurface water there are large dissipations of the pairs of the values of water levels - the loss to the underground, so the curve of losses cannot be defined.

It is concluded that in the precipice karst area the isolation of a comparatively small drainage basin, as in the considered case the drainage basin to Tribistovo reservoir is, can significantly reduce the downstream discharges - the hydrograph of the mean monthly discharges in Ričica reservoir (Figure 3). The losses of water from the karst reservoirs depend a great deal on the saturation of the underground with water, and for that reason the curve of water losses from the reservoir depending on the water levels in the reservoir cannot possibly be defined (Figure 4).

References

[1] Raić, V., Ahac, A., Papeš, J. (1976) - Basic Geological Map of SFRY 1 : 100 000. Paper of Imotski K 33-23, Federal Geological Institute, Belgrade.

[2] Raić, V., Papeš, J. (1978) - Basic Geological Map of SFRY 1 : 100 000. Interpretation for the Paper of Imotski K 33-23, Federal Geological Institute, Belgrade, 1-51.

[3] Žugaj, R. (1995) - Regional Hydrologic Analysis in the Karst of Croatia, Croatian Hydrological Association, Zagreb, Croatia, p. 139 (monograph)

[4] Stepinac, A. (1978) - Ričica reservoir - Hydrology, preliminary design, book 2, Elektroprojekt Ltd., Zagreb, Croatia

[5] Žugaj, R., Plantić, K. (1997) - Hydrological Analysis for the Needs of Ričica Reservoir, Study, Energy Institute Ltd., Zagreb, Croatia.

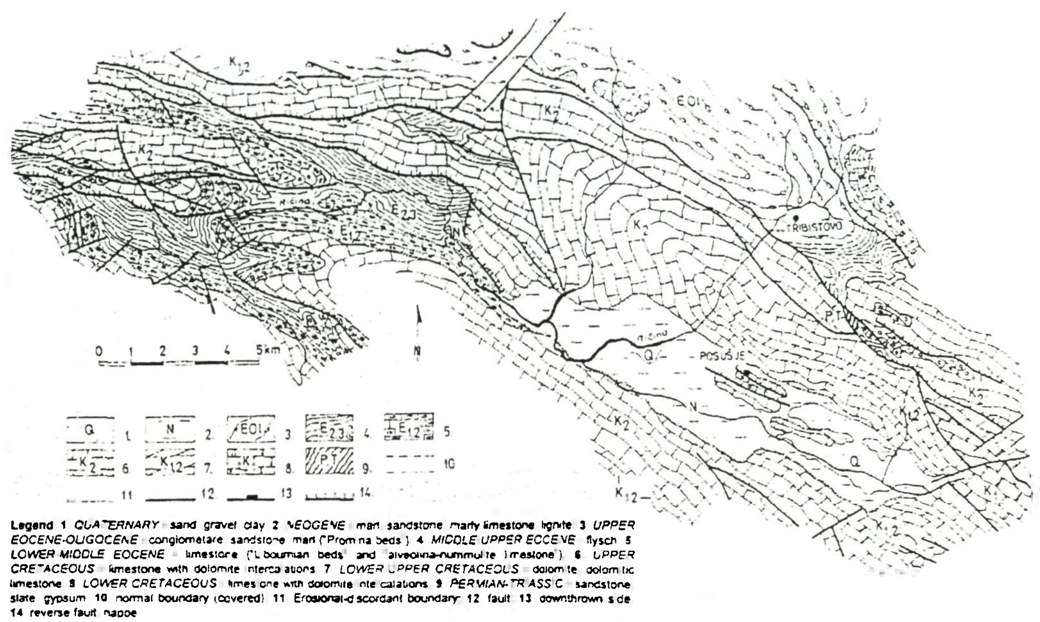

Figure 1. Simplified geological map of the study area – costructed according to [1]

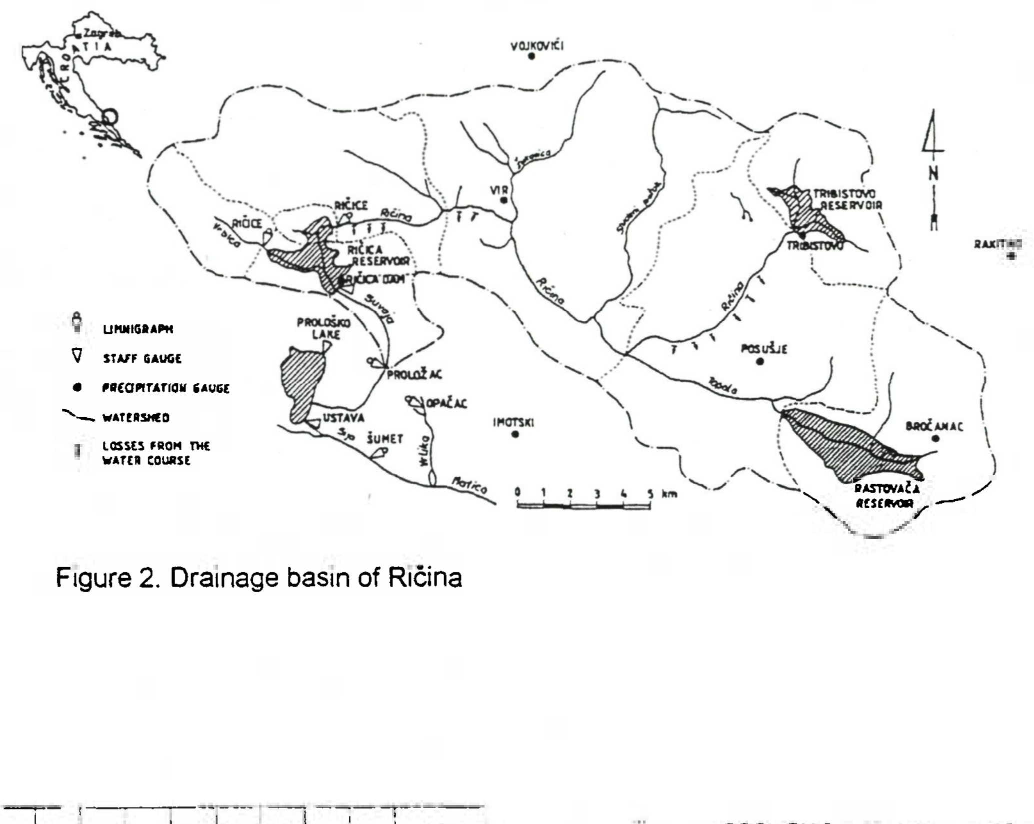

Figure 2. Drainage basin of Ričina

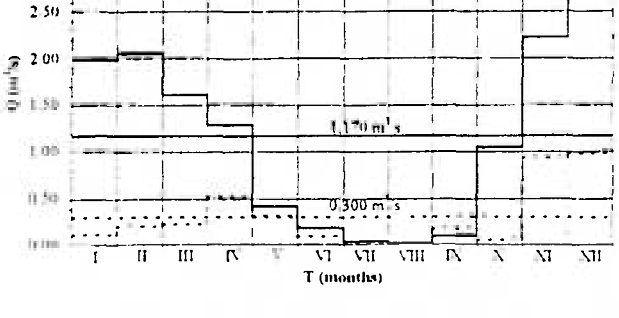

Figure 3. Ričica dam: mean monthly discharges

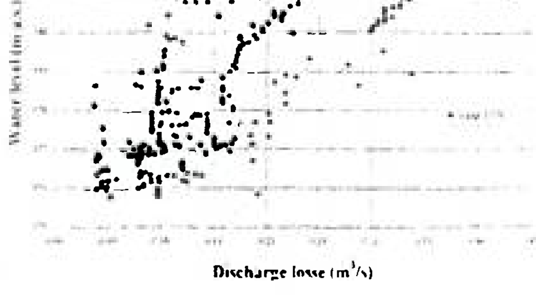

Figure 4. Discharge losses depending on water levels in Ričica reservoir

Data collection

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Standards in hydrometry in the Environment Agency of England and Wales

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Abstract

The Environment Agency was established by the Environment Act of 1995 and became fully operational on 1 April 1996. The main aim of the Agency is to protect and improve the environment and to contribute to the delivery of sustainable development through the integrated management of air, water and land.

One of the specific responsibilities of the Environment Agency is the management of water resources, a task which demands timely, accurate, consistent hydrometric data.

Hydrometry in England and Wales was for many years operated and managed in a fragmented fashion. Only through the formation of the National Rivers Authority, which subsequently became part of the Environment Agency, did the opportunity arise for a consistent, national approach.

This paper will explain in more detail the historical perspective and the initiatives put in place over the last few years to achieve an acceptable level of consistency in hydrometry and hydrometric data. These initiatives include the development of tailored training courses for hydrometric staff, production of a hydrometric manual for field staff and a marked reduction in the variety and type of equipment in use, including software packages.

The Environment Agency also recognises the importance of British, European and International Standards for hydrometry. Reference will be made to Agency representation and progress in this area of work.

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Instrumental methods applied to the data acquisition in several small watersheds near Madrid in order to develop distributed hydrologic models for ungaged rural watersheds[1]

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Abstract

The purpose of this presentation is to describe the instrumental methods applied to the monitoring activities in several small rural watersheds (< 50 Km^2), and the modelling efforts that are destined to reach a better knowledge of the present methodologies for the hydrologic analysis of ungaged rural catchment. Issues like the monthly runoff and the peak discharge in small ungaged watershed are very important in Mediterranean countries, where small dams located in this kind of catchment are usual in the establishment of new irrigation zones and water supply for rural populations.

Beginning in February 1998, we established two gauging stations near Madrid in order to assess the response of several distributed models developed in a GIS environment. The first was constructed within the *Monte stream* watershed. The land use on its 708 *ha* is predominantly cereal crops. The second station is located at *Valdelamasa stream* (1.717 *ha*) and the land use is predominantly forest and meadow.

The gauging stations (rainfall-runoff) is based on an **area-velocity flow measurement method**. This methodology strategy was selected for several reasons :

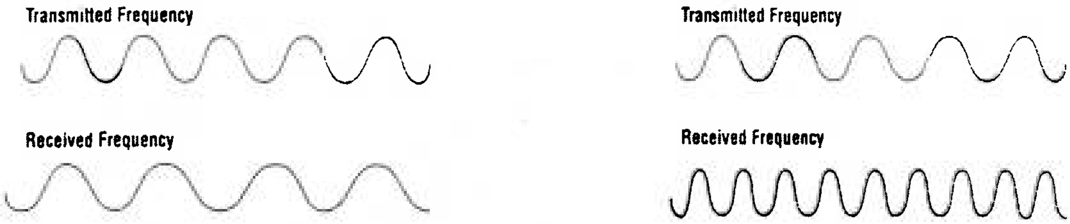
- Spanish Government Water Agencies required that ours works in the stream do not suppose an obstacle in the natural channel stream, so we could not build weirs and flumes.
- We needed high precision data, so we could not use equations which depend on characteristics like slope or roughness coefficients of the channel.
- The knowledge of additional data like the flow velocity will be useful in other research activities like sediment transportation and erosion.

The area-velocity methodology combine the measure of depth and flow velocity. The depth measurement is used to calculate the flow area based on a known channel shape. Eventually the flow rate is calculated by multiplying the area of the flow by its average velocity. There are several technologies to measure flow velocity, including Doppler, electromagnetic and transit time. All of these methods utilise no moving devices, present minimal obstruction to the flow, creating minimal

[1] Research funded by the Proyect HID96-1291 of the *Comisión Interministerial de Ciencia y Tecnología* of Spain.

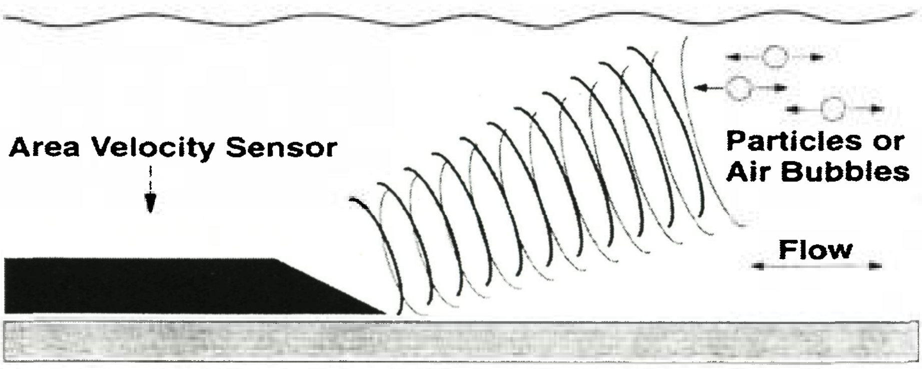
head loss and provide bi-directional velocity measurement. We have selected the Doppler technology because of it is being used successfully in several places across the United States (Engel, 1997; Parker, 1995).

Gage works have been carry out in both streams, consisting of the transformation of the natural river bed in a 4 m long, reinforce concrete channel with a trapezoidal cross section. They have been equipped with a **Doppler effect sensor and a pressure transducer** and also with a raingauge. A Doppler velocity sensor transmits a high frequency sound wave into the flow. Suspended particles and air bubbles in the flow reflect this sound wave. The sensor then detects the frequencies of the reflected sound waves that are related to the velocity of the points in the flow stream at which the reflections occurred. Data measured at fifteen-minute intervals are stored in data-loggers (ISCO 4250) and collected monthly by means of a portable computer.



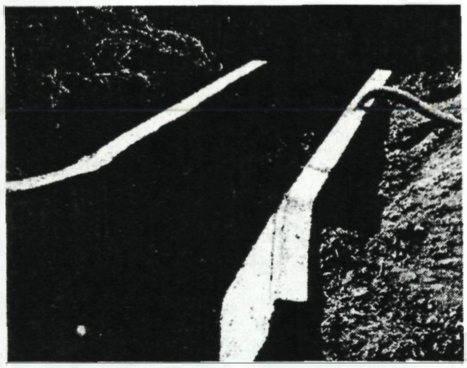
If particle moves towards the sensor, received frequency is greater

If particle moves away the sensor, received frequency is lower



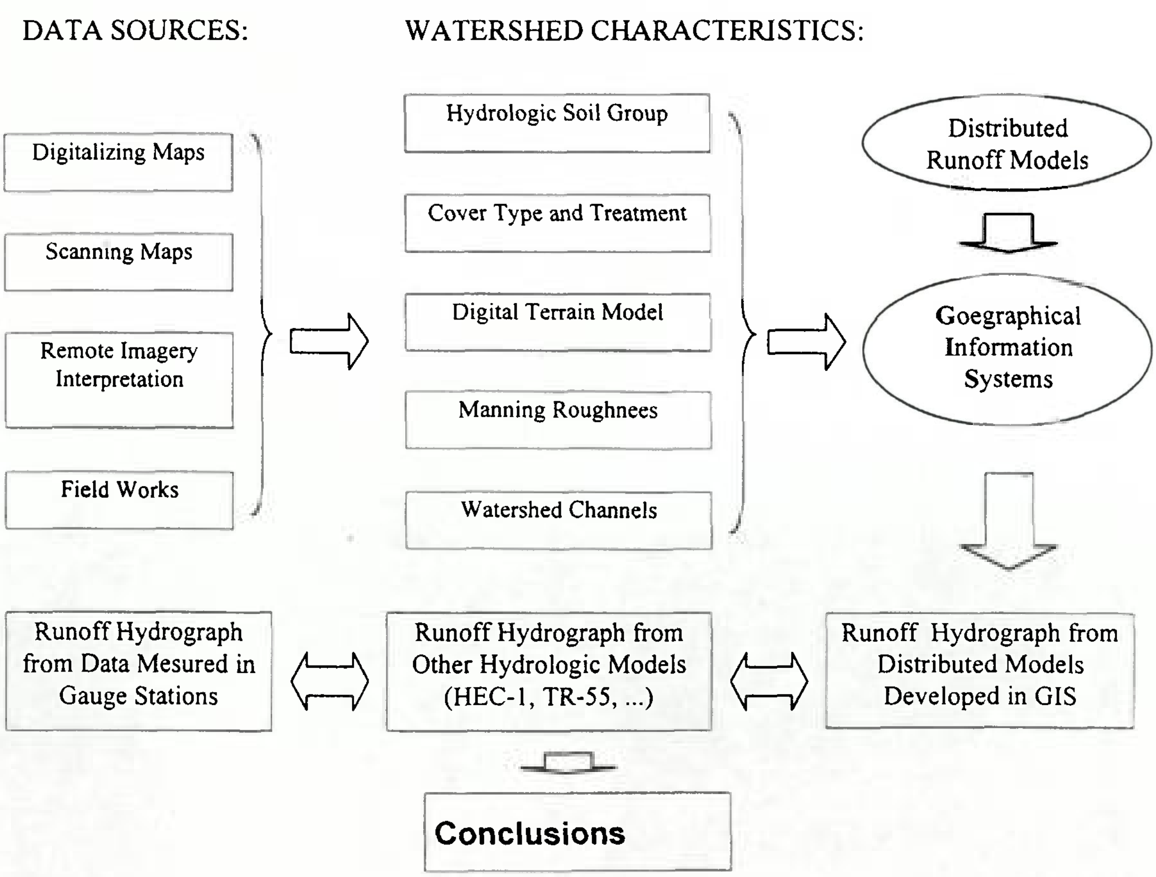
Doppler effect measurement technology (Image from "ISCO open channels flow measurement Handbook")

Besides the advantages of this technology we have found two important limitations. The first is related with sedimentation after a discharge, that is able to bury the sensor, located on the channel bottom. Next discharges disinter the sensor and event data are collected. The second is related with algas growth over the sensor, that is able to prevent the flow velocity measurement by Doppler effect. This problem is also eliminated during a discharge.



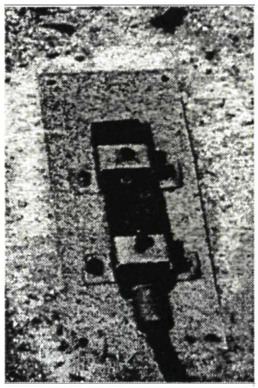
Gage work

Collected data are used to asses the behaviour of different distributed hydrologic models developed in a Geographical Information System (GIS) environment and aimed to study the discharge hydrograph of single events. This models are based on the physic characteristics of the watershed (hydrologic soil group, cover type and treatment, slope, surface manning coefficients and so on) that has been obtained by digitalizing and scanning of existing maps, interpretation of remotely sensed imagery and field works. The registered hydrographs, after separating the base flow by means of a straight line between the beginning of the hydrograph and the end of direct runoff, were compared with those obtained with the SCS classical lumped method and with the proposed distributed method. The simplified methodology is as follows:



Results in the modelling show that the use of GIS as a tool for studying events in small ungaged watersheds on the basis of physical and geomorphologic characteristics that are easily observed in the field offers important advantages over classical systems. The main advantages derive from the possibility of carrying out a distributed treatment as opposed to the traditional lumped treatment, which allows spatial variability of implied variables and parameters to be considered, which, a posteriori, results in a considerable improvement in the quality of the results.

In the light of the limited data available so far, the proposed model has considerable capacity in the simulation of hydrograph shape. However, the transition from total to effective rain, based on SCS equations, poses an important problem because of the treatment given to the state of preceding humidity. In this connection, possible improvements are being reviewed that provide a continuous relation between the CN and the state of preceding humidity (Hjemfelt, 1991).



Pressure and Doppler Sensor located on the bottom of the channel

References

A. T. Hjemfelt, 1991, “Investigation of Curve Number Procedure”. Journal of Hydraulic Engineering, No. 117, pp 725-737

B. Engel, H. Maguerra, K. Kosky, S. Foster, A. Spacie and G. Parker, 1997, “Hydrologic and Water Quality Data Acquisition and Monitoring in the IndiaPine Watershed, Indiana”, Paper nº 972155, 1997 ASAE Annual Meeting, Minneapolis, U.S.A.

C.T. Hann, B.J.Barfield and J.C. Hayes, 1994, “Design Hydrology and Sedimentology for Small Catchment”, Academic Press, San Diego, California, U.S.A.

D.M. Grant and B. Dawson, 1996, “ISCO Open Channel Flow Measurement Handbook”. ISCO Environmental División, Lincoln, Nebraska, U.S.A.

G. Parker, B. Engel and A. Spacie, 1995, “A Completión Report on the Indiana Pine Pilot Watershed Project”, Annual Report to the Indiana Department of Natural Resources, Purdue University, Indiana, U.S.A.

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Optimizing and reducing monitoring networks for groundwater levels

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Introduction

Monitoring networks for observing groundwater exist in germany in all states, large cities, water winning areas etc. They are operated either by state government, communities or owners of water works, who register the groundwater levels regularily.

The continuous observation of groundwater is of high importance for several reasons, e.g.:

- to have knowledge of groundwater occurence and groundwater resources.
- to provide data for extensive groundwater prospection and water resources management.
- to have basic criterion for planning and executing measures connected with interventions in groundwater balance, e.g. tapping of groundwater in water winning areas, building measures.
- to facilitate the longterm observation of groundwater regime and its possible changes.
- to assess anthropologic operations and interventions into nature and water balance for forcasting the effects of human influence and for environmental decision making.

Usually these monitoring networks have developed historically, which means they have not been planned systematically. For this reason they are often dimensioned largely and the observation and maintenance of the monitoring networks require alot of time, personnal costs and therefore large expenses.

Since in all administrations, municipal authorities, communities etc. there is a compulsion to reduce expenses, it is necessary to conceive the networks more economically. This reduction of expenditures strived for can be achieved by optimizing the existing monitoring networks and possibly reducing the amount of groundwater observation wells usefully. It is a requirement though, that in the frame of this reduction no loss of information occurs and the level of quality can be preserved.

Due to the great amount of data, optimizing and reducing large groundwater networks can often not be achieved by usual methods, such as comparison of groundwater hydrographs. Executing this method no objective standard of assessment is available and the result is always dependant on the respective specialist. Therefore other methods have to be developed and executed.

In the following a method is presented, which is based on a pure mathematical approach (regression analysis and cluster analysis), in which the results are examined under hydrogeological, geographical and technical aspects. Compared to a sheer visual handling of the data as mentioned above, a mathematical proven basis is then available for this examination. The idea is, to assess observation wells - so called "leading wells", which are able to represent other wells situated closely and showing similar measuring values. The operation of the other measuring sites can then be stopped and the measuring values for these wells can be calculated by the values of the "leading wells", considering the ascertained correlation coefficient.

Methodology

In a first step all available data and measured values are collected and examined with regard to completeness and obvious mistakes, so the data can be prepared for automatic data processing. Afterwards the mathematical procedures regression analysis and cluster analysis are executed. At first the coefficient of correlation between all observation wells is determined. In order to do this at first the common hydrographs (overlapping measuring periods) have to be assessed. The first results of the regression analysis are depicted cartographically, so spatial correlations can be recognized more easily. Based on the results of the regression analysis the cluster analysis is ececuted. In the frame of this groups of observation wells are determined, which will be examined more detailed in a following step. At the beginning of the optimization a more or less arbitrary grouping takes place, which means 2, 3 or more subgroups are determined. Every observation well in each subgroup is then tested as a "leading well" and given a valuation. The valuation is equal to the minimum of all correlation coefficients between the "leading well" and each other well in the respective supgroup. Afterwards the grouping is improved continuously by cyclic exchanging of observation wells between the subgroups. If no further improvement can be achieved, a local optimum is determined and under the mathematical point of view the best "leading well" has been investigated.

After this optimization the examination of the results is executed with regard to hydrogeological, geographical and technical aspects. For this investigation geological, topographical and hydrographical maps as well as other (hydro)geological data concerning the groundwater storeys, stratigraphy, construction of the wells etc. supply helpful aid.

Summarizing the course of action, the following steps can be subdivided:

1. Registration, collection and examination of all data available with regard to completeness and obvious mistakes
2. Application of the mathematical procedures regression analysis and cluster analysis in order to ascertain senseful groupings with optimal subgroups
3. Examination of the results considering hydrogeological, geographical and technical aspects
4. Establishment of the representative "leading wells" so the final new monitoring network is conceived.

Results of executed investigations

During the past 3 years the described method has been applied successfully for three different monitoring networks, which are all located in the north of germany:

1. Hanseatic City of Bremen
2. State Department for Water and Waste (StAWA)Brake
3. State Department for Water and Waste (StAWA)Cloppenburg

The monitoring networks vary concerning their size and the number of groundwater observation wells operated, as well as with regard to their geographical, topographic and natural situation (coastal or interior location, influence of tides, lowland or low mountain ranges etc.). Considering the geological and hydrogeological conditions they are partially similar, e.g. in all investigated regions the upper aquifer is developed in quartanary sediments, partially though there exist several storeys of aquifers, which had to be considered in the investigation.

The following summarizes some basic information concerning the area and number of groundwater observation wells of the investigated monitoring networks as well as the results which could be achieved:

	Area (km^2)	Investigated groundwater observation wells	Remaining groundwater observation wells
Bremen	404	208	139
StAWA Brake	4.500	281	135
StAWA Cloppenburg	3.500	447	161

These results show, that due to the executed investigations and applied mathematical procedures it was possible, to optimize and reduce the existing monitoring networks for groundwater levels by approx. 30%, 50% and 60%. This could be achieved without having a loss of information or a reduction of quality level.

Taking the Hanseatic town of Bremen as an example, the optimization of the monitoring network showed, that instead of 208 observation wells the groundwater levels can be determined by 139 wells in the future. It was ascertained, that 33 "leading wells" can represent 69 measuring sites located closely to them. The remaining observation wells cannot be represented by “leading wells”, which means the ground water levels have to be registered here continuously as well.

As originally planned, the city then equipped the remaining wells of the optimized network with data logger. Before the groundwater levels had been registered by mechanical recording observation wells. Due to this measure the expenses for observing and maintenance the measuring sites could be reduced considerably. The resulting savings are estimated by the city at DM 140.000,-- to DM 150.000,-- annually.

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The modern problems of river hydrometry

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Hydrometry comprises the methodological basis for the system of regular hydrological measurements. Not long ago hydrometry was considered only as a practical manual on making measurements and processing the database without the necessary methodological substantiation and synthesis of general hydrological and hydraulic data and metrology requirements taken into account. At the present time a number of methodological developments have been carried out in the river hydrometry enlarging its role as a scientific discipline. The modern methodological aspects of river hydrometry include:

- optimising the system of hydrological observations (station distribution, substantiating the composition, measurement frequency with taking account of economic criteria);
- studying the kinematic structure of stream flows, genesis of velocity and stage pulsation as the factors influencing the accuracy of hydrometric data;
- advancing the methods for measuring discrete values of stages, water discharges and sediment yield and a set of models to compute them;- developing and advancing the methods for accelerated integration measurements for water discharge by using ultrasound devices and from moving boats;
- developing and introducing the metrologically substantiated techniques for carrying out measurements at hydrological stations;
- improving the methods for regular and operative accounting of water and sediment discharge by the hydrometric data;
- calculating channel water and sediment discharge balances as the basis for hydrological control over using water resources and assessing ecological conditions on river basins.

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Extrapolation of rating curves by using the water surface calculations software HEC-RAS

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Introduction

Today discharge from our gauging stations is based on water level measurements. For calculating discharge we have to convert water level in to discharge by using a rating curve. The rating curve is described as an exponential function where the discharge $Q=k*(H-dH)^N$. The curve fitting is composed by the method of least squares.

The extrapolation of the rating curve upper section is often done without proper data. Because of lack of flood measurements. The curve fitting is then based upon discharge measurements on lower water level. The rating curves under flooding conditions are therefore often incorect. In many cases utility points are used for supplementing the measured discharges when the curve fitting results are giving unreasonable flooding values.

Huge flooding occur rarely. Performance of discharge measurements by using current meter, dilutions methods or ADCP, presuppose a physical presence when the flood occur. This timing could be particular difficult when the catchment area are small where the flooding occurs very quickly and the duration are short. Discharge measurements under flooding conditions are often hard to carry out.

The main object of this project is to obtain an improved data basis for rating curves of better quality, especially for flooding conditions. The HEC-RAS software will calculate the water surface at all actual water levels on the basis of measured geometric data. We have then an objective basis for curve fitting, even if measurements for high discharges are missing. The fieldwork could be done under favourable weather and flooding conditions during the summer, and a good rating curve could be made on a previous stage. We need:

- Geometric data that describes the rivers geometry
- Hydraulic model that gives us the relation between water level and discharge. (We are using the software HEC-RAS)
- Interdependent water level and discharges for model calibration.

The target group is users of discharge data in extensive sense and especially users who need flooding discharge values with good quality. e.g the forecast service of NVE hydrology department.

Fieldwork/ profiling with presentation of data and equipment for measurements

The hydraulic models basic data are geometric data from the riverbed. The river is mapped by cross sections in the controlling section of the water level gauging station. (In many cases over a waterfall.) All cross sections must have the same common reference level. The water gauges measuring staff or a benchmark will normally be used as elevation basis. The cross sections have to be measured up to a higher elevation than highest probable water level. The water line is measured on both riverbanks. The distance between the cross sections, on both sides must also been noted.

Levelling telescope
Adequate equipment for measuring cross sections in minor rivers is levelling telescope, levelling staff and measuring tape. The elevation basis is determined by surveying the benchmark of the gauging station. It could be handy to establish secondary bench marks of each profile and establish a connection in level between the secondary benchmarks. The distance between the cross sections is measured by using measuring tape on both riverbanks.

ADCP
ADCP is an effectively and accurate tool for measurements of cross sections in greater rivers in the wet area. When the distances are greater between each cross sections, it will be sensible to establish a benchmark for each cross section. Cross section and water surfaces are referenced to the benchmark in the first time. Surveying in to a common elevation basis, can be done on a later stage. Cross sections measurements could also be done by using a echo sounder and GPS, where GPS are used for positioning each depth measurement.

Theodolite
Cross section measurements could be done in minor and medium sized rivers, and above the water surface of major rivers. When using a theodolite, one need at least two benchmarks, where the elevation is known at one of the benchmarks. The theodolite is measuring horizontal, vertical angle and slope length. An electronic measuring book connected to the theodolite, will facilitate the work allowing directly data transmission in to a PC witch calculates the co-ordinates.

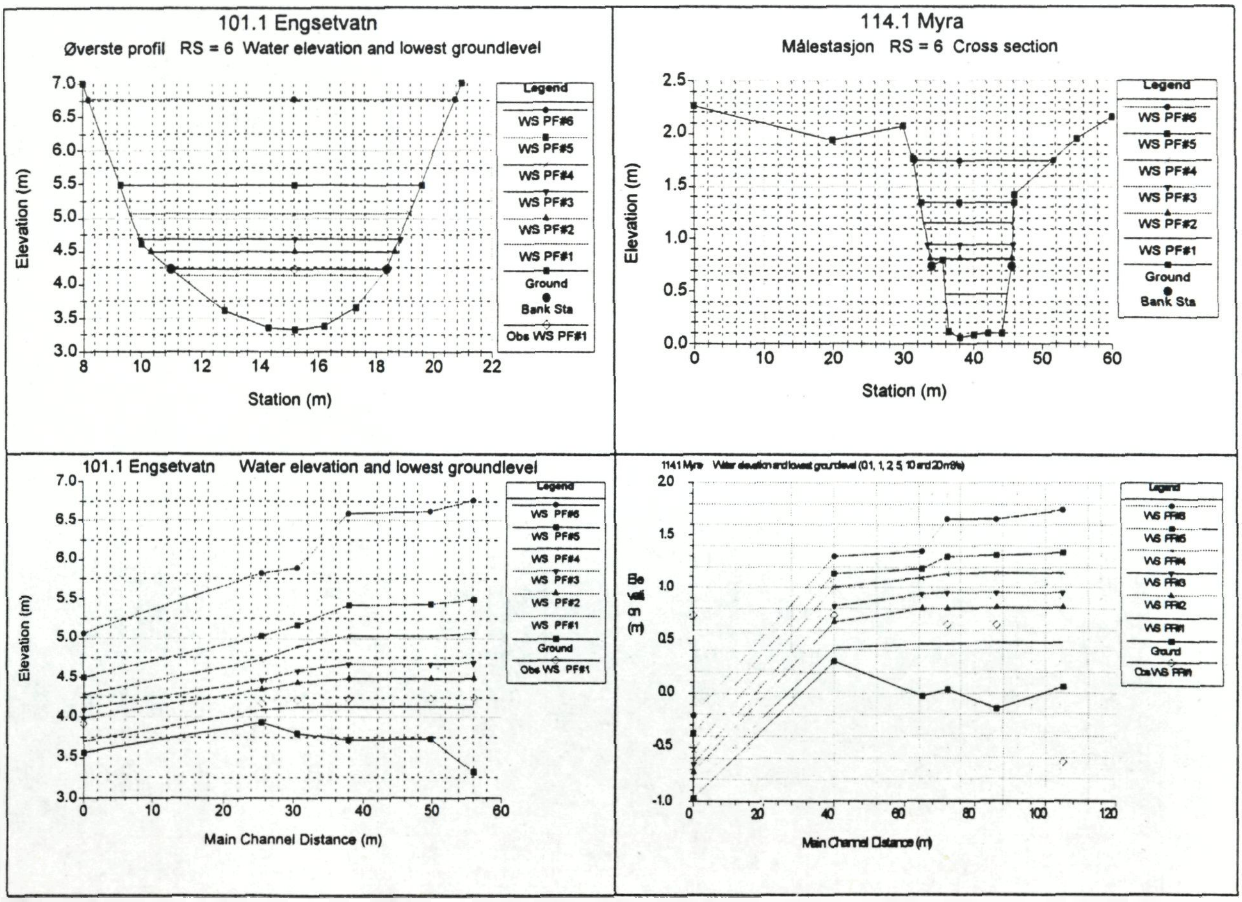
101.1 Engsetvatn
This gauging station is located in the outlet from Engsetvatn lake where two bridges and rim walls are making a 5 m wide channel, wich are determining the water level in the Engsetvatn lake. The riverbed is stable and consist of concrete, stone wall, and stones in the riverbed. Engsetvatn is a station with a good rating curve, measured by a current meter. The difference between the highest measured discharge and highest measured water level are small. This station are used as a verification of the method by measure the cross sections and use a water surface calculations software for extrapolating the rating curves.

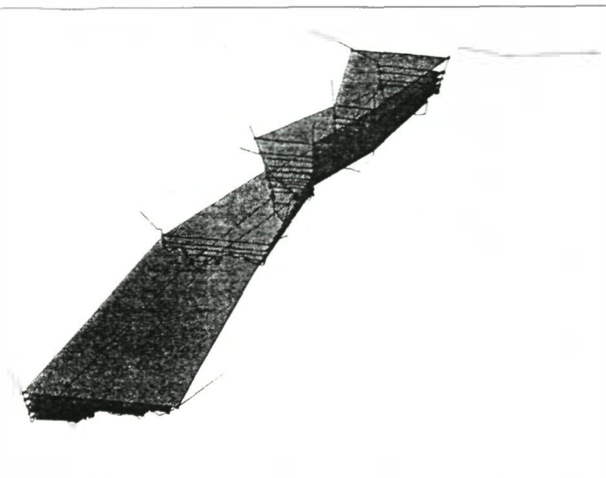
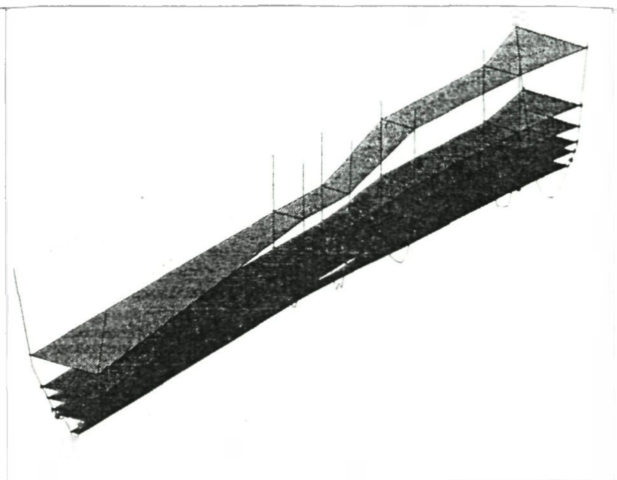
114.1 Myra
This station is located in a calm river section. The riverbed is made of rock. 40 m downstream the gauging station there is a narrow passage under a bridge, and 65 m downstream there is a waterfall. Myra is a gauging station who have only a limited number of discharge measurements at high water levels. The rating curve is therefore uncertain for high discharges. This gauging station is used to indicate that the rating curve can be improved by using water surface calculations for extrapolating the rating curves.

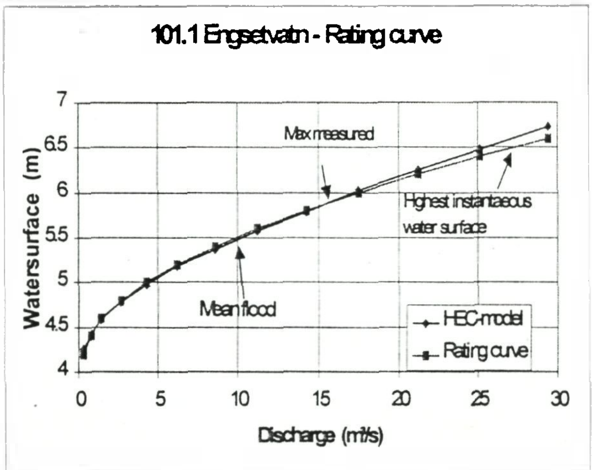
Conclusion
Engsetvatn is a gauging station, with a reliable rating curve measured by using current meter. The difference between highest measured instantaneous water surface and highest discharge measurement is small. One can se that it is good correspondence between the existing rating curve and the rating curve calculated using the water surface calculations software HEC-RAS. This verifies the model.
Myra is a gauging station with a limited number of discharge measurements on high water levels. The difference between the existing rating curve and the curve calculated by using the water surface calculations software HEC-RAS is large. One can therefore make this conclusion :
Extrapolation of rating curves by using water surface calculations is an useful tool to improve rating curves where the difference between the highest measured water levels and the highest measured discharge are large.

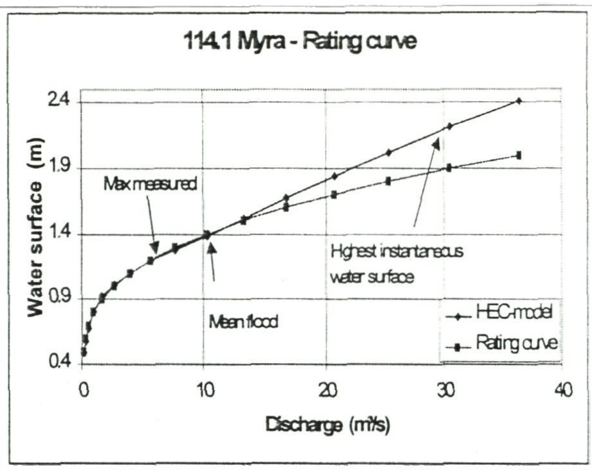
Reference: HEC-RAS River Analysis System Hydraulic Reference Manual July 1995, US Army Corps of Engineers

	Engsetvatn	Myra
Observation period	1923-TD	1989-TD
Technical equipment	surge pipe, .SFT-logger, optical shaft encoder	Surge pipe, .SFT-logger, optical shaft encoder
Catchment area (km²)	40,0	15,9
Average discharge (m³/s)	2,37 (4,46 m on rating curve)	0,940 (0,80 m on rating curve)
Mean flood (m³/s)	9,97 (5,51 m on rating curve)	10,72 (1,42 m on rating curve)
Highest observed daily mean discharge (m³/s)	25,7 (6,43 m on rating curve)	16,73 (1,60 m on rating curve)
Highest instantaneous water surface (m³/s)	27,0 6,49 m on rating curve)	46,2 (2,15 m on rating curve) The HEC model give 29,3m³/s this is a more reliable value
Highest discharge measurement (m³/s)	15,71 (water surface 5,85 m)	6,04 (water surface 1,22 m)
Number of discharge measurements	26	13







101.1 Engsetvatn			114.1 Myra		
Discharge (m³/s)	Rating curve WS (m)	HEC-RAS WS (m)	Discharge (m³/s)	Rating curve WS (m)	HEC-RAS WS (m)
0,3	4,2	4,26	0,12	0,50	0,49
0,76	4,4	4,42	0,28	0,60	0,58
1,42	4,6	4,58	0,55	0,70	0,68
2,67	4,8	4,78	0,97	0,80	0,80
4,29	5	4,98	1,7	0,90	0,92
6,26	5,2	5,18	2,70	1,00	1,01
8,57	5,4	5,37	4,03	1,10	1,10
11,20	5,6	5,57	5,71	1,20	1,20
14,20	5,8	5,79	7,71	1,30	1,28
17,50	6	6,02	10,30	1,40	1,39
21,20	6,2	6,25	13,30	1,50	1,51
25,10	6,4	6,48	16,70	1,60	1,67
29,40	6,6	6,73	20,70	1,70	1,84
			25,30	1,80	2,02
			30,50	1,90	2,21
WS : Water surface			36,30	2,00	2,41

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Soil moisture: Accuracy of measurements and scaling problems

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Introduction

Soil moisture influences all physical, biological and chemical processes in the unsaturated zone. Knowledge about its interrelations to the forcing meteorological variables, about its dependence on soil-physical characteristics and on the changing vegetation cover is important for solving problems connected with hydrology, water management, ecology, agriculture, forestry and civil engineering.

The appropiate measurement methods of soil moisture currently available are point measurements. In order to get averages of soil moisture over large areas - increasingly important for solving problems of runoff generation, of areal evapotranspiration or prediction of land use change and land surface representations in global circulation models - scaling procedures are required. Therefore we are confronted with two important problems:

- the accuracy of recently used point measurements,
- the possibility of upscaling.

The problem of upscaling

Regarding the problem of upscaling we should take into consideration that processes of geomorphology, soil and river net formation cause organized spatial soil moisture patterns. Such spatial patterns can be obtained by measurements and modelling. The only measuring method, providing spatial averages over large areas are remote sensing techniques. Their main disadvantage is the considerable influence of the vegetation which only provides representative patterns of a very thin surface layer of bare soil. Therefore modelling of spatial patterns becomes increasingly important. There are topographic indices (e.g. Blöschel, 1996) or alternatively distributed hydrological models. Starting from our experience we prefer distributed models. But concerning the problem of parametrization and calibration of such models we can only successfull proceed in this way if there are accurate point measurements and a reliable upscaling by networks in well observed representative and research basins. In such basins we have a good availability of digitiesed topographic data and other domain attributes such as soils, vegetation and land use. These data together with a carefully established network of soil moisture stations offer best possibilities to the experimental determination of spatial soil moisture patterns in the research area and therefore for calibration and validation of distributed models. Therefore it remains the problem of accuracy of point measurements frequently uncritically considered in recent studies.

The accuracy of point measurements

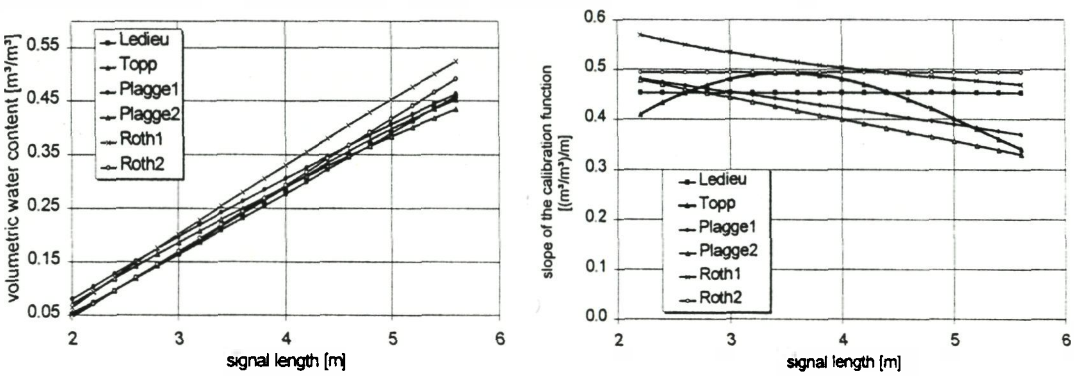
Amongst the currently used point measurements the Time Domain Reflectometry (TDR) is generally prefered. Therefore our considerations should be related to this technique. Because it is an indirect measurement of soil moisture the different methods of calibration are very decisive for the accuracy of the measurement. There are a number of calibration algorithms to describe the interrelation between the dielectric properties of the soil and its water content (Ledieu et al., 1986; Topp et al., 1980; Roth et al., 1989) with the aim of finding a general function over a wide spectrum of soils. With the increasing number of users the number of available calibration functions have increased (Dasberg & Hopmans, 1992; Plagge et al., 1996; Yu et al., 1997). The main causes of measurement errors are the heterogenity of the soil (Wilpert et al., 1998) and the procedure of installation (Peschke, 1997; Rothe et al., 1997). Further problems such as high contents of organic material and clay or partly frozen soils lead to additional problems (Gray & Spies, 1995; Weitz et al., 1997; Spaans & Baker, 1995).

The experimental investigations have been carried out at the Zittauer Ecological Research Station (Sambale, 1998). The soil is an homogeneous loamy clay with a porosity of 45 - 50 % and a bulk density of 1,3 - 1,5 g cm^{-3}. The equivalent wilting point is about 20 Vol.-%.

The soil moisture is measured by TRIME-probes of the firm IMKO (Stacheder, 1996). This system uses the algorithm of Topp. The probes are installed in different horizons in a weightable lysimeter, which allows an additional integrating gravimetrical calibration over the whole lysimeter volume. The temporal change of the soil water content corresponds to the difference in the mass of the lysimeter. This calibration allows to examine the changes in soil moisture by the easier and more accurate method of weighting.

In order to estimate the absolute value of soil moisture by gravimetric method undisturbed soil samples were taken in the neigbhourhood of the lysimeter.

For the use in hardly investigated sites it is important to know the error interval by using the standard calibration functions (Topp et al., 1980; Ledieu et al., 1986; Roth et al., 1989; Plagge et al., 1996).

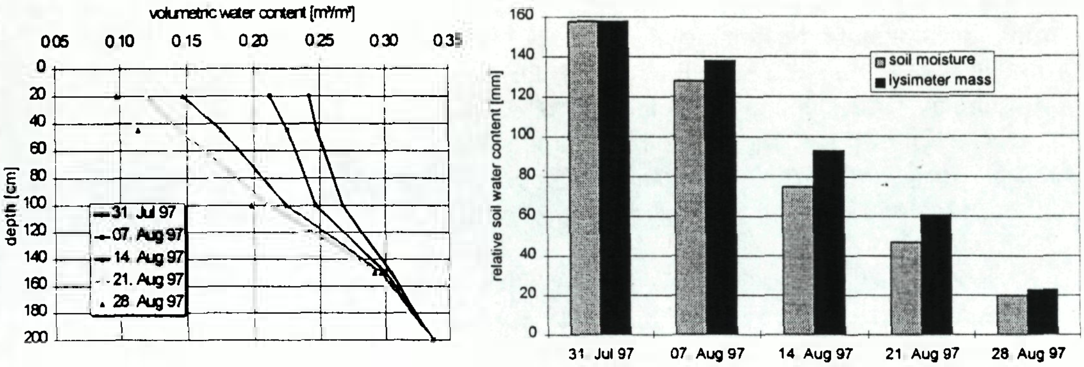


(a) *(b)*

***Fig. 1:** Comparison of different calibration functions for the calculation of the soil moisture from the signal length of the TDR-measurement; (a) the absolute soil moisture; (b) changes in soil moisture.*

The different functions (fig. 1a) provide differences in the calculated soil moisture of about 0,1 m^3 m^{-3} under wet and about 0,05 m^3 m^{-3} under dry conditions. Very often the knowledge of relativ change in soil moisture is sufficient. It corresponds to the first derivation of the calibration functions (fig. 1b). The slope of the calibration functions fluctuates between 0,32 and 0,57 m^3 $m^{-3} \cdot m^{-1}$. This means, that a change of the signal length of 0,1m causes soil moisture changes between 0,03 and 0,057 m^3 m^{-3} depending on the initial conditions and the used algorithm. For medium soil water contents from the different functions result differences in the soil moisture change of about 20 % and for extremly dry or wet conditions of about 30 %.

Let us now consider the calibrations of soil moisture measurement as mentioned above. The different soil moisture profiles (fig. 2a) show the extraction of water by evapotranspiration. The mass of this loss should be equal to the difference of the lysimeter mass. Figure 2b shows the relative soil water content of the monolith and the corresponding relative mass for the profils in figure 2a. Over the whole period we observed a good agreement between the changes of mass and water content. Therefore the used calibration function (Topp) seems to fit the real changes in soil moisture quite well.



(a) *(b)*

***Fig. 2**: Soil moisture profiles in the lysimeter, measured by TRIME-probes (a); changes in soil water content, calculated from the soil moisture profiles and from the mass of the lysimeter (b).*

In order to get a calibration of the absolute soil moisture we determined the soil moisture gravimetrically. Figure 3 shows the drastic underestimation of the soil moisture by the TRIME-measurement. We have found an constant deviation of about 13 percent of volume between the TRIME (with Topp calibration) and the gravimetric measurement.

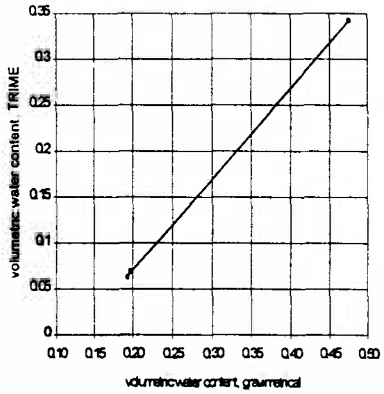


***Fig. 3**: Comparison of the gravimetrical and the TRIME soil moisture measurement.*

Discussion

To get reliable soil moisture averages over great areas it seems to be necessary to have

- accurate point measurements and
- an appropriate upscaling procedure.

Our analysis shows that TDR - point - measurements using universal well known calibration functions only provide absolute values with an error interval of about 10 to 13 percent of volume. Decreasing of these errors requires additional calibration.

The appropriate upscaling should be done by distributed mathematical models. Their parametrization and calibration should be based on reliable point measurements in a careful installed network of soil moisture stations in a research area with known spatial distributions of terrain attributes. Thus calibrated models enable the transition into regions without soil moisture data but with known spatial distributions of terrain attributes.

Literatur

BLÖSCHEL, G., (1996): Scale and Scaling in Hydrology. *Wiener Mitteilungen Wasser - Abwasser - Gewässer*, 132.

DASBERG, S. & HOPMANS, J.W., (1992): Time Domain Reflectometry calibration for uniformly and nonuniformly wetted sandy and clayey loam soils. *Soil Sci. Soc. Am. J.*, 56, S. 1341-1345.

GRAY, A.N. & SPIES, T.A., (1995): Water content measurement in forest soils and decayed wood using time domain reflectometry. *Can. J. For. Res.*, 25, S. 376-385.

LEDIEU, J., DERIDDER, P., DECLERK, P. & DAUTREBANDE, S., (1986): A Method of Measuring Soil Moisture by Time Domain Reflectometry. *J. o Hydrol.*, 88, 319-328.

PESCHKE, G. (1997): Soil moisture measurements in skeletal soils. In: „*Monitoring and modelling of soil moisture: Integration over time and space*“, Workshop, 5th Scientific Assembly of the International Association of Hydrological Sciences, RABAT, Marocco, 23. April -3 May 1997.

PLAGGE, R., ROTH, C.H. & RENGER, M., (1996): Dielectric soil water content determination using time domain reflectometry (TDR). In: *IMS workshop*, Electromagnetic wave interaction with water and moist substances.

ROTH, K., FLÜHLER, H. & ATTINGER, W., (1989): TDR - Eine Methode zur Messung des volumetrischen Wassergehaltes. *Bull. d. Bodenkundl. Ges. d. Schweiz*, 13, S 117-122.

ROTHE, A., WEIS, W., KREUTZER, K., MATTHIES, D., HESS, U. & ANSORGE, B., (1997): Changes in soil structure caused by the installation of time domain reflectometry probes and their influence on the measurement of soil moisture. *Water Res. Research,* Vol. 33, No. 7, 1558-1593.

SAMBALE CH. (1998): Experimentelle und modellgestützte Wasserhaushaltsuntersuchungen im System Boden - Pflanze - Atmosphäre. IHI-Schriften, Heft 8, Zittau.

SPAANS, E.J.A. & BAKER, J.M., (1995): Examining the use of time domain reflectometry for measuring liquid water content in frozen soil. *Water Resour. Res.*, Vol. 31, 2917-2915.

STACHEDER, M., (1996): Die Time Domain Reflectometry in der Geotechnik. *Schriftenreihe Angewandte Geologie Karlsruhe,* Heft 40, Karlsruhe.

TOPP, G.C., DAVIS, J.L. & ANNAN, A.P., (1980): Electromagnetic determination of soil water content: Measurements in coaxial transmission lines. *Water Resour. Res.,* Vol. 16, Nr. 3, S. 574-582.

WEITZ, A.M., GRAUEL, W.T., KELLER, M. & VELDKAMP, E., (1997): Calibration of time domain reflectometry technique using undistributed soil samples from humid tropical soils of volcanic origin. *Water Res. Research*, Vol. 33, No. 6, 1241-1249.

WILPERT V. K., NELL U., LUKES M. & SCHACK-KIRCHNER H., (1998): Genauigkeit von Bodenfeuchtemesungen mit „Time Domain-Reflektometrie“ und „Frequenz Domain-Sensoren“ in heterogenen Waldböden. Z Pflanzenernähr. Bodenk., 161, 179-185.

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Sampling Strategies for Estimating Suspended Sediment Loads in the River Elbe

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Introduction

The knowledge of nature and behaviour of transported solids in rivers is fundamental to answer questions relating to navigation, water resources, water quality and ecology aspects. As fine solids can serve as a transporting agent, measurements of suspended solids are a necessary basis for quantification of actual as well as potential loads of particle bound transport of organic micropollutants and heavy metals and further water quality assessment. Nowadays, these measurements are carried out at many rivers world-wide giving estimates of e.g. annual loads of sediments and pollutants.

As the often highly fluctuating suspended sediment concentration depends on many interdependent factors sediment discharge proves to be a complex dynamic process. In general water discharge and suspended sediment concentration do not correlate well as the variability of suspended sediment concentration is very high at instationary discharge conditions: for a given discharge concentrations can be several times greater on the rising limb of the hydrograph than on the falling limb. From numerous investigations it is well known that at least in smaller catchments the major part of the annual sediment yield is transported during short periods of high flows whereas in the most of time the sediment transport is comparatively low. Schmidt (1994) reported for a catchment in Germany with 101 km² that 80 % of the annual load was transported in 3 % of the time. Similar observations have been reported by Walling and Webb (1981).

As the discharge of suspended solids cannot be measured directly the common practice is to take discrete water samples, to determine the sediment concentration by means of filtration and to estimate the sediment discharge as a product of water discharge and sediment concentration. Beneath problems arising with filtration the main deficiency of this method is that no continuous monitoring is achieved. To get information about concentration continuously turbidity measurement frequently is used as this parameter can be related to sediment concentration sometimes to a high degree. As with this technique problems are involved as well (in addition to the dependency on concentration results of turbidity measurements depend on type of measuring system; size, shape, surface roughness and colour of grains; ratio of mineral to organic material, thus calibration often appears to be unstable) the traditional method of taking discrete water samples is still prevalent.

Aims and scope

To obtain load estimates within an acceptable range of accuracy and precision (i.e. unbiased estimates with low variance) under economical restrictions efficient and adequate sampling programmes have to be applied. Sampling is efficient if estimates with low variance are obtained even when sample sizes are small. The aim of all sampling strategies is to ensure a sampling procedure by which the required representation of the process is achieved at minimal expense. However, the main deficiency of most long-term sampling programmes is that they mostly are not well adapted to processes showing high variability as they do not take account of the statistical character of the process observed. As a consequence a great number of unnecessary samples are taken at concentration conditions with low variance whereas the sampling frequency is inadequate at the rare significant events associated with high variance. Many authors have stressed the fact, that sampling frequency has significant effects on the accuracy and precision of load estimates and that a great need exists for adequate sampling programmes (Dickinson, 1981; Olive, Rieger, 1988).

The lack of a theoretical basis is the reason, why the application of 'subjective' sampling programmes is inefficient and does not give answers to the following questions:

- How many samples have to be taken to estimate sediment yield with defined precision ?
- How to distribute these samples in time in view of the high variability of the process ?
- What are the statistical properties of the estimates ?

To overcome these deficiencies strategies have to be based on sample survey theory.

The Federal Waterways and Shipping Administration (Wasser- und Schiffahrtsverwaltung des Bundes - WSV) maintains 69 measuring stations in the German waterways. At these sites water samples are taken by hand in a daily interval (in general only workdays) to determine suspended sediment concentration. The results of the analyses done by the Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde - BfG) allow estimation of sediment concentration, sediment transport and loads at each site. As most of these measuring stations are controlling great drainage basins the streams do not show very rapid event response at these sites and sample sizes of about 250 per year may give reliable load estimates. Taking into account the costs of collecting and analysing the huge amount of samples the operation of this monitoring network would greatly benefit from the application of well adjusted sampling strategies. Moreover, errors introduced by inadequate sampling could be avoided. Therefore investigations have been done to define strategies which ensure an improved sampling efficiency (Binding, 1998; Schmidt, 1999), i.e. reducing the number of measurements in comparison with the operation today, with the aims of relating sampling effort to the desired precision of load estimates and getting unbiased estimates with known statistical properties. The results of all simulations have been compared to estimates obtained by the sampling programme practised today. Among the strategies tested have been very simple ones, like simple random sampling, each sample having the same probability of being taken, sampling with probability proportional to the magnitude of estimated sediment transport and stratified sampling.

Stratified sampling

The concept of stratified sampling is to devide the population into several strata within which the subpopulations are relatively homogeneous ('minimization of variance'), whereas the heterogeneity between the strata is stressed ('maximization of variance'). In order to get estimates with desired statistical properties the population has to be approximately normally distributed. In general this is not the case for suspended sediment data, but it is nearly always possible to define subpopulations by stratification which more closely approach normality. To apply stratified sampling, the empirical distributions of the variables by which the strata are defined have to be known. In case of suspended sediment data useful variables could be e.g. water level, water discharge, tendency of water level or water discharge (rising or falling), rate of change of water level or water discharge and time (seasonal influences). Careful stratification may require a combination of several variables.

The precision of a sample is given by

$$d_{\bar{x}} = k\,\sigma_{\bar{x}} = k\,\sigma/\sqrt{n}$$

in which $\sigma_{\bar{x}}$ is the standard deviation of the sample mean, σ is the standard deviation of the population, k is the value of the standard normal distribution for a chosen level of confidence and n is the sample size (Leiner, 1994). If the standard deviation of the population σ is unknown the sample estimate s has to be used with t (value of the t-distribution) instead of k.

From this equation the number n of samples to be taken is determined as

$$n = (k^2 \sigma^2) / d^2_{\bar{x}}$$

i.e. the sample size increases as the level of confidence will be chosen higher, as more precise the estimate has to be and as higher the variance of the population units will be.

In the case of stratified sampling the total number of samples n to be taken is determined as

$$n = t^2 / d^2_{\bar{x}} \left(\sum_{s=1}^{S} N_S/N \cdot s_S \right)^2$$

in which N_S is the time in stratum s and N is the total time in the period under consideration. The total number n of samples is distributed amongst the strata according to

$$n_S = n \cdot N_S \cdot s_S / \sum_{s=1}^{S} (N_S \cdot s_S).$$

Constant sampling rates for each stratum can be calculated by the ratio n_S/N_S. In applying stratified sampling the samples can be taken either at constant rates or randomly distributed corresponding to these rates.

The design of sampling strategies of course requires historical data. Records of e.g. water discharge and of concentration data of at least one year should be available to get some estimates of the statistical properties of the process. As the appropriate definition of the strata is decisive for satisfactory application it is advisable to use data of more than one year and to analyse the characteristics of the concentration data carefully with respect to the parameter(s) defining the strata.

Results

For testing the efficiency of stratified sampling with regard to the estimation of yearly loads a 6-year-record (1992-1997) of daily samples at *Pirna* (River Elbe, km 34,7) has been chosen. The methodology outlined above has been applied to a period of two years (1994 and 1995) of this record to define appropriate sampling frequencies. A confidence level of 90 % and an accepted deviation from true yearly mean load of ±15 % was chosen. With water discharge as the only variable (flow stratified sampling) three strata have been defined by choosing thresholds of 400 m^3/s and 700 m^3/s. The calculated sampling rates for a time base of one year (Table 1) show that to get estimates with same precision the sampling effort differs considerably from stratum to stratum, a clear proof that stratifying this record makes sense. Most of the time in the year one sample in three weeks would be adequate (if this level of precision is accepted) as the variance of the concentration is low when water discharge is below 400 m^3/s. Using these results simulations have been done for the years 1992-1997 at constant rates starting sampling on the first day in each stratum. From the results presented in Table 2 the conclusion can be drawn that the sampling rate in this part of the River Elbe - as far as yearly loads are concerned - could be reduced significantly in comparison to daily sampling if a statistically based strategy is applied and the sampling scheme is well adjusted to the nature of the process by means of historical data.

Stratum	Time	Time	Number of samples	Sampling rate	Sampling rate	Chosen Sampling rate
	Days	%	-	samples/day	days/sample	days/sample
Q < 400 m³/s	215,5	59	9,91	0,046	21,76	22
400 = Q < 700	102,0	28	14,18	0,139	7,20	7
Q = 700 m³/s	47,5	13	25,06	0,528	1,90	2
Totals	365	100	49,15	-	-	-

Tab. 1: Sampling frequencies for Pirna (precision $\pm 15\%$; $\alpha = 10\%$) calculated for 1994-1995

Stratum	Sampling rate	1992	1993	1994	1995	1996	1997	Mean
	days/sample	samples	samples	samples	samples	samples	samples	samples
Q < 400 m³/s	22	14	16	11	9	11	12	12
400 = Q < 700	7	8	3	12	18	14	13	11
Q = 700 m³/s	2	7	3	22	26	15	12	14
	Samples per year	29	22	45	53	40	37	38
	Percentage of daily sampling	8%	6%	12%	15%	11%	10%	10%
	Deviation from 'true' load	-1,6%	-0,7%	2,8%	-6,6%	5,8%	0,2%	0%

Tab. 2: Results of simulations with stratified sampling at Pirna (River Elbe, km 34,7)

References

Binding, J. (1998): Anwendungsbezogene Strategien zur Entnahme diskreter Schwebstoffproben. Diplomarbeit an der TFH Berlin.

Dickinson, W.T. (1981): Accuracy and precision of suspended sediment loads. IAHS Publ. No. 133, June 1981, pp.195-203

Leiner, B. (1994): Stichprobentheorie. R. Oldenbourg Verlag GmbH, München.

Olive, L.J., Rieger, W.A. (1988): An examination of the role of sampling strategies in the study of suspended sediment transport. IAHS Publ. No. 174, Dec. 1988, pp.258-266

Schmidt, A. (1994): Schätzung des Schwebstofftransports in kleinen Einzugsgebieten auf der Grundlage von Abflußmessungen. Mitteilung Nr. 123, Institut für Wasserbau und Wasserwirtschaft, TU Berlin

Schmidt, A. (1999): Probenahmestrategien zur effizienten Schätzung von Schwebstofffrachten der Elbe. BfG-Bericht (in preparation)

Walling, D.E., Webb, B.W. (1981): The reliability of suspended sediment load data. IAHS Publ. No. 133, June, pp. 177-195

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Principles of hydrological network distribution in Russia

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In Russia a hydrological network has been established and proved to be reliable for making measurements on rivers, canals, lakes and reservoirs. In addition to the hydrological network, there is also a federal network for water quality observations. The present report deals with the hydrological network only. The total number of hydrological stations in Russia is about 3000 on rivers and 405 on lakes and reservoirs. Though it was reduced during the last years, it is still optimal for the European territory of Russia and somewhat insufficient for the Asian part. In the European Russia this network density provides sufficient reliability of water discharge interpolation with the mean square root error: 5-10 % for mean annual discharge and up to 10-15 % for maximum and minimum discharges.

Principles and criteria for optimum hydrological network distribution have been developed and are being permanently improved at the State Hydrological Institute (SHI). In the present report they are considered as applied to characteristics of the hydrological regime annual water discharge and sediment yield. The criteria are based on the discrete-continuous representation of the field of hydrological components. This means that every hydrological component, for instance, annual water discharge, is determined for a discrete region – drainage area (A). At the same time, when considering large areas (hydrological zones) one can be based on ideas about continuous distribution of characteristics of the component.

The distance between the observation sites is to be, on the one hand, sufficient to record the spatial changes (gradients), and on the other hand, not too long to preserve correlation of the study characteristics. On the basis of these preconditions the gradient and correlation criteria of the network density have been obtained that corresponded to drainage areas: A_{gr} and A_c restricting the optimum value of A_0: $A_{gr} < A_0 < A_c$.

The criterial values of drainage areas are determined for the main physiographic zones of Russia and roughly comprise: Ao = 15 000 km^2 for tundra, Ao = 5 000 km^2 for forest, and Ao = 2 000 km^2 for steppe.

In most cases optimum values of Ao correspond to catchments of mid-sized rivers characterised by the zonal features of runoff formation. As for other rivers – small azonal ones with drainage areas A< Ao, large (polyzonal) rivers with A>Ao, as well as rivers with anthropogenic changes in runoff, they are satisfied with the object-by-object principle of the station site depending on the river system structure.

The river system can be presented as a tree-shaped graph where outer peaks indicate flows, and inner peaks show the points of flow confluence. The river system parameters possess indicate properties relative to hydrological processes. Many characteristics of river regime such as averaged and maximum water discharges ice thickness and others can be presented as the function of river order: 1, 2, 3, . . .K.

The transfer of hydrological characteristics from observation objects to other ungauged objects is carried out in the subset of elements of the same order. Thus, observation stations are to be sited in general case in all the links of hierarchical chain of flows of different orders, as minimum, on those being of the most importance for users.
When determining the optimum number and distribution of stations for sediment yield measurements on rivers with natural and disturbed regimes the zonal principle was used. In accordance with this principle, in every physiographic zone from tundra to semi-desert, it is necessary to have a sufficient number of stations to reliably assess the spatial sediment yield variability and to describe its regime with the necessary accuracy (with the necessary square root error of 15-20 % for annual means). The following number of stations is recommended for sediment yield measurement (in percentage of the number of stations for water discharge) 60-70 % in the zone of water deficit; 40-50 % in the steppe zone of variable water availability; 10-20 % in the forest-steppe zone with water surplus.
At the present time the scientists of the SHI are developed the criteria for determining the minimum necessary number of hydrological stations under the conditions of reducing funds for these stations operation.

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Long-term water balance and erosion intensity in small forested mid-European watersheds with a catastrophic flooding in 1997

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Abstract
Four small fully forested watersheds and one not forested very much with long-term series of climatic and hydrological elements there are in the Jeseníky and Beskydy Mts. near by the border of three countries - Czech, Slovak Republics and Poland. Thorough investigation of forest hydrology in these small watersheds, three of them in the time of calibration period and following forest renewal process under air pollutions showes that the relationship between precipitations and outflows depends more on interrelated natural and geographic fluctuations of elements than on management methods used in forests. But only management techniques with favourable impacts on the ecology have to be used. The heavy rainfall in July 5th-8th, July 1997 caused the catastrophic flooding in the basins of Morava (Danube) and Odra (Oder) rivers. We have recorded that the forests could not reduce the highest peaks of outflow waves. The torrent control works there are important to be made in this area.

Introduction
Research into the influence of forest stands on water balance, flooding and erosion of forest soils and torrents, the circulation of nutrients in headwaters of the Morava-river was established 1928 in two representative watersheds, 1954 in headwaters of the Odra-river - two experimental watersheds in the Beskydy Mts., and 1988 in one representative watershed the Jeseníky Mts. The Beskydy Mts. form a NW part of the Carpathian range. Both representative watersheds, **Kýchová** (KY; 4.15 km^2; 95.4 % forest cover) and **Zdichov** (ZD; 4.18 km^2; 4.6 % forest cover), have measurements in progress. Both experimental watersheds, **Malá Rástoka** (MR; 2.07 km^2; 100 % forest coverage) and **Èervík** (CE; 1.85 km^2; 100 % forest coverage) suffered after a 12 years long calibration period of the rainfall-runoff relationship from an accelerated forest renewal programme in strips. To date more than two thirds of the total area have been renewed. The representative watershed **U vodárny** (JS; 1.45 km^2; 100 % forest coverage) in the Jeseníky Mts. is calibrated only since 1988. All these watersheds suffer air pollution with apparent damage to the forest stands but there has been some improvement in the last nine years.

Thorough investigation on relationship between elements of water balance showes to be very a complex task. The rainfall-runoff process depends more on interrelated natural and geographic elements than on methods in the management of forests used. Even major changes in management techniques and in levels of air pollution have slight effects on water budget and they are often masked by climatic fluctuations. In order to determine decisive changes and trends, climatic and hydrological elements have to be measured frequently and analysed only in long-term time series. Since the data are collected from open systems, the analysis of short-term measurements would give misleading results. We tried to analyse all the data from the Beskydy Mts. because there is no clear pattern in their behaviour. However, it was found that the influence of vegetation on runoffs can be explained well by an examination of water losses in our watersheds investigated.

Main results of analysis

We have registrated many changes in the KY and CE watersheds, in their quantity and structure of forest cover, during the period of measurements. The forest cover increased in the ZD watershed to 30 % in 1950s. The management of forests in KY, ZD and the renewal of forest stands in stripes without a great damage to soils in the CE watershed did not significantly increase the annual runoff sums. An increase of runoffs in the MR watershed occured in the 1980s only in warm periods of years. This may have answer from a change in commercial species (with the substitution of beech to spruce), deterioration of forest stands by air pollution, climatic fluctuations or other still undetected factors.

The line of discharges below 100-200 l/s km^2 is formed by a volume of groundwater and not very much influenced by vegetation in this area. Minimum runoffs occured only in rainfall-free periods. A tendency towards a slight increase of outflows was noted in the period of running renewal process. During the final stages of the accelerated forest renewal programme a tendency towards a slight increase in minimum of runoffs was noted but it was too small to be of practical use.

Melting of snow is a climatic effect in this region having no marked change due to forest renewal. At this time no peaks of outflows were greater than 1/5 of the highest peaks in summer. The retention of water in our watersheds investigated reaches to some 50 mm. Heavy rainfall (greater than 80-100 mm/day) with its high intensity gave rise to damaging flooding, but the slowdown of peaks of outflow waves was significant. All waves were caused only by a heavy rainfall when the soils were saturated with water. No increase of outflow waves was recorded during the period of forest renewal nor under air pollution.

During the 45 years long time period were recorded only ten peaks of waves in MR and five in CE watersheds. The most heavy rainfall in July 1997, 223.8 mm on 6^{th} and 585.7 mm between 5^{th} - 8^{th}, caused very dangerous flooding not only in headwaters but also in the Odra-river in Poland and Germany too. The forests were able to slowdown limitelly the ascending part of the wave of outflow but not to reduce prevently all risks.

The erosion intensity in forested watersheds converted to mean soil decrement of .045 and .090 mm is below the potential erosion and is fully covered by natural soil generation. The heavy flooding in July 1997 caused very intensive transport of sand, gravel, trees etc. with serious implications for the stability of bridges and for the disagreeable flooding of adjoin lands and houses. The accelerated forest renewal programme has not been proved to be the main cause of a soil and torrent erosion. But the torrent control works are very important in this area as well. The dynamics of water elements were more influenced by air pollution than by forest renewal works but the water outflowing from forested experimental basins was and is the best one for drinking fast at all time.

Conclusions

Long-term measurements in small north-Moravian forested watersheds show that the forests protect this region very well. The forests exist as a biosystem which is able to dampen limitelly external impulses. We have to take appropriate measures of the forest management methods to help protecting of all lives and property of citizens. The flooding has to be reduced because of deleterious influences on mankind. That is why only forest management techniques with favourable impacts on the ecology have to be used. Predatory forest management with excessive harvesting works is not advantageous. The forests protect this area well but naturally limited and they cannot prevent from unpredictable and dangerous flooding. The torrent control there is very important and effective all the time.

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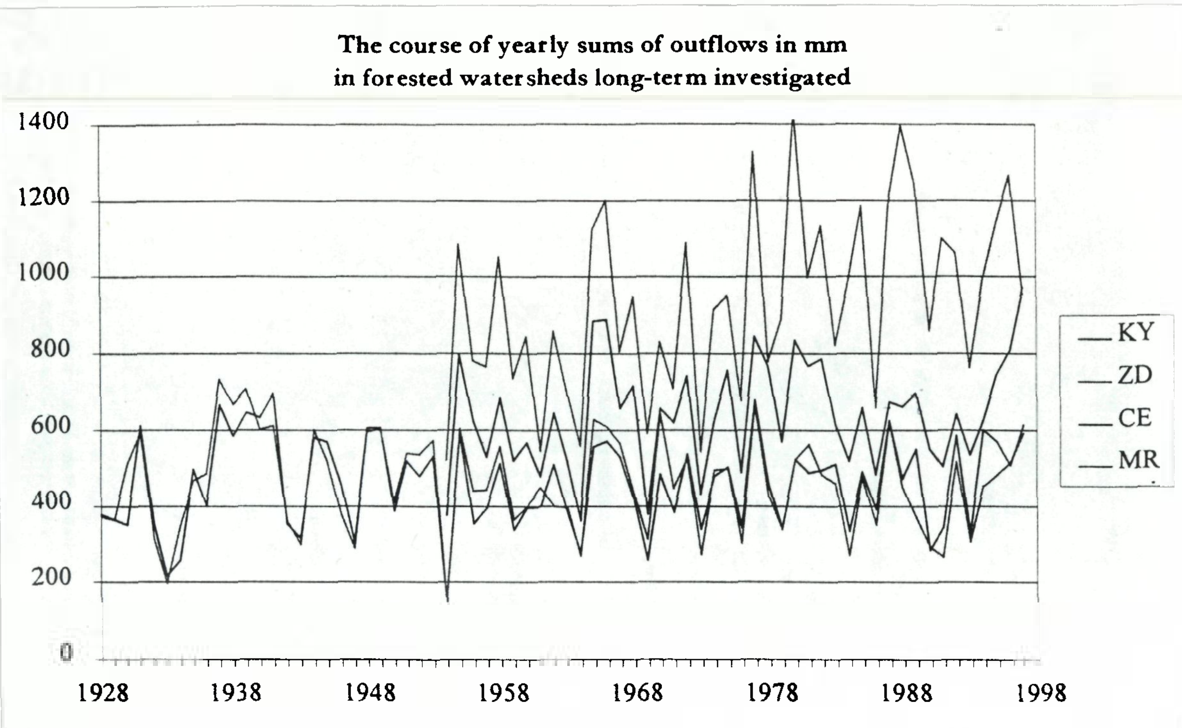
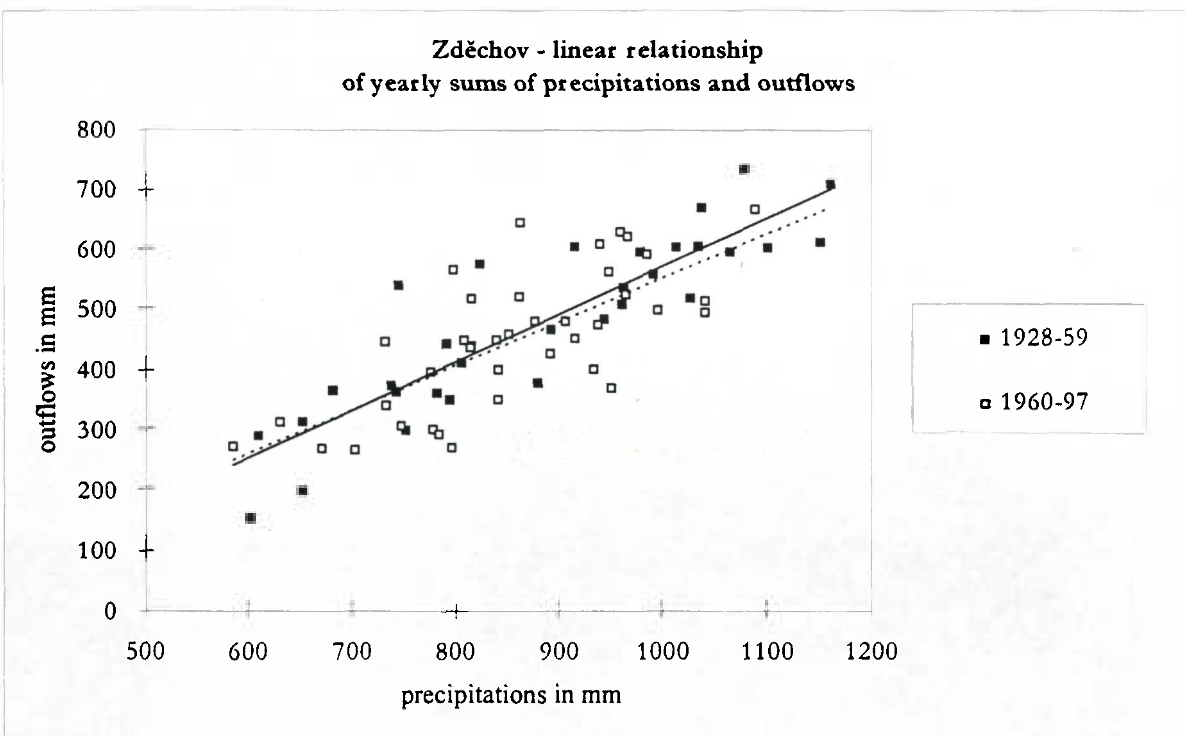
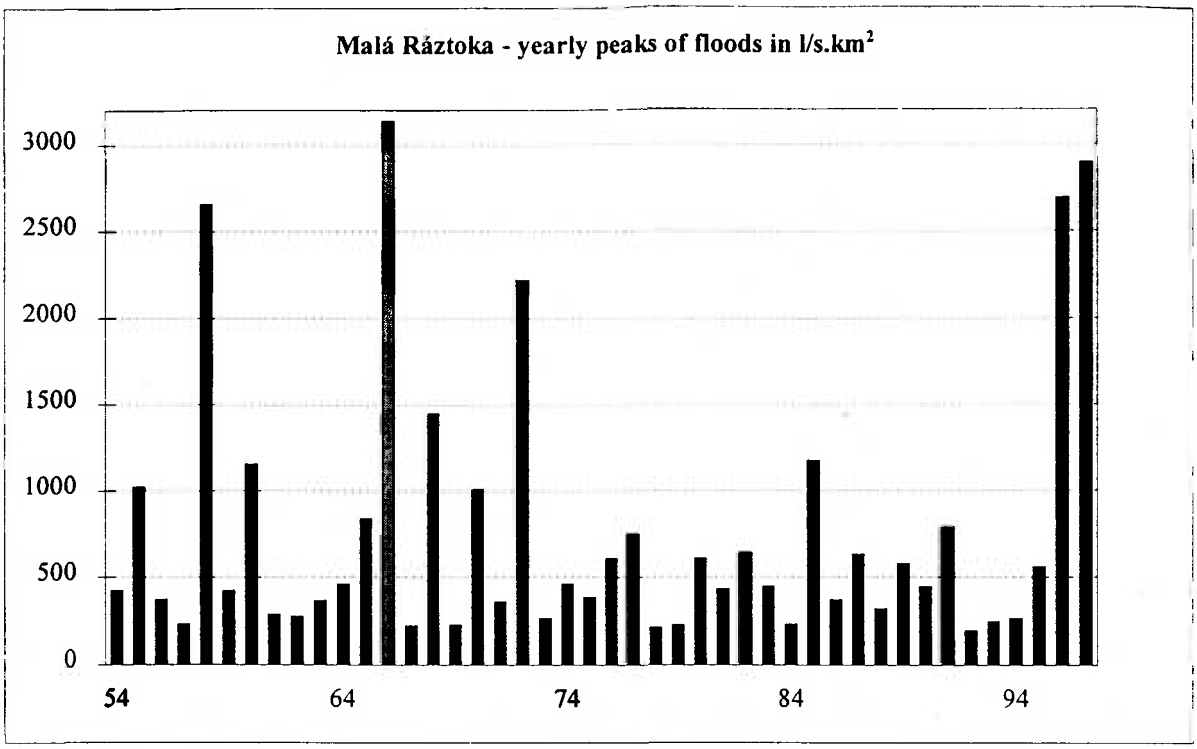
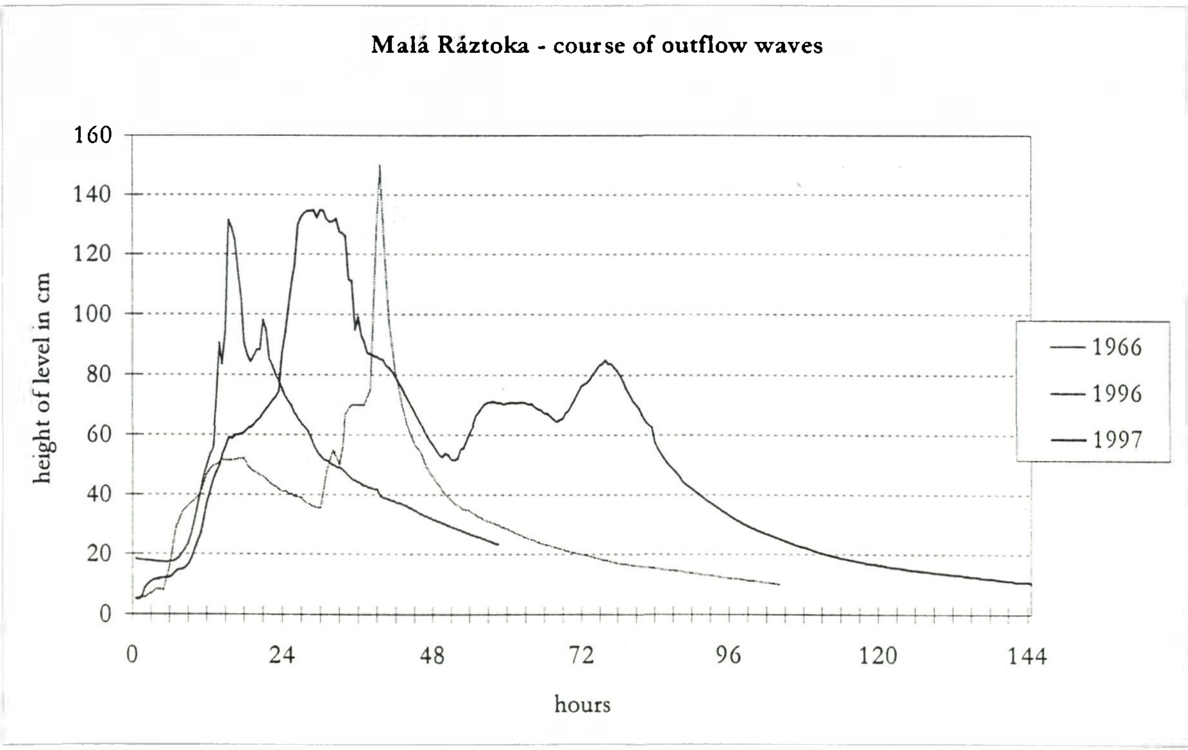

The course of yearly sums of outflows in mm
in forested watersheds long-term investigated
1400
1200
1000
800
600
400
200
0
1928
1938
1948
1958
1968
1978
1988
1998
KY
ZD
CE
MR


Zděchov - linear relationship
of yearly sums of precipitations and outflows
outflows in mm
800
700
600
500
400
300
200
100
0
500
600
700
800
900
1000
1100
1200
precipitations in mm
1928-59
1960-97


Malá Ráztoka - yearly peaks of floods in l/s.km²
3000
2500
2000
1500
1000
500
0
54
64
74
84
94


Malá Ráztoka - course of outflow waves
160
140
120
100
80
60
40
20
0
height of level in cm
0
24
48
72
96
120
144
hours
1966
1996
1997

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Research on the environmental impact of gabion and reno mattresses structures

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A double twist wire mesh gabion structure is considered a “living structures” where filtration siltation and consequent growth of natural vegetation create the conditions for an effective river bank rehabilitation.

The growth of natural vegetation on a gabion structure is well documented by a long list of photographic comparisons and technical literature. Recently, research has been conducted to analyze several rivers’ reaches protected by gabion/mattress structures from a global environmental approach, and to compare them to unaltered reaches of the same rivers .

This analysis has been carried out in Europe on 7 different sites where gabions and mattresses have been installed over the last 10-40 years.

A multidisciplinary team investigated the selected sites for one year.

Hydrologic and hydraulic analyses, geotechnical classifications of the sites, analysis of the local vegetation, investigation of the biological situation and analyses of the micromammals living on the selected sites were carried out.

These investigation proved that gabions and Reno ® mattresses enhance the growth of indigenous plant life, showing the product’s potential ability to help the natural recovery of destroyed or partially damaged biocoenosis.

In spite of evidence of these structure’s “natural greening” ability largely collected at every site, a new designing process for natural re-greening is now spreading out.

It consists of using both gabions and Reno ® mattresses along with “living materials” by applying environmental engineering techniques.

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Groundwater quality in Austria. A unique groundwater monitoring system

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Background

Groundwater is one of the most important drinking water resources in Europe as well as in other parts of the world. The existing European regulations set high priorities to protection of the ground water for drinking water supply (EEC). In Austria more than 99% of drinking water is taken from groundwater. About 50% of this comes from carbonate and crystalline rocks (karst and fractured aquifers) of differing ages the most important of which are located in more remote Alpine areas where tourism is significant. Due to their particular structure karst aquifers are more vulnerable to pollution than groundwater in porous aquifers. The remaining 50% is abstracted from quaternary and tertiary sediments (porous media). These sedimentary basins are densely populated areas where the land use is generally agricultural and industrial. The complexity of the properties and the dynamics of the various aquifers in Austria means that conditions vary markedly over small areas. This means that it is essential to run a dense monitoring network in order to ensure that pollution problems are detected early so that appropriate prevention measures can be taken.

The Austrian water quality monitoring system (AWQMS)

New legislation and administrative procedures forming the basis for the AWQMS for ground water and surface waters were adopted in 1990 with the primary goals being to achieve a representative knowledge of the overall ground water quality in order to establish background impacts, trends and the compliance with legislation (Ordinance on Water Quality Monitoring ("Wassergüte-Erhebungsverordnung")). Both federal and regional authorities as well as many private laboratories are involved in implementing the monitoring system itself. This is shown in Fig. 1.

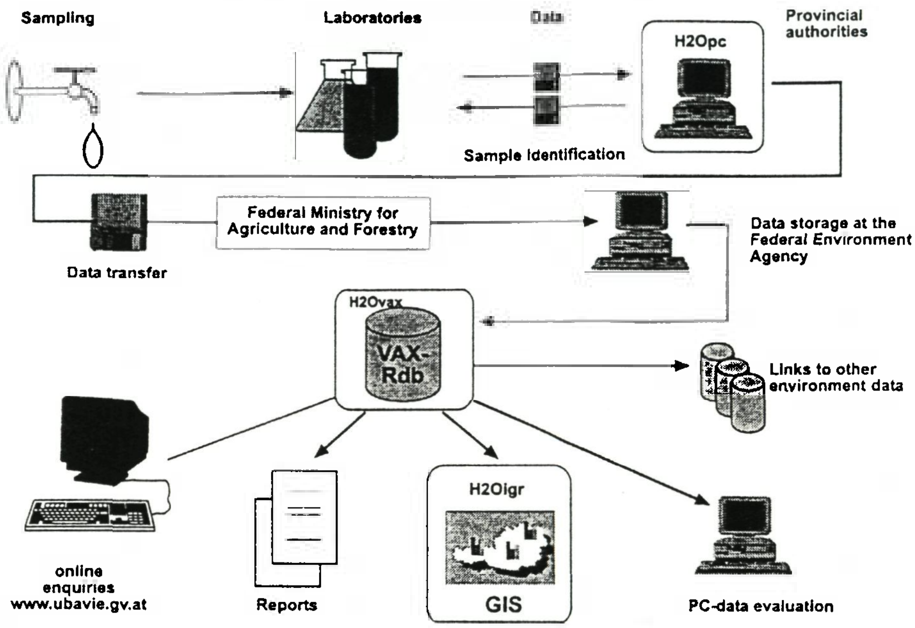

Fig1 The collection and dissemination of water quality information in Austria

The network for monitoring water quality consists of about 2000 sampling sites selected by experts on the basis of hydrological, geological and geochemical knowledge (Fig. 2). 1782 of the monitoring points are situated in the 150 porous groundwater bodies of large basins and glacial overdeepened alpine valleys. In these regions a sampling density of about 10-15 km^2 per sampling site is attained. A combination of specific monitoring points, domestic wells, industrial abstraction points and water supply boreholes are used as sampling sites in order to obtain a more or less regular pattern of monitoring sites. The remaining 237 monitoring points are situated in the Alpine karstic and fractured rocks with a density of between 160-360 km^2 per sampling site.
Since 1991 all wells and springs have, for the most part, been sampled four times a year with between 50 and 100 physical and chemical parameters being analysed for each sample. The analysis of the samples is conducted by private laboratories with special attention being paid to standardisation and analytical quality assurance.
The laboratories are selected through competitive call for tenders with inspections of the laboratories being conducted before the awarding of a contract as well as regularly thereafter by an independent central laboratory. The total annual costs for sampling and analytical work are about 2.9 Mio ECU. Easy access to the data for every parameter and sampling site can be had through the inter-net (**http://www.ubavie.gv.at**) and biennial expert reports (WWK/UBA 1993, 1995, 1997).

GROUNDWATER IN POROUS MEDIA

The quality of groundwater in porous media is threatened by both diffuse and point sources of pollution. The most significant pollutants in Austria are nitrate and pesticides but chlorinated hydrocarbons are also important. Whereas nitrate and pesticides are mainly from diffuse, agricultural sources, chlorinated hydrocarbons are from point sources such as industries and contaminated sites. The most significant results of the groundwater quality monitoring programme and assessment for these substances are given below.
The Ordinance on Groundwater Limit Values (Federal Legal Gazette No 502/91 and 213/97) establishes threshold values for groundwaters. These are set in line with the precautionary principle and, as a general rule are less than or at most equal to drinking water supply standards. If these threshold values are exceeded over a period of 2 years or more at least 25% of sampling sites within a groundwater body remediation measures have to be introduced by the regional authority.

Tab. 1: Nitrate in Austrian groundwaters in porous media (period 1991 to 1995)

Classes \ Provinces		*Ktn*	*NÖ*	*OÖ*	*Sbg*	*Stmk*		*Vbg*	*W*	*A*
% < 10 mg/l	*34.2*	*39.8*	*26.8*	*22.6*	*65.5*	*30.6*	*64.9*	*83.9*	*13.9*	*36.4*
% >10 – 30 mg/l	*20.9*	*37.9*	*31.8*	*39.0*	*26.7*	*31.5*	*34.4*	*15.9*	*18.2*	*31.6*
% >30 – 45 mg/l	*9.4*	*11.4*	*14.1*	*23.5*	*6.6*	*15.1*	*0.6*	*0.1*	*12.0*	*12.8*
% >45 – 50 mg/l	*2.9*	*2.0*	*3.7*	*4.9*	*0.7*	*4.8*	*0.1*	*0.0*	*3.8*	*3.2*
% > 50 mg/l	*32.5*	*8.9*	*23.6*	*10.1*	*0.5*	*18.0*	*0.0*	*0.1*	*52.2*	*16.0*
Total No of analyses	*1402*	*2123*	*4034*	*2774*	*832*	*3052*	*1489*	*768*	*577*	*17051*

Bgld: Burgenland; Ktn: Carinthia (Kärnten); NÖ: Lower Austria (Niederösterreich); OÖ: Upper Austria (Oberösterreich); Sbg: Salzburg; Stmk: Styria (Steiermark); T: Tirol; Vbg: Vorarlberg; W: Vienna; A: Groundwater in porous media in Austria.

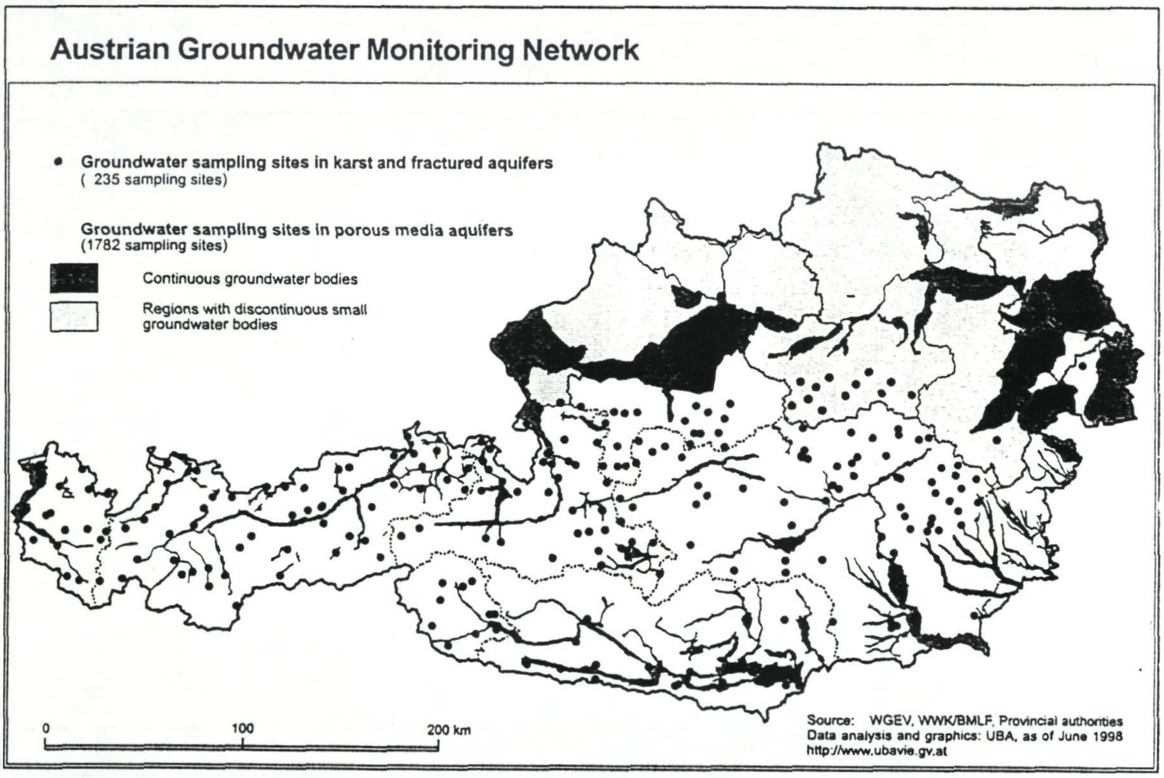

Fig. 2: Groundwater monitoring in Austria (1998). Porous aquifers and spring sampling sites.

Nitrate

Results for nitrate in groundwater are given in Tab. 1 for each of the nine Austrian provinces as well as for Austria as a whole. Detailed analyses of time series from 1992 to 1995 showed that, taking Austria as a whole, there has been no significant change in concentrations during this period (details in BRANDSTETTER & SCHWAIGER, 1997; PHILIPPITSCH; 1997).

Atrazine

Although the use of Atrazine in Austria was banned in 1995, of the 47 pesticides for which samples were regularly analysed it main decomposition product desethylatrazine remain the most frequently present (GRATH et al. 1997), with the concentration exceeding in many cases the level of 0,1 µg/l set as a threshold value in the Ordinance on Groundwater (see above) and drinking water standards. However, new evaluations show a clear falling trend (annual report 1997).

The percentage of groundwater samples with concentrations of atrazine and desethylatrazine above 0.1 µg/l is given in Table 2 for each of the nine Austrian provinces as well as for Austria as a whole (1.1.1992 – 30.6.1995).

Volatile chlorinated hydrocarbons in porous groundwater

The occurrence and frequency of chlorinated hydrocarbons in groundwater in porous media can be found in GRATH and BONANI (1997). The specific characteristics of the transport of various chlorinated hydrocarbons and the possibilities of detection of these substances in this monitoring network are discussed in WWK/UBA (1993).

In the following table the four most frequently found hydrocarbons are presented. Tetrachlorethene (called Perchlorethylene or "Per") is the most frequent substance reported in

Tab. 2: The presence of atrazine and desethylatrazine in Austrian groundwaters in porous media (1.1.1992 – 30.6.1995)

		Ktn	*NÖ*	*OÖ*	*Sbg*	*Stmk*		*Vbg*	*W*	
Total N^O of samples	*1351*	*2116*	*3941*	*2774*	*832*	*3033*	*1486*	*767*	*480*	*16780*
% Atrazine > 0.1 µg/l	*27*	*11*	*22*	*39*	*6*	*35*	*5*	*3*	*32*	*23*
% Desethylatrazine > 0.1 µg/l	*28*	*26*	*27*	*52*	*11*	*46*	*11*	*5*	*45*	*32*

Bgld: Burgenland; Ktn: Carinthia (Kärnten); NÖ: Lower Austria (Niederösterreich); OÖ: Upper Austria (Oberösterreich); Sbg: Salzburg; Stmk: Styria (Steiermark); T: Tirol; Vbg: Vorarlberg; W: Vienna; A: Groundwater in porous media in Austria.

Groundwater, followed by Trichlorethene, 1,1,1-Trichlorethane and Chloroform. Other substances such as Tribrommethane, Bromdichlormethane, Dibromchlormethane, Dichlormethane, 1,2-Dichlorethane, Tetrachlormethane and 1,1-Dichlorethene) are detected at few monitoring sites only.

Table 3: Selected chlorinated hydrocarbons in groundwaters in porous media (7/93- 6/95)

Substances	*< MDL*		*≥MDL ≤6 µg/l*		*>6 ≤10 µg/l*		*>10 µg/l*		*Total No. of monit. Sites*		*Maximum µg/l.*
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	
Trichlorethene	*1508*	*91.4*	*134*	*8.12*	*4*	*0.24*	*4*	*0.24*	*1650*	*100*	*16.21*
Tetrachlorethene	*1334*	*80.9*	*289*	*17.5*	*8*	*0.5*	*19*	*1.1*	*1650*	*100*	*351.6*
1,1,1-Trichlorethane	*1533*	*92.5*	*117*	*7.1*	*1*	*0.1*	*5*	*0.3*	*1657*	*100*	*19.30*
Chloroform	*1539*	*92.9*	*118*	*7.1*	*0*	*0*	*0*	*0*	*1657*	*100*	*3 16*

MDL: Minimum detection limit

GROUNDWATER IN KARST AND FRACTURED AQUIFERS

The water quality in more than 90% of the samples from karst and fractured crystalline rock aquifers is excellent. Where "elevated concentrations" are found, they are in reality only slightly above natural median concentrations. The situation is quite different from groundwaters in porous media, where the concentrations of contaminants are usually much higher. It is also important to note, that that the concentrations in karst spring waters should not be summarised as mean values because the degree of dilution varies greatly depending on precipitation, snow melt etc.

Pollution sources of spring waters

Temporary microbiological contaminations of karst water is considered to be a problem for drinking water supply (KRALIK 1999). These are caused by intensive tourism, cattle or game and occur in spring waters mainly after heavy rainfalls. In many cases this potential for contaminations necessitates specific treatment of karst water for drinking water supply.

Ninety percent of the waters sampled showed a natural composition far below any limit values. During the investigation period maximum admissible drinking water values were exceeded in just 9% of the samples. However, 24% of the 237 sampled springs exceeded the limit values temporarily. These concentrations are caused by the natural leaching of sulphate and chlorides of gypsum, salt formations. Human contamination e.g. phosphate and pesticides (atrazine) is also likely to play a role. Many of the other analysed contaminants exceed the detection limit (>MDL;Tables 4 and 5) in just few percent of the analysed samples. The maximum admissible drinking water concentration for nitrate is exceeded in one sampling point. Admissible concentration levels of atra-

Tab. 4: Mean and other statistical data of selected groundwater contaminants in karst and fractured crystalline aquifers. (1995-1997)

Parameter	*Mean*	*Median*	*Min**	*Max*	*10%*	*25%*	*75%*	*90%*	*n*	*>MDL*
										(%)
NO_3-Karst (mg/l)	*3.8*	*2.7*	*<1.0*	*40.7*	*1.18*	*1.7*	*4.5*	*7.1*	*1919*	*95.0*
NO_3-Fract. (mg/l)	*4.8*	*1.68*	*<1.0*	*127*	*<1.0*	*1.2*	*3.5*	*10.5*	*594*	*87.5*
As-Karst (mg/l)	*0.0004*	*<0.001*	*<0.001*	*0.049*	*<.001*	*<.001*	*<.001*	*<.001*	*1253*	*9.8*
As-Fract. (mg/l)	*0.0009*	*<0.001*	*<0.001*	*0.022*	*<.001*	*<.001*	*<.001*	*<.001*	*396*	*31.8*
Pb-Karst (mg/l)	*0.0004*	*<0.001*	*<0.001*	*0.020*	*<.001*	*<0.001*	*<.001*	*0.001*	*1220*	*15.2*
Pb-Fract. (mg/l)	*0.0011*	*<0.001*	*<0.001*	*0.225*	*<.001*	*<0.001*	*<.001*	*0.001*	*384*	*13.8*

*>MDL: Percentage of measured samples is above the given "Minimum Detection Limit" (Federal Legal Gazette: BGBL1991a); * Min: Minimum (the official MDL are given here, although some laboratories have even lower detection limits); 10%: 10% percentile e.g. 10% of the measured values are below the 10 Percentile, , 90% above etc; Fract.: fractured crystalline rock aquifers*

zine and desethylatrazine were exceeded on 7 occasions in the hills and basin of SE Styria

Tab. 5: Mean and other statistical data of AOX and selected chlorinated hydrocarbons and in karst and fractured crystalline aquifers. (1995-1997)

Parameter		*Median*	*Min**	*Max*	*10%*	*25%*	*75%*	*90%*	*n*	*>MDL (%)*
AOX-Karst (µg/l)	*1.42*	*<1.5*	*<2*	*77.6*	*<1.5*	*<1.5*	*2.5*	*4.1*	*819*	*35.7*
AOX-Fract. (µg/l)	*0.67*	*<1.5*	*<2*	*8.1*	*<1.5*	*<1.5*	*<1.5*	*2.9*	*280*	*20.4*
111-Trichlorethane	*<0.1*	*<0.1*	*<0.1*	*0.29*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1098*	*0.3*
111-Trichlorethane	*<0.1*	*<0.1*	*<0.1*	*0.6*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*323*	*0.9*
Tetrachloreth.(Per)	*<0.1*	*<0.1*	*<0.1*	*0.8*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1098*	*1.2*
Tetrachloreth.(Per)	*<0.1*	*<0.1*	*<0.1*	*0.2*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*323*	*0.3*
Tetrachlormethan	*<0.1*	*<0.1*	*<0.1*	*1.4*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1098*	*0.1*
Tetrachlormethan	*<0.1*	*<0.1*	*<0.1*	*0.3*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*323*	*0.3*
Trichlorethen (Tri)	*<0.1*	*<0.1*	*<0.1*	*0.6*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1098*	*0.8*
Trichlorethen (Tri)	*<0.1*	*<0.1*	*<0.1*	*0.3*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*323*	*0.6*
Trichlorm.(Chlorof.)	*<0.1*	*<0.1*	*<0.1*	*7.1*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1098*	*2.9*

Trichlorm (Chlorof.)	*<0.1*	*<0.1*	*<0.1*	*1.5*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*323*	*3.7*
Atrazine Karst(µg/l)	*<0.1*	*<0.1*	*<0.1*	*0.31*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1297*	*1.6*
Atrazine Fr. (µg/l)	*<0.1*	*<0.1*	*<0.1*	*0.83*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*468*	*3.4*
Desethylatrazine K.	*<0.1*	*<0.1*	*<0.1*	*0.61*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1297*	*2.7*
Desethylatrazine F.	*<0.1*	*<0.1*	*<0.1*	*0.88*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*468*	*8.8*
Desisopropylatrazine Karst and Fract.			*<0.1*	*0.01*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1765*	*0.1*
Metolachloro Karst and Fract. (µg/l)			*<0,1*	*0.01*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1711*	*0.1*
Prometryn Karst and Fract. (µg/l)			*<0,1*	*0.01*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1712*	*0.2*
Propazine Karst and Fract. (µg/l)			*<0,1*	*0.01*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1712*	*0.1*
Simazine Karst and Fract. (µg/l)			*<0,1*	*0.01*	*<0.1*	*<0.1*	*<0.1*	*<0.1*	*1712*	*0.2*

Legend see Table 4

where intensive agriculture is practised. Traces of chlorinated hydrocarbons below limit values. occur in springs which have tourism and small-scale industrial use in their drainage areas (Table 5).
Although the concentration of pollutants in remote alpine areas is low their apportionment is possible through factor analysis. Agricultural sources are characterised by elevated levels of NO_3, atrazine or desethylatrazine. while sewage are indicated by elevated PO_4-B concentrations and atmospheric pollution may be indicated by NH_4-NO_2 concentrations . Elevated PO_4-B concentrations are most frequent around sedimentary basins in Carinthia, Salzburg and Vorarlberg, where traces of chlorinated hydrocarbons occur is some places
Heavy metals concentrations are generally below or just above the minimum detection levels (MDL), but only exceed the limit values in a few springs. They are generally attributed to natural mineralisations in the Fischbacher Alpen (As), the Steirisches Hügelland (Pb, Zn, As, Hg) and the Northern Calcareous Alps (Pb, Zn, Hg). Concentrations just above the minimum detection levels (MDL) of lead in some springs in Vorarlberg have yet to be explained.

Literature

BGBL (Bundesgesetzblatt) (1991a): Verordnung des Bundesministers für Land- und Forstwirtschaft über die Erhebung der Wassergüte in Österreich (WGEV). No.338/1991.

BGBL (Bundesgesetzblatt) (1991b): Verordnung des Bundesministers für Land- und Forstwirtschaft betreffend der Schwellenwerte für Grundwasserinhaltsstoffe (Grundwasserschwellenwertverordnung - GSwV) Nr. 502/1991.

BGBL (Bundesgesetzblatt) (1997): Verordnung des Bundesministers für Land- und Forstwirtschaft mit der die Grundwasserschwellenwertverordnung abgeändert wird. Nr.213/1997.

BRANDSTETTER & SCHWAIGER, K. (1997): Nitrat. In: WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt): Wassergüte in Österreich - Jahresbericht 1996, 90-98. Bundesministerium für Land- und Forstwirtschaft, 231 S., Wien. (http://www.ubavie.gv.at)

GRATH, J. & BONANI, M. (1997): CKW im Grundwasser. In: WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt): Wassergüte in Österreich - Jahresbericht 1996, 114-119. Bundesministerium für Land- und Forstwirtschaft, 231 S., Wien. (http://www.ubavie.gv.at).

GRATH, J., HALBWIRT; H. & BONANI, M. (1997): Atrazin - Desethylatrazin. In: WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt): Wassergüte in Österreich - Jahresbericht 1996, 77-89. Bundesministerium für Land- und Forstwirtschaft, 231 S., Wien. (http://www.ubavie.gv.at).

KRALIK, M (1997): Karst- und Kluftgrundwässer. In: WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt): Wassergüte in Österreich - Jahresbericht 1996, 123-160. Bundesministerium für Land- und Forstwirtschaft, 231 S., Wien. (http://www.ubavie.gv.at)

KRALIK, M (1999): Karst- und Kluftgrundwässer. In: WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt): Wassergüte in Österreich - Jahresbericht 1997, Bundesministerium für Land- und Forstwirtschaft, Wien (In press).

PHILIPPITSCH (1997): Auswertung nach Kriterien der Grundwasserschwellenwertverordnung. In: WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt): Wassergüte in Österreich - Jahresbericht 1996, 99-113. Bundesministerium für Land- und Forstwirtschaft, 231 S., Wien. (http://www.ubavie.gv.at)

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt) (1993): Wassergüte in Österreich - Jahresbericht 1993, Bundesministerium für Land- und Forstwirtschaft, 192 p., Wien

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt) (1995): Wassergüte in Österreich - Jahresbericht 1994, Bundesministerium für Land- und Forstwirtschaft, 392 p., Wien

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt) (1997): Wassergüte in Österreich - Jahresbericht 1996, Bundesministerium für Land- und Forstwirtschaft, 231 p., Wien

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Quality assurance

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Quality control of discharge data

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Abstract
Discharge data is a crucial parameter for most water-related studies. The discharge is observed at a large number of gauging stations. The operation of these stations is undertaken by regional or national institutions in most countries. Data is stored in national databanks. There are a number of potential sources of errors affecting the measurements as well as the subsequent processing and storage of the data. It is therefore of importance to develop a systematic approach to data quality control, as well as documentation of the data. This was recognised by the Nordic hydrological institutions, which formed a working group studying this problem. The group produced a report, Roald (1977), which describes sources of errors as well as methods of detecting them. The proposed methods have been included in the current system for data quality control, and have later been extended to cope with other types of instruments.
This paper intends to present some aspects of data quality control with examples taken from the current system Hydra II, operated by the Norwegian Water Resources and Energy Directorate (NVE), Taksdal & Beldring (1999). NVE operates most of the national networks and the national hydrological database of Norway. The network comprises currently approx. 740 gauging stations with rating curves and additional water level stations in approx. 650 reservoirs and natural lakes. Hydra II comprises a total of more than 3000 Norwegian gauging stations of which a substantial part has been closed down.
Data quality control should be integrated into every step of the data collection and subsequent processing. It is necessary to define and follow well-defined rules and standards of the fieldwork as well as of the subsequent work in the office afterwards. Each station and data series should be well documented. Hydra II requires that co-ordinates, and some other mandatory information are given before any data can be stored on the database. Most gauging stations have been situated at natural profiles in Norway. It is therefore of crucial importance to obtain good rating curves, and to detect when a natural profile has changed.
Water levels have traditionally been observed on fixed staff gauges where the observer read the level once a day. The staff gauges were gradually supplemented with chart recorders, mostly of the OTT-type. These instruments were based on a float in a stilling well as sensor. The charts were collected from once a week to once each half-year, depending on the accessibility of the station. The recordings were traced on a digitising table, producing data of higher time resolution. Now data-loggers have replaced most of the chart recorders, using a pressure sensor instead of a float. Changes in instrumentation may lead to systematic changes in the observed data. It is therefor necessary to keep a record of changes in the instrumentation in order to interpret the data correctly. A host of different equipment within the same network tends also to create problems. It is therefore advisable if costly to standardise the instrumentation as much as possible.
Data is received as books or data sheets, charts, data-logger memories or directly transmitted from stations linked to the telephone network, by cellular telephones or utilising radio transmission by satellites. The arrival of data should be logged in an administrative sub-system as soon as data is

received at the office. A recurring error in large databases (also in the FRIEND database) is mistakes in the identity of a data series. The identity of a data series should be verified and linked to the correct station at the arrival of the data at the gauging authority. Data from sheets, books and charts are digitised. The digitised data should be corrected for minor errors in time or levels compared to observers notes. The format of the logger memory should be checked prior to loading the data to the database. NVE utilises PC-based software for this. The operation of the directly transmitting stations should be supervised continuously and actions should be taken if data is not received.

The data should be controlled after loading to the data to the database. The primary control may include tests on jumps between the end of the previous record and the start of the current, which may indicate a possible mistake in the identity of the series. Spurious peaks and troughs should be examined and removed. The data should be compared to predefined test limits of allowable range and day to day change. These test limits may vary with the

annual cycle. Obvious errors may be corrected manually, but it is preferable to mark such data as suspicious, and to perform a manual correction. All data should be displayed and inspected manually before it is stored permanently. Whenever a data is changed, a flag is attached to the data telling by which method the correction has been made. Hydra II does not store derived discharges, but the water level and the rating curve. Whenever a discharge is extracted from the database, it is calculated from the water level using the current rating curve. Although data is observed with a higher time resolution than daily values, daily values are still calculated since this forms the bulk of the archive, and is used for most practical purposes. The water level stored on a daily basis is the levels corresponding to the mean daily discharge.

The rating curve is established by simultaneous measurements of the water levels and the discharge. The discharge is established by use of current meters, dilution methods, and more recently by use of Doppler methods (ADCP). The station network in Norway is quite widespread, with many stations at remote locations. It is therefore a general problem to obtain discharge measurements at high floods. Many rating curves have been established based on heavy extrapolation of the rating curve. Markhus & Bogetveit (1999) are discussing this problem, and describe how the rating curves can be verified.

Backwater effects may affect the relationship between water level and the discharge. A frequent cause is ice or vegetation in the river channel, tidal effects from the sea or backwater from downstream tributaries. Most gauging stations are situated upstream hydraulic jumps in Norwegian rivers. There is however a considerable problem with ice in the winter at many river stations. It is possible to measure the discharge through the ice, but the uncertainty of such measurements is considerable. Winter data should be corrected for backwater due to ice. Some experiments have been made in Finland, using a procedure based on neural networks, and rainfall/runoff models have also been used to estimate the winter runoff in Sweden. In a winter regime with occasional ice and long ice-free spells will these methods probably be less useful than in regimes with a stable ice-cover throughout the winter. Backwater because of vegetation growth is not a severe problem in Norway, but other countries, such as Denmark has to include a systematic way of handling their data in order to cope with this problem.

Gaps in the data can also be a problem. Short gaps, when there are no indications of a flood event, may be filled in by linear interpolation based on the series itself. Longer gaps should be filled in by use of data from comparison stations, or data simulated by a rainfall-runoff model. In Norway gaps are filled in for daily data, but not for data with high time resolution, as the necessary comparison data is usually not available.

Many large river systems comprise a large number of lakes, reservoirs, and river sections with several gauging stations. The water level is usually monitored in the reservoirs and larger lakes. If the relationship between the water level and the volumes is known for these reservoirs and lakes, and the diverted discharge is known between the intake and the outlet point, it is possible to correct for regulations and to check the water balance for sub-catchments between the nested stations. This type of calculation is performed on a routine basis in Norway for the larger river basins. A check based on the water balance within such basin is a powerful tool for detecting errors, see also Stanescu (1999). The control may also utilise meteorological data, possibly in combination with a rainfall-runoff model to verify the observations. This requires however fast access to representative meteorological data, which is a problem in Norway partly because of the topography.

Changes in the controlling profile can be detected, utilising homogeneity tests. The most common tool is double- mass analysis, combined with a test of the significance, Alexandersson (1986). It is also possible to apply various techniques for time series analysis such as trend- and jump tests. Schumann (1994). It is however necessary to evaluate whether changes has occurred because of human activities within the basin or river channel as well as changes induced by climate variability.

How to improve the quality assurance

A good quality assurance system requires that all aspects of the data production is well documented. Rystam (1996) has mapped the data production lines of NVE, co-operating with the staff operating the various sub-networks. The documentation describing the various production lines were catalogued and stored on a database. This work resulted in pinpointing some crucial weaknesses in the current data processing. It was proposed to write a number of handbooks for the field engineers and for certain critical aspects of the subsequent office work, in particular ice correction. A good quality assurance system requires that the staff is aware of the importance of following the predefined standard and routines. This requires both motivation and education of the staff. A lot can also be achieved by introducing checks and restrictions in the software, preventing some common errors.

The establishment of an efficient quality assurance may affect the entire organisation of the gauging authority. Mosley and McKerchar (1989) describes the system which has been implemented in New Zealand, which has come far in establishing a sound way of handling the data quality aspect.

A word of warning

Large international databases comprise data, which has been transferred at one time from a primary data source. Data quality control is however a continuous process, and old data will be corrected when errors are detected. This is often the case after some time, because changes in the homogeneity first can be detected after some time after the shift. Some errors are first realised when data are analysed in depth. It is therefore recommended to inquire with the data-providing organisation if changes have taken place, and to obtain a more recent data-set if the data has been provided a long time ago.

References

Alexandersson, H. 1986: A homogeneity test applied to precipitation data. *Journal of climatology*, 6, 661-675.

Markhus, E. & Bogetveit, L.J. 1999: Extrapolation of rating curves by using the water surface calculation software HEC-RAS. International Conference Quality Management and Availability of Data for Hydrology and Water Resources Management. Koblenz 22-26 March 1999.

Mosley, M.P & McKerchar, A.I. 1989: Quality assurance programme for hydrometric data in New Zealand. Hydrological Sciences Journal, 34,2,4,1989, 185-202.

Roald, L.A. (ed) 1977: Kvalitetskontroll av hydrometriske data (Quality control of hydrometric data). *Nordic IHP Report* No 4.

Rystam, P. 1996: Kvalitetsäkring av hydrologiske data (Quality assurance of hydrological data). *NVE Publikasjon* Nr 07 1996.

Schumann, A. 1994: Description of the Jump3 program. Internal paper, Ruhr- Universität, Bochum.

Stanescu, V.A. 1999: Methods of correction of data and quality control procedures used in Romania. International Conference Quality Management and Availability of Data for Hydrology and Water Resources Management. Koblenz 22-26 March 1999.

Taksdal, S. Beldring, S. 1999: Hydra II – a comprehensive hydrological database system . International Conference Quality Management and Availability of Data for Hydrology and Water Resources Management. Koblenz 22-26 March 1999.

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Quality Assurance in the Meteorological Subprogram within the framework of the German Network on intensive monitoring of forest ecosystems (European Level II - Program)

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1. Introduction to the Pan-European network on intensive monitoring of forest ecosystems (Level II)

In order to gain a better understanding of the effects of air pollution and other stress factors on forests, a Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems (Level II) has been implemented. In this context 863 permanent observation plots for intensive monitoring of forest ecosystems have now been selected (512 in the European Union and 351 in several non-EU countries) (EC&UN/ECE 1998).

The Intensive Monitoring Programme aims at the assessment of crown condition, increment, the chemical composition of foliage and soil on all plots over a period of at least 15 to 20 years. Additional measurements are carried out on a limited number of plots including atmospheric deposition, soil solution chemistry and meteorological parameters. Within each of these sub-programmes, a number of mandatory and optional parameters have been defined (PCC & UN/ECE 1998).

In order to set up procedures for the validation, storage, distribution and evaluation of the data at European level , a Forest Intensive Monitoring Co-ordinating Institute (FIMCI) has been set up being a contractor of the European Commission (EC). By the end of 1997, the National Focal Centres submitted data and the data accompanying reports (DAR) for the second time, including first informations on soil solution chemistry and meteorological measurements (EC 1998). The DAR questionnaires supply methodological metadata on key issues such as sampling layout and equipment, quality control and data processing. They should be updated whenever methodological changes occur.

The main objective of meteorological monitoring within the scope of level II monitoring is to contribute to the explanation of actual forest condition and its change over time, and notably to:

- describe the climatological characteristics of a level II plot
- investigate the meteorological conditions and supply possibilities for the explanations and relationship to the state of health, growth and development of trees on the plots
- identify and investigate stress factors for trees on the plot
- identify driving variables for modelling of ecosystem responses under actual and changing environmental conditions (e.g. water budget, water availability for the stand, growth, nutrient cycling, etc) (PCC & UN/ECE 1998; EC 1998).

The variables to be measured in the programme are given in Table 1. In general the measurements (with the exception of soil temperature, soil moisture and stand precipitation) may be taken either above the canopy of the forest stand at the plot or at an open field station within the forest area in close proximity (in general less than 2 km distance) to the level II plot.

Mandatory	Optional
Precipitation (PR)	UV-b radiation (UR)
Air temperature (AT)	Soil temperature (ST)
Air humidity (RH)	Soil moisture:
Wind speed (WS)	Matric Potential (MP) , Water Content (WC)
Wind direction (WD)	Stand Precipitation (Quantity): Throughfall
Solar radiation (SR)	(TF), Stemflow (SF)

Table 1: Meteorological and hydrological variables to be measured in the Level II – programme (in brackets: variable codes for data reporting)

2. The Quality Assurance Group within the German Level II - Program

In Germany the responsibility on forest matters is with the 'Länder'. Therefore the intensive monitoring program in Germany comprising 89 plots, in reality consists of 15 different regional programmes (Bremen is not participating). The overall co-ordination is ensured by an expert panel of representatives of the German 'Länder' and the Federal Ministry of Food, Agriculture and Forestry (BML 1997 a, b).

In 1997 several working groups have been installed covering different aspects of the forest intensive monitoring activities in Germany. One of these groups, the AK G1 "Quality assurance", has the strong intention to further harmonise and streamline the methods of the Länder in order to promote good monitoring practice (so to speak "GMP") within the field of meteorological, hydrological and flux measurements. In a first step our work focuses on the meteorological measurements and here on the six defined mandatory variables (see table 1). One of the main objectives for the time-being is to carry out a quality evaluation of the state-of-the-art concerning applied instruments, installation characteristics as well as station documentation, maintenance and calibration procedures. This is done by referring to relevant international and federal background documents (WMO 1996, DWD 1998, VDI 1985).

3. Results

Station types

All plots are equipped with automatic recording facilities storing the measured quantities in time resolutions between 5 and 60 minutes. The majority of the plots are dependent on solar electricity and have no possibilities for direct data transfer via modems. On the other hand some are part of regional environmental networks being combined with air quality assessments thus restricting the influence on sensor positioning. On 58 plots all six mandatory variables are obtained in open field situations (figure 1). At four sites only precipitation is recorded in the open field, while at eight plots measurements above the canopy are carried out from towers (3 plots) or other installations.

Sensor positions

As the open field is the standard situation for meteorological measurements in weather service networks, special attention is paid to this type of installation. The check of reported sensor positions vs. given standards reveal some inhomogeneities (fig. 2), the largest being detected for windspeed and wind direction sensors. Besides it becomes obvious that for air temperature and relative humidity a combined sensor is used by all participants. In 5 cases the minimum height of 1 m for precipitation (PR) is not fulfilled, which may cause unreliable data due to insplashing from the ground.

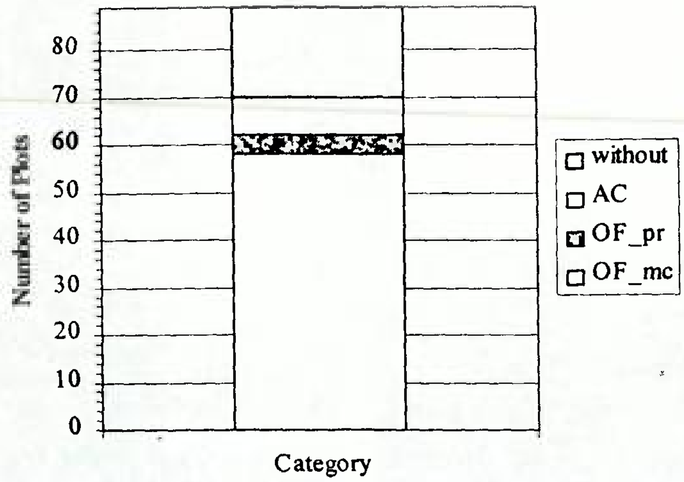

Figure 1: Classification of meteorological (meteo) measurement sites within the German level II program (n_{max} = 89): without = no meteo; AC = above canopy; OF_pr = open field, only precipitation; OF_mc = open field, meteo complete in open field.

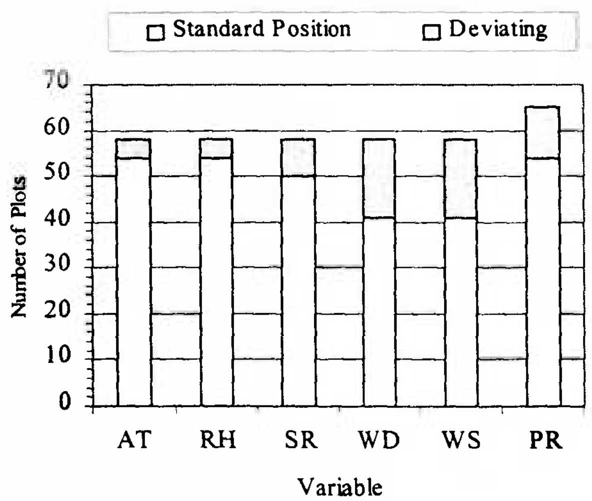

Figure 2: Accordance of present installations with vertical standard position for mandatory variables as adopted in German Level II Manual (BML 1997a)

Calibration activities

In the DAR questionnaires information was asked on what sensors are calibrated and in what time steps. The overall compilation for the German subprogram shows that relative humidity (RH) is said to be calibrated in 12 out of 15 cases being followed by precipitation (PR), global radiation (SR; 9 each) and air temperature (AT; 8). The wind sensor are the least calibrated instruments. The calibration potential between the Länder –(varieties) varies greatly from one sensor (variable) in Saxony and Schleswig-Holstein to all sensors, in e.g. Thuringia, Mecklenburg-Pommerania. Up to now no information is available on practical recursion cycles for calibrations.

4. **Outlook on future work**

Based on the ongoing evaluation a catalogue of feasible quality objectives for forest meteorology shall be developed and put down in an updated manual in. Being aware of the crucial role of quality assurance for correct data interpretation especially in long-term monitoring activities, it is strongly felt that the digital combination of data and metadata in a database is the prerequisite to guarantee cost-effective reliability on a regional as well as national level. Thus the implementation of such quality systems shall be promoted. An example for such an ambitious system is given with the ECO database management system of Lower Saxony (Schulze & Hoppe 1997).

5. References:

BML (Bundesministerium für Ernährung, Landwirtschaft und Forsten) (Ed.), 1997a, Dauerbeobachtungsflächen zur Umweltkontrolle im Wald (Level II) – Methodenleitfaden, 152 pp., Bonn.

BML (Bundesministerium für Ernährung, Landwirtschaft und Forsten) (Ed.), 1997b, Dauerbeobachtungsflächen zur Umweltkontrolle im Wald (Level II- Erste Ergebnisse, 148pp. (English summary), Bonn.

DWD (Deutscher Wetterdienst) (1998): Richtlinie für automatische Klimastationen. Fassung vom Mai 1998; 70 Seiten; DWD Offenbach.

EC (European Commission) (Ed.) (1998): Protection of Forests against atmospheric pollution. European Programme for the Intensive Monitoring of Forest Ecosystems: Basic documents for the implementation of the intensive monitoring programme of forest ecosystems in Europe. 142 pp.; DG VI F.II.2, Rue de la Loi 120, B 1049 Brussels.

EC (European Commission) & UN/ECE (United Nations Economic Commission for Europe) (Eds.) (1998): Intensive Monitoring of Forest Ecosystems in Europe, 1998 Technical Report. prepared by De Vries, W.; Reinds, G.J.; Delstra, H.D.; Klap, J.M.; Vel, E.M ; 104 pp.; Brussels – Geneva.

PCC (Programme Coordination Centre Hamburg) & UN/ECE (United Nations Economic Commission for Europe) (Eds.) (1998): Manual on Methods and Criteria for Harmonized Sampling, Assessment, Monitoring and Analysis of the Effects of Air Pollution on Forests. 4th edition, lose-leaf folder; Hamburg.

Schulze, A.; Hoppe, J. (1997): Qualitätssicherung bei der Bilanzierung von Stoff- und Wasserflüssen in Waldökosystemen durch datenbankgestützte Arbeitsorganisation. in: W. Geiger, Jaeschke, A.; Rentz, O.; Simon, E.; Spengler, Th.; Zilliox, L.; Zundel, T. (Hrsg.): Umweltinformatik '97. 11. Internationales Symposium der Gesellschaft für Informatik (GI), Straßburg 1997;Umwelt-Informatik aktuell, Band 15 (1), 216-224; Marburg, Metropolis Verlag.

VDI (Verband Deutscher Ingenieure) (1985): Meteorologische Messungen für Fragen der Luftreinhaltung. In: VDI/DIN-Handbuch Reinhaltung der Luft 1 B, 3786; Düsseldorf.

WMO (World Meteorological Organization) (1996): Guide to Meteorological Instruments and Methods of Observation. Sixth Edition. WMO - Guidelines 8; Secretariat of WMO, Geneva.

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On quality aspects of raingauge measurements

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Extended abstract

Measurement techniques and treatment of rainfall data have profoundly been modified by the use of rainfall-runoff simulation programs requiring digital rainfall series instead of statistical rainfall data. In the past, the main objective of urban hydrology was simple design of conduits in towns, and thus approximations such as the "design storm" concept proved to be sufficient. Today, the shift of focus towards environmental protection requires detailed simulation of complex systems based on accurate rainfall series with a sufficient temporal and spatial resolution.

Today, rainfall is measured by various institutions. Recorded rainfall series are used by practitioners who analyze and utilize these data and compare them to the quality and usefulness of the data provided by meteorological services. Questions regarding data quality, use of the historical series in raw or modified form, modelling based on the data etc. are of paramount interest to urban hydrologists.

In particular, questions linked to standards and procedures on an international level become more and more important since results of different models need to be compared. If rainfall data of different quality are used, a comparison of model results may turn out to be simply impossible. Therefore, a harmonization of procedures for rainfall data treatment and rainfall data quality assessment is required.

Rainfall measurements and spatial representativity

Point rainfall measurements are of limited validity for an area. The representativity of a point rainfall measurement for a catchment decreases with

- larger catchments,
- rare events,
- shorter event durations.

Most of the currently used urban drainage models can handle rainfall data input from more than one raingauge, i.e. taking into account the spatial distribution of rainfall. Therefore it is important to have information about the spatial distribution either from a raingauge network or from radar measurements. Critical is the use of (old) historical data where measurements by only one raingauge have been made.

Traditionally, the spatial distribution of rainfall has been either neglected or taken into account in a very simplified manner by applying areal reduction factors. This has proved to be sufficient for modelling peak discharges in both urban and rural areas. However, the use of areal reduction factors are questionable in combination with calculation of hydrographs based on historical rain data input.

On one hand it is clear, that the spatial variation of raingauge measurements may be large even over a small area. An investigation in a flat semi-urbanised area (Einfalt et al., 1997) of some 20 km^2 comprising three raingauges with more than 40 years continuous data each has taken place. An analysis of the extreme values for the design significant rainfall duration of three hours was performed. The 20 most significant events were screened for each of the raingauges for overall volume and for common event dates. The areal rainfall volume for an area of 20 km^2 for the most severe events from 43 years presented volumes that were on average 30% lower than the values at each of the raingauge stations. This could indicate a justification of Areal Reduction Factors.

On the other hand the overall volume of the three gauges for the same events differed by less than 2%, indicating that statistically the extreme events did occur at all three places, although not at the same time. Therefore the use of Areal Reduction Factors would lead to maximum values being systematically too small on the upstream catchments if implemented as a factor on the rain intensities. This calls for a closer evaluation and demand engineering choices.

Current applications in urban hydrology (apart from scientific studies) are based primarily on ground level rain gauges. This approach is likely to be changed in the near future. Up to now weather radars have only seldom been used for urban models due to the following reasons:

- A substantial uncertainty in the calculated rain intensityis still observed,
- No time series are available for long-term simulation
- A lack of knowledge on the possibility of using this new tool within the society of urban hydrologists.

Measurement data quality

A quite new topic is the interest in raingauge data quality. Historically not much effort has been put into this question. However, a number of procedures has been developed and applied in routine data screening. The development is due to mainly two reasons. Firstly, for risk evaluation of hydrological applications (from real-time control applications to basin design) it is of paramount interest to identify the reliability of the data. Secondly, many more measurement programs have been started which closely look into measurement data and compare between them.

Data quality control can take place on several levels: from the technical (instrument) level up to the digital data analysis level (Jørgensen et al., 1997). At the Danish Meteorological Institute, most of the procedures for checking data quality are semi-automatic, i.e. a part of the control is automatically performed in order to identify suspicious data by applying rigid plausibility checks. These suspicious data are afterwards manually screened in order to support or to reject the finding of the automatic procedure.

Furthermore, the manual procedure consists of

- comparison with neighbouring daily raingauges,
- control of large differences by use of meteorological weather charts,
- control of the shape of the hyetograph, and
- final marking of each observation hour as being reliable or not.

In Germany, many data still are collected on paper charts which have to be digitized. After digitization, the digital data are screened for outliers, i.e. extreme values will be checked in detail before being accepted (Maul-Kötter and Einfalt, 1997). This control is performed on peak volumes per minute, per 5 minutes, per hour, and per day in a list-driven form. Furthermore, a graphical control compares the present data to the ones of a daily or continuously recording gauge on a graphical basis (see figure 1). Parameters are the maximum daily value per month, the monthly rainfall volume and the yearly rainfall volume.

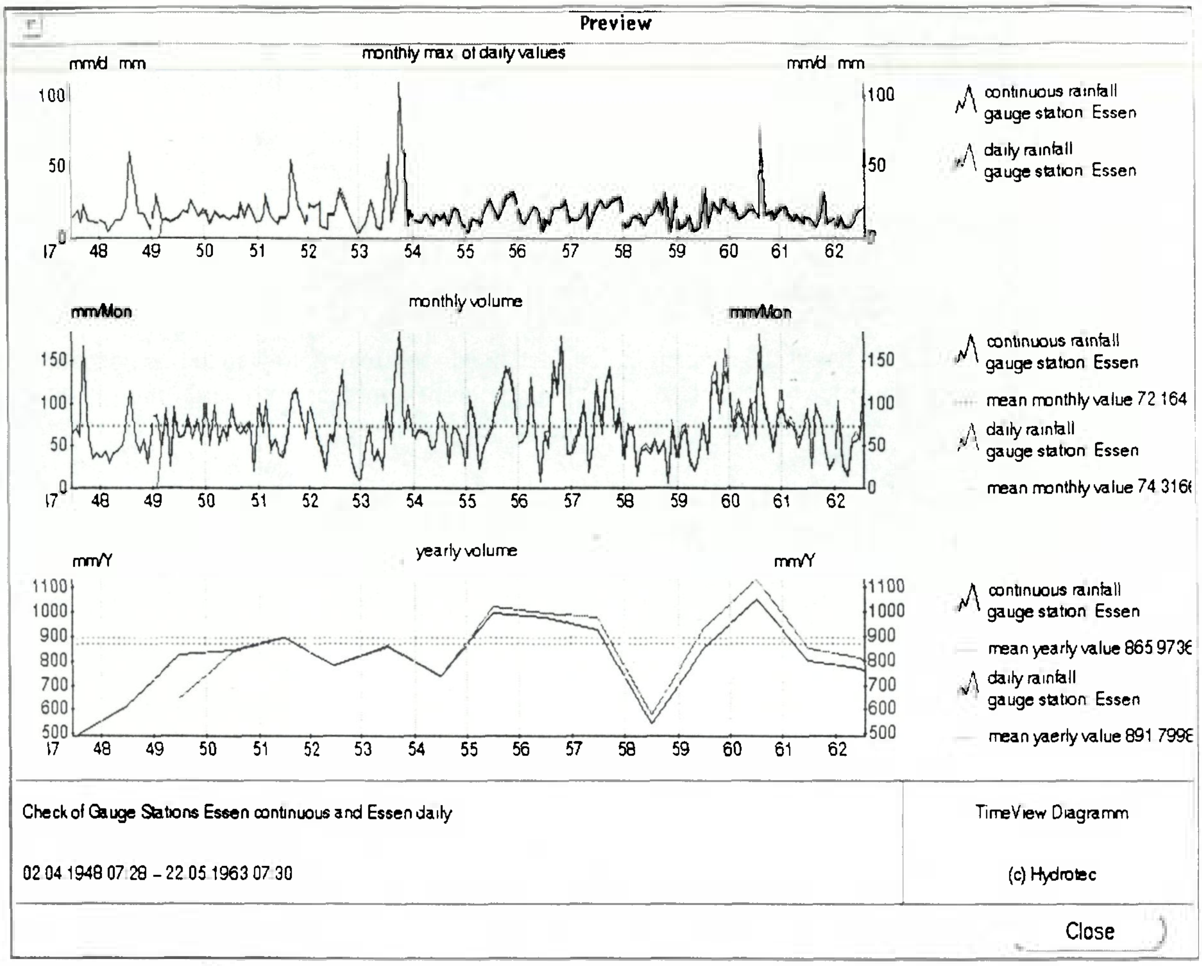

Figure 1: Comparison of extreme values in graphical form

Implausible data are rejected and the corresponding time interval regarded as a missing measurement. All measurement gaps, be it original ones or those created by the data quality screening procedure, are filled by a procedure that has been defined by the state water authority.

The objective of a procedure for filling gaps is not to reconstruct the true event at a rainfall recording station but to create a time series which is plausible according to the rainfall series of neighbouring stations and which would hold in rainfall statistics analyses. The procedure requires daily values of neighbouring raingauges and original data including possible gaps of other continuously recording raingauges in the vicinity. The daily gauge usually is much closer to the raingauge to be corrected because of a higher density of daily gauges as compared to continuous gauges.

The data processing results in a data set without gaps where missing and implausible data have been replaced by plausible ones. The main objective for the data treated in this way is long term simulation for urban or rural catchments.

Available procedures and standards

Since standards and procedures for raindata quality control and data preparation for use in rainfall runoff models are very different and yet the results of the model simulations have to be comparable, a comparative technical and scientific report on the „Current status in rainfall data measurement and processing for model use in urban hydrology“ will be prepared by the Working Group on Urban Rainfall within the Joint IAHR/IAWQ specialist Group on Urban Storm Drainage, supported by IAWQ. This report will give an overview over the current practice and the standards in a range of different countries in the world.

At present, there are countries with written procedures for rainfall data processing, countries with procedures that cover some of the aspects of rainfall data processing, and countries where there is a non-formalised way of treating the collected rainfall data. Therefore, the knowledge from these different sources has to be collected and prepared for comparison and discussion.

The resulting report is targeted towards

- engineers in countries where a system for data preparation is being developed or changed
- practitioners and researchers for whom there is need for knowledge of procedures used in other countries (e.g. universities, companies, state agencies).

A main objective of the report is to collect and disseminate knowledge on procedures used in different countries in order to be able to compare different approaches towards the reliability of rainfall data and to understand different model results based on these raindata.

The work described above will hopefully lead to a broader discussion and exchange of experience between practioners of different countries.

The Working Group on Urban Rainfall within the Joint IAHR/IAWQ specialist Group on Urban Storm Drainage will pursue its activities to collect, structure and disseminate information on rainfall related problems with particular emphasis on the viewpoint of practitioners. Further events (conferences, workshops, etc.) will be organized or co-organized, and the contact with related working groups of other organisations will be initiated or intensified.

References

Einfalt, T., Johann, G., and Pfister, A. (1997). On the spatial validity of heavy point rainfall measurements. *Preprints Third International Workshop on Rainfall in Urban Areas*, 4 – 7 December 1997, Pontresina, Switzerland.

Jørgensen, H.K., Rosenørn, S., Madsen, H., and Mikkelsen, P.S. (1997). Quality control of rain data used for urban runoff systems. *Preprints Third International Workshop on Rainfall in Urban Areas*, 4 – 7 December 1997, Pontresina, Switzerland.

Maul-Kötter, B. and Einfalt, T. (1997). Correction and preparation of continuously measured raingauge data: a standard method in North Rhine-Westphalia. *Preprints Third International Workshop on Rainfall in Urban Areas*, 4 – 7 December 1997, Pontresina, Switzerland.

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Precipitation data quality

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Abstract

As recognized by the United Nations, the main problem of mankind in the 21st century will be associated with water. In general, precipitation is the main source of fresh water renewal on the Earth. National hydrological and meteorological services register precipitation fall on the territories of the appropriate countries regularly. Special measuring equipment is used for precipitation observations which differs in various countries and even differs on the same areas during different periods of the historical time. Thus, the collected precipitation data are heterogeneous not only in the way of getting information but they differ in the characteristics of the initial data quality.

The assessment of the available data quality shows that systematic and random errors in these data are so great that they cannot be used without a special correction to get reliable results when water balance and energy balance computations are made as well as to estimate anthropogenic changes in the global climate and in the forecasts of water resources variations. Therefore, an assessment of errors of the method of precipitation measurements, both up-to-date and previous applied ones, as well as correction of the available data series are extremely important items in numerous international programs for investigation climate changes and for prediction of water resources variations.

Intercomparison of the results of precipitation measurements by standard national methods were made many times by individuals and at national and international levels, under the auspices of the WMO included. Until recently, however, it has been impossible to get a solution suitable for applications. The results obtained were most often of a relative (qualitative) nature, because the characteristics of the references data quality were not estimated objectively, and the method of references measurements was developed for liquid precipitation only.

In 1963 a special experimental plot for precipitation measurements was organized at the State Hydrological Institute; since that time investigations and intercomparison of the results of precipitation measurements by different instruments are made. The Valdai Control System (VCS) is used on this plot as a reference means for precipitation measurements (Golubev & Simonenlo, 1992; Golubev et al., 1995). Long-term investigations show (Golubev et al., 1997) that a systematic error of measurements (ΔP) according to the VCS negligibly small, and the random error (δ) may be described by the following equation:

$$\delta = \pm\, 0.11 \times P^{0.33},$$

where P is measured depth of liquid, solid or mixed precipitation (mm).

The assessment of the measured precipitation quality by different national instruments in different countries (Golubev, 1991; Golubev & Simonenko, 1992; Golubev et al., 1995) show that systematic and random errors differ within wide ranges (Table 1).

A systematic error depends on the precipitation gauge type, on precipitation kind, meteorological

conditions, characteristics of the place where precipitation gauge is installed and on the observation meteorology. This error may be studied and excluded from the results, requires coordinated efforts of hydrometeorologists both in the selection of reference measurements and in the assessment of the corrected data quality.

Table 1. Assessment of quality of precipitation measured by different precipitation gauges if compared with the results by VCS

Type of precipitation	Error of total 12-hour solid precipitation (%)		Error of total monthly precipitation for the cold season (%)		Error of total monthly precipitation for the whole year (%)	
	ΔP	± δ	ΔP	± δ	ΔP	± δ
Tretjakov precipitation gauge surrounded by a double fence (DFIR)	-9	16	-9	10	-7	7
IRPG	-51	48	-44	26	-23	20
Tretjakov precipitation gauge	-43	45	-34	22	-18	15
Precipitation gauge Niffer shield	-58	56	-43	26	-19	19
Hellman precipitation gauge	-67	57	-56	32	-27	24

A random error may be reduced either due to a greater number of simultaneous measurements (more instruments installed at the observation site) or due to a longer period of summing precipitation values. During the last WMO intercomparison of the solid precipitation the reading of the Tretjakov double-fences precipitation gauge were accepted as the intercomparison reference gauge (DFIR). The results of measurements by this gauge contain not so great errors if compared with the other national means of measurements. Systematic and random errors, however, are so close to each other that a deletion of the systematic error should be an obligatory procedure if the results of measurements by that pan are used.

An interim international precipitation gauge (IRPG), previously recommended by the WMO as a reference precipitation gauge, catches much less precipitation than the DFIR.

Hellman precipitation pans are characterized by the lowest data quality among the considered precipitation gauges.

By the present time, method for a correction of the precipitation data have been developed for a great number of the national precipitation gauges. The objective assessments of the corrected data quality are very scarce in scientific publications.

The analysis of the results of the assessments made by the authors shows that the correction usually makes the data quality higher, as it leads to reduced systematic and random errors (Table 2). Not all methodologies are equally effective (Golubev, & Simonenko, 1992), therefore, a careful verification of the corrected data quality is requires for each methodology, whatever reliable methodology it might be from the theoretical viewpoint.

The practical experience on the data correction collected by the authors has led them to a conclusion that the majority of the available methods practiced for data correction do not take into account the error caused by the water condensed on the inner sides of the receiving vessel (Golubev et al., in print). This effect is revealed at the relative air humidity of 90% and higher and it is most evident in case of mixed precipitation fall (Fig.1).

Thus, it is necessary to introduce corrections to the reading of each precipitation gauge at every observation site to get homogeneous series of better quality out of available heterogeneous precipitation series.
The parameters of the correction models may be obtained by calibration, on the basis of the results of reference measurements of the specified quality. The assessment of the corrected

Table 2. Assessment of the quality of the corrected precipitation data if compared with that by the VCS

Type of precipitation gauge	Errors of total 12-hour solid precipitation (%)		Errors of total monthly precipitation for the cold season (%)		Errors of total monthly precipitation for the whole year (%)	
	ΔP	± δ	ΔP	± δ	ΔP	± δ
Tretjakov precipitation gauge surrounded by a double fence (DFIR)	2	18	-1	6	-1	5
IRPG	-	-	1	15	-	-
Tretjakov precipitation gauge	-4	34	0	11		
Precipitation gauge with Niffer shield	-	-	-6	14	-	-
Hellman precipitation gauge	-	-	20	26	-	-

data quality, however, should be an obligatory procedure and the corrected data series should be supplied with a certain information with the notion relative to what reference measurements theses assessments have been obtained, what method has been applied for correction and what is the magnitude of the non-excluded systematic and random errors in theses assessments. Taking these circumstances into account, as well as necessity to study new methods for precipitation measurements, it is reasonable to take appropriate measures to maintain a certain number of national and regional centres of intercomparison of means of precipitation measurements organized under the auspices of the WMO during the last intercomparison period.

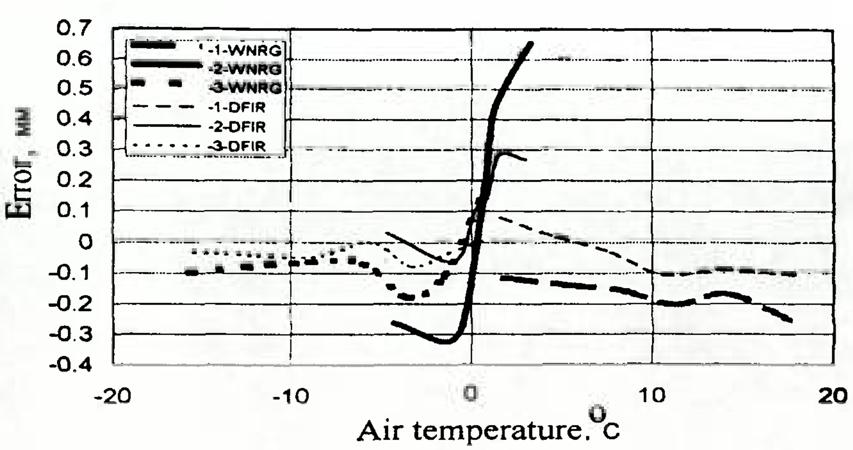

Fig.1 Distribution of not excluded systematic errors of the corrected results of the total 12-hours precipitation, measured by the Tretjakov precipitation gauge (WNRG) and by the intercomparison reference gauge of the WMO (DFIR), depending on the air temperature. 1 - rainfalls; 2 - mixed precipitation; 3 - snowfalls.

References

Golubev V.S. (1991). Preliminary assessments of the accuracy of a precipitation gauge surrounded by a double fence. - Meteorol. and Hydrol., No. 2, p. 116-121 (in Rssian).

Golubev V.S. & Simonenko A.Yu. (1992). Results of the comparison of network methods for precipitation measurements in winter. - Meteorol. and Hydrol., No. 5, p. 100-107 (in Russian).

Golubev V.S. Koknaeva V.V., Simonenko A.Yu. (1995). Results of precipitation measurements by the national standard precipitation gauges of Canada, Russia and USA. - Meteorol. and Hydrol., No. 2, p. 102-110 (in Russian).

Golubev V.S., Konovalov D.A., Simonenko A.Yu., Tomach Yu.V. (1997). Assessment of errors of precipitation measurements by the Valdai Control System. - Meteorol. and Hydrol., No. 7, p. 108-116 (in Russian).

Golubev V.S., Konovalov D.A., Simonenko A.Yu., Tomach Yu.V. (in print). Correction of precipitation measurements and the corrected data quality. - Meteorol. and Hydrol. (in Russian).

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Quality Assurance Program for the Assessment of Water Quality in Austria

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Introduction

An important part of environmental protection in Austria is the quantitative assessment of the quality of groundwater and streams.

The legal framework for water quality control as well as aspects of water management is set by the Act on Hydrography and the Ordinance on Monitoring Water Quality (Federal Legal Gazette No. 338/1991). Since 1991 the Federal Ministry for Agriculture and Forestry (BMLF) together with the Federal Environment Agency (UBA) and the nine Federal States ("Bundesländer") have monitored according to uniformly determined criteria 1800 ground water measuring points (observation: 4 time per year) and approx. 250 running waters measuring points (observation: 12 times per year). The major targets of the water monitoring network are the complete spatial determination and description of the water quality, to detect possible contaminations and to take measures against them promptly.

In this program up to 100 parameters (e.g. inorganic ions, heavy metal ions, chlorinated hydrocarbons and pesticides) are measured.

The overwhelming part of operational activities (sampling and analysing) is put out for an EU-wide call for tender every second year. The tender constitutes a detailed part of stringent provisions to assure quality of sampling process and monitoring results. The level of performance for those applicants is fixed by criteria of the BMLF. Usually the analytical work are executed by private accredited laboratories (EN 45000). The contract is awarded according to price and quality criteria („principle of best cost/benefit offer"). The program is financed to 2/3 by the Federal Republic and to 1/3 by the Federal States. From 1991 to 1998 approx. 320 millions ATS (46 millions DM) were spent on analytical work.

The results of the call for tenders are published regularly by the Ministry of Agriculture and Forestry disclosing prices and further details in order to provide guidance to interested laboratories (Pavlik, 1996).

The data storage and archiving is operated in a central database in the Federal Environment Agency. The analysis and interpretation of the data takes place in co-operation of the Federal Ministry for Agriculture and Forestry and the Federal Environment Agency. The results are made available to the general public via annual reports published by the BMLF (WWK/UBA 1993, 1994, 1996, 1997) and via Internet by the Federal Environment Agency's homepage (http://www.ubavie.gv.at).

This monitoring system for groundwater and running water in Austria has found Europe-wide acceptance and fulfils largely the provisions of the EU-Water Framework Directive. The Austrian model that constitutes a comprehensive and periodically repeated program for initial surveillance, has been copied for both running waters and ground waters into the Water Framework Directive.

In a European-wide context a very good price was obtained due to the basis of public callings for tender and due to the large number of samples thus leading to a high degree of laboratory automation, as well as due to the fierce competition. The total cost for a ground water sample is about ATS 4000.- (approx. DM 570.-) for about 70 analytes including sampling, and about ATS 5000.- (approx. DM 715.-) for a running water sample.

In spite of the good price a very high and constant data quality was guaranteed through special QA provisions.

Basic Provisions and Results

In the following the most important QA provisions are introduced which constitute a constant element of the Austrian water monitoring system.

1. Declaration of analytical figures of merit in the offers:

All offers have to provide the analytical figures of merit and results of basic method validation (e.g. limits of working range, standard deviation, recoveries, blanks, use of control charts, duplicate measurements, frequency of (re-)calibration.) for the respective analyte. If this data is not provided the offer will not be considered further. Applicants have to prove accreditation as well as special courses attended for sampling.

In addition information on personnel, as well as on the technical and economic capacity, results from intercomparison studies and previous customers have to be provided.

2. Assessment of the accredited laboratories before awarding of contracts:

In the course of the last offer-period (1998) one of the authors (W.W.) started as an independent, external and internationally recognised expert in the area of quality assurance - with these initial audits. Primary target in these audits is the full traceability of all QA measures indicated by the laboratories. During this process 4(!) of 12 laboratories, that originally have been chosen on the basis of their offers have withdrawn their offers. A main cause was their lack in technical efficiency.

A negative evaluation has consequences for these accredited laboratories, as the result of the audit is made available to the Austrian or German accreditation boards.

Particularly laboratories from neighbouring countries offering for the first time left the visiting auditors with the impression that the adherence to the performance conditions in a tender from public institutions is not taken seriously enough. This, of course, only reconfirmed the necessity of an initial audit.

3. Inspection of accredited laboratories during the monitoring period:

Several months after the start of a monitoring period a second audit is conducted in the laboratory. Then external experts are testing the audit trail for current results. Problems have to be corrected immediately, the remedial action has to be documented, financial penalties are imposed for a serious breach of the contract. During the period of seven years only two contracts had to be revoked. This is considered to be a very positive result.

4. Test sample system - compulsory participation in current interlaboratory comparisons:

Due to the rather infrequent organisation of national or international interlaboratory comparison studies, the BMLF has decided to initiate a test sample system. Test samples with elevated levels of analytes and a matrix mimicking real samples are constantly introduced into and processed by the water quality monitoring system. This should help to avoid a „special treatment“ of interlaboratory comparison samples as known from proficiency testing systems.

Since 1995 the technical co-ordination and execution of the test sample program have been charged by an independent laboratory, the Analytical Centre of the Institute for Agrobiotechnology (IFA) in Tulln / Austria, that has also been appointed an official partner of the IRMM of the EU in the meanwhile. This Institute in turn is surveyed by the Austrian Analytical Quality Assurance Advisory Council run by EURACHEM-Austria.

IFA-Tulln is currently monitoring the quality for 6 different groups of analytes (nutrient parameters, heavy metal ions, triazines, chlorinated hydrocarbons, chlorinated organic pesticides and PAHs, all important parameters in the water monitoring system.

Since 1995 about 460 laboratories have taken part on a compulsory basis, and about 300 laboratories in Austria and abroad on a voluntary basis. For the latter a charge is levied. In total 65 (!) control checks have been completed. Up to now the incurred costs of the system for the Federal and State-Governments for the 4-year period have been approx. ATS 1.3 millions (about DM 185000.-). Compared to the total cost of ATS 125 millions (about DM 18 millions) for chemical analysis of running waters and groundwater this is only about 1% - a very good cost/benefit ratio. This QA measure is probably one of the most efficient one to constantly monitor routine laboratory performance with samples close to real ones.

5. Obligatory participation of the laboratories at national or international interlaboratory tests:

The laboratories have to participate in national or international interlaboratory tests on an obligatory basis. So far since 1991 ten national interlaboratory tests with international participation under the auspices of the Federal Ministry for Agriculture and were executed. This takes place in co-ordination with the Austrian accreditation authority in the Federal Ministry for Economic Affairs and the Ministry of Health. It has to be stated that the Austrian laboratories fare generally very well being mostly ranched in the upper third of all participants- this can be regarded as a result of the rigorous quality assurance program imposed.

Summary

As the past experiences showed, a strict and efficiently executed quality assurance even for a large monitoring program is essential. In the long run not only the governmental clients who have to deal carefully with the tax payers money will make much profit from the definition and practice of a strict quality assurance program but also reputable contractors will profit greatly from good references and high QA standards in the laboratories with the definition and also practice of a rigorous QS program.

Since the water quality monitoring network has been in operation it is updated currently. These adaptations were made by the Federal Ministry of Agriculture and Forestry as well as the Federal States due to the experiences with the network in practice. Also proposals made by experts or laboratories are taken into account. Thus a flexible network operating to the needs of daily use can be guaranteed.

Literature

Bundesgesetzblatt für die Republik Österreich Nr. 338/1991: Wassergüte - Erhebungsverordnung.

Pavlik H., Schwaiger K., Schimon W. (1996): Erhebung der Wassergüte in Österreich, Ergebnisse der Ausschreibung 1994/95 und 1995/96; Wasserwirtschaftskataster Wien.

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt), 1993: Wassergüte in Österreich, Jahresbericht 1993, Bundesministerium für Land- und Forstwirtschaft.

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt), 1995: Wassergüte in Österreich, Jahresbericht 1994, Bundesministerium für Land- und Forstwirtschaft.

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt), 1997: Wassergüte in Österreich, Jahresbericht 1996, Bundesministerium für Land- und Forstwirtschaft.

WWK/UBA (Wasserwirtschaftskataster/Umweltbundesamt), in press: Wassergüte in Österreich, Jahresbericht 1997, Bundesministerium für Land- und Forstwirtschaft.

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Correction of daily precipitation for systematic measurement error in Switzerland

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Abstract

The common precipitation measurements using elevated can-type gauges are subject to systematic error mostly due to wind field deformation above the precipitation gauge orifice, wetting and evaporation losses, splash-out and splash-in, blowing snow, etc. The wind-induced error during snowfalls can be ten times larger than that for rain and can amount up to 60 % of measured precipitation for unshielded gauges and wind speeds greater than 4 ms-1 as is shown in the Word Meteorological Organization, WMO Solid Precipitation Measurement Intercomparison report (Goodison et al., 1998). Correction procedures are different for rain and snow and have been developed for different types of precipitation gauges and various time intervals according to the availability of necessary input data, such as the precipitation intensity, wind speed, temperature, rain/snow amounts etc. Such procedures are based either on empirical field methods, that is intercomparison measurements using the WMO reference (pit gauge with anti-splash grid for rain, see Sevruk and Hamon, 1984, and double fence for snowfall, see Goodison et al., 1998) or numerical simulation as described by Nespor and Sevruk (1998). In this case the error is estimated by computing the the wind field around the gauge using computational fluid dynamics, CFD, commercial software (e.g. PHOENICS) and by simulating precipitation particle trajectories in the computed flow field. The simulation has many advantages as compared with the rather costly empirical methods. Once the methodology is developed, correction procedures for any type of a gauge can be made on computer very fast, within weeks. For field tests more years are necessary. Having developed a correction procedure for a given type of a gauge, the problem consists primarily, in the availability of input data at sites where in addition to precipitation no other meteorological variables are observed. For the long-term average monthly precipitation different kinds of parametrization and interpolation of missing variables can be done with sufficient accuracy as, for instance, showed by Sevruk (1986), but for the actual hourly and daily values, the accuracy of parametrizated and interpolated variables is generally low and direct measurements at the gauge site are much better. This poses no problems for the automatic meteorological stations where hourly values of many variables are available on line but it is a serious disadvantage of daily precipitation gauge sites. The modern national precipitation networks usually consist of a mixture of automatic and common precipitation stations whereas the latter generally prevails. In Japan, all precipitation gauges are automatic. But, for example, in Switzerland, there are up to 70 automatic stations regularly distributed over the whole territory including high altitude regions up to 4000 m asl and providing hourly values of almost all meteorological variables on line. Further, there are approximately 26 climatic stations with half-daily values of selected meteorological variables, and as many as 390 daily precipitation stations without observations of other meteorological variables. At the former the heated tipping-bucket precipitation gauges are installed and at the latter the Hellmann gauges elevated 1.5 m above ground are used. In this connection the question arises on how to use the information from automatic stations to correct all daily precipitation

observations in the national network. Concerning the wind-induced error the following variables are needed: hourly wind speed at the level of precipitation gauge orifice, precipitation amount and rain/snow separation and in the summer season, the weather situation to assess the structure of rain. The rain/snow separation can be assessed at the automatic stations using temperature. The fact that the level of wind measuring instruments is commonly higher up to 20 m above that of precipitation gauge orifice can be accounted for using the reduction procedure based on the logarithmic vertical profile and degree of gauge site protection as shown by Sevruk and Zahlavova (1994). The situation changes in the case of daily measurements. Interpolations are needed practically of all variables. Concerning the hourly precipitation the possible precipitation-altitude relationships have been studied during the time period of December 1996 to February 1997 with no success at all. Even taking daily and more day periods into account no significant trend was evident. On some days the altitudinal gradients of precipitation really existed, mostly in February, and the coefficient of determination R2 was high. Up to 70 % of variance of precipitation was explained by the altitude. Yet on other days the altitudinal gradients were inverse or non-existent (e.g. December). In addition to the season and the length of the time period considered, differences existed also between the regions, sub-regions and topographical units such as the valleys. Generally, the smaller and better defined area (e.g. the north-south oriented valleys) the better the precipitation-altitude relationship. Consequently, the interpolation method of hourly precipitation based on kriging and no accounting for the altitude at all as developed by Jensen (1989) was applied to subdivide the daily precipitation to hourly one. To increase the accuracy of interpolated values, the interpolation was applied regionally. Similarly, all other input variables have been interpolated. The results showed that on the average of December 1996 to February 1997 period, the correction amounted to 16 per cent of the corrected precipitation. The maximum daily value of 68 % was obtained on the top of Saentis (2490 m asl) on the 14th February 1997 during the snowfall with a strong wind of 8 ms-1. The maximum hourly correction value at the same site amounted to 90 %.

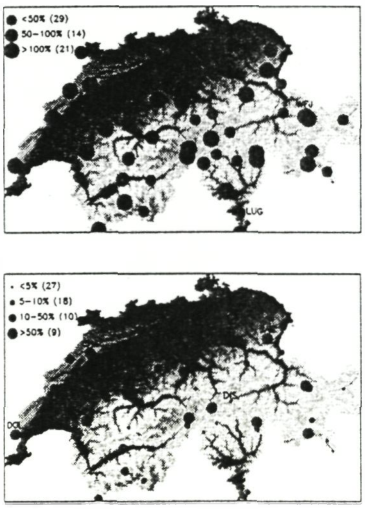

Figure 1: **Top:** Correction of the hourly values for 64 automatic gauges during the period of December 1996 to February 1997. **Bottom:** Mean of the 10 largest hourly correction during the period of December 1996 to February 1997 for 64 automatic gauges. In brackets: Number of gauges in each class.

References

Goodison, B. E., P.Y.T Louie and D. Yang. WMO solid precipitation measurement intercomparison, World Meteoprological Organization, Geneva, Switzerland, WMO/TD-No. 872, 212pp, 1998.

Jensen, H. Raeumliche Interpolation Stundenwerte von Niederschlag, Temperatur und Schneehoehe, Zuercher Geographische Schriften, Swiss Federal Institute of Technology, ETH Zuerich, No. 35, 70pp, 1989.

Nespor, V. and B. Sevruk Estimation of wind-induced error of rainfal gauge measurements using a numerical simulation. J. Atmos. Ocean. Techn, 1998 (in press).

Sevruk, B. Correction of precipitation measurements: Swiss experience. In: B. Sevruk (Ed.) Proc. Workshop on the Correction of Precipitation Measurements. Z=FCrcher Geographische Schriften, ETH Z=FCrich, No. 23, p. 187-196, 1986.

Sevruk, B. and W.R. Hamon International comparison of national precipitation gauges with a reference pit gauge. Instruments and Observing Methods Rep., World Meteorol. Org., Geneva, No. 17, 135 pp., 1984.

Sevruk, B and L. Zahlavova Classification system of precipitation gauge site exposure: Evaluation and application. Internat. J. Climatol., 14(6), 681-689, 1994.

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Methods of correction of data and quality control procedures used in Romania

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1. Methods of correction of data

The intense use of water leads to the alteration of the natural discharges and to changes in the river flow regime. Therefore, corrections of the measured water discharges should be necessary. Depending on the manner in which the water use works influences the natural river flow, they are classified as follows (Diaconu *et al.*, 1980 a):

- Permanent water uses, which refer especially to the demands of the drinking and industrial water supply.
- Temporary water uses, which refer to the irrigation demands, irregularly influence the discharges during the vegetation period.
- Reservoirs which modify both the water flow values and their distribution in time.

For the permanent and temporary works, the basic equation for the assessment of the reconstructed (natural) discharges Q_n function of the measured ones Q_m at a hydrological station, is:

$$Q_n = Q_m \pm \sum_{i=1}^{n} Q_i \tag{1}$$

where Q_i are the withdrawals (sign +) or the restitutions (sign –) upstream the considered station.
For a reservoir, the basic equation is:

$$Q_n = Q_m \pm \frac{\Delta W}{\Delta t} \tag{2}$$

where $\pm \Delta W$ represents the variation of the volume of water during the time Δt. In case of a cascade of l reservoirs the equation (2) becomes:

$$Q_n = Q_m \pm \sum_{i=1}^{l} \frac{\Delta W_i}{\Delta t} \tag{3}$$

where ΔW_i represents the variation in the reservoir storage. In general, for a river reach, upstream a gauging station where there are all types of water use works, the equation for the assessment of the natural discharges is:

$$Q_n = Q_m \pm \sum_{i=1}^{n} Q_i \pm \sum_{i=1}^{l} \frac{\Delta W_i}{\Delta t} \tag{4}$$

1.1. The procedure of reconstructing the natural water flows in case of permanent and temporary water use

Having in mind that the measured discharges might be affected by errors lying between ±(5-10%), the procedure of reconstructing the natural river flow should take into account only the water use works whose total discharges ΔQ relative to the natural discharge of the river Q_n exceed this error threshold. It is obvious that, their selection depends on the magnitude of the measured discharges. Therefore, in case of the low flows many water uses should taken into consideration as compared with the case of the mean flows and possibly, no water use is selected for the reconstruction of the discharges during high flows. The corrections are „strictly necessary" if $\Delta Q/Q_n > 0.1$ and „necessary" if $\Delta Q/Q_n > 0.05$. The reconstruction is „unnecessary" if $\Delta Q/Q_n < 0.05$.

1.2. The procedure of reconstructing the natural river flow regime in case of the existence of reservoirs

For a reservoir located upstream a gauging station, the reconstruction of the natural discharges over a certain period Δt is made according to the relation (2).

If $|\Delta W/\Delta t| \geq 0.1 Q_n$ then the reconstruction is necessary and unnecessary if $|\Delta W/\Delta t| \leq 0.05 Q_n$. Writing the equation (2) as:

$$Q_n = Q_m \left(1 \pm \frac{\Delta W}{Q_m \Delta t}\right) = Q_m (1 \pm K) \tag{5}$$

One can observe that the accuracy of the evaluation of Q_n depends not only on the precision of the measurement of Q_m but also on the magnitude of the water storage in the reservoir and the length of the lapse of time Δt.

In Figure 1, for different ranges of variation of the ratio K, the accepted errors in evaluating ΔW are presented. The graph is performed under the condition that the maximum error of estimation of Q_n does not exceed ± 15%.

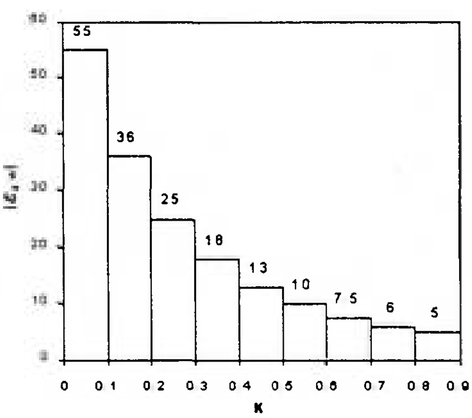

Figure 1. Accepted errors of ΔW function of ratio K

1.3. The reconstruction of river flow regime in the general case

In this case the relation (4) is applied and it may be written:

$$\Delta Q_{TOT} = \sum_{i=1}^{n} Q_i \pm \sum_{i=1}^{j} \frac{\Delta W_i}{\Delta t} - Q_{in} - Q_{out} \tag{6}$$

where Q_{in} and Q_{out} are the inflows and outflows from or to contiguous basins, respectively. The corrections for reconstructing the natural regime should be made if $0.1 Q_n \leq \Delta Q_{TOT}$. Other wise, if $\Delta Q_{TOT} \leq 0.05\ Q_n$ is not necessary to apply the reconstruction procedure.

1.4. The reconstruction of the flood hydrograph

In case of the existence of a reservoir, and knowing the outflows (effluent discharges Q_{e_i}) the natural inflows Q_{a_i} are determined according to the equation (Diaconu et al., 1980b):

$$Q_{a_i} = Q_{e_i} + Q_{e_{i-1}} + \frac{2(W_i - W_{i-1})}{\Delta t} - Q_{a_{i-1}} \tag{7}$$

where: W_{i-1}, W_i are the volumes stored in the reservoir at the moments i–1, i (determined by use of $W = f(H)$ curve, H being the water level in the reservoir). One can observe that the reconstructed discharge Q_{a_i} at each moment *i*, depends on Q_{e_i}, $Q_{e_{i-1}}$ and on the ratio $\left(W_i - W_{i-1}\right)/\Delta t$. The latter may be significantly deviated from the correct value due to error in evaluating the volumes at the moments *i*, *i* – 1. This error (let suppose to be positive) affects the estimate of Q_{a_i} which is over evaluated. Then, at the next moment *i* in the relation (7) the value Q_{a_i} becomes $Q_{a_{i-1}}$ which is abstracted from the right term of the equation and therefore the estimate $Q_{a_{i-1}}$ is under evaluated, and so on.

Thus the values Q_{a_i} computed by use of such iteration procedure are successively affected by negative and positive errors and the reconstructed discharges of the rise and decreasing limbs of the hydrograph do not monotonically increase and decrease, respectively.

2. Data quality control

The accuracy of the instantaneous or daily discharges depends on the correctness of recorded levels, their significance (recording frequency) and on the manner in which the rating curve represents a stable relationship between the levels and the discharges.

An advanced computerized method to control the data quality applied within Romanian Hydrological Service consists in the check of the water flow balance between subsequent gauging stations located along the main course of a river. The check of the water flow balance is made on characteristic periods: Low flow, high low and monthly/yearly periods.

During the mean and low flows, when precipitation is not significant, the water volume balance equation for the considered lapse of time is written. Let A and B two gauging stations located on the main river course in a catchment where the mean flows Q_A and Q_B are respectively recorded. The water flows Q_i of some tributaries from the sector $A - B$ having areas F_i are gauged at their outlets by *n* gauging stations (Figure 2). Then, the mean water flow equation during the considered period is:

$$Q_B = Q_A + \sum_{i=1}^{n} Q_i + Q_{RB} \qquad (8)$$

where Q_{RB} represents the mean flow formed over the rest of the uncontrolled basin of area F_{RB}. This area is composed of *m* uncontrolled subbasins each of them having area $F_j^* \left(F_{RB} = \sum_{j=1}^{n} F_j^* \right)$. The total area F_{RB} is shared into subbasins in such a way that these should be as homogeneous as possible from physiographical point of view. Relied upon the recorded values of Q_i a regionalization relationship between the mean altitudes H_i of the subbasins and the mean specific water flows is $q_i = Q_i / F_i$ (Figure 3).

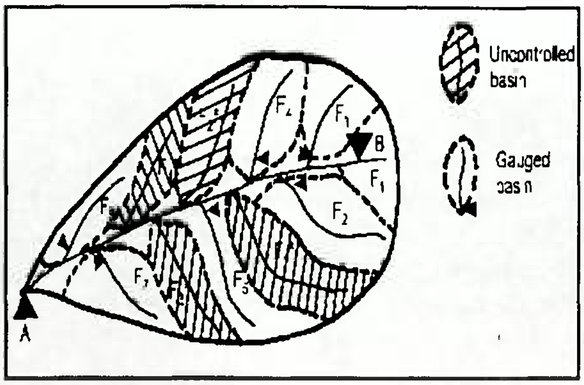

Figure 2. Scheme for evaluating the uncontrolled basin flow

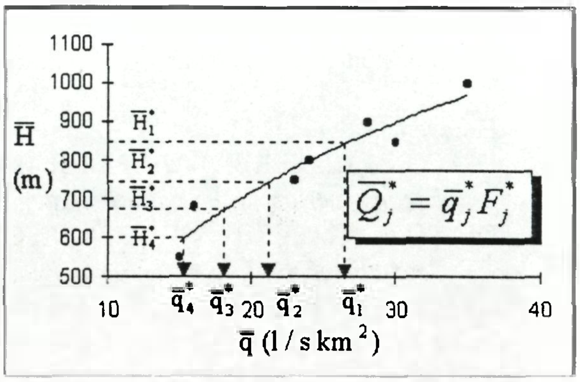

Figure 3. Relationship between mean specific and flow the mean altitude

From that relationship the water flows of the uncontrolled subbasins of the mean altitudes H_j^* are estimated. Thus, the total computed contribution of the basin area to the flow in the point B is:

$$Q_B^{'} = Q_A + \sum_{i=1}^{n} Q_i + \sum_{j=1}^{m} Q_j^{*} \qquad (9)$$

Accepting an error of ± 10% of the flow balance check, the quality of recorded data of the gauging stations located on the main river course and on the tributaries is acceptable if:

$$0.9Q_B^{'} < Q_B < 1.1Q_B^{'} \qquad (10)$$

During a high water period the volumes of floods W_A and W_B (the base flow included) recorded at the gauging stations A and B as well as those at the stations controlling the n tributaries (W_i) are considered in the quality control procedure. Relied on the depths of runoff h_{s_i} and the rainfalls h_{r_i} for each tributary i = 1, n the runoff coefficients $\alpha_i = h_{s_i}/h_{r_i}$ are computed. Then, the runoff coefficients $\alpha_j \ (j = 1, m)$ for each uncontrolled subbasin are assigned taking into account the physiographical similitude as well as the depth of rainfalls h_{r_j} (Stanescu and Oancea, 1993).

Finally, the flood volumes for the uncontrolled subbasins is:

$$W_j = \alpha_j h_{r_j} F_j^{*} \qquad (11)$$

The computed total flood volume of the catchment area F_B is :

$$W_B^{'} = W_A + \sum_{i=1}^{n} W_i + \sum_{j=1}^{m} W_j^{*} \qquad (12)$$

If $0.9W_B^{'} < W_B < 1.1W_B^{'}$ the flood volume balance is considered satisfactory and the data quality at the gauging stations is valid. An example is presented in the paper.

For the monthly/year period the quality control procedure as described above (relations (9) and (10)) is applied.

Conclusions

1. To bring to homogeneity of the data series, is case of an intense water use a set of corrections to the measured flow is applied. This procedure is called the reconstruction of the natural river flow regime.
2. In case of the permanent and agriculture water use the corrections are applied in such a way that the relative values of the withdrawals or restitution should represent at least 5% of the natural discharge.
3. In case of the reservoirs, the corrections depend on the measured value of the discharge, the accuracy in assessing the reservoir volume variation as well as on the lapse of time.
4. Besides the basic, very well known quality control, an advanced procedure relied on the water flow balance along a river reach combined with a flow formation evaluation over a catchment, based on the hydrological regionalisation techniques and on the principle of physiographical similitude, represents an important tool for data validation.

References

DIACONU C., SERBAN P., PASOI I., (1980a) *Methodological and Technical Guidelines for the Reconstruction of the natural Water Flow Regime of the Rivers* (in Romanian) IMH, Bucharest

DIACONU C., SERBAN P., STANESCU V.Al., (1980b) *Some possibilities for reconstructing the data corresponding to natural hydrological conditions. Casebook of Methods of Computation Changes in the Hydrological Regime of River Basins due to Human Activities*, UNESCO, Project 5.1 of the IHP

STANESCU V. Al., OANCEA V., (1993) *Procedures for Hydrological Regionalization applied in Romania.* Proceedings of the 2nd International Conference FRIEND, Braunschweig. IAHS Publ. No. 221, pp. 519-525.

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Rainfall input uncertainty in hydrological models

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Introduction: different uncertainty-sources in hydrological modelling

A lot of uncertainties are involved in mathematical hydrological modelling: uncertainties about the model input (e.g. spatial rainfall input), model simplifications of the physical reality and biases and uncertainties about the model parameters. These uncertainties are often large and can make the results of hydrological modelling very uncertain. When engineering designs or water management decisions are based on such results, the risk of setting out designs not meeting the requirements, or the risk of taking inconsistent decisions truly exists.

The total uncertainty about the results of mathematical modelling can be quantified in practice by comparing model simulation results with measurements. Therefore, the model residuals are analysed and described in terms of probability distributions. In hydrological applications, as one is dealing with time-variable processes, the uncertainty structure of the model output is often described in time by a stochastic model. It is the result of a time series analysis of the residuals.

The uncertainty estimation about the model results becomes applicable for many purposes. Engineering designs and management decisions can be based on the derived uncertainty structure and designs/decisions can be obtained which may be considered 'sufficiently safe'. The uncertainty assessment can also form the basis of model improvement. In many practical cases, during the uncertainty estimation procedure, biases are noticed in the deterministic model as differences between modelled and mean values (following the probability distributions) of some state-variables. Whenever these biases are mentioned, the model can be adjusted in order to curtail the biases and to represent the physical reality in a far more adequate way. Moreover, when the uncertainty structure of the model-output variables is known, calibration of the model parameters becomes less problematic. In the calibration, the highest weights can be given to the most accurate model-output values. The calibration can be performed, for instance, by maximizing the 'likelihood function' of model-output.

Different uncertainty-sources contribute to the total uncertainty about the model results and the separate quantification of these sources may be advantageous. The most important advantage is the transparency of the derived uncertainty structure of the model: the different uncertainty-sources have a direct physical interpretation. This physical interpretation also allows the modeller to make an estimation of the uncertainty-sources. Whenever no measurement data of model-output is available in the application (for instance in the design stage of a system), it is still possible by this reason (although in a less accurate way) to quantify the total uncertainty about the model-results. Another advantage of the uncertainty-separation is the possibility to find most efficient ways to curtail the total uncertainty about the model results, by weighing out the different uncertainty-contributions. In that way, the total uncertainty about the model results can be reduced either by more detailed measurement campaigns or

larger modelling efforts, depending on which uncertainty-contribution takes up the largest part of that uncertainty.
Generally, three types of uncertainty-sources exist in mathematical modelling: input uncertainty, model uncertainty and parameter uncertainty. This separation of uncertainties is based on the physical nature of the model entities to which the uncertainties are related. Input-uncertainty is related to the model-input variables, model uncertainty to the simplified model structure and parameter uncertainty to the parameters of the model. The uncertainty-cataloguing is also based on the physical nature of the uncertainties themselves: model-input uncertainty has to do with measurement errors (if the model input is directly measured) or estimation/model errors (if the input is estimated or modelled); model uncertainty is related to model structure simplification (or model detail); parameter uncertainty is related to model identifiability and model calibration (if the model is calibrated) or it is related to the practical experience of the model user (if the model parameters are estimated on the basis of experience). The smaller the amount of data which is available for calibration of the model and the larger the model detail, the larger the uncertainties about the calibrated model parameters.

Rainfall-input uncertainty
In hydrological applications, a large part of the total uncertainty about the model-results is caused by the rainfall-input uncertainty. This input-uncertainty can be further separated into different types:

- rainfall measurement errors
- uncertainty by non-representativeness of the used rainfall measurements for the catchment under study
- uncertainty by rainfall simplification, e.g. the assumption of uniform rainfall over the catchment.

Referring to the third uncertainty type, the assumption of uniform rainfall over the catchment is often forced by the model. Whenever lumped hydrological model are used (e.g. models with macroscopic spatially-averaged processes), only one time series of rainfall input can be used. This rainfall is considered (in some way) representative to the rainfall over the whole catchment and it is derived from the different time series of rainfall data (e.g. rain gauges) that are available in and around the catchment. The time series with the smallest rainfall-input uncertainty should be derived. Anyhow, this optimal rainfall representation is difficult to find in practice and, therefore, it is often assumed that the optimal representation can be approximated well by catchment-averaged rainfall. Even when distributed models are used, one is often forced to use uniform rainfall by the limited availability of rain gauge data. In most hydrological applications, rainfall data with high measuring frequency (e.g. at least 1/hour) is needed and such data is only available at a limited number of stations.

The uncertainties of the second type especially appear when the rain gauges are located outside the catchment. In some cases, no rain gauges with sufficiently large measuring frequency are available in the catchment under study. Rainfall data of other neighbouring gauges are then used, introducing rainfall-input uncertainty. Whenever only one rain gauge is available, this rainfall-input uncertainty can be related to the distance of the rain gauge to the catchment centre. The additional uncertainty by the spatial variability of rainfall (the third uncertainty-type, as described above) can then be estimated by simulating many different spatial rain storms (thousands) in the model and by comparing the simulation results with the ones after simulating the point rainfall in the catchment centre as uniform rainfall. Both measured data (either data from a dense network of rain gauges or radar data) and simulated data by a spatial rainfall model (or a generator) can be used as spatial rainfall data in such application.

The first uncertainty-type, the rainfall measurement errors, can be separated further into different types:

- resolution error of the rain gauges (e.g. volume of the bucket for tipping-bucket rain gauges)
- calibration error of the rain gauges
- errors by variable wind velocities and local disturbances of air flow.

Rain gauges have to be calibrated (derivation of the mean relative deviation of the measurements in function of rainfall intensity) and the calibration error can be represented by confidence limits (prediction variances) on the calibration curves. The errors by time-variable wind velocities and local disturbances of air flow (trees, buildings, ...) can only be estimated roughly on the basis of a very limited number of publications about the subject.

Case-studies

The rainfall-input uncertainty has been quantified and compared with the other uncertainty-sources in mathematical modelling for two case-studies:

- lumped conceptual rainfall-runoff modelling of a Belgian brook catchment (Molenbeek brook in the Dender catchment at Erpe-Mere; total runoff area of 41 km^2)
- modelling of sewer system overflow emissions both by a full hydrodynamic model and a conceptual reservoir model for a combined sewer / waste water treatment system (system with a storage sedimentation tank at Dessel, Belgium).

In both applications, the use of uniform rainfall over the catchment is forced by the application. By the limited availability of rain gauges with high measuring frequency (1/hour for the catchment-runoff application; 1/10min. for the sewer system application), the uniform rainfall is equalized to point rainfall (located inside the catchment in the second application, located far outside the catchment in the first application). The uncertainty resulting from the assumption of uniform rainfall has been assessed by using data from a dense network of twelve rain gauges at the city of Antwerp (Belgium). The distances between the gauges of this network approximate three kilometres. This is small compared to the average spatial extent (7 to 8 km) of the smallest sub-elements of rain storms: the rain cells. The spatial extent of the network is comparable to the extent of hydrographic and the largest urban catchments. By these reasons, the network data are very useful in the present case-studies. A hundred rain storms (for various extreme rainfall intensities) are simulated and the uncertainty-contributions to the model results (spatially-averaged rainfall-runoff discharges, overflow discharges and volumes) are calculated in terms of absolute and relative values.
The rainfall-input uncertainty resulting from the location of the rain gauge outside the catchment in the first application has been studied by comparing measured rain storm volumes of many rain gauges at different distances (using data of both the mentioned dense network and the climatological network of the Royal Meteorological Institute of Belgium (IRM/KMI)). An exponential decrease of the correlation of rain storm volumes with the distance has been found.

The rain gauge in the second application is of the 'tipping-bucket' type (resolution error of 0.2mm) and, after calibration, a calibration error of 1% is found. In the first application, 10 min. rainfall data of IRM/KMI at Uccle/Ukkel are used for which the resolution and calibration error can be neglected.

In the sewer system application, it has been shown that the model uncertainty of the simple rainfall-runoff model, the rainfall measurement errors and the uncertainties resulting from the assumption of uniform rainfall have the largest uncertainty-contributions. Although the contributions can be ranked in the mentioned order, their magnitudes are comparable. The model uncertainties of the full hydrodynamic sewer system model are much lower and, therefore, this model can be considered 'unnecessarily detailed' for the application. Even for the very simplified conceptual reservoir model, the model uncertainties are rather low if compared to the rainfall-input uncertainties.
In the catchment-runoff application, the model is less accurate and a balance has been mentioned between model uncertainty and rainfall-input uncertainty. The model detail can thus be considered 'optimal' in this application and, whenever one tries to improve the results, equal weight should be given to model improvement and rainfall data collection.

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Anomalies, 'noises' and oscillations in hydrological time series need not be errors

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The rainfall-runoff simulations for several small and medium-sized basins in the Czech part of the Elbe River basin carried out recently (*e.g. Buchtele et al, 1997*) provide the opportunity to check also the reliability of observed flows. Some illustrations have been aquired which show that the consequences of air-temperature and even air pressure for runoff process are more complex as it is assumed, namely by the structure of usually applied models and/or detectable without consideration of other phenomena (vertical gradient of air temperature, frozen water in soil, equilibrium of air- and water pressure in the soil mantle). These phenomena are noticable during low flow intervals.

Depression in flow series after abrupt decrease of air-temperature in winter periods

We have been faced with this phenomenon in trials to detect the effects of withdrawls of drinking water from one aquifer in the Metuje River basin ($P = 93\ km^2$) which increased between years 1978 and 1995 from $Q_W = 180$ l/s to $Q_W = 320$ l/s. However, a bit suprisingly, the flow duration curves in Fig. 1 exhibit quite opposite course in interval $P \geq 98\%$ than it could be expected. The search for period which causes it has pointed to two winter intervals in years 1963 and 1970, namely to winter 1962/63 with frost lasting several months.

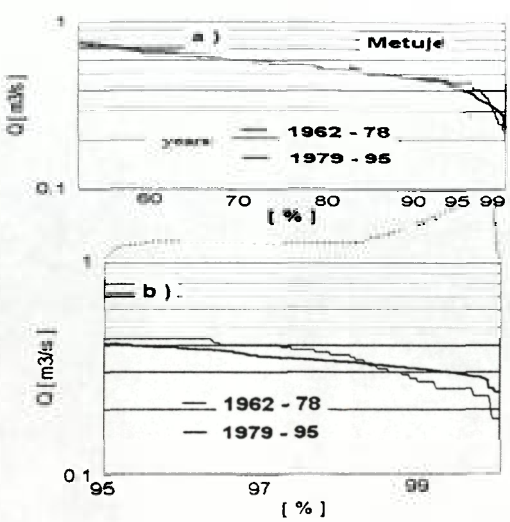


Fig. 1: Flow duration curves

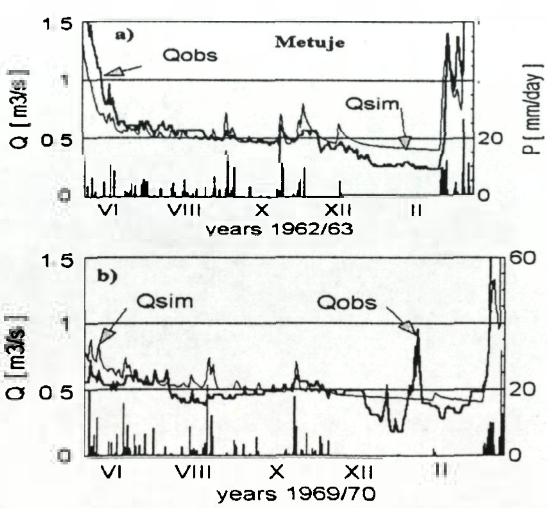


Fig. 2: Decrease of flows in winter

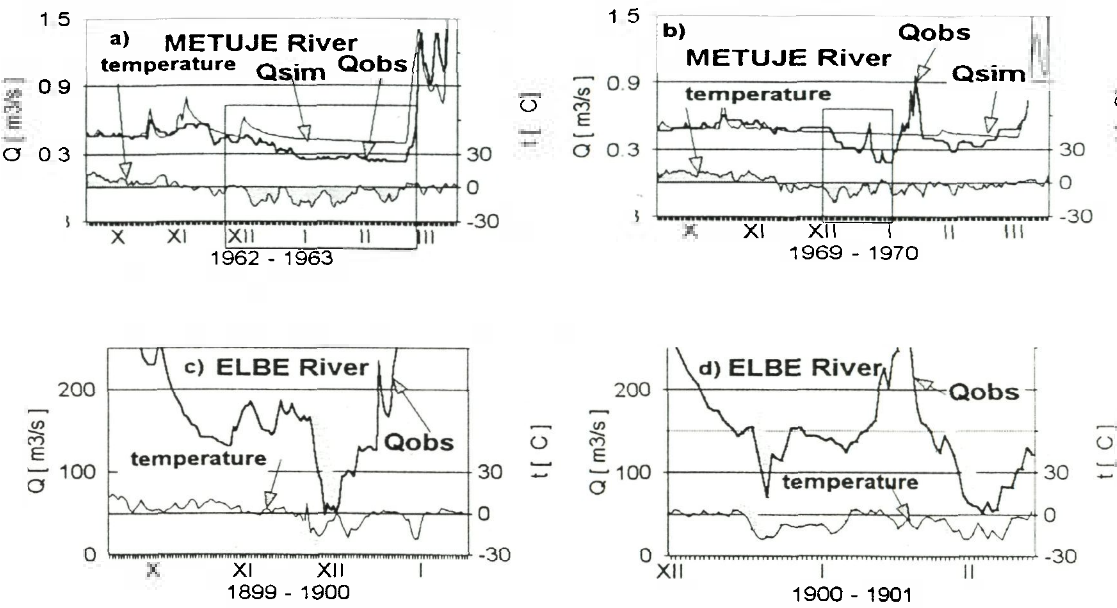


Fig. 3: Abrupt decrease of observed flows compared with simulations

Figs. 2 and 3a illustrate the diverse tendencies in recession curves during dry summers and cold winters. In both cases comparison with simulated discharges seems probably to indicate that this anomaly is not caused by errors in measurements[1]. As an explanation could be considered the fact that the frost prevents water to outflow into streams. It seems to be in agreement with assumptions of some models of moisture transport in frozen soil *(Deangelis & Wood, 1998)*.
Another situation is presented in *Fig. 3b* illustrating runoff decrease after abrupt air-temperature fall below freezing point in the relatively large basin of the Czech Elbe River. Both illustrations are from periods without artificial effect, and snowmelting.

Recession curves during summer rainless period

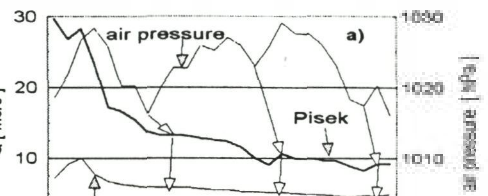


Fig. 4 illustrates one of possible reasons for discreapencies between recession curves and observed flows. It is assumed that during rainless period the shape of recession part of hydrograph should be smooth and convex. But, it could be misleading to derive its parameters without considering e.g. the effect of decreases of air pressure - a phenomenon which may distort the smooth shape. Network with several tenths of rainfall stations used for ascertaining the rainless periods in the basin with the area P ≅ 2500 km^2 excludes the possibility that there have been some non-registered precipitations and serious errors in discharges are unlikely, because its trend has been similar in several stations.

Fig. 4.: Examples of interrupted recession process in rainless period

[1] The simulations have been carried out using SAC-SMA model *(Burnash, 1995)*

The given example - and other similar situations - indicate that runoff rise is clearly noticable after abrupt air pressure decrease. But, other factors could play sometimes important role, e.g. water withdrawals.

The role of vertical gradients of air temperature in snowmelt process

Fig 5a presents the discreapancy between the observed and simulated discharges of Jalovecky Creek in the Low Tatra Mountains, where again the SAC-SMA model has been used as the modeling tool. This example represents an exceptional situation among mostly successful simulations of snowmelt in the hilly region, namely thanks to the provision included in the model to take into account the vertical variability of snow deposits. However, occuring inversion situation in air temperature vertical gradient caused the disagreement as only air temperature observation in lower part of the basin was available. After re-consideration of this effect using two other stations in neighbouring basin - see *Fig. 5c* - the successful simulation have been reached.

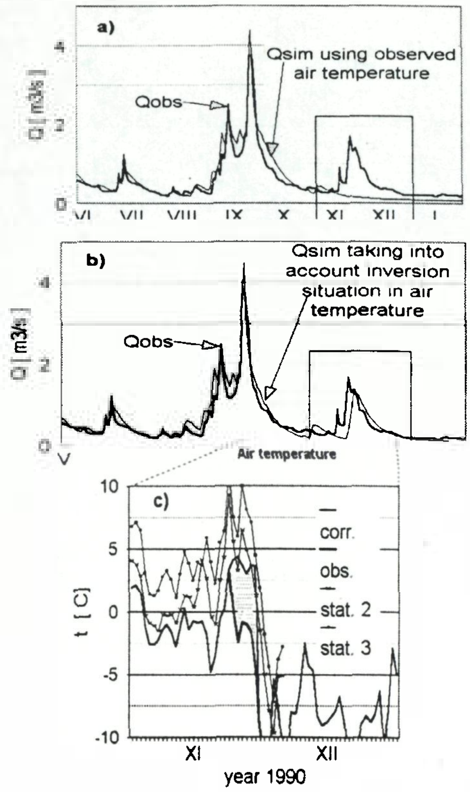


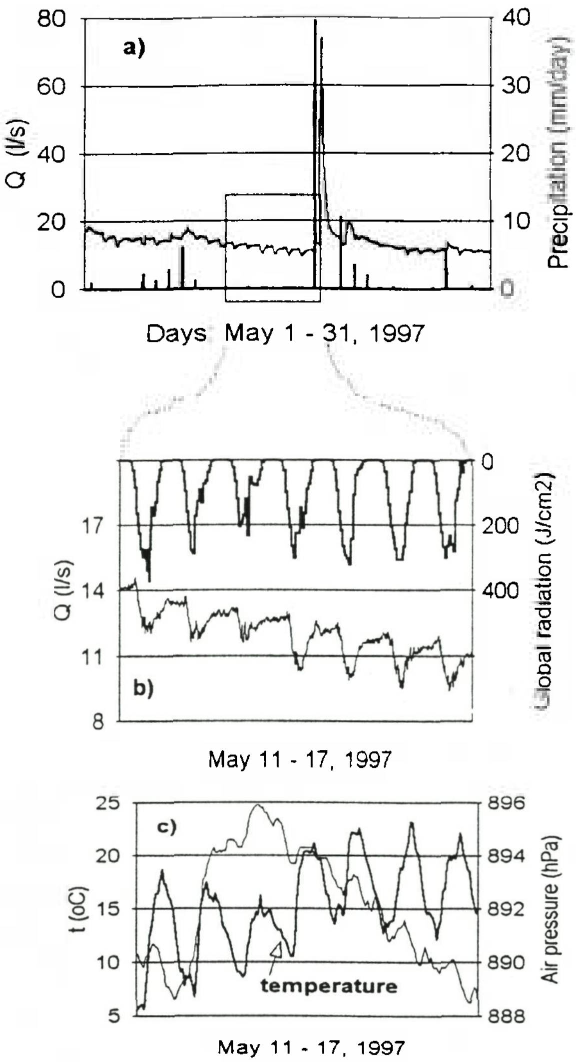
Fig. 5: Effect of neglected inverse vertical gradient of air temperature

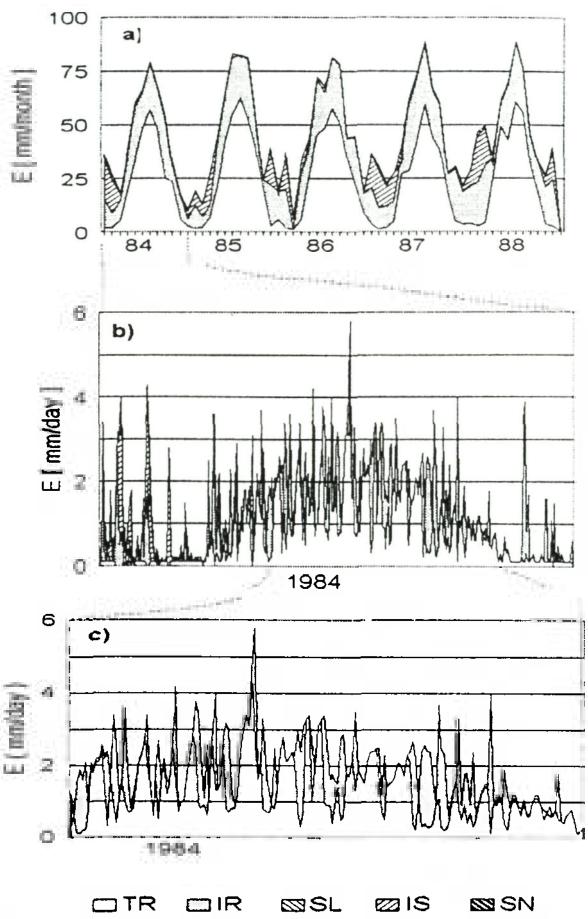
Daily and seasonal variability of evapotranspiration

The sensitivity of runoff to evapotranspiration is widely known, however quite rarely the comprehensive observations are available or presented, which would demonstrate this effect in short-time scales, i.e. with daily or even shorter time interval.

Figs. 6 and 7 present the results for the experimental basin (Liz - P ≅ 1 km^2) in Boehmerwald at the Czech site of the Austrian-German borders, which indicates that daily cycles in natural flows appear as an usual situation during drought periods. *Kirnbauer & Haas (1998)* assume that this oscillation - as they have observed it in small Alpine catchments - is due to daily variability of transpiration. Other reasons could also contribute to that, e. g. air-temperature and air-pressure.

Fig. 7 shows components of evapotranspiration as obtained in simulations of rainfall-runoff process of the Liz basin using Brook model *(Federer, 1993)*. The detail, i.e. output in daily scale suggests certain complementarity of some of its components - namely of transpiration and rain intereception.This fact probably causes that even simplified assesment of this kind of water ´loses´ are satisfactory for many purposes.





TR ... transpiration, IR ... rainfal interception,
SL ... soil evaporation IS ... snow interception
SN ... snow evaporation

Fig. 6: Daily variation of observed discharges - Liz basin, P = 1 km^2

Fig. 7: Components of evapotranspiration as output of the BROOK model

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References

Buchtele, J., Buchtelová M., Fořtová, M.(1997):Comparisons of simulated runoff in basins with different vegetation and geomorphology. *Conf. FRIEND'97*, Postojna, Slovenia, Sept. 1997. LOC proceedings of poster presentation - FRIEND'97. *Acta hydrotechnica* 15/19 (1997), Ljubljana, p. 79-84.

Burnash J.C.R. (1995): The NWS River Forecasr System - Catchment Modeling. In.: Computer Models of Watershed Hydrology (ed. by V.P. Singh), *Water Resources Publications* Colo., p. 311-366, ISBN No. 0-918334-91-8.

Deangelis, M. L. & Wood, E.F. (1998): A detailed model to simulate heat and moisture transport in frozen soil. *Proc. of the HeadWater' 98 Conf.*, Merano, Italy, April 1998, p. 141-148, IAHS Publ. No. 248.

Federer C.A. (1993): BROOK 90 - a Simulation Model for Evapotranspiration, Soil Water and Streamflow. USDA Forest Service, Durham , NH, USA.

Kirnbauer, R. & Haas, P. (1998): Observations on runoff generation mechanisms in small Alpine catchments. *Proc. of the HeadWater' 98 Conf.*, Merano, Italy, April 1998, p. 239-248, IAHS Publ. No. 248.

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Studying three methods determined river discharge from its level by mathematics model

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Abstract

In this paper a flood hydrograph is imitated by simple mathematics model:

$$\tilde{H} = -\cos\frac{\pi t}{T} + H_0$$

$$\tilde{Q} = \sin\frac{\pi t}{T} + Q_0$$

Where H is a river level ;Q is a Discharge ;T is a flood duration ; t is time ,which varies in segment [0,3/2T].

On the basis of the model ,some measuring times distribution is built .The connect measuring point method ,correcting level method and average line method are applied to determine river discharge from its level .Analysing mathematics quality of the three methods it is possible to obtain method error for determing discharge and relationship between method error and measuring times and distribution of measuring times .These results can show that the correct level method is superior among the three methods .

Availability of data

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Availability of Data

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Abstract

Considering the availability of hydrological data we may become confronted with the following two extreme views:

View A: There are already enough data available, which need to be analyzed in a more comprehensive and intelligent way in order to describe and model hydrological processes. What is further needed, is just a set of base line data continuously recorded to identify trends and extraordinary phenomena.

View B: Data availability is insufficient in many respects. A number of data are totally missing, at least at places where they are needed, many data are incorrect, for instance, due to rating curve errors, others are insufficient in terms of spatial and temporal resolution, regional coverage etc.

Both positions have a rational point and the truth is clearly somewhere in between. View A may be classified as rather conventional, focussing to much on historical data demands. But the historical view leads us to the understanding that the issue of data availability is always related to data needs which are changing with time. For instance, in the beginning of the development of hydrology water levels were of primary interest. Later on, river discharges became equally important, while water quality became an issue only after the industrial revolution due to the increasing water pollution. Similarily the demand for hydrometeorological data increased from initially temperature, humidity and precipitation only to radiation characteristics, chemical composition of precipitation, or better said, quality of wet and dry atmospheric deposition etc.

Today we are faced with several new data demands, wider in scope and more complex than ever before. This is especially due to the ongoing global change process in terms of changes in climate and land use, overuse and degradation of nature resources etc. Many of these processes (atmospheric, hydrological, ecological and other processes) are interdependent and interacting with each other in rather complex ways. To understand and model these interdependencies and interactions various atmospheric and land surface ecological and hydrological and other data are required, many of which are not or not sufficiently available. A typical example is, for instance, the monitoring of carbon fluxes at the land surface atmosphere interface, important for understanding the global cycling of Carbon. Only some years ago a network called FLUXNET was suggested, and the development initiated. At present a number of stations belonging to this network are in operation, primarily in Europe (EUROFLUX) and in North America (AMERIFLUX).

Accordingly, in the following the issue of data availability will be discussed with taking into account the data demands to develop and improve our understanding of global change. This implies, of course,

the question whether hydrological data series can further be considered as stationary or how instationarities caused by changes in the controlling climate and land use / land cover characteristics can adequately be assessed. The ongoing discussions on the validity of flood peak flow distribution functions derived in the past, clearly reflect this situation and illustrate the demand for new and more reliable flood data.

A most important support in the investigation of this kind of changes is to model the relevant processes. The scope and complexity of this modelling is clearly increasing along with the increasing computing capacities. For this modelling two types of data are needed:

i) spatial geo-referenced, GIS-based data on topography, land use / land cover, soils, hydrogeology etc.
ii) time series data of meteorological, hydrological, ecological and other characteristics.

Concerning the spatial data, it can be said that they became generally available worldwide, but often only in rather low resolution.This development was greatly supported by the increasing use of remote sensing techniques. High resolution data required for more detailed process studies at smaller scales, e.g. for flood simulation, are also available, at least in many developed countries, but largely missing in the rest of the world. To overcome this deficiency downscaling techniques may help to a certain degree as was proven in recent studies.

Time series data of basic hydrological characteristics, such as water levels and river discharges, are quite well available except in some parts of the developing world, e.g. Africa. More critical is the situation with water quality data although a remarkable amount of data has been collected worldwide in the frame of the Global Environmental Monitoring System (GEMS). Many data are also available on plot- or patch-related vertical water and associated biogeochemical fluxes at the land surface atmosphere interface and below, especially in the upper soil layer. Powerful modelling techniques are available to extrapolate these data to larger areas.

Rather different is the situation with the lateral flows of water and associated sediments, solutes etc. There are still problems in the correct description of overland flow and subsurface stormflow and ultimately flood streamflow, especially in case of extreme heavy rainfall leading to flash floods. Not only infiltration excess (HORTON flow) is difficult to assess but also the dynamically varying extent of saturated areas (DUNNE flow). Even less understood are the different subsurface stormflow mechanisms which clearly contribute with quite considerable amounts to flood stream flow. However, by applying tracer techniques it became clear that only a small percentage (10-20 %) of this component flow represents event water, whereas the rest is "old", pre-event water, somehow and somewhere replaced by event water within the watershed. There are clear deficiencies in understanding these processes and in the required data concerning the flowpaths and residence times of different subsurface flow components, which are so important for the retention of contaminants, and thus water quality. Data availability in this field of interest is far behind the needs. Complex field studies combining conventional monitoring of hydrological characteristics with data from remote sensing and tracer applications and also from spatially distributed modelling are required.

Another demand for hydrological data is due to their function as indicators of global change. The use of cryosphere characteristics, for instance glacier extent and volume, as such indicators is generally known. In addition, runoff in connection with the two other important water balance components precipitation and evaporation may serve as hydrological indicator of climate change impacts in watersheds where direct human impacts are missing or negligible. This condition is fulfilled in particular in remote high-mountain watersheds, which therefore have been suggested to be continuously monitored, coupled with modelling.

Finally, a very unfortunate and unfavourite development needs to be pointed out: the restriction of data availability due to commercialisation. This development should be avoided or overcome.

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The ERICA 1 : 250K Pilot Databases

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Introduction

Since 1990 the European Environment Agency (EEA) has pursued its mission to provide the Community and Member States with *"objective, reliable and comparable information at a European level enabling them to take the requisite measures to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the state of the environment."* In terms of supranational and regional hydrological and water quality investigations, unique and consistent data-sets are needed to show the location and connectivity of the natural features such as rivers and lakes, and those features that are man-made such as canals and reservoirs, coastlines and catchment boundaries. These data-sets are not available on a Pan-European scale. Hence, the Institute of Hydrology, Wallingford (IH), the National Environmental Research Institute, Silkeborg (NERI) and the Institute of Hydrology at the University of Freiburg (IHF) carried out a joint research work to provide a River and Catchment Boundary Database. The project is entitled ERICA (European Rivers and Catchments). The ERICA project comprises two objectives: (1) the compilation of a Catchment Geographical database at a 'lower resolution' (1 : 1M) and (2) a database pilot study at 'medium resolution' (1 : 250K).

The ERICA database at 'lower resolution' compiles a Geographical database to support the assessment and mapping of environment indicators for major river catchments at a European scale. This part of the ERICA project, conducted by IH, is not treated in the present paper.

Specific objectives of the medium scale pilot study

The purpose of the medium resolution (1:250K scale) pilot study database is to identify and better understand the challenges and costs of producing a pan-European data-set at this scale. A specific objective of the database generation was to provide to EEA an insight view into the technical and logistic challenges of producing a pan-European database at a medium scale resolution based on experience gathered at two river basins within Europe. This implies an investigation of the difficulties of acquiring, combining and processing data from different sources and in different formats and projections. The requirements which a 1:250K database fulfils are:

- Provision of tools for monitoring hydrological phenomena or the state on the hydrological system.
- Supplying basic data bases for EU Research Programmes which involve regional and supra-regional modelling in subject areas such as hydrology, eutrophication, acidification, erosion, etc.
- Inherent geomorphologic information, such as drainage density within catchments, which can be used for analytical purposes, particularly if integrated within other compatible environmental databases such as on land use, soils, pollution sources, population density etc.

- Reporting, data capturing and storage of data and information, which is a central issue for the EEA, EU institutions and the European Commissions. Among many other requirements, a harmonised reporting system demands an agreed and consistent understanding of rivers and catchments in the area of interest.
- Data visualisation of hydrological features on the scale at which the EEA operates.

The 2 pilot study areas

The work was conducted in two pilot study areas: the Meuse catchment in France and Belgium (study area of NERI) and the Miño catchment in Spain and Portugal (study area of UF). The two study areas were chosen in accordance with a set of criteria. They should contain a transboundary area, show contrasting terrain e.g. mountainous/flat, show contrasting hydrology e.g. drainage density, highlight the mixed availability and quality of digital data, highlight the availability, quality and overlap of different paper-map series, and show contrasting land-use/population density.

The river Miño rises in the Sierra de Lorenzana in the Galicia region of north-west Spain. It flows south-east through Orense before defining the boundary between Spain and Portugal and reaching the Atlantic at Portugal's north-westerly tip. It has a catchment area of just over 17,000km^2.

The river Meuse rises in the Haute-Marne "departement" of north-east France. It flows north through Charleville before crossing the border into Belgium. There, it continues north through Liege and crosses the border with the Netherlands, close to Maastricht before exiting into the North Sea close to Rotterdam. It has a catchment area of 17,400 km^2.

Quality of the basic data

In both pilot studies paper map sheets were used to control the quality of the acquired digital data. In both cases manual digitising was inevitable to complete the databases. The purchased/provided digital data was generally of good quality and comparable to information found on corresponding paper maps. However, as expected, areas of overlap of digital data showed different degrees of generalisation. If mating had to be done, there is no alternative to manual/subjective intervention. Additional good quality data could be obtained through manual digitising of paper maps providing that complete meta-data was available relating to the projection of the paper map and that suitable geo-reference points are clearly marked. In the production of a pan-European database at 1:250K, access to such information should be an overriding criteria in the selection of paper-based maps.

Derivation of catchment boundaries

The digital data-sets acquired did not contain any catchment boundaries. Therefore a suitable method of catchment derivation was sought. Two methods were tested: the automated derivation using a Digital Elevation Model (DEM) and manual digitising.

The automated method of catchment derivation is known as the "burning in" technique. A digital DEM is used in combination with a data-set of digital drainage network. The vector drainage network is converted to a grid and overlaid on the DEM. Grid values on the DEM that are coincidental with the drainage network grid are reduced by a set value e.g. 50m. This provides exaggerated valleys. The "burning in" of the drainage channels encourages neighbouring grid cells to flow into the known drainage network. The flow direction grid created afterwards can then be used as an input grid for hydrological functions in a GIS. These allow derivation of catchment boundaries. The method of manual digitising of catchment boundaries involves visual interpretation of contour lines. The catchment boundaries are derived from paper maps, drawn on transparencies and digitised.

Comparison of the two methods shows that the paper map method led to better results with an acceptable time input. The paper map method shows a high degree of user control. Concerning the structure of the drainage network and according to the catchment coding system which is to be applied, subcatchments can be identified and their boundaries derived. In the case of the DEM method, uncontrolled results can be caused by deviations between the terrain information of the DEM and of the vector drainage network. Further problems are caused by the shortcomings inherent in the DEM such as relative lack of vertical accuracy, particularly in flat areas.

Costs of a 1 : 250K European data-set

Based on the experiences in the two pilot study areas, an estimation of the costs for a pan-European 1 : 250K database is made. The estimate includes the cost of paper map acquisition (2.625 ECU/10000km^2), the cost of digital data acquisition (450 ECU/10000km^2), the time input for data processing (151.6h/10000km^2), the time input for digitising, if digital data not available (75h/10000km^2) and the cost per hour for GIS expert/technician (22.7 or 15.1ECU/h resp.). The estimate amounts to a total of 1,371,933 ECU for a pan-European digital 1 : 250K database.

The project could be completed by a team of ten GIS experts/cartographers and two technicians within a period of three and a half years. This estimate includes a six month period of identifying data sources.

Results

The following points summarise the experiences of compiling the Meuse and Miño pilot areas:

- Data acquisition is a significant time factor. Manual digitising is labour intensive for large areas. The actual financial cost can sometimes be compared with the upper range of the price of licensed digital data but it is the time input that makes it an unattractive option. Hence, it should be done only in limited areas and where national 1:250K digital data-sets are not available.
- Establishing firm contact and an understanding with data providers is very importantto assure that the building of the data base can be conducted without interruptions.
- Though data processing within the Miño catchment provided no major problems, some steps of work such as transformation of projections, correction of errors and insertion of additional attributes required significant manual input. In all cases, interactive corrections will be necessary. The use of paper maps as an additional information and for quality control purposes is essential.
- Commercially available maps for the French area of the Meuse were not suitable for digitising because water features are obscured by other features. This suggests that if it were necessary to manually digitise in certain areas of Europe, access to cartographers blue plates would be the preferred option. This would have unknown costs - both time and financial.
- Catchment boundary derivation remains a problem. Manual drafting and digitising from paper-maps led to acceptable results, but the sheer size of a pan-European 1:250K database demands an automated method. Further investigation using a higher resolution DEM is recommended.

Further work

Several questions risen during the compilation of the two pilot study areas could be subject to further investigations.

Is there a better catchment derivation method than the paper map method ? Another test of the DEM catchment derivation method should be made using a DEM of higher resolution and accuracy. A successful application of this method would result in substantial savings of processing time. Probably other problems would arise as DEM data-sets are more expensive as e. g. digital river networks. DEM data-sets also demand large amounts of disk storage place and processing power.

Is it possible to establish quality standards for catchment geographic 1:250K data ?. As a criterion for the level of generalisation of the digital 1:250K drainage network database, the drainage density of sample areas in the scale 1:25K could be determined and compared with the 1:250K drainage density. The benefit of this additional information could be twofold: 1) the user of the database would receive information about the quality of the different input data, and 2) ideally, a lower limit for the quotient of drainage density 1:250K (km/km^2) and drainage density 1:25 000 (km/km^2) could be established. Data at 1:250K with a lower value of the quotient would have to be excluded from use for the ERICA database.

Could existing pan-European databases be used for the ERICA project ? PETIT (Pathfinder towards the European Topographic Information Template) is a planned pan-European 1:250K topographic data-set, derived from VMap (a database produced by the US National Imagery and Mapping Agency). From this source, pan-European 1:250K digital topographical data, including some hydrographical features, could become available. After extension and completion (drainage basin boundaries will not be part of the data-set) this data could be used for the ERICA database. The ERICA 1:250K database could, in a first step, be created for one or several large European catchments (e. g. the Rhine and Loire catchments) and the investigation of the remaining questions carried out at the same time.

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Groundwater quality mapping in the Belgian and Dutch provinces of Limburg and Liège : availability of data and methodology

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Abstract

In the scope of an INTERREG project supported by the 'Stichting EUREGIO Maas-Rijn' in Maastricht, transboundary groundwater quality maps in the province of Liège, Dutch Limburg and Belgian Limburg have to be completed. It will be the end-product of investigations and work of three teams : LGIH University of Liège, LISEC Genk supported by the Ministry of the Flemish Region (AMINAL) and NITG-TNO Delft. The project was started in June 1997 and by now, first results in terms of availability of data and about the developed methodology can be described.

The four-step methodology comprises: (a) hydrogeological schematisation, (b) collecting existing groundwater quality data, (c) data quality control, and (d) additional sampling and analysis. Data are stored in databases and maps will be created using GIS.

Introduction

Large parts of the provinces Belgian Limburg, Netherlands Limburg and Liège (fig. 1) are located insite the hydrological basin of the River Meuse (Maas) so that large amounts of water from rainfall are channeled by the surface-water network or groundwater systems to the Meuse. There are no important natural boundaries between the three concerned provinces. The regional hydrological system - including surface water as well as groundwater - shows important transboundary aspects and groundwater quality in the main aquifers is undoubtedly one of them.

Data collection is intended to lead to the creation or improvement of databases to be used for groundwater quality maps. It is the intention to show general waterquality aspects of the main aquifers but also the possible anomalies in order to better understand the consequences of possible contaminations. The hydrochemical maps will be useful for decision makers as well as for public institutions and scientists.

Hydrogeological schematization

First of all, hydrogeological schematization and dressing of cross-sections (fig. 2) were constructed in the entire area to understand the continuity between the different geological layers and to correlate the different formation names.

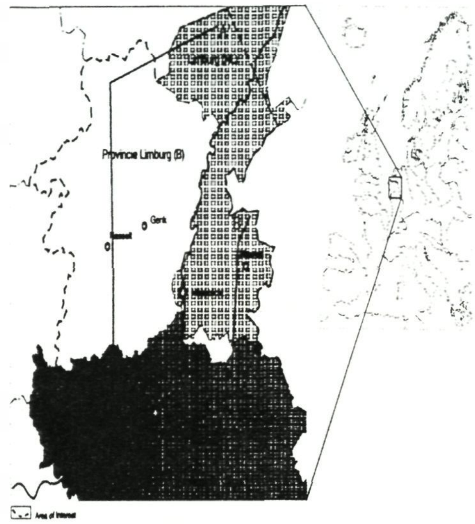
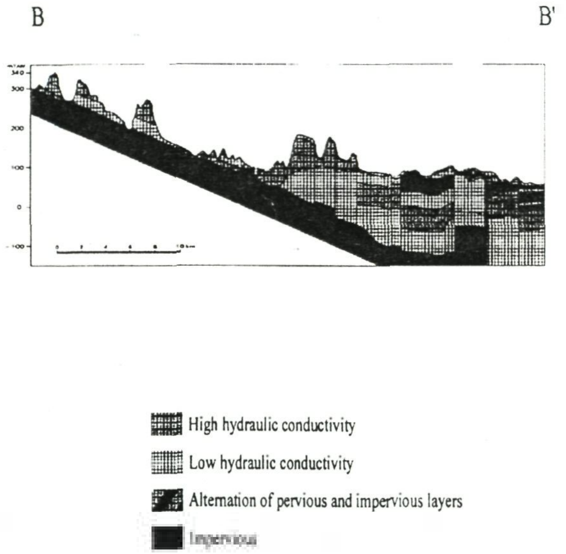


Fig. 1. Map of the study area and location of the hydrogeological cross-sections (AA' and BB')



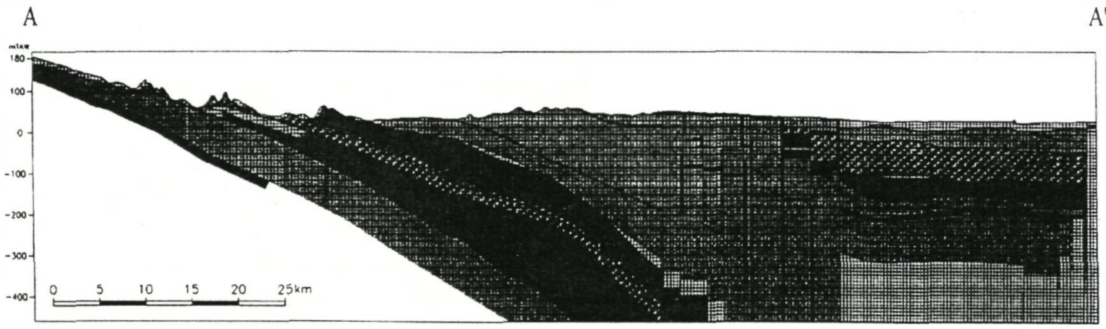


Fig. 2. Hydrogeological cross-sections AA' and BB' showing the main aquifers for which groundwater chemical data are collected.

In the area concerned, the main aquifers where continuous transboundary hydrochemical trends are expected are : (a) the chalky aquifers of the Cretaceous, (b) the sandy-silty formations of the Paleogene (Paleocene, Eocene and Oligocene) and Neogene (Miocene and Pliocene), (c) the Meuse alluvial sediments including all terraces of the Quaternary.

Collection of existing data

A second step is collecting existing groundwater quality data from different sources. Groundwater quality data are until now scattered between Ministries, public and research institutions, public and private water companies. In Belgium, the water policy is now under the mandate of the Regions (Flemish and Walloon Regions).

For the Province of Belgian Limburg, the main providers of data are AMINAL (Flemish administration for environment, nature and land-infrastructure), the VMW (Flemish company for drinking water supply) and the BGD (Belgian Geological Survey).

For the Province of Liège, the main providers of groundwater quality data are the two public water companies, the SWDE and the CILE. Data are also available at the Ministry of the Walloon Region. On the other hand, the LGIH possess some specific data in the Meuse alluvial sediments (chemical analysis carried out during pumping tests). Other data are also collected from private companies.

For the Province of Netherlands Limburg data are mainly provided by the RIVM (National Institute of Public Health and Environment), the Province of Netherlands Limburg, N.V. Waterleiding Maatschappij Limburg (Water Supply Company Limburg), N.V. Nutsbedrijven Maastricht (Water and energy supply of the city of Maastricht) and N.V. Waterleidingmaatschappij Oostelijk Brabant (Water Supply Company of east Brabant). Furthermore miscellaneous data are obtained from industries and various geohydrological studies, partly carried out by NITG-TNO. The list of considered chemical parameters will allow to obtain an idea about (Broers 1996): (a) the groundwater general characteristics (Cl^-, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}), (b) acidification (pH, Al^{3+}), (c) overfertilisation (K, PO_4, NO_3 and redox parameters Fe^{2+}, SO_4^{2-}, NO_3^-, O_2) and (d) other contaminations (Zn^{2+}, Cd^{2+}, AsO_n, ...).
Even if it is not the priority of the project, time variation in all these elements/parameters will be taken into account for helping to possible eventual trends in time, in relation with the groundwater flow pattern and anomalies.
For a reliable interpretation, additional data may be collected concerning local land use, soil type, surface water locations and characteristics, exact depth of the screens within the aquifer, etc.

Quality control of groundwater chemical data

A third step is data quality control. A data quality index is calculated, based on four controls that are currently being used in the groundwater database of NITG-TNO (Meer *et al.*, 1998):

(a) the cation/anion balance : a positive number means that either there are excess cations or insufficient anions in the analysis, whereas a negative balance indicates the opposite. A reasonable balance for routine analysis is generally considered to be less than 5%. So when the balance exceeds 10%, particular attention will be given to the reliability of the analysis. As mentioned by Deutsch (1997), several possible reasons, alone or combined, can cause an electrical imbalance in the reported data : (1) the design of the sampling program neglected a major dissolved species, (2) laboratory errors, (3) using unfiltered water samples that contain particles that that dissolve in the sample when acid is added for preservation purposes, (4) the precipitation of a mineral in the sample container, and (5) the dissolved species of the element or compound may not correspond to the typical species used in making the ion balance calculation.

(b) the comparison between calculated and measured electrical conductivity. When a difference higher than 20% is found, additionalchecks are needed.

(c) test on extreme values. If a measured concentration is far higher (i.e. three times higher) than the expected maximum for this species, additional checks are required.

(d) test on unrealistic combinations of elements. The unrealistic arrangement of elements are found out as for example : (1) unrealistic combinations of pH and CO_3/HCO_3 ratio ; (2) unrealistic combinations of pH and Mg + Ca ; (3) unrealistic combinations of pH and Al ; etc.

The data quality index is a four digit number giving respective information for each of the four above mentioned tests. This index is stored as a separate number and is used to select unreliable analysis data to exclude them from further evaluation.
Hydrochemical data taken from 'too old' wells or wells where different aquifer beds are not screened separately will be excluded as well.

Additional data

After collecting all available data, additional sampling and analysis will be performed during the years 1998-1999 in areas where the density of reliable data is unsatisfactory. A complete chemical analysis will be performed for each additional sampling point.
Collected data are stored in a database; the design of the databases used by each team should facilitate exchange of data. Maps of the data will be created using an Arc/Info GIS.

Expected results

The result of this INTERREG project will consist in the publication of an interpretative report together with 1/100000 thematic integrated maps of the groundwater quality in the different aquifers of these three provinces. The maps and reports will be available in July 2000 and will be 'public domain' documents. However, the access to the databases for consultation will be in reserved in principle to the providers/owners of the data. Other accesses will probably be strictly reglemented.

Acknowledgements
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References

Broers, H.P., 1996, Evaluatie van het meetnet grondwaterkwaliteit van de provincie Drenthe. TNO rapport GG R 96-79(A) unpublished.

Deutsch, W.J., 1997, Groundwater geochemistry, Fundamentals and applications to contamination, Lewis Publishers, 221 p.

Meer, van der M., Straaten, van der H. C., Hummelman, H. J., 1998, User manual OLGA 98 (Dutch version), part III Groundwater quality
(in preparation), Netherlands Institute of Applied Geoscience TNO - National Geological Survey

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Mesoscale hydrological modelling - Possibilities of validation

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Introduction

Escalating industrial, agricultural, and societal water demands make accurate forecasting and management of available water supplies increasingly imperative. Beside the simulation of the water balance components the goal of hydrological river basin modelling involves the identification of different flow components as a basis of the solute transport modelling. Usually, hydrological models are classified according to the description of the physical processes as either conceptual or physically based, and according to the spatial description of catchment processes as either lumped or distributed (e.g. Refsgaard, 1997). The application of fully distributed physically based hydrological models is constrained by the availability of required input data. An alternative is to use semi-distributed models with physically meaningful parameters (HBV-96: Lindström et al. 1997, SWIM: Krysanova et al. 1998, ARC/EGMO: Pfützner et al. 1997) for river basin modelling at different scales.
The present study using the ARC/EGMO model, which based on EGMO (Becker 1975, Becker and Pfützner 1987), illustrates problems in model validation resulting from the complexity of the model and the availability of data at various scales, especially for the mesoscale. Besides the usual method of comparing measured and simulated river discharge hardly exist possibilities of validation for mesoscale models. We have evaluated the range of validation methods in our research project "Landuse Impacts on the Water and Matter Dynamics of the Elbe River and its Drainage Basin" (Becker et al., 1998). The performed analyses emphasise the increasing demand for accurate and consistent data at various spatial and temporal scales to be used for parameterisation, calibration and validation of mesoscale river basin models.

Model description

The aim of mesoscale hydrological modelling is to describe all relevant hydrological processes at a scale of about 10^2-10^5 km² basically. No attempt is made to calculate the real conditions at any point (or field; 1-10^4 m²) such as moisture in different soil layers. The model ARC/EGMO is conceived as a tool box which contains different algorithms to describe the partial hydrological processes. This facilitates its application at different scales. The model components are divided into predominantly vertically or laterally directed processes (see Fig. 1). Concerning the vertical components, the different algorithms to describe the surface processes such as

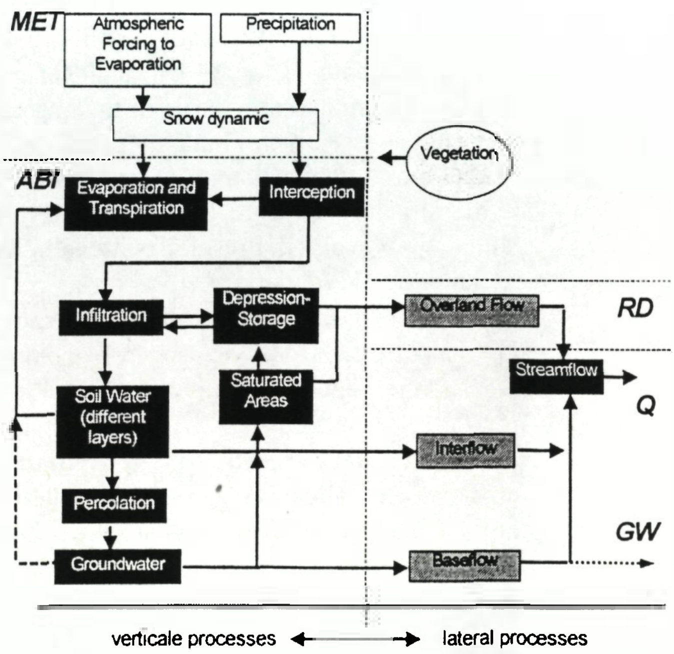

Figure 1: Modules of ARC/EGMO

evapotranspiration, snow dynamics, interception or infiltration mostly originate from different field scale models. This implies that they are developed and tested in the framework of vertical models without any relation to the influence of lateral effects. Multi storage concepts are used to describe the vertical water transport. Lateral components describe the surface, subsurface and ground water flow and the river routing with different levels of complexity depending on the chosen spatial resolution.

Input data requirements

The development of more sophisticated hydrological models has enlarged the data needs for these models. Shortcomings are obvious both for the spatial data (which often provide an insufficient resolution) and for the time series data needed to provide the necessary meteorological input and to validate the model results.

The spatial distribution of meteorological input variables plays a key role in hydrological modelling. Reliable results can be provided only if the density of meteorological stations is high enough. Since precipitation is the most important input variable, a high density network of precipitation stations is necessary to generate reliable interpolation patterns. The density of climate stations providing time series for temperature, humidity, sunshine duration etc. does not have to be so high, because the spatial heterogeneity of these input parameters generally is not as high as for precipitation. In order to include realistic distributions of these variables in the simulation calculations, an appropriate interpolation method must be used. The method used in ARC/EGMO (extended quadrant method) provides acceptable results if the dependence from elevation is taken into account (Lahmer et al. 1999).

The model parameters and their spatial distribution are deduced from the spatial input data (soil, landuse, groundwater level, topography, hydrogeological layer, ...). On the basis of these input data quasi-homogeneous areas with respect to their hydrological behaviour are defined in ARC/EGMO which represent the smallest modelling units. The shape and size of these elementary units can vary considerably depending on the spatial resolution and information variety of the input maps.

The subbasin division is done on the basis of a Digital Elevation Model and topographical maps according hydrological guide lines (LAWA, 1993). Depending on the modelling goal and the available digital river net, the simulations can be performed on the basis of all or only main rivers inside the basin.

An important problem in mesoscale hydrological modelling is the spatial difference between the above ground and the underground watersheds. Therefore information about the underground watersheds is used by ARC/EGMO and proved to be important for the quality of the model results.

Model test and validation

Model tests are generally performed by comparing the measured and the simulated river discharges because of the lack of other suitable regional quantitative data. One of the main criteria of model performance is the efficiency R^2 (Nash and Sutcliff, 1970). The suitability of this method and the problems related to initialisation, calibration and validation of distributed and semi-distributed models are summarised by Rosso (1994) and Refsgaard (1997). Usually, models have a lot of free parameters, but the calibration on the basis of the observed outflow at the basin outlet delivers only one parameter set from the ensemble of many possibilities.

Thus, we tried to check and compare the results of the different submodels of ARC/EGMO. Because of the structure of semi-distributed mesoscale models it is impossible to perform a single point validation of submodel results as it can be done for the validation of fully distributed models in small catchments. All validation efforts for mesoscale hydrological models except discharge comparison are only realistic in the framework of the fuzziness of the model and its input information.

For our investigations we use only commonly available data from the German Weather Service (DWD), the Federal Institute of Hydrology (BfG), the regional authorities and partly observations from other research institutes. Therefore, the developed methods can be transfered to other approaches of model validation. Within the restrictions imposed by these data we see the following possibilities for the model validation, especially in the form of submodel validation. The investigations were done for the Saale and the Havel basins, two main contributors of the Elbe river.

Snow model:
Snow is an important component of the hydrological cycle, but it is difficult to measure accurately because of spatial and temporal variations in the depth, density and cover of a snowpack, together with access problems (Archer, 1996). Intensive snow measurements like those done by Soulsby et al. (1997) in a little catchment do not exist for our river basin. Therefore, we need another way to check the quality of our snow model.
At the main climate stations of the DWD the snow depth and the snow water equivalent are measured. From these measurements the regional distribution of the water equivalent can be calculated in dependence from elevation (Rachner et al., 1997) and compared with the model results. In addition, the simulated snow water equivalent for the few elementary units containing a climate station is compared directly with the observed data of this particular climate station. The results will be presented.
Comparisons including statistics about snow days like the mean duration of snow cover in Germany (Rachner et al., 1997) represent a simple qualitative check of the model. A better way to check the spatial distribution of the modelled snowpack is the comparison with estimated snow cover based on remote sensing data (like done with NOAA-AVHRR scenes and the results from HBV-96, Lindström et al., 1997). An overview about the potential of remote sensing for snow observing is given by Archer et al. (1994). It seems that remote sensing data will become important for snow detection in the near future.

Evapotranspiration and soil water content:
The simulated evapotranspiration can be tested qualitatively by comparison with maps of longstanding mean values calculated by other procedures. The evapotranspiration amounts simulated with ARC/EGMO are in agreement with the long-term average rates in Thuringia as calculated by GEOFEM (Thüringer Ministerium für Landwirtschaft, Naturschutz und Umwelt, 1997).
Another way is the comparison of the water balance simulations with results of other model approaches, especially agricultural field models and forest models on the basis of identical input data. This is planned for 1999 for selected regions inside the Elbe basin and we will report on our first results.
Substantial research efforts to determine the usability of remote sensing data for detection of the evapotranspiration and the surface soil moisture was done in the last years (Famiglietti and Wood, 1995; Mauser et al., 1998 and others), but until now remote sensing provides only restricted possibilities for model validation on this field.

Vegetation:
Depending on the complexity of the involved vegetation model (specific crop/forest models, surface covering functions, etc.) there exist different ways for model testing. As an example, the crop growth module in SWIM – based on the EPIC approach – was regionally tested on the basis of statistical yield data in the state of Brandenburg (Krysanova et al., 1998). Until now, only a very simple vegetation approach is implemented in ARC/EGMO, its results cannot be compared to a real vegetation at elementary unit level.

Discharge:
For all river basins modelled with ARC/EGMO the simulated daily river discharge is compared with the observed outflow at the basin outlet and simultaneously at the outlets of representative subbasins. As an example, the following observed discharges were used for model validation:

- Saale (23.990 km²) basin outlet at gauging station Calbe (whole basin) and outlet from 18 subbasins of the Saale (180 – 4175 km²) partly nested such as Unstrut basin as a main contributor of the Saale at the gauging station Oldisleben (4175 km²) with its subbasins Nägelstedt (720 km²), Erfurt (843 km²) and Hachelbich (524 km²)
- Nuthe (1790 km²) basin outlet at gauging station Babelsberg (whole basin) and outlet from 6 subbasins of the Nuthe (139 – 738 km², partly nested)

The achieved efficiency R^2 ranges between 0,3 and 0,7. Problems appear in subbasins, which are strongly influenced by human activities, especially if there are big towns and/or water reservoirs. More detailed information has be to taken into account to describe these effects with hydrological models.

A supplementary model test is the comparison of the amount and the dynamic of the calculated flow components with the results of other model approaches like runoff component analysis with DIFGA (Schwarze et al., 1997) or other mesoscale models (HBV-96, SWIM). This comparison results in an acceptable agreement for the subbasins of the Saale river (Becker et al., 1997). As an example, the share of the different flow components in the Gera basin (gauging station Erfurt, 845 km^2) have been calculated with the models ARC/EGMO and HBV-96 for the period 1983-88. The calculated amounts taken as long-term average values are the same for the surface runoff (2%), the interflow (49 %) and the base flow (49 %).

Conclusions

The mesoscale hydrological model ARC/EGMO was applied to various subbasins of the Elbe river of different size and using different spatial resolution of input data. The dynamics of the simulated discharges show a sufficient correlation with the daily measurements for the majority of the considered river basins. The results demonstrate the usefulness of the developed GIS-based modelling concept and provide a better understanding on the spatial and temporal data necessary for a physically based hydrological modelling at different scales. Further improvements of ARC/EGMO are planned in form of implemention of more deterministic submodels such as one for vegetation description which need further effort in parametrisation and validation.

The separate validation of the particular components of mesoscale hydrological models is an efficient but very difficult methode to reduce the amount of free model parameters. This is on the one hand caused by the impossibility to measure some processes such as the evapotranspiration directly and, on the other hand, due to the problems in determining the real distribution of the observed variables. We could show that there exist some suitable validation possibilities based on commonly usable data. During the last decade there has been significant progress in the field of vegetation and soil surface detection by remote sensing. Problems come from discrepancies between temporal and spatial resolution of the scenes. We believe that the potential of remote sensing data justifies thorough investigation which we are about to start in the very near future.

References

Archer, D.R. (1996). Snow measurement. In: R. Herschy (ed.), Encyclopaedia of Hydrology

Archer, D.R., Bailey, Barrett, E.C, Greenhill, D. (1994). The potential of satellite remote sensing of snow over Great Britain in relation to cloud cover. Nord. Hydrol., 25, 39-52.

Becker, A. (1975). The integrated hydrological catchment model EGMO. Bratislava: Int. Symp. And Workshops Appl. Math. Models in Hydrology and Water Res. Syst. In: Hydrol. Sci. Bull. 21, 1.

Becker, A., Behrendt, H. (1998). Auswirkung der Landnutzung auf den Wasser- und Stoffhaushalt der Elbe und ihres Einzugsgebietes. BMBF Projekt, Zwischenbericht

Becker, A., Pfützner, B. (1987). EGMO-System Approach and Subroutines for River Basin Modeling. Acta Hydrophys., Berlin 31, 3/4, 125-141.

DVWK (1996). Ermittlung der Verdunstung von Land- und Wasserflächen. DVWK Merkblätter zur Wasserwirtschaft 238

Krysanova, V., Müller-Wohlfeil, D.-I., Becker, A. (1998). Development and test of a spatially distributed hydrological/water quality model for mesoscale watersheds. Ecological Modelling 106, 261-289

Lahmer, W., Klöcking, B., Pfützner, B. (1999). Meteorological Input Variables in Meso and Makroscale Hydrological Modelling. International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management', Koblenz, 22-26 March, 1999

LAWA (1993). Fließgewässer - Richtlinie für die Gebietsbezeichnung und die Verschlüsselung von Fließgewässern, LAWA-ad-hoc-Arbeitskreis "Verschlüsselung von Fließgewässern"

Lindstöm, G., Johansson, B., Persson, M., Gardelin, M., Bergstöm, S. (1997). Development and test of the distributed HBV-96 hydrological model. J. of Hydrology 201, 272-288

Mauser, W., Schädlich, S., Wege, C. (1997). Modelling the spatial distribution of evapotranspiration using remote sensing data and PROMET. J. of Hydrology (in press)

Nash, J.E.; Sutcliffe, J.V. (1970): River flow forecasting through conceptual models, 1. A discussion of principles. J. of Hydrology 10, 282-290

Pfützner, B., Lahmer, W. and Becker, A. (1997) ARC/EGMO – A program system for GIS-based hydrological modelling. Short documentation to version 2.0. Potsdam Institute for Climate Impact Research, unpubl.

Refsgaard, J.C. (1997). Parametrisation, calibration and validation of distributed hydrological models. J. of Hydrology 198, 69-97

Rosso, R. (1994). An introduction to spatially distributed modelling of basin response. In: Rosso, A., Becchi, I., Bemporad, G.A. (eds.), Advances in Distributed Hydrology, Water Resources Publications, 3-30

Schwarze, R., Dröge, W., Opherden, K. (1997). Regional analysis and modelling of groundwater runoff components from small catchments in solid rock areas. Landschaftsökologie und Umweltforschung 25, 259-262

Soulsby, C., Helliwell, R.C., Ferrier, R.C., Jenkins, A., Harriman, R. (1997). Seasonal snowpack influence on the hydrology of a subarctic catchment in Scotland. J. of Hydrology 192, 17-32.

Thüringer Ministerium für Landwirtschaft, Naturschutz und Umwelt (1997): Grundwasser in Thüringen – Bericht zur Menge und Beschaffenheit

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Spatial extrapolation of meteorological variables within Central Asia territory

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Introduction

Determination of precipitation sums P, mean values of air temperature T and absolute humidity H for the areas of river basins, continents and globe as a whole is one of the main stages in a system of analysis, modelling and forecast of hydrological cycle elements at the regional and global scales. For scientific and applied tasks it is necessary to have both long-term series of meteorological characteristics and their statistical parameters. It is known that the modern networks of point measurements of precipitation, air temperature and humidity have very uneven spatial density. Also there is a big difference in the duration of series.

Regions with complex topography and especially mountainous areas cover more than 20% of the continents and greatly influence the processes of atmosphere circulation and the water and energy cycle. Models with distributed parameters are necessary for estimation of spatial and temporal variability of precipitation, air temperature and humidity. The considered research is related to the plain and mountain Central Asian areas and covers the following issues.

- compilation and improvement of high quality data bank of mean values and long-term series of precipitation, air temperature and humidity;
- revealing and substantiation of the method for optimal extrapolation of the measured meteorological data to the grid points as well as method for extrapolation of T, P, H data in the arbitrary points along to altitude;
- validation, analysis and geographical presentation of the simulated long-term series of the meteorological variables.
- utilisation of the obtained results for modelling and forecasting of hydrological processes.

Initial data and methods

Precipitation, air temperature and humidity are the meteorological variables most commonly required for hydrological and ecological models. Regional models of the natural processes designed for wide utilisation, besides of using representative initial data, have to include also reliable methods of spatial extrapolation of meteorological variables in the coordinate system: t – time, φ – latitude, λ – longitude, z – altitude above sea level. The last variable is especially important in Central Asia conditions where are located highest mountain areas of the Earth.

It is possible to mark out two rather independent tasks in the problem of spatial extrapolation T, P, and H.

1. Elaboration of regional empiric dependencies $T=T(z,\varphi,\lambda)$, $P=P(z,\varphi,\lambda)$, $H=H(z,\varphi,\lambda)$ for climatic norms of precipitation, air temperature and humidity.

2. Creation of regional information data base and development system of extrapolation of long-term series *T*, *P*, and *H* measurements on basic network into arbitrary points of Central Asia territory.

The following initial data were used in this research to solve both tasks:

- Climatic norms of monthly sums of precipitation and monthly means of air temperature and humidity by data of 660 meteorological stations and posts located within Central Asia area in the ranges: altitude 0.60 – 4.2 km above sea level, latitude 35 – 45°N and longitude 67-81°E.
- Long-term series of ten day sums of precipitation and mean ten day values of air temperature and humidity at 22 basic meteorological stations during January-December mainly for 1935 -1995.

Solution of the first task is obtained by means of development and analysis of linear and nonlinear versions of multivariate equations: $T=T(z,\varphi,\lambda)$, $P=P(z,\varphi,\lambda)$, $H=H(z,\varphi,\lambda)$. Some results of this work are presented in the Tables 1-2.

Table 1. Coefficients of correlation of precipitation regional dependencies from z, φ, λ within Central Asia territory

Months	$P(z)$	$P(z \div z^2)$	$P(z \div z^3)$	$P(z \div z^4)$	$P(z,\varphi,\lambda)$	$P(z \div z^4,\varphi,\lambda)$
I	0.53	0.54	0.57	0.58	0.74	0.77
II	0.51	0.52	0.53	0.55	0.73	0.75
III	0.58	0.59	0.62	0.65	0.76	0.81
IV	0.62	0.63	0.67	0.70	0.76	0.82
V	0.65	0.73	0.82	0.85	0.72	0.86
VI	0.53	0.54	0.57	0.58	0.66	0.77
VII	0.30	0.51	0.59	0.59	0.60	0.76
VIII	0.28	0.48	0.55	0.55	0.57	0.72
IX	0.30	0.52	0.60	0.60	0.54	0.71
X	0.68	0.70	0.75	0.79	0.74	0.82
XI	0.57	0.58	0.60	0.63	0.70	0.75
XII	0.53	0.53	0.55	0.58	0.71	0.76

Table 2 Correlation coefficients of regional dependencies *H* and *T* from z,φ,λ within Central Asia territory

Months	$T(z)$	$T(z,z^2)$	$T(z,\varphi,l)$	$T(z \div z^2)$	$H(z)$	$H(z,z^2)$	$H(z,\varphi,\lambda)$	$H(z \div z^2,\varphi,\lambda)$
I	0.78	0.79	0.85	0.87	0.76	0.79	0.87	0.91
II	0.84	0.84	0.89	0.90	0.77	0.80	0.89	0.93
III	0.80	0.80	0.84	0.84	0.81	0.83	0.91	0.94
IV	0.95	0.95	0.98	0.98	0.82	0.84	0.87	0.90
V	0.96	0.96	0.98	0.98	0.85	0.87	0.88	0.91
VI	0.91	0.91	0.94	0.94	0.84	0.85	0.87	0.89
VII	0.95	0.95	0.98	0.98	0.75	0.76	0.83	0.85
VIII	0.94	0.95	0.97	0.98	0.71	0.72	0.80	0.81
IX	0.94	0.94	0.97	0.98	0.71	0.72	0.79	0.82
X	0.93	0.93	0.97	0.96	0.80	0.81	0.87	0.90
XI	0.82	0.84	0.91	0.94	0.87	0.88	0.94	0.95
XII	0.78	0.79	0.85	0.85	0.78	0.81	0.89	0.93

The following conclusions are based on the data presented in Tables 1-2.

1. Altitude is main argument of one-dimensional dependency of precipitation during of nine months from twelve ones within Central Asia area inside of 35 – 45°N and 67-81°E. Moreover the linear

relations turned out to be rather weak during of year, especially from July to September. Application of nonlinear approximation is noticeably enhanced the correlation relationship for $P(z)$ dependencies in majority of cases. Correlation coefficients of linear relations $P=P(z,\varphi,\lambda)$ is essentially better in January-December in comparison with $P(z)$. If in the three-dimensional approximation for P we will introduce z as nonlinear term we receive formula which is fully applicable for spatial and temporal extrapolation of precipitation climatic norms.

2. As it could be seen from Table 2, the simplest form has formula described spatial and temporal variability of air temperature climatic norms within Central Asia territory. The correlation coefficients of one-dimensional dependency $T=T(z)$ for seven months from twelve ones turned out to be rather high. Application for $T=T(z)$ one-dimensional non-linear formula didn't improve practically the quality of T computations in January-December. Including of latitude and longitude into formula for linear extrapolation of air temperature is enhanced correlation coefficients of the three-dimensional dependencies $T=T(z,\varphi,\lambda)$ for all months of year.

3. Application of linear variants of H spatial and temporal variability within Central Asia territory turned out to be similar to linear one-dimensional and three-dimensional approximations of air temperature distribution. However, the most acceptable for spatial extrapolation of humidity became formula $H=H(z,\varphi,\lambda)$.

To develop the scheme of temporal ranges $T=T(t,z,\varphi,\lambda)$, $P=P(t,z,\varphi,\lambda)$, $H=H(t,z,\varphi,\lambda)$ spatial extrapolation let us write formula for calculation some of these variables X in an arbitrary point X_2 by data in a basic point X_1:

$$X_2 = X_1 + [X_1 \cdot \{(X_2 - X_1)/X_1\}], \tag{1}$$

where term of the expression between figured brackets would be denoted as certain parameter

$$a = (X_2 - X_1)/X_1$$

Then possibility of computation or extrapolation $X_1 \rightarrow X_2$ depends from temporal variability of a. If $a \approx const$ we'll receive simple and rather reliable extrapolation procedure:

$$X_2 = X_1 + \bar{a} \cdot X_1,$$

where

$$\bar{a} = (\bar{X}_2 - \bar{X}_1)/\bar{X}_1.$$

To control hypothesis $a \approx const$ were used long-term series of precipitation, air temperature and humidity measurements at several meteorological points of Central Asia. This study is showed that $a \approx const$ assumption could be accepted undoubtedly for extrapolation of mean monthly values of air temperature and humidity between points located on different distances. The same hypothesis is valid also as the first approximation for precipitation spatial extrapolation, however application of the empirical dependencies $a=a(t)$ could improve the quality of results. It is expedient to use averaging of computed values on several basic points in order to make more reliable an extrapolation to arbitrary point $X(z,\varphi,\lambda)$, i.e.

$$x_i(t,z_0,\varphi_i,\lambda_i) = 1/N\sum_{j=1}^{N} x_{0j}(t,z_0,\varphi_{0j},\lambda_{0j}) + \bar{a}_{0j}(t) \cdot x_{0j}(t,z_o,\varphi_{0j},\lambda_{0j}), \tag{2}$$

where

$$\bar{a}_{0j}(t) = (\bar{x}_{0j}(t,z_0,\varphi_{0j},\lambda_{0j}) - \bar{x}_{0i}(t,z_0,\varphi_{0i},\lambda_{0i}))/\bar{x}_{0j}(t,z_0,\varphi_{0j},\lambda_{0j}). \tag{3}$$

In a mountainous area the considered procedure have to be added by linear and nonlinear formulae for computation of meteorological variables on the arbitrary altitude z . Solution of the outlined task is obtained on the example of Central Asia territory within 35-45°N and 66-81°E where the fields of T,

P, and H are presented by climatic norms computed in the nodes of regular grid. These grids are computed for all months of year and for several altitudinal levels. It is supposed that spatial variability of T, P, and H within each altitudinal level depends only from the geographical coordinates (latitude φ and longitude λ). The described presentation of T, P, and H fields allows to solve the following problems.

- Extrapolation of X element values from m basic meteorological stations $X_m(Z_{0m}, \varphi_{0m}, \lambda_{0m})$ to n arbitrary points $X_n(Z_{0n}, \varphi_{0n}, \lambda_{0n})$ within certain altitudinal level having constant elevation $Z_0=const$.
- Analytical approximation of the vertical profile of meteorological element X in the point with coordinates Z_0, φ, λ. For this procedure a set of $x(z_L, \varphi, \lambda)$ values in the nodes of regular grid is used. These ones are estimated by grids on L-altitudinal levels for each t-th month of year.

It should be noted that the indices i,j in formulae (2-3) are related to the numbers of points but not to the nodes of regular grid. In this connection it is necessary to calculate the terms $x_{0j}(t,z_0, \varphi_{0j}, \lambda_{0j})$, and $x_i(t,z_0, \varphi_i, \lambda_i)$ by means of data in the four of nearest grid nodes. Using methods of analytical geometry it is easy to determine distance till these nodes. Further knowing x values in the each node we may find terms $x_{0j}(t,z_0, \varphi_{0j}, \lambda_{0j})$, and $x_i(t,z_0, \varphi_i, \lambda_i)$ as mean weighted on distance to the four nearest nodes. Numerical experiments have shown that the described procedure is improved essentially the quality of extrapolation.

Estimation of the methods's quality and its application

Estimation of meteorological variables extrapolation quality was performed by comparison of measured and computed long-term series of T and P on seven meteorological stations located on elevations from 1.5 till 4.2 km above sea level. An analysis has shown that correspondence between measured and computed values of precipitation, humidity and air temperature for meteorological stations located within broad range of altitudes and geographical conditions could be considered as rather satisfactory.

The method described here is used for computations hydrological regime and annual mass balance of Pamir-Alai glaciers. Area of contemporary glaciers of this mountain region estimates as 14 800 km^2 and its volume as 700 km^3 . Here are located the upper watersheds of largest Central Asian rivers: Amudarya, Vakhsh, Pyandge, Zeravshan, left-side tributaries of Syrdarya river where is formed about 70% of total runoff volume in the Aral Sea basin. Computed long-term series of glaciers runoff values were used to elaborate the forecasting methods of seasonal runoff of Vakhsh and Zeravshan rivers, which have adopted for utilization in Hydrometcenters of Uzbekistan and Tadjikistan.

Once more example of the method efficient application is possibility to compute mean values of precipitation or air temperature for whole area of river basin or any other part within 35-45^{0}N and 66-81^{0}E. It is found out that spatial representativity of these values much more higher than data in separate points. For example, values of air temperature averaged for whole river basins or their parts are revealed as most informative variables to forecast until 2000 year the annual runoff of Vakhsh, Pyandge and Chirchik rivers.

Conclusion

A universal methodic of spatial and temporal extrapolation of monthly precipitation sums and mean monthly air temperature has been developed for the Central Asia territory in the ranges of 35-45^{0}N and 66-81^{0}E. The method is part of a model with distributed parameters used for determination of hydrological regime and mass balance of glaciers aggregations and groups of them in the river basins of Central Asia. Quality estimates of the method has shown quite satisfactory convergence of the computed and actual air temperature and precipitation sums at meteorological stations and fulfilling the condition of balance between the layers of solid precipitation and their melting on glacierssurface at the altitudes lower than maximum elevation of snow line.

For practical extrapolation T, P and H are prepared long-term series of ten days precipitation and mean ten days values of air temperature and humidity on 22 basic meteorological stations of Central Asia.

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Comparison of data requirements and performance of two semi-distributed hydrological models of different complexity

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Introduction

Hydrological models are classified as physically based or conceptual ones, and the physical soundness of the model is usually related to the extent to which the flows of mass and energy are represented by the basic mathematical equations. Regarding the spatial description of processes, the models are either lumped, or distributed. The physically based approaches tend to be distributed in space, while the conceptual models are usually lumped. Besides the two "pure" model classes, there are a large number of intermediate tools, which can be related to the semi-distributed class of models. They usually combine the physically interpretable parameters and equations with the empirical ones, and their data requirements are lower than that of physically based approaches.

The level of model complexity, spatial disaggregation, data requirements, and scale of application are interconnected. The physical soundness of the hydrological models is critically reviewed in recent literature (Beven, 1989 & 1996; Refsgaard *et al.*, 1996). More complex models have a tendency of overparametrization, and their transferability to other regions is restricted. Besides, the performance of simpler models in some cases is better than that of complex models. This is especially true for larger scale applications (> 1000 km^2). Therefore it is suggested (Beven, 1996) to move "towards simpler, more robust, and more easily calibrated representations of distributed hydrology rather than introducing ever more complexity and ever more parameters to be defined".

In this paper two models: SWIM and HBV, which belong to a class of semi-distributed models, but have different levels of complexity, are analysed regarding their data requirements, hydrological performance and reliability for different applications.

Models

SWIM (Soil and Water Integrated Model, Krysanova *et al.*, 1996) is a continuous-time semi-distributed model, simulating hydrological processes, vegetation, erosion and nutrient dynamics (nitrogen, N and phosphorus, P) at the river basin scale. A three-level scheme of areal disaggregation "basin - subbasins - hydrotopes" plus vertical subdivision of the root zone into a maximum of 10 layers derived from a soil data base are used. A hydrotope (or Hydrologic Response Unit, HRU) is defined as a set of elementary units within the subbasin, having a unique land use and soil type. SWIM has an interface to the GRASS GIS, which was modified from the SWAT/GRASS interface (Srinivasan *et al.*, 1993). The interface is used to initialise the model by extracting spatially distributed parameters of elevation, land use, soil, climate, and the routing structure.

The simulated hydrological system consists of four control volumes: the soil surface, the root zone, the shallow aquifer, and the deep aquifer. The water balance for the soil column includes precipitation, evapotranspiration, percolation, surface and subsurface runoff. The percolation from the soil profile is assumed to recharge the shallow aquifer. The water balance for the shallow aquifer includes ground water recharge, capillary rise to the soil profile, lateral flow, and percolation to the deep aquifer.

Return flow from the shallow aquifer contributes to the streamflow. Regarding the nutrient flows, runoff with surface and subsurface flows is more important for nitrogen, while phosphorus is transported mainly with erosion.

The conceptual semi-distributed hydrological model HBV (Bergström, 1992; Lindström et al., 1997) was developed at the Swedish Meteorological and Hydrological Institute for runoff simulation and hydrological forecasting. We use a new UNIX-based version of the model, HBV-D (Krysanova et al., 1998). This model enables the basin to be discretized into subbasins, then every subbasin can be subdivided into 10 elevation zones, and every elevation zone can be further subdivided into 2 vegetation zones. In addition, a lake area can be indicated for the elevation zones. The input climate data are first averaged for every subbasin, and then the altitude-correction factors are used to estimate the temperature and precipitation for every elevation zone.

HBV-D consists of three main components: 1) snow accumulation and melt, 2) soil moisture accounting, and 3) response and river routing. The number of parameters to be adapted to the site conditions is kept small: 2 parameters for the snow routine, 3 parameters for the soil moisture, and 5 parameters for the runoff response. The potential evapotranspiration can either be given as monthly values, and then corrected for altitude, or calculated using a simple temperature index method. The actual evapotranspiration is calculated, taking into account soil water storage. Lakes are assumed to evaporate at potential rate, and the net lake precipitation and a part of the catchment runoff are routed through the lake.

Data requirements

Input data requirements of the both models are summarized in Table 1. All maps can be provided in ARC/INFO or GRASS format. The first three maps are necessary for SWIM to run the SWIM/GRASS interface and to initialize the model. They can be also used to initialize HBV-D. The fourth, subbasin map, can be created in GRASS using the ***r.watershed*** program. The river network map is necessary for comparison with the streams derived from the DEM and for checking the routing structure. In addition, maps of climate stations and river gages are needed.

The problem of fundamental significance for hydrological and water quality modelling is how to choose an adequate spatial resolution for a basin. First of all, the spatial resolution and the time increment of the model are interrelated. SWIM is not designed for detailed modelling of flood processes with $\Delta t < 1$ day, while HBV-D can be used for that. Also, we exclude very flat areas with many lakes, where travelling time becomes too large. These problems require specific modelling tools. With these exceptions, the problem of spatial resolution appears in at least three questions: 1) how is the resolution of the Digital Elevation Model (DEM) related to the basin area, if we need to delineate the watershed boundaries, 2) in what ways may the resolution of the DEM influence model results, and 3) should there be any restriction on the average subbasin area?

Answering the first question, on DEM resolution and the subdivision of the basin area, we suggest to use the "thousand-million" rule from Maidment (1996): take the area of the region under study and divide it by one million to give the appropriate cell size to be used, then multiply the cell size chosen by one thousand which is then the minimum drainage area of watersheds that should be delineated from this DEM. For example, a 460 m resolution should be used for delineation of a watershed with the drainage area of 1000 km^2, 90 m for a 40 km^2 watershed, and 30 m for a 5 km^2 catchment. This is in agreement with our modelling experience from the studies performed in the Elbe drainage basin, where 100 m resolution was acceptable to represent a catchment of 64 km^2, 200 m resolution was sufficient to delineate a watershed with an area of 535 km^2, and 1000 m resolution was satisfactory for extracting 3,000-4,000 km^2 basins.

Table 1. Input data requirements of SWIM and HBV-D models (⊕ - is needed)

Input data	*SWIM*	*HBV-D*
GIS data		
Digital Elevation Model	⊕, resolution is important	⊕, resolution is less important
Land Use	⊕, resolution is important	⊕, resolution is less important
Soil	⊕, resolution is important	⊕, resolution is less important
Subbasin boundaries	⊕	⊕
River network	⊕	⊕
Climate and other relational data		
Temperature	⊕, average, max and min daily	⊕, average daily
Precipitation	⊕, as many stations as possible	⊕, as many stations as possible
Solar radiation	⊕	
River discharge	⊕	
River cross-sections	⊕, at least in several gages	
Water quality measurements	⊕	
Crop management data	⊕	
Soil parameters		
Clay, silt, sand content, %	⊕	
Bulk density, g/cm^3	⊕	
Porosity, Vol. %	⊕	
Available water capacity, Vol. %	⊕	
Field capacity, %	⊕	⊕
Organic Carbon content, %	⊕	
Organic Nitrogen content, %	⊕	
Saturated conductivity, mm/hr	⊕ (or can be estimated)	

Answering the second question, on the influence of DEM resolution on model results, is more difficult. It requires special scaling experiments with the models. From our experience we conclude that the spatial resolution is more important for SWIM, as soon as a number of model parameters, like subbasin area, average slope length and slope steepness for subbasins, channel length, width and depth are derived directly from the DEM. Some of these parameters are sensitive to the DEM resolution (like the slope steepness), and this can affect the modelling results. On the other hand, the spatial resolution is less important for HBV-D: it is needed only to correctly derive the elevation zones.

The third question, about the restriction on the average subbasin area, is important for SWIM, because the routing starts from the subbasin outlets. Therefore, it is important to delineate subbasins in such a way that the effect of the river network can be neglected within the subbasin. According to Beven and Kirkby (1979), the effect of the channel network becomes important for basins larger than about 10 km^2, where the time constant of the network (i.e. travel time through it) becomes as long as for the infiltration phase. Hence the following pragmatic conclusion might be drawn: an average subbasin area, where the effect of the river network may be neglected, should be in a range of 10 to 100 km^2.

Besides the GIS and climate data, soil parameters are important to initialize SWIM. They are needed for several soil layers. The model is most sensitive to the saturated conductivity and the soil depth. In case the saturated conductivity is not available, it can be estimated internally as dependent on soil texture, bulk density and organic carbon content. The soil depth can be related to the rooting depth. HBV-D requires only one soil parameter - the field capacity (to initialize FC - the calibration parameter in HBV-D). Uncertainties in both relational and spatial data can lead to difficulties and problems in model validation.

Comparison of the model performance

The performance of the two models as hydrological tools can be compared based on the applications in the Stepenitz and the Mulde basins (see e.g. Krysanova et al., 1997 & 1998). Summarising our experience, we have to admit that it is easier to prepare input data and to get satisfactory results in terms of river runoff using HBV-D than SWIM, especially for larger basins. Hence we would recommend to use this tool for modelling river discharge and runoff components, especially in the data poor situation. The latter one is more complex and more demanding model. On the other hand, due to its complexity and more meaningful parametrization, SWIM can also predict more reasonable internal hydrological state variables (like soil moisture dynamics, evapotranspiration, etc.) than HBV-D. Although the validation for the internal state variables is not easy and requires additional data, which are usually difficult to obtain, this is generally an advantage of SWIM model.

Besides, the simplified conceptual models like HBV-D can hardly be linked to the processes of nutrient dynamics and vegetation growth, as the soil processes are underrepresented there. On the hand, SWIM already includes the vegetation and nutrient submodels. The sensitivity of both SWIM and HBV to land use change has to be studied in smaller catchments with homogeneous land use or using the real data of land use change and its impact on hydrology. For this, the land cover representation in HBV should be improved to allow more than 2 dominating types of land cover to be included. Furthermore, it is not clear whether and to what extent the direct impact of land cover conditions on runoff generation processes, e.g. infiltration capacity of the soil surface or roughness and storage effects by vegetation types and/or specific agriculture practices can be represented by the current model approaches.

References

Bergström, S. (1992) The HBV Model - its structure and applications. *SMHI RH* no. **4**, Norrköping.

Beven, K.J. (1989) Changing ideas in hydrology: the case of physically-based models. *J. Hydrol.*, **105**, 157-172.

Beven, K.J. (1996) A discussion of distributed hydrological modelling. In: Abbott, M.B. & Refsgaard, J.C. (eds.) *Distributed Hydrological Modelling*, Ch. 13, Kluwer Academic Publishers.

Beven, K.J. & Kirkby, M.J., 1979. A physically based, variable contributing area model of basin hydrology. *Hydrological Sciences Bulletin*, **24** (1,3): 43-69.

Krysanova, V., D.-I. Mueller-Wohlfeil D.I. & Becker A. (1998) Development and test of a spatially distributed hydrological / water quality model for mesoscale watersheds,*Ecological Modelling*. **106**, 2-3, 261-289.

Krysanova, V., D.-I. Mueller-Wohlfeil, A. Bronstert and J. Fleckenstein (1998) Modelling runoff dynamics of the Elbe drainage basin: an application of the HBV model. *Hydrology in a Changing Environment*, Vol. 1. Global hydrological processes, Ecological and Hydrological Interactions, John Wiley & Son.

Lindström, G., Johansson, B., Persson, M., Gardelin, M. & Bergström, S. (1997) Development and test of the distributed HBV-96 hydrological model, *J. Hydrol.*, **201**, 272-288.

Maidment, D.R., 1996. GIS and Hydrologic Modeling - an Assessment of Progress. In: *Proceedings of the Third Int.l Conf. on Integrating GIS and Env. Modelling*, CD-ROM. Publisher: Santa Barbara, CA: National Center for Geographical Information and Analysis.

Refsgaard, J.C. & Knudsen, J. (1996) Operational validation and intercomparison of different types of hydrological models. *Water Resources Research* **32**, no. 7, 2189-2202.

Srinivasan, R., & Arnold, J.G., 1993. Basin scale water quality modelling using GIS. Proceedings, *Applications of Advanced Inform. Technologies for Manag. of Nat. Res.*, June 17-19, Spokane, WA, USA, 475-484.

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Meteorological Input Variables in Meso and Macroscale Hydrological Modelling

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Abstract The water balance components calculated for meso and macroscale river basins depend strongly on the spatial distribution of meteorological input variables. Studies performed in the Elbe basin and some of its sub-basins demonstrate that the spatial interpolation of climatic input variables plays a key role in large scale hydrological modelling. The present study illustrates problems resulting from the availability and accuracy of meteorological data. The performed analyses emphasize an increasing demand for accurate and consistent data at various spatial and temporal scales, which can be used to study the impacts of climate and land-use changes on the hydrological cycle.

Key words: Hydrological modelling at different scales, spatial interpolation of meteorological input variables, water balance calculations

Introduction

The study of human impacts on the hydrological cycle plays a growing role in today's hydrological research. In order to forecast the effects of climate and/or landuse changes, appropriate models and high resolution data at various spatial and temporal scales are necessary. The availability of high resolution hydrometeorological data is especially important, since only by a sufficient density of such data all necessary input parameters can be appropriately taken into account in the simulation calculations. The present study illustrates problems resulting from the availability and accuracy of such data and their spatial interpolation on various scales, which are important in the modelling of large scale river basins.

The modelling approach

The large scale application of fully distributed physically based hydrological models is constrained by the availability of required input data. In addition, their use in prediction at the regional level is often of limited value. Therefore, simplified (conceptional) models with physically meaningful parameters are needed which can be applied at different scales. Such models must be able to use directly the information provided by digital maps and to handle different temporal and spatial discretization levels. The modelling approach used in the present study is based on variable spatial disaggregation and aggregation techniques and consequently uses the GIS-based derivation of model parameters from generally available spatial data. A key element of the approach is the modelling system ARC/EGMO (Pfützner et al. 1997). Basis for all simulation calculations is the so called 'elementary unit map', generated by a Geographic Information System from all necessary digital maps. This map consists of 'elementary units' (EU's), which represent the smallest modelling units and can be considered homogeneous with respect to their hydrological behaviour. Their shape and size can vary considerably, which is especially important in simulating land-use changes, as such changes may be restricted to rather small and widely distributed parts of the study region. Simulation runs can be performed on the level of EU's or on spatially aggregated areal units like hydrotopes, hydrotope classes, sub-basins, or the basin as a whole. Applications in several mesoscale river basins in the northern part of Germany (Lahmer et al. 1997, Becker and Lahmer 1997) and in the whole German part of the Elbe river basin (Lahmer 1997) demonstrate that the disaggregation of a study region into such subareas represents an effective modelling approach.

Spatial interpolation of meteorological data

Data requirements

Driven by the above mentioned scientific goals the development of hydrological models has enlarged their data needs. Shortcomings are still obvious both for spatial data (which often provide an insufficient resolution) and for time series data needed to provide the necessary meteorological input and to validate the model results. The analyses presented here are based on daily time series and, in general, include all meteorological stations available in the study region. However, due to missing values or too short measuring periods, many stations had to be excluded from the simulation calculations. In addition, the calculation of potential evaporation according to more sophisticated approaches normally was not possible, since there is only a small number of climate stations providing all specific parameters for a longer period.

The interpolation method

Due to its high influence on the calculated water balance components, the spatial distribution of meteorological input variables plays a key role in hydrological modelling. In order to include realistic distributions of these variables in the simulation calculations, an appropriate interpolation method must be used. Since the interpolation is performed for every time step of the simulation period, the method must be fast, excluding too sophisticated and time consuming methods. The interpolation algorithm used in ARC/EGMO is characterized by i) the selection of stations by the quadrant method (see Fig. 1), ii) a linear inverse distance interpolation of the respective variables, and iii) the inclusion of other dependencies (elevation, exposition or slope) based on mean annual values. This method has turned out to be the most effective approach for large scale modelling, producing rather realistic spatial distributions of all meteorological input variables. The result of such an interpolation is shown in Fig. 2 for the case of the climatic water balance in the Elbe basin (~96.500 km²). The daily interpolation patterns calculated on the basis of EU's are aggregated to annual means for the period 1983 - 1987. For the spatial interpolation of the meteorological variables 33 climate and 107 precipitation stations were used.

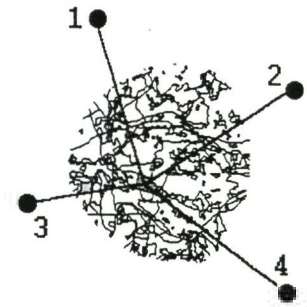

Fig. 1: Schematic representation of the interpolation method used in the simulation calculations.

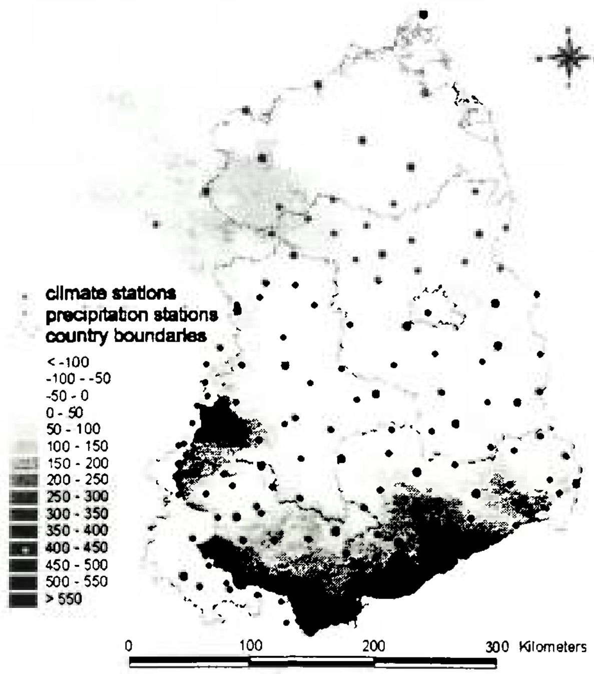

Fig. 2: Spatial distribution of the climatic water balance in the Elbe river basin for the period 1983-1987 (mean annual values calculated on the basis of elementary units).

Reliability of simulation results as function of the meteorological input data

The quality of calculated water balance terms like evaporation, percolation or surface runoff formation depends both on the basic spatial maps and on the meteorological input. In the meso and macroscale hydrological studies performed so far, particular focus was on the analysis of influences of the meteorological input on the model results. These influences may be due to i) lacks in the time series for various input parameters, ii) uncertainties of measured parameters, and iii) a too low station density. In general, for hydrological calculations the hydrometeorological time series data should be available for a period of at least some years. This is especially true for climate impact studies where time periods of 50 to 100 years are studied and the conditions of the present state must be simulated as reliably as possible.

Completion of time series

In order to include as much information as possible in the simulation calculations, also time series were used which do not provide the necessary parameters for the whole simulation period. The missing values were interpolated from those of neighbouring stations by the interpolation method described above. An example for this kind of data completion is shown in Fig. 3 for the case of the Stepenitz river basin (~575 km²). For one of the 24 precipitation stations used in the simulation runs data for two months (March/April 85) were replaced by "missing data". These data were then interpolated from those of the neighbouring stations. Though the method turns out to work rather well, of course local precipitation events cannot be reconstructed.

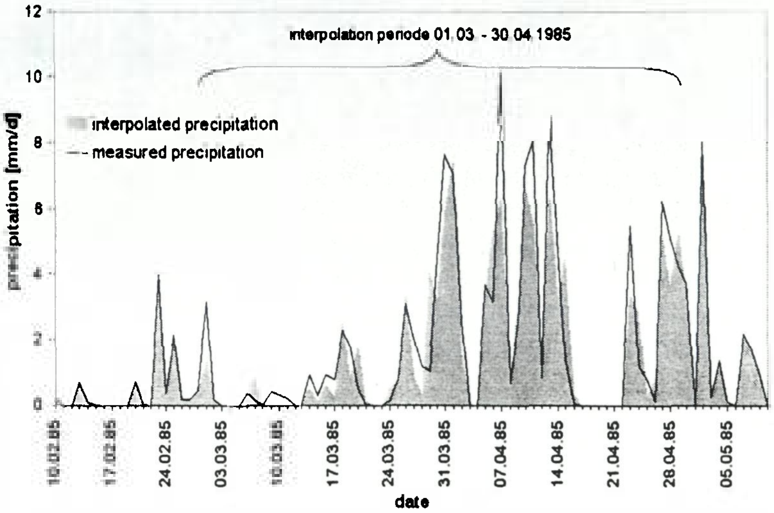

Fig. 3: Example for the completion of time series: Missing data for one of the used precipitation stations in the Stepenitz river basin are interpolated from those of the neighbouring stations. The agreement between measured (line) and interpolated values (shaded) demonstrates the quality of the used method.

Propagation of uncertainties

Among the various meteorological input data precipitation is, in general, characterized by the largest uncertainties. In order to demonstrate the uncertainty propagation in the model results, simulation runs were performed assuming a general error of 12% in precipitation. In Fig. 4 the effects on various water balance terms are demonstrated for the Stepenitz river basin.

Station density

Meso and macroscale hydrological modelling can provide reliable results only if the spatial and temporal resolution of meteorological information is high enough to represent the meteorological heterogeneities of the basin. As shown for the German part of the Elbe basin, the reliability of calculated water balance terms depends strongly on the station density (Lahmer 1997). The number of meteorological stations to be included in the simulation runs depends on i) the size of the basin, ii) the basin characteristics (topography, meteorological heterogeneity), and iii) the specific needs of the used interpolation method. For flatland regions like the Upper Stör basin (~1.100 km²) a rather small number of stations is sufficient to achieve reliable results (Lahmer et al. 1997). On the other hand, a higher station density is necessary in mountainous regions, where the meteorological heterogeneity is much larger.

In general, the number of precipitation stations should be rather high to generate realistic interpolation patterns. Since the number of climate stations providing information for temperature, relative humidity, radiation, sunshine duration etc. is generally much lower, additional information like the station height should be included to derive realistic spatial distributions. This was done, for example, in the Unstrut basin (~4.200 km²) characterized by an elevation difference of about 800 m, where only 5 climate stations were available. The effects of station density in the Elbe basin can be seen in Fig. 2, where the spatial resolution of the climatic water balance is rather good for most of the basin. The resolution is rather low, however, for the north-western part, where almost no meteorological data were available.

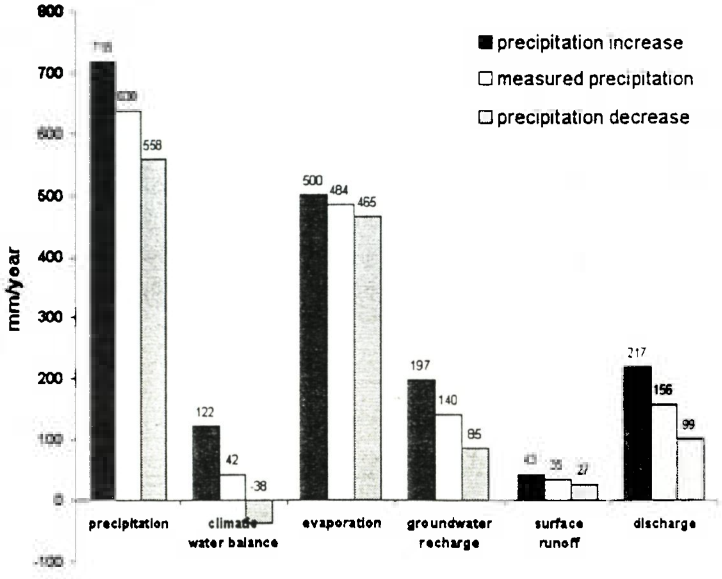

Fig. 4: Influence of precipitation uncertainties on various water balance terms in the Stepenitz river basin: Mean annual values (time period 1989-1993) assuming a precipitation increase or decrease of 12% as compared to the measured precipitation amounts.

Conclusions

The results obtained in the Elbe river basin and some of its sub-basins provide a better understanding on the spatial and temporal data necessary for a physically based hydrological modelling at different scales. The spatial distribution of climatic input variables has proven to be a key issue in hydrological modelling at these scales. Nevertheless, there is a growing need for a higher density of meteorological stations which is generally too low for large scale studies. This is especially true for the number of climate stations providing long-term data of at least a few decades, because these data represent the basis for the development of climate change scenarios. Therefore, this study strongly supports any effort to establish international co-operation towards the acquisition of reliable and high quality data to face today's challenges of hydrology, like climate impact research and sustainable development studies.

References

Becker, A. and Lahmer, W. (1997) Large Scale Hydrological Modelling. Final report within the research program "Regionalization in Hydrology" of the German Research Society (DFG) (in German, unpubl.)

Lahmer, W., Müller-Wohlfeil, D.-I., Pfützner, B., Becker, A. (1997) GIS-based Hydrological Modelling with the Integrated Modelling System ARC/EGMO. International Conference on Regionalization in Hydrology, Braunschweig, FRG, March 10-14, 1997. Accepted for IAHS publication

Lahmer, W. (1997) Modelling of Water Balance Components in the German Part of the Elbe River Basin using large Scale Aggregation Principles. Report to the Potsdam Institut for Climate Impact Research, October 1997 (in German, unpubl.)

Pfützner, B., Lahmer, W. and Becker, A. (1997) ARC/EGMO – A program system for GIS-based hydrological modelling. Short documentation to version 2.0. Potsdam Institute for Climate Impact Research (in German, unpubl.)

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Saline-fresh water interface identification: Data requirements and accuracies for ground water development strategies in coastal delta complexes in India

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Background

Coastal ground water systems in the Indian sub-continent constitute, a very important resource for drinking, irrigation, agriculture and industrial sectors of the country and play a vital role in the growth and development of the rural base. These coastal systems are interfaced with oceanic basins on one side and upland regions with major river valley projects on the other end and become targets for subsurface hydrodynamic and hydrochemical changes on either side causing saline water ingression inland into the fresh water systems. Physico-chemical processes accompanying such ingression, aquifer reservoir charactreristics and paleohydrogeological processes in different sub-systems of the deltas are the major elements required to be studied and quantified. These would help to develop appropriate optimization schemes, models with predictive capabilities on physico-chemical changes, their space, time variations and protective measures for sustained development of fresh ground water resources.

Over the last two decades or so the fresh ground water resources in coastal deltas have been subjected to large scale stresses in the form of ground water withdrawal, resulting in reduction of water levels and fresh water storage potentials causing saline water ingression processes inland into fresh water systems. This situation is being further threatened by global warming processes and possible sea level rise events in future which may further deteriorate the situation. It is therefore vitally necessary to obtain the first hand information on the existing fresh ground water systems, their areal spread and boundary conditions and their inter-relationship with adjoining saline water bodies. These are site specific problems and are required to be studied basin wise all along the coast in different deltas and interdelta regions.

Data requirements and problems

The most important problem in the Indian coastal delta system is identification of interface/diffusion boundaries. Fresh/saline water interface boundary is a complex and dynamic phenomenon and could occur in a variety of combinations and shapes such as : (i) fresh water aquifers either overlying or underlying saline water aquifers (ii) fresh water aquifers sandwitched between two saline water aquifers or vice versa (iii) alternate system of fresh and saline aquifers and (iv) fresh water aquifers wedging towards the coast or saline water aquifers wedging towards the continent. All these complex combinations of saline/fresh water aquifers make the well field development strategies rather difficult and demands very accurate data structure and analyses in relation to : (a) thicknesses of fresh/saline aquifers and their interface boundary. (b) Nature of interface or diffusion boundary (c) estimations of wedging of saline/fresh water aquifer and their geometrical variations (d) estimations of depth levels for concrete plugging in the gravel packs to avoid vertical saline water inflows and mixing and (e) designing appropriate monitoring observational network particularly near the wedge shaped aquiclude boundaries where fresh and saline water systems come into juxta positions and (f) assessment of possible vertical leakages through aquitards from fresh aquifers to saline aquifers and vice versa. All the above described porblems call for precise estimations of subsurface hydrogeological boundaries and interestitial water quality characteristics as precisely as possible. Though several techniques are available like surface geophysics, remote sending, hydrogeological and hydrogeochemical and packer tests, none of these methods help us to accurately quantify the depth levels of interface/difusion boundaries, interestitial water qualities and wedging of aquifers and aquicludes. A reasonably powerful tool for estimation of interface/diffusion boundaries and water quality characteristics in multi aquifer systems of coastal deltas is borehole geophysical techniques.(Pal H.Jones ,1957).

Methodology development

In most developing countries spontaneous potential and electric resistivity logs are being widely used to delineate bed boundaries, lithological correlations and to define saline-fresh water interface boundaries which will ultimately assist in the appropriate well field development strategies. Very limited efforts so far have been made to quantify the water quality parameters zone wise. A method has been developed in the following paragraphs to demonstrate the efficacy of self-potential logs towards this goal. The Sp log potential response in an electrical log profile in general is affected by several factors like borehole diameter, bed thickness, shalyness of the formation, quality of the formation water, mud filtrate invasion and temperature. The electrochemical potential generated in such logs is given by the following formula :

$$Sp = -k \log R_{mf}/R_w \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where :

Sp = log deflection (mV) against a zone ;
k = a factor generally taken to be equal to 70, but deviates marginally with temperature ; $60 + 0.133T$
where T = borehole temperature (^{o}F) ;
R_{mf} = Resistivity of mud filtrate(Ωm^{-1});
R_w = Resistivity of formation water((Ωm^{-1})

The above equation is essentially based on the following assumptions : (i) both the borehole fluid and formation waters are sodium chloride solutions; (ii) the shale formations are ideal ion selective membranes and the sand formations have no ion sieving properties;
(iii) the borehole fluid has a much greater resistivity than the combined resistivity of the sand and shale (Keys and McCary, 1971) . The above relationship is used effectively in the oil industry to estimate R_w (resistivity of water) through Sp logs since NaCl is the dominant salt in solution and the interrelationships between concentration, activity and resistivity are well established. This can't be applied directly in the water industry because the medium generally is not dominated by NaCl waters. To avoid this constraint the following method is adopted to evaluate and quantify the water quality parameters for unknown zones at depths through Sp-curves.

(1) A number of sites are selected for which water analyses and electrical log data are available. A linear relationship between R_w and Total dissolved solids (TDS) for the ground water system under consideration is obtained.
(2) The R_w - R_{we} interrelationship for NaCl waters and $NaHCo_3$ waters are plotted on double log scale and the factor of deviation is obtained.

(3) Based on analytical results selected for a set of samples, scatter trend diagrams between TDS and different anions and cations are prepared. These graphical trends serve as standard diagrams for the area under consideration.

(4) R_w values for unknown zones are calculated and TDS and other ions are interpreted with the help of graphical trends.

Results and analyses: Comparisions of hypothetical and actual chemical analyses in Mahanadi - Baitharni - Brahmini Delta Complex in Orissa :

1. Based on the vertical and lateral changes of water qualities in a ground water system, standard graphical intererelationship between R_w (true resistivity of water) and total dissolved solids, has been built for coastal Mahanadi-Baitarni-Brahmini complex along the Indian coast. This is possible when several water analyses of ground water samples from selected wells and therir R_w values, are available.

2. The R_w and R_{we} relationship between NaCl waters and $NaHCo_3$ waters are obtained by plotting R_w values from chemical analysis and the derived equivalent resistivity values (R_{we}) obtained through numerical calculations of Sp logs using equation(1). The factor of deviation obtained between NaCl waters and $NaHCo_3$ waters is used to derive true resistivity (R_w) of groundwaters which is of the order of 1.8. The data obtained by adopting the above procedure for different deep aquifers in Mahanadi-Baitarni-Brahmini delta complex are given in the following table.

Table I

Results obtained from Self Potential log analyses

Site and location	Zone depth(m)	Sp	R_{mf}	R_{we}	R_{mf}/R_{we}	R_w
Sp log data for shallow aquifer systems						
Arilo	0-60	+22.5	6.50	13.63	0.48	24.525
(Long.86°13'38"	60-96	+12.5	6.50	9.81	0.66	17.650
Lat.20 °12'15"	96-107	-15.0	6.50	3.97	1.64	7.143
Machagaon	0-50	+22.5	5.00	10.48	0.48	18.865
(Long. 86°16'0"	50-100	-25.0	5.00	2.20	2.27	3.954
Lat.20 °4'0"						
Patalia	20-40	+10.0	6.00	8.34	0.72	15.006
(Long. 86°2'35"	40-80	0.0	6.00	6.00	1.00	8.430
Lat. 19°57'25"	80-110	- 7.5	6.00	4.69	1.28	8.430
Sp log data for deeper aquifer systems						
Jajang	85-105	-47.5	5.90	1.24	4.76	2.226
(Long. 86°25'52"	105-250	-15.0	5.59	3.60	1.64	6.483
Lat. 19° 31'24")						
Kherang	120-140	-50.0	9.50	1.83	5.19	3.301
(Long. 86°45'	150-165	-25.0	9.50	4.17	2.28	7.513
Lat. 20°59'30")	180-190	-20.0	9.50	4.92	1.93	8.356
	190-210	-20.0	9.50	4.96	1.91	8.900
	220-240	-30.0	9.50	3.54	2.68	6.374
	240-265	-40.0	9.50	2.55	3.73	4.587
Adjhori	65-95	+10.0	6.00	8.34	0.72	15.006
(Long. 86°45'	96-140	+14.6	6.00	9.63	0.62	17.330
Lat. 20°34')	140-155	+29.0	6.00	15.37	0.39	27.760
	165-220	-7.5	6.00	4.69	1.28	8.430

The data have been further analyzed and interpreted by constructing a set of graphical trends between TDS vs. bicarbonates, chlorides and sulphates and also between TDS vs. Na+ K, Hardness, Ca+Mg. These are the standardized graphs specifically for this part of the coastal system and can not be universalized. The interpreted R_w values for different deep unknown zones could be therefore further quantified in terms of TDS, and different cations and anions. A comparitive analysis of different hydrochemical parameters obtained from chemical analyses and interpreted Sp logs are presented in table II.

Table II

Hydrogeochemical parameters (laboratory and interpreted values)

Well site and zone Depth(m)	Values based on laboratory analysis of water samples (ppm): Sp cond. (μmhos cm^{-1})	TDS	Cl	SO_4	HCO_3	Ca+Mg	Na+K	TH[1]	values interpreted from sp logs (ppm): Sp Cond. (μmhos cm^{-1})	TDS	Cl	SO_4	HCO_3	Ca+Mg	Na+K	TH[1]
Hydrogeochemical parameters for shallower ground water systems at selected wells/zones																
Arilo 150-372 (60-90)	725	471	44	-	232	45	-	135	560	365	38	20	50	70	153	
Patalia 60-387 (80-110)	1041	677	142	-	329	16	-	145	1200	780	200	95	60	220	160	
Machagaon 140-350 (0-50)	747	485	47	-	232	34	-	105	525	340	30	165	48	83	173	
Hydrogeochemical components for deeper groundwater systems at selected wells/zones																
Jajang 100-253 (115-200)	1648	707	199	-	115	28	-	135	1570	1020	323	140	60	300	160	
Kherang 195-450 (190-210)	830	540	115	50	161	17	135	141	1015	660	150	77	52	190	160	
Adjhori 60-387 (165-220)	983	639	180	-	165	31	-	205	1200	780	200	95	69	220	160	

TH[1] = total hardness

The above methodology developed had helped to build up quantified water quality parameters for deeper aquifer zones in a complex coastal system like Mahanadi-Baitarni-Brahmini delta in India. Based on these results an interface configuration map for the entire region has been prepared and the saline water intrusion processes/mechanisms have been explained taking the flow dynamics into consideration. This methodology perhaps could be adopted in similar systems elsewhere in the world.

References

Jones,P.H. and Buford, J.B.,1957. Electric logging applied to Groundwater Exploration. Geophysics, 16(1): 115 - 139.

Keys,W.S. and McCary, L.M., 1971. Application of borehole geophysics to water resources investigation. Book 2, Techniques of Water Resources Investigations of the United States Geological Survey.

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The problem of data incompleteness in simulation of transboundary pollution transport for accidental spills

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The problem of accidental spills as one of the emergency sources of water contamination is very acute and common for all the countries [1-3]. One of the main components of Accident Emergency Warning System to prevent environmental pollution and drinking water contamination is the simulation of contaminant transport for accidental spills. An adequate model has to forecast water quality as quickly and accurately as it is necessary for responsible authorities to make decisions for taking actions to prevent the water sources contamination. As to this a key problem for the efficient operation of the simulation systems is the uncertainty of initial data, both as far as contaminants discharge parameters (chemical composition, quantity and time of the discharge, also a more detailed information on the time dependence of the spill) are concerned, and the data on hydrological parameters of the water stream, along which the pollutants spreading is taking place. Existing simulation systems usually consider these data to be known accurately [4-6], or, if it is not the case, they are not flexible enough to choose among adjustment parameters, resulting from calibration. The problem arises as for how to choose algorithms possessing these features.

This paper deals with the forecast algorithm of pollutant transport for accidental spills under the conditions of incomplete data, a case study being the Tura river (Russia). The forecast is based upon the usage of preliminary information on the discharge and potential sources of pollutants. To calculate the time of the contaminant stain spread and to perform an initial evaluation of the maximum concentration, the method of "transfer function", applied to modeling of complex systems, was used [7,9].

The Tura (1,030 km long) is the biggest in the Sverdlovskaya Oblast (Russia). Its catchment area is 80,400 km^2 and more than 2,5 million people live along its shores. The river's biggest part flows through the Sverdlovskaya Oblast, the latter being highly industrialized with heavy industries located on the Tura banks. The downstream Tura (258 km) flows through the Tumenskaya Oblast and the town of Tumen. Tumen, situated 80 km below the Sverdlovskaya – Tumenskaya Oblast boundary, uses the Tura as a drinking water supply source. That is why Tumen is very vulnerable as far as the discharges from the Sverdlovskaya Oblast (situated upstream) are concerned, so efficient forecast of accidental spill pollutant transport is highly needed. Thus, for the problem under consideration there is one more source of uncertainty, dealing with the problem of the relationship between these two relatively independent territories.

In the case of an accidental spill all interested organizations and bodies have to be warned, these authorities being engaged in the water quality monitoring, control over accidental spill, taking actions to prevent and fight accidental discharge consequences, warning of the public, inter-regional information, etc. In their turn these bodies have to inform the territories downstream about the discharge (spread time estimated, type, quantity and concentration of the polluting substance).

A draft agreement on the joint use and protection of the transboundary Tura water quality, developed by RosNIIVKh [8], includes regional cooperation and taking actions to prevent and fight accidental spills consequences. Under this agreement it is planned to set up a monitoring station at the borderline of the Sverdlovskaya Oblast. It would enable to constantly control water quality and warn interested bodies about the contaminants passing the border. At present the agreement exists only as a draft and more often than not necessary measures are not taken. As a result accidental spills present a problem for the downstream Tura. As for Tumen its main challenge in the case of an accident is to know "what, when and how much" is going to be arrived to the borderline and water intakes.

Within the framework of the above agreement a system for transboundary pollution transport for accidental spills was developed as means of early warnings, water supply and management protection to take preventive measures to fight and release accidental spills consequences. Also studied were the problems of the interface between off-line software for pollution transport simulation and automatic monitoring system, if there is only one monitoring station located at the borderline of the two oblasts [6,7]. For each industry, viewed upon as a potential polluter, a list of contaminants was made (these contaminants threatening water quality during accidents), as well as discharge characteristics typical of a certain industry. This database is a component of the warning system, as well as the databases of corresponding hydrological, chemical and geographical information. The forecast can be based upon preliminary knowledge of the discharge and information on the potential sources of pollution. And in our model the transfer function to the neighboring area is characterized only by two parameters: time delay and relative spread of the pollution stain. Formally, the contamination spread model is quite rough; however, it corresponds to the expected uncertainty of initial data, being optimal from this point of view. Moreover, the transfer function method is a very flexible algorithm, providing for efficient model calibration as to the observed accidental spills or theoretical models, as well as correction of the model in real time by the monitoring stations data.

References

1. Clark,R.M., Vicory,A.H.,Goodrich,J.A. (1990) The Ohio river oil spill: A case study. *J.Am.Wat. Wks Ass.*, **3**, 1990, p. 39-44.
2. van Hout, P.J.M. and Brinkman, U.A.Th. The Rhine Basin Program, *EWPC Journal, V.3, number 5, 1993, p.29-38.*
3. H.Hartong et al., The Danube Accidental Emergency Warning System, Europ.Water Poll.Control, **4**, 1994, p.41-44.
4. van Gils, J.A.G. Modeling of accidental spill as a tool for river management, *Delft Hydraulics,No.431,The Netherlands,* 1990.
5. REMM: *Riverine Emergency Management Model,* User Manual and Program Documantation, Pomerlean R., ver.2.0, US Army Corps of Engineers, St. Paul, 1993.
6. Shagalova,N.N.,Shagalov,A.G.&Tretjakov,S.V.The water quality modeling for accidental pollution spills as a component of river basin monitoring and management systems.*Proc.Monitoring Tailor-made.September 20-23, Beekbergen,The Netherlands,*328-331, 1994.
7. Shagalova N.N. Accidental pollution simulated system and pollutant transboundary transport problems for the River Tura. IAHS Publ. no. 239, 1997, 275-278.
8. Tchernyaev,A.M. et.al (1994) The Draft of the Agreement about Common Use and Protection of Transboundary Water Bodies of the Tura River Basin between Sverdlovsk and Tumen States of Russian Federation. *Final report. The Russian Research Institute for Complex Utilization and Protection of Water Resources, Ekaterinburg, Russia*
9. Dreiss, S.J. Regional scale transport in a karst aquifer. *Wat. Resour. Res.*, 25, 126-134, (1989)

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Temporal and spatial downscaling of hydrological data for river ecology studies and small water projects

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Monthly streamflow volume time series data have been traditionally used in South Africa for management and development of water resources in medium to large catchments. These data are available as i) observed records cumulated with a monthly time step, ii) monthly inflow volumes to major dams calculated by water balance method, iii) simulated time-series from system analysis and basin study reports commissioned by the Department of Water Affairs and Forestry of South Africa (DWAF). After the update of the nation-wide study on the Surface Water Resources of South Africa (Midgley *et al*, 1994) synthetic monthly data are also available for 1946 small and normally ungauged incremental drainage subdivisions ('quaternary catchments') throughout the entire country. The average area of quaternary catchments is 650 km^2 but it varies from 80-100 km^2 in humid regions to 2000 km^2 in arid regions. Quaternary catchments are grouped into approximately 80 hydrologically homogeneous zones. It may be concluded that monthly streamflow data are available at the level of spatial resolution which would satisfy most of the large and medium water projects. However, an increased attention to environmental considerations in water resources management on one hand, and development of small water supply schemes in rural areas - on the other, has led to the growing demand for i) analyses based on daily streamflow data and ii) techniques for streamflow estimation in catchments smaller than quaternary (subquaternary scale).

Characterisation of daily flow regimes in South Africa from observed data is possible only at a limited number of sites. At the same time, even the existing observed daily flow records are not always suitable for direct use since they i) often contain large gaps due to missing data, ii) may be non-stationary because of the time variant land-use effects or water abstraction pattern, iii) may be available only for a very short observation period, iv) are rarely coincident in time with the time series from other sites within a basin and may therefore represent different sequences of dry and wet years. Generating a time series of daily flows by deterministic rainfall-runoff models is a commonly used but rather expensive and time consuming approach. At the same time, given a wide availability of monthly streamflow data, a low-cost methodology may be developed which allows daily streamflow characteristics to be derived from synthetic monthly.
For many practical purposes a Flow Duration Curve (FDC) is a valid substitute for a complete time series. FDC is a relationship between any given discharge value and the percentage of time that this discharge is equaled or exceeded. It gives a summary of the flow fluctuations at a site and may be constructed from either daily (1-day FDC) or monthly data (1-month FDC), for the whole year (long-term average FDC), particular season or calendar month.

For any site in a river, the variability of daily flows is higher than that of monthly. In high-flow months, maximum daily average discharges are higher than the monthly average. In low-flow months minimum daily average discharges may be much lower than the monthly average. In semi-arid and arid regions a river may completely dry up for most of the low-flow month, while the average monthly discharge will remain non-zero. It may be expected that within month variations of daily flows in similar sized catchments within a hydrologically homogeneous region are equally similar. Consequently, there may exist a robust relationship between 1-day and 1-month FDCs for each such region. The most straightforward form of such a relationship is a regional „ratio curve" which is established as follows:

- In a hydrologically homogeneous zone (e.g. as outlined in „Surface Water Resources of South Africa 1990) identify a representative streamflow gauge(s) with good quality data. The size of the gauged catchments should ideally be in the range of quaternary catchment areas in this zone.

- Construct both 1-day and 1-month FDCs using this gauge's data (either for the whole year or for each calendar month)

- Calculate ratios of 1-day flows to 1-month flows for several percentage points and plot these ratios against the percentage point values to produce a „ratio curve" for a site. If several representative flow gauges are identified in the zone - repeat the exercise for each gauge and calculate the average „ratio curve" for the zone.

- The established „ratio curve" represents a regional conversion function from 1-month to 1-day FDC. It can now be used in combination with synthetic streamflow data for quaternary catchments in the zone to establish 1-day FDC.

The approach has been tested and regional ratio curves have been established in several hydro zones in South Africa using the streamflow data from more than 50 gauges with records representing natural flow conditions in gauged catchments. The technique has therefore been provided to convert synthetic monthly data at quaternary level of spatial resolution into representative 1-day FDCs frequently used in South African hydrological practice. Such a curve is useful in its own right, but, once established for an ungauged site, it may be converted further into a complete daily flow time series using non-linear spatial interpolation algorithm (Hughes & Smakhtin, 1996; Smakhtin et al, 1997). The algorithm is based on 1-day FDCs for each month of the year, designed as a tool for daily time-series patching/extension/generation without sophisticated modeling techniques, and was found useful in many engineering applications throughout southern Africa.

The described approach for dissagregation of monthly data into daily was developed within the context of South African information environment. However, the general principle of this technique (establishing a regional relationship between 1-day and 1-month FDCs) may equally successfully be applied in other cases/regions, e.g. to convert a time series simulated by any monthly rainfall-runoff model or obtained from water balance calculations into a 1-day FDC (or further - into a completedaily flow time series). Monthly rainfall-runoff models are operational in many countries (Lall & Olds, 1987; Midgley, *et al,* 1994; Vandewiele & Atlabachew, 1995; Middlekoop, 1998; Mohseni & Stefan, 1998) and, compared to daily models, represent a less resource intensive exercise.

For small catchments (e.g. less than 100 km^2) neither monthlynor daily streamfow data are normally available from national databases. In South African national context the problem of flow estimation in small catchments (at subquaternary scale) is not properly addressed. The current practice often implies a straightforward weighting of quaternary flow characteristics and/or monthly time series by the ratio of the catchment areas of the subquaternary site and quaternary catchment. One of the critical aspects of this pragmatic approach is that streamflows at even closely adjacent sites are rarely linearly related to catchment area. The unit mean runoff from various smaller parts within a larger catchment may be either higher or lower than that from the entire catchment (e.g. due to large spatial gradients in rainfall). The variability of daily flows in a smaller catchment may be higher than that in a larger. Small streams, if not fed by permanent springs, may experience long zero-flow periods while the larger streams are more likely to have a permanent hydraulic connection with the main growndwater body. In general, the flow regime of a small stream is normally very dependent on small-scale variability of physiographic and meteorologic factors and simple fractioning of larger quaternary flows may lead to gross over- or underestimation of streamflow characteristics at subquaternary scales. At the same time, it would still be a logical step to make use of quaternary monthly flow data and to develop a technique by which daily flow characteristics can be reliably estimated at subquaternary scales.

The approach that has been investigated to address this problem includes the development of regression relationships between selected flow characteristics at quaternary and subquaternary scales as well as at subquaternary scales and corresponding physiographic parameters. The approach has been tested using the observed daily streamflow data from 80 small gauged catchments with areas ranging from 3 to 220 km^2 drawn from different parts of the country. Their corresponding quaternary counterparts have catchment areas in the range of 120 to 600 km^2.

The flow characteristics selected include mean flow, percentage of time with zero-flow conditions and several low-flow and high-flow indices (discharges exceeded by different % of the time on average throughout the year). The attempts to establish the regression relationships between subquaternary and quaternary flow characteristics directly were not entirely successful, which only illustrated the effects of local physiographic anomalies and orographic gradients on streamflow generation in small catchments. All gauged subquaternary catchments were then located on the national 1' X 1' grid GIS coverages of Mean Annual Precipitation (MAP) and altitude. Areal weighted values of MAP and altitude as well as corresponding spatial maxima within all these catchments have been estimated. The subsequent regression analysis has illustrated that a flow characteristic in a subquaternary catchment is normally related to the corresponding quaternary characteristic and ratios between subquaternary and quaternary MAPs, altitudes and catchment areas. The possibilities to derive 1-day FDCs for small catchments from quaternary catchment's monthly time series data are currently being investigated.

The approaches described in the paper represent low-cost methodologies of data acquisition and contribute to the general availability of streamflow data at fine temporal and spatial scales required by many river ecology studies and/or small water supply projects.

References

Hughes, D.A., and Smakhtin, V.Yu. (1996) Daily flow data time series patching or extension: a spatial interpolation approach based on flow duration curves. *Hydrol. Sci. J.* **41**(6): 851 - 871

Lall, U. & Olds, J. (1987) A parameter estimation model for ungauged streamflows. *J. Hydrology* **92**: 245-262

Middlekoop, H. (1998) Statistical downscaling of discharge series from the Rhine for peak flow analysis under changed climate. Proc. of Int. Conf. „Hydrology in a Changing Environment". Exeter, UK July 1998, J. Wiley and Sons, Vol 1 : 175 - 190

Midgley, D.C., Pitman, W.V. and Middleton, B.J. (1994) Surface Water Resources of South Africa 1990. *Water Research Commission Report No* **298/5.1/94**, Pretoria, South Africa

Mohseni, O and Stefan, H.G. (1998) A monthly streamflow model. *Water Res. Res.* **34**(5): 1287-1298

Vandewiele, G.L. & Atlabachew, E. (1995) Monthly water balance of ungauged catchments obtained by geographical regionalisation. *J.Hydrology*, **170**: 277-291

Smakhtin, V.Yu., Hughes, D.A. and Creuse-Naudin, E. (1997) Regionalisation of daily flow characteristics in part of the Eastern Cape, South Africa. *Hydrol. Sci. J.* **42**(6): 919 - 936

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Remarks on data requirements for hydrological models

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Abstract

Two problems are discussed:

I. what to do with observation gaps?

II. what consequences to the model output follow from a change in measurement techniques and evaluation of input variables or in a way of lumping spatial variables?

It is in linear systems only (e.g. Papoulis, 1965)

$$y(t) = \mathrm{L}[x(t)], \tag{1}$$

where x can be a single variable or a vector and t denotes the time, that the mean value of the output process $y(t)$ is obtained by transformation of the mean value of the input process $x(t)$

$$\mathrm{E}\{y(t)\} = \mathrm{L}[\mathrm{E}\{x(t)\}] \tag{2}$$

Therefore, if the only interest is in the expected value of $y(t)$ but not in the serial structure or in higher order moments then the expected value of $x(t)$ can be used to feed the system.

With the progress of computerized data processing and software development, more attention is paid to easy access to the data than to their relevance for particular problem investigation. Let us take as an example the calculation of evaporation from an open water surface. Both components of the Penman equation (Penman 1948) and the weighting factors are nonlinear functions of the input variables which show high diurnal and seasonal fluctuations. Despite of these, the mean daily, weekly or monthly values are used to calculate the potential evaporation rate.

Filling in missing values and extension of short records belong to routine practices of hydrologists. The first known techniques used in hydrology for filling in missing values came from climatology. They are based on the linear regression equation

$$y_i = \bar{y}_k + r_k \frac{S_k(y)}{S_k(x)}(x_i - \bar{x}_k) \qquad i = k+1, \dots, N, \tag{3}$$

where k denotes the concurrent period of X and Y records and N is the period of the X variable records. They were gradually extended for multiple linear regression and time series models. In order to preserve the variance of Y in the extended sequence, the absolute value of the correlation coefficient in equation (3) was forced to be one. Consequently, the serial correlation and higher order moments of the extended series are as those of X-series. The XIX century technique based on r_k equaled one makes a comeback (Hirsch, 1982) under the acronym MOVE (Maintenance Of Variance Extension). Its simplified versions which had been used in climatology are: (1) equal standard deviations of X and Y, which result in equal deviations of X and Y from the respective means; (2) equality of the values of the coefficient of variation of both variables, which results in the constant ratio of values x_i and y_i.

The theoretical background of the information transfer technique to fill in the missing values can be deduced from the ML-estimation of parameters of already defined uncompleted sample taken from the normal population of two-dimensional variable (Veron, 1960, Kaczmarek, 1967). One can read from the ML-equations (Strupczewski, 1969a) that:

(1) the estimator of the mean of Y is related to the estimator of the mean of X by the linear regression equation;
(2) there is no additional information in the sequence $(x_k, x_{k+1}, .., x_N)$ in respect to the regression coefficient;
(3) and consequently, there is no change in the value of residual variance estimator if compared to one of the completed k-element sample.

Therefore, if there is no serial correlation, the proper technique of both filling in missing observations and extending records must fulfil the above conditions. Strupczewski (1969a) proved that the only way to achieve it is the multiple Monte-Carlo generations of the missing observations: $(y_{1,m},...,y_{i,m},...,y_{k,m},y_{k+1,m},...,y_{i,m},...,y_{N,m})$, where $m = 1,..,M$ and M – number of realizations

$$y_{i,m} = y_i \quad \text{for } i \le k \tag{4a}$$

$$y_{i,m} = \bar{y}_k + r_k \frac{S_k(y)}{S_k(x)}(x_i - \bar{x}_k) + S_k(y)(1 - r_k^2)^{1/2}\varepsilon \quad \text{where } \varepsilon \in \mathrm{N}(0,1) \text{ for } k < i \le N \tag{4b}$$

There is no way to get the values of the ML-estimators of parameters by using the single values for filling gaps unless the error of estimation of missing values is negligibly small. The use of regression equation ensures concordance of the first moment only, while underestimates the variance. The only way to get the values of ML-estimators is the use of the Monte Carlo generated records for the missing values. Therefore, instead of operating with the sequence of length N, one shall deal with the sequence of the (N*M)-length or with M realizations of length N each. Criteria for improving the estimators of parameters were given by Matalas and Jacobs (1964).

The multivariate case, censored observations, the simple Markov chain and several patterns of uncompleted samples were considered by Strupczewski (1969a,b). The ML equations have analytical solution for multivariate uncompleted sample if all variables but one have concurrent observation period (N) and the short sequence of length k is concurrent with all others sequences. All other cases need numerical solution or they can be solved approximately using the Monte Carlo generated records for the missing values. Following the concept described above, the proper model for every case can be applied and used to generate the missing records. It remains the open question, why the MC-generations have not been applied to fill in missing values and to extend short records, and of that a class of MOVE methods is recommended instead. Is the substitution of single value for the missing observation essential for any use of time sequence? Is not too high price paid for seeming order in data?

The similar reasoning holds for derivation of continuous surface from its discrete representation. The kriged surface is more flat than the true one. Combining the kriging with the Monte-Carlo experiments for multiply generation of hydro-meteorological variable surface would solve the problem. However, it leads to huge computational problem due to both the sequential character of the generating grid point values procedure and the necessity to process every simulated surface in hydrological model. This pushed us (Strupczewski & Mitosek, 1992) to use the multiquadric method which, although does not have so strong statistical motivation (Strupczewski & Mitosek, 1990), leads to realistic surface shape.

From the above, two questions arise:

(1) is it realistic in hydrology to expect the filled value to be close enough to the missed observations, i.e. to get approximate conformity of at least the two first moments and serial correlation? ;
(2) is the conformity of the first moment only, sufficient for some applications?

The answer to the first question depends on a hydro-meteorological variable. Unfortunately, precipitation which is the main input variable to hydrological systems shows highest variability both in space and in time of all hydro-meteorological variables and moreover the discrete-continuous character of the variable makes estimation problem sharply nonlinear. In particular, convectional

precipitation gives high rainfall intensity over a comparatively small area of tens or, at most, hundreds kilometers with the total lifetime of about 30 minutes to 12 hours. Our experience from Monrovia County (West Africa), which has relatively dense raingauge network, shows lack of spatial correlation for rainfall depth of a single storm event. Several other more detailed studies confirm the finding. Therefore, the only hope can be credited to combine weather radar systems and geostationary satellites information with point measurement data. Because of the essentially random nature of the rainfall time-space distribution from a single event, the spatial variability decreases as an increasing number of events are averaged. Using data from the standard raingauge network of the Polish Tatra region for multiquadric rainfall surface derivation (Strupczewski & Mitosek, 1990), the influence of topography on the rainfall surface has been detected for a period not shorter than one month.
The answer to the second question is provided by the systems theory. It is only in a linear system that averaged input process is transformed into averaged output process. Obviously, if a final goal of filling gaps is mean value estimation for water resources planning or to produce maps for a hydrological atlas, any technique ensuring unbiased estimator of missed values will serve for the purpose. Unfortunately hydrological systems show nonlinear properties and therefore nonlinear models are usually applied. If the time series to be used for model calibration contains observation gaps or some observations are missing while operating the model, it may be difficult to assess in advance whether the MC-generation is necessary and if so what is the number of required realizations. This shall be only assessed by trial and error. Obviously, the existence of active thresholds values in its structure, as in the effective rainfall models, indicates a necessity of the MC experiments.
A good illustration is provided by Krickij-Menkel (1952) graphical method of the maximum possible flow regulation by reservoir in the deterministic conditions. The method named "the stretched thread method" had been widely used in the sixties and then identified (Strupczewski, 1973) as the exact solution of the convex-programming problem with the linear constrains for finite volume of the reservoir. It was a good lesson of humbleness for automatic control specialists who were able to get only approximate solution of the problem. Taking for simplicity annual inflow series and then the mean annual flow value to fill its gaps we find that the outflow process properties depend on the number of gaps to be filled. Using such inflow series to derive the necessary volume of reservoir to get constant outflow equaled to the mean inflow, we find that with increasing number of observation gaps to be filled in, the solution approaches to zero. Obviously the use of Monte-Carlo numerical experiments for filling gaps and averaging results got from numerous realizations is the proper approach to the problem.

Conclusion:
Filling gaps is like making prosthesis. It should not be made independently of its purpose, as the perfect prosthesis does not exist. For some problems, a single prosthesis, i.e. the expected value, can be sufficient, while for others several of them, generated by Monte-Carlo method, are necessary. Therefore, it is better to leave the gaps blank, if high accuracy of estimation can not be achieved. Needless to say that analytical approach, i.e. analytical transformation of stochastic processes in hydrological system (Napiorkowski & Strupczewski, 1995) is the most correct way. Then the time series is represented by parameters of process, but not by its realization. However, due to the non-Gaussian character of hydrological processes, complexity and nonlinearity of hydrological models, such an approach seems to be quite unrealistic.
Parameters of any hydrological model, or at least some of them, are derived by optimization method using input-output data. Let us start to discuss the second problem from the common case of experimental physics, where variables Y and X are functionally related by a given form, e.g. linear, with unknown values of parameters, which shall be determined experimentally. If the error of measurement of both Y and X exists then neither regression Y|X nor X|Y produce the correct values of physical parameters even in asymptotic case. If exact values of X are known then regression line Y|X converges asymptotically to physical relationship, provided that the measurement of Y is unbiased. However, the exact values of X are rarely known in hydrologic research. The random error of the X measurements influences the variance of $\hat{X}$ in the regression equation, which is the total of variance of X and variance of error, leaving the covariance value unchanged, if the X and Y errors are

not correlated. Therefore the value of regression coefficient, i.e. the slope, depends on accuracy of input data measurements. Concluding, the model can not be used with data of accuracy differing from those applied for its calibration. In case of change of measurement techniques, for more or less accurate one, the model needs to be recalibrated. To make things worse, one shall recall that there are mainly indices of physical variables, which are related in a model. Therefore a change of measurement techniques or methods of spatial variables evaluation can cause a change of mean value, i.e. bias change in respect to physical variable, which also affects the values of model parameters. Since non-parametric tests for jumps detection required long time series, the simultaneous use of old and new methods seems to be the only solution.

References

1. Hirsch R.M., 1982 A comparison of Four Record Extansion Techniques. *Water Resour. Res.*, vol.18, no 4, pp. 1081-1088.
2. Kaczmarek Z., 1967. Ocena parametrów rozkładu log-normalnego na podstawie związków korelacyjnych pomiędzy zmiennymi. *Przegl. Geofiz.*, 3-4.
3. Krickij S.N., Menkel M.F., 1952. *Vodochozjajstvennyje rascoty.* G.M.Izdat. Leningrad.
4. Matalas N.C., Jacobs B., 1964. A Correlation Procedure for Augmenting Hydrologic Data. *U.S Geological Survey Professional Paper* 434-E, pp. E1-E7.
5. Napiorkowski J.J., Strupczewski W.G., 1995. Towards the physical structure of river flow stochastic process. *New Uncertainty Concepts in Hydrology and Water Resources. Z.Kundzewicz (ed)*, Cambridge Univ. Press P.V, Ch.8, 261-269.
6. Papoulis A., 1965. *Probability, Random Variables and Stochastic Processes.* Chapter 9. Mc Graw Hill, Inc.
7. Penman H.L., 1948. Natural evaporation from open water, bare soil, and grass. *Proc.R.Soc. London.* Vol.A193, pp.120-145.
8. Strupczewski W.G., 1970 Estimation of the statistical characteristics of some event on ground of the information gained from some observations of other correlated phenomena. *Symposium IAHS, Wellington. Publ. No.96*, 236-246.
9. Strupczewski W.G., 1969. Estimate of the statistical characteristics of some events on ground of the information gained from some observations of other correlated phenomena (in Polish). *Acta Geophysica Polonica.*a: Part I – Vol.XVII, No 2, 133-156; b: Part II – Vol XVII, No 3, 253-298.
10. Strupczewski W.G., 1973. Square programming model of reservoir regulation, *Przegl. Geof.XVI(XXIV),* 1-2, 89-110.
11. Strupczewski W.G., Mitosek H.T., 1990. Deterministic model of rainfall surface with topographic information. *Acta Geoph. Pol.*, XXVIII, 2, 169-189.
12. Strupczewski W.G., Mitosek H.T., 1992. Rainfall surface built on topography. In: *Geostatistical Methods: Recent Developments.* Editor A. Bardossy, Cambridge Univ. Press.154-161
13. Veron R., 1960. *Dans quelle mesure et cooent ameliorer l'estimation des parametres d'adjustment d'une loi normal.* EDF. Unpublished memorandum.

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Rainfall input requirements for hydrological calculations

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Introduction

For many design calculations, rainfall data is the most important input, e.g. for sewer system design, assessment of combined sewer overflows, flood risk assessment, river discharges and river water quality. Long historical rainfall series should be used for such calculations, followed by a statistical analysis on the design parameters, because of the high temporal variability. Ideally, also spatially distributed rainfall should be used. The proper consideration of rainfall variability in time and space is the main challenge in hydrological design. Although it is obviously necessary to include these variations, this approach is often in conflict with the economical reality. In hydrological design often very detailed models are used, which require long calculation times. Performing long term simulations with these models, would lead to very time consuming and practically unfeasible calculations. This problem is often solved by simplification of the rainfall input into uniform rainfall and single design storms, using only limited statistical information about the rainfall. The question can be raised if this is the optimal simplification. In case of linear systems, it can be assumed that the frequency of the effect, which is simulated, is equal to the frequency of the rainfall which leads to this effect. An example is the design of combined sewer networks, where high return periods are used. In other hydrological applications, however, the system reacts in a non-linear way : whenever the system contains several subsystems with different response times, whenever the studied return periods decrease and whenever the system contains non-linear components (e.g. pumps, non-linear boundary conditions, ...). In these cases, it is often not necessary to use very detailed models. It is obvious that there must be an optimum between the degree of model detail and the degree of detail for the rainfall used. If models or rainfall data are simplified, the accuracy of the design will decrease. It is important to simplify the parameters which have a low influence on the accuracy. One should aim at an optimal balance between model uncertainty and uncertainty on the input parameters and input data. This optimum is not fixed, but a function of the application and of the availability and accuracy of the data.

Research set-up

To face this problem, different research projects where carried out at the Hydraulics Laboratory of the University of Leuven to identify the rainfall input requirements and the optimal degree of model detail for different hydrological design applications, such as sewer system design, impact assessment of combined sewer overflows, flood risk assessment for brooks and rivers, ... In this research, most attention was paid to the temporal variability of the rainfall. The spatial variability has been investigated in less detail until now, because of the limited availability of data. Most attention is paid to sewer design and emissions of combined sewer overflows to the receiving waters, because this was the initial goal for this research, but the extension to other systems was a logical consequence.

Temporal variation

Rainfall has a large intrinsic temporal variability, certainly during thunderstorms. For sewer system design, the maximum time step for the rainfall data is 10 minutes for the accurate calculation of the peak discharges in the upstream branches. For rivers, the time step can be larger. As rule, the time step must be considerably smaller than the concentration time of the system.

The rainfall also varies from season to season. Short heavy thunderstorms often occur during summer, while in winter rainfall intensities are lower and rainfall durations are larger. Depending on the system characteristics, one or the other type of rainfall can be critical. Apparently, the rainfall also seems to vary quite a lot over the different years. This variation mostly has a larger effect than the seasonal variation. For that reason, it is absolutely necessary to use long historical rainfall data of at least several decades for hydrological design. Because of the high rainfall variability from one year to another long time series are also necessary to identify long time trends. The measurement uncertainty is often quite high and the measurement environment is changing with time, which leads to high uncertainties on observed trends.

Design storms

For sewer design, where the concentration times are small and runoff originates mainly from impervious areas, it is acceptable to use single design storms for high return periods. In Flanders, these design storms are based on IDF-relationships (Intensity/Duration/Frequency-relationships). For one return period, all IDF-relationships up to a duration of 360 minutes are included in one composite storm. Also, antecedent and posteriori conditions are included for durations up to 120 minutes. The accuracy in predicting peak discharges and water levels with these composite storms has been checked by comparison to detailed simulations with the original long time rainfall series for a limited number of sewer systems.

For the overland flow to brooks and rivers, the same approach is tested. Anyhow, in this case, the major runoff originates from pervious areas. The initial soil moisture conditions, which are very important, vary very much during the year. Therefore, the rainfall variation over the seasons is investigated. This resulted in high peaked summer design storms and more flattened winter design storms with a total duration of 15 days. When using these design storms, the initial conditions and runoff model parameters must be chosen carefully. Besides, base flow (groundwater flow) must be added to the overland flow calculated with the design storms, because the response time for the base flow is often even larger than 15 days. Although this looks an acceptable design method for peak flows and flooding problems, it can only give a rough estimation of the frequencies of peak discharges and water levels, because the real temporal rainfall variability is neglected in this method.

Simplified models for long time simulations

Because of the importance of the rainfall variability, for a lot of hydrological calculations long time simulations are inevitable to reach a good probability estimation of the effects. Often, after appropriate calibration, simple physically based conceptual models give almost as good results as very detailed hydrodynamic calculations. Using simplified models reduces the calculations times enormously (up to a factor 10^6), while leading to an optimum between model accuracy and uncertainty on the input data. This approach is tested as well for emissions at combined sewer overflows as for runoff to and flow in brooks and rivers and gives remarkably good results. The major constraint to use this approach on a wide scale is the calibration of the simplified models. The calibration requires good data and modelling experience. However, new techniques of data analysis and modern computer possibilities have made this calibration more easy and more straight forward. This approach has the additional advantage that only the important parameters are included and modellers become more aware of how the system behaves.

Short time series

Another possibility to reduce the calculation time is to select only the relevant rainfall data from the long time series. Historical rainfall series contain a lot of dry periods or periods with little rainfall which will never lead to an important effect. This approach is used for the frequency estimation of emissions at combined sewer overflows and for the design of sewer systems. The rainfall selection tool is different for both cases.

For the selection of short time series for emission calculations, a simple reservoir model is used. In a first stage, a global set of short times series is deduced for a wide range of possible sewer system parameters, which can occur in Flanders,. The main parameters are storage in the system, throughflow capacity and concentration time. Because only the most important parameters are used in a simplified model, some safety margins must be added while selecting the short time series. Each rainfall event that leads to an overflow event in one of the cases (different model parameters), is selected with antecedent and posteriori periods. With this approach, the historical rainfall series could be reduced with a factor 10 to 15. However, this does not mean that the calculation time is also reduced with this factor, because the skipped periods with low rainfall usually run faster in a model than the selected periods with more severe rainfall. In a second stage, a further reduction is obtained by deducing more specific sets of short time series for a smaller range of sewer system or even for one specific sewer system. In this way, the length of the rainfall time series for one specific sewer system can be reduced with a factor 100 to 200.

For the selection of short time series for sewer design purposes, IDF-relations are used. For all storms with durations up to 720 minutes and a return period larger than or equal to 1 year, a reduction in rainfall input can be obtained with a factor 200.

Spatial rainfall variation

The spatial variation of rainfall is a more recent field of interest. This is mainly due to a lack of data and insufficient tools to investigate it and to perform simulations with it. Nowadays, more dense networks of rain gauges are installed and also radar measurements become available. Including the spatial variability of the rainfall requires even more powerful calculation tools, so that model simplifications are consequently necessary.

Rainfall can be very local. The mean diameter of a rain cell, as the smallest sub-element of a rain event, has been estimated as 15 kilometres. This makes it practically impossible to set up a global network of rain gauges to measure this spatial variability. Moreover, a point rainfall measurement will seldom register the maximum intensity of a storm. For that reason it is not acceptable to use simple areal reduction factors smaller than 1 as a function of the catchment size, in combination with point rainfall measurements. Often uniform rainfall is used over a catchment, but the consideration of the movement of a rain storm over a catchment can have a large influence. For example, if the main flow in a sewer system occurs in the same direction as the main moving direction of the rain storm, an accumulative effect occurs. This can lead to an increasing risk for flooding or larger overflow emissions.

Often, differences in geography and land use can lead to a local microclimate, as around cities, hills and large rivers. Because of the high variability of the rainfall and the limited data availability, it is difficult to prove such effects and to assess the differences. Besides, also the measuring equipment and environment are different and changing in time, so that measured differences and changes not necessarily correspond to climate differences and changes. However, it is not even obvious that rainfall measurements at one place can be used somewhere else, even if the situation and climate look similar. Rainfall data from different regions in England were compared with Belgian rainfall data and differences were found which can have a major impact on hydrological design.

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Special observation data in Russia and its use for monitoring of the land humidity regime changes (Russian Plain case study)

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Introduction

The moistening regime in the top soil (or land humidity regime) is the basic component of hydrological regime. It depends on numerous factors of the environment. Unfortunately, a lot of these factors are not considered by investigators due to missing or inadequate observations. As a rule, the humidity regime of land is characterised usually by air humidity, precipitation and evaporation. It is not sufficient to analyse processes occurring on a top soil. The modelliers were the first to understand the need in some additional data to study land water and heat turnover processes. Manabe and Delvorth (1989) concluded that soil moisture, for example, was very important for the Climate system and, hence, for the hydrological regime. According to their statement the function of soil moisture anomalies for land is similar to that of sea surface temperature anomalies over the ocean, "providing a storage and for forcing that is longer than the time scale of the atmosphere." Later, this conclusion was confirmed by empirical investigations (Vinnikov, Yeserkepova, 1991). Thus, soil moisture may be considered as an integral indicator of the moistening regime in the top soil or "land humidity". But the soil hydrology is affected by different natural processes and cannot be studyed using soil moisture data only. That is why a variety of special observations is used for investigations of the land hydrology and, in particular, hydrological regime and water resources. It includes observations on soil moisture content, groundwater regime, evaporation, snow, etc. Only joint analysis of these variables allows to improve understanding of environmental processes as a whole and to clear up uncertainties in their relationships. Information about these data and some examples of their use for the hydrological regime analysis are discussed in the paper.

Special networks in Russia related to observations of moistening regime components

Special networks in Russia related to the land humidity regime observations are as follows: water balance stations, agrometeorological and meteorological stations with special sites for water balance measurements, and evaporation network. Special networks in Russia began to operate since late 1940s - early 1950s according to standard programmes. These data are mainly published in yearbooks and some of them exists in manuscript form. At present this information is partly organised in special archives. Some hydrological information was included in the FRIEND European Water Archive.
Water balance stations (WBS) comprise a system of small research basins in different physiographic zones. 25 WBSs' were organised in 8 physiographic zones of the FSU and 6 of them are operating in Russia at present time. Each WBS has the system of meteorological and hydrological observations including standard synoptic observations, observations of precipitation and snowpack, runoff, evaporation, soil moisture content, dynamic of soil freezing and thawing and ground water table. More detail information about WBS network is in (Zavodchikov & Zhuravin, 1982).

The network of special meteorological and agrometeorological stations includes more than 200 permanent sites for measurements of different components of the soil hydrology. Besides, approximately 40 heat-balance stations, which began to operate at 1970s' were added to this network. A network of 190 pan evaporation stations with homogenous data series since 1951 was selected in the FSU on the basis of the analysis of complete station descriptions. More details about this network presented in (Golubev & Zmeikova, 1991).

Use of special network data for monitoring of land humidity regime

Numerous studies of changes in hydrological regime under the influence of climate change were made since the end of 1970s when the trend to a substantial increase of winter air temperature and annual precipitation was observed. The standard network provided information on the spatial and temporal changes in climate and river runoff, but detailed information about changes in hydrological regime and moistening regime in the top soil is provided by the data of special networks, WBSs' in particular (Georgievsky, Zhuravin and Ezhov, 1995). It allows to estimate trends in the observed changes of annual cycles of soil moisture content and ground water table for the period of about 40-45 years in the European Russia.
Data on soil moisture content in the top soil of 1m deep were used for 49 special stations. Linear trend estimates of soil moisture content were used to estimate tends of this component of land hydrology. Analysis of empirical data shows that some changes in soil moisture content did occur for every month during the period of 1975-1990(92). In Fig.1, a distribution of soil moisture content changes over the European Russia in April is shown. These changes are observed all over the territory under study. The most intensive changes (1) are indicated in the northern and eastern parts (up to 60-80 mm), meanwhile in the western and north-eastern parts of the territory these changes (2) are most insignificant (up to 10-15 mm). Over the central part of the territory under the study, these tends are similar and do not exceed 50 mm. In this analysis, tends are not divided by directions and gives, of course, only some general notion about intensity of these changes. But these estimations allow to get information where we can expect the most substantial changes in soil water content for future.

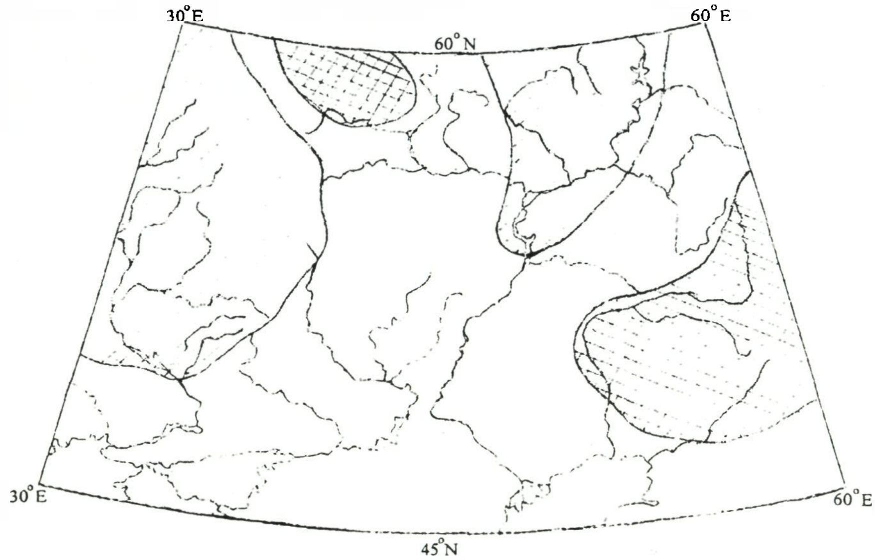

Fig.1. Distribution of soil moisture content changes over the central part of the European territory of Russia at the end of April.

-1 -2

Substantial difference in changes (including sign of tends) of soil moisture content over the area is related to the mosaic combination in distribution of soil types and depth of ground water table as well as due to the changes in annual precipitation cycle. At the same time, general tend to the increase of soil moisture content during autumn-winter seasons and to its decrease in spring-summer may be noted, despite the trends in potential evaporation obtained by data of pan evaporation network, which

is the indirect indicator of energy components (turbulent exchange and solar radiation) since end of 1970s.
In Fig.2, interannual variations of area-average pan evaporation and diurnal air temperature range of the standard deviation anomalies from the mean long-term values are shown.

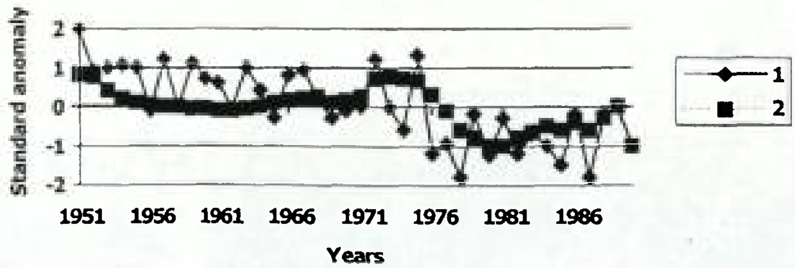

Fig.2 Variations of pan evaporation (1) and diurnal temperature (2) range of the standard deviation anomalies from mean long-term values

These results support the idea that pan evaporation is decreasing and is correlated negatively with cloudiness with a mean r^2 of 0.34 for the region. Temperature and hydrological cycles have changed in tandem over the past 50 yars, and the features of this recent climate change include decreases in potential evaporation (Peterson, Golubev and Groisman, 1995).
Data obtained at WBS network confirm the increase of soil moisture content in autumn-winter period, while spring-summer period became dryer in uplands of forest and forest-steppe zones due to the combination of factors assisting to the increase of evapotranspiration (high level of the capillary fringe, in particular, Fig.3). Soil moisture content in a flat steppe zone increases for the whole year as a result of low draining capacity, despite the increase of evapotranspiration (up to 60-100 mm per year). This substantial increase in evapotranspiration occurs in contradiction with the trends in potential evaporation that should be the object of further analysis.
This information gives the basis for verification of models used for estimation of runoff regime under long-term climate variations.

Conclusions
Data obtained in special networks support the statement that land humidity have a tend to increase for autumn-winter seasons and to decrease for spring-summer seasons in European Russia in general, despite the decrease in potential evaporation. These data confirm more frequent summer droughts of the past years, meanwhile low flows and precipitation increased in general and indicate the favourable situation in the moistening.
The reasons of this complicated process are in the combination of climate, land surface and hydrogeological factors, which should be considered also in combination. A comprehensive analysis of trends in the hydrological regime requires the use standard and special network data.
Special hydrological information is also an important basis to verify hydrological models used to estimate hydrological regime changes under the influence of climate variations.

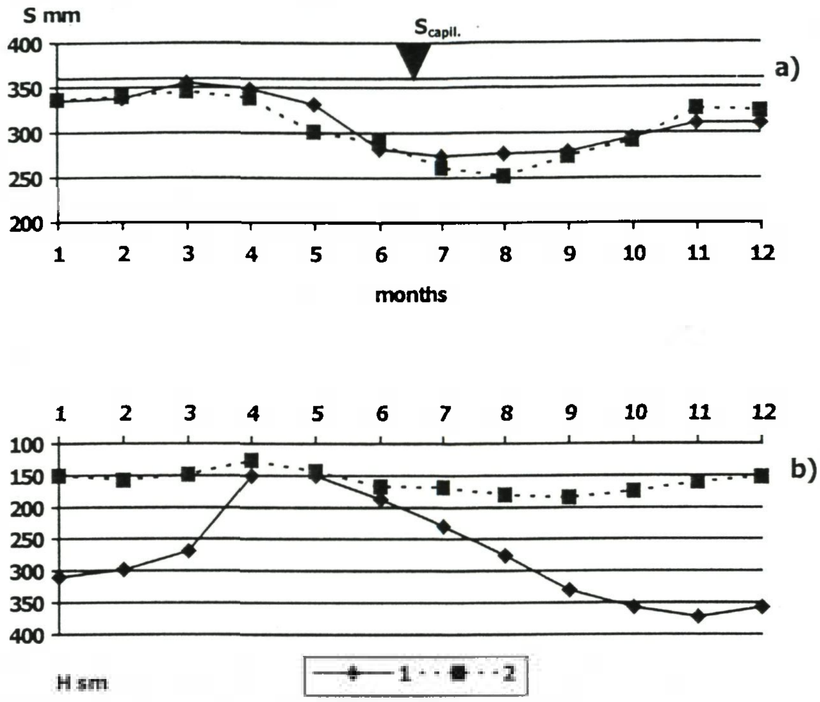

Fig.1 Typical year cycles of soil moisture content (a) and ground water table in upper horizons (b) for 1950s (1) and 1990s (2) in the uplands of forest-steppe zone

References

Delworth, T. and S.Manabe, 1989: The influence of soil wetness on near-surface atmospheric variability. J.Climate, 2, 1447-1462.

Georgievski, V.Yu., Zhuravin, S.A. & Ezhov A.V. (1995) Assessment of trends in hydrometeorological situation on the Great Russian Plain under the effect of climate variations. Proc. of American Geophysical Union, 15th Annual Hydrology Days, pp.47-58

Golubev, V.S. & Zmeikova, I.C. (1991) The monitoring of environment in the Aral Sea Basin. Gidrometeoizdat, Leningrad, pp.80-86 (in Russian).

Peterson, T.C., Golubev, V.S. & Groisman, P.Ya. (1995) Evaporation losing its strength. Nature, vol. 377, p.687-688.

Vinnikov, K.Ya. and I.B.Yeserkepova, 1991: Soil moisture: empirical data and model results. J. Climate, 4, 66-79 pp.

Zavodchikov, A.B. & Zhuravin, S.A. (1982) Investigations at water balance stations of the USSR: the results and prospects. Transactions of the State Hydrological Institute, 282, pp.88-101 (in Russian)

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The atlas of Polish lakes - A source of information for hydrologists and ecologists

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Poland is a country abounding in lakes. Whenever we have a set of many objects characterised by a large number of parameters, it is advisable to arrange them in such a way as to make them readily accessible. In the case of lakes, the matter is further complicated by the fact that they are of interest to a wide range of people who often need quite different data.

The Atlas of Polish Lakes is the first to be published in this country. So far, only three catalogues have been published which merely provide information about the location of lakes and their known morphometric data [1,2,10]. For a substantial number of lakes these data do not include capacity and depth, because not all the lakes had been sounded.

The Atlas of Polish Lakes presents all the lakes exceeding 10 ha in area, of which there are nearly 2,900. It does not embrace artificial water bodies and individual lakes at an advanced stage of being overgrown, with mere remnants of a free water surface. *The Atlas* will appear in three volumes, two of which have come out already, the third is being prepared.

Each volume consists of three chapters:

Chapter I.	Introduction and subject matter.
	Tabular part including data on the location of lakes, lake basin mor- phometry, and water chemistry.
Chapter II.	Cartographic part including simplified bathymetric charts of each lake.
Chapter III.	Analytical part presenting a statistical summary, fluctuations of the water levels of the lakes under study, and lake water resources in the particular subcatchments.

From among morphometric indices, nine most characteristic ones have been chosen (though a choice of this kind must necessarily be disputable): area, capacity, maximum depth, average depth, maximum length, maximum width, coastal line length, development of shore line, index of exposure.

Making a choice of chemical indices turned out to be a major problem, because it is difficult to find indices essential to water quality evaluation and specified for most of the lakes. Finally, six factors were decided on: conductivity, pH, oxygen consumption, and the contents of calcium, sulphates and chlorides. These indices were determined for almost all the lakes in the Institute of Meteorology and Water Management (IMGW) in the 1980s. They roughly reflect the water quality of each lake. There is a separate table listing those lakes for which there are more precise physico-chemical data.

The main element of each atlas is its pictorial-cartographic part. Nothing can illustrate the spatial aspect of a lake basin better than a bathymetric chart. In order to include so many charts, it was decided to present their simplified version; anyway, for some of the lakes there were no soundings necessary to compile more detailed charts. The soundings were carried out in two centres - in the Institute of Inland Fishing (IRŒ) and the Institute of Meteorology and Water Management. In the IRŒ, the soundings were made mainly in the 1950s and 1960s, manually from the ice surface, usually in a grid of 50 m by 50 m quadrats. In the IMGW, the soundings were made in the 1980s from a boat by an electronic echo-sounder. The isobath interval on *The Atlas* charts is usually 5 m. For deep lakes where the 5 m interval at the scale involved would be unreadable, isobaths were drawn at 10 m intervals. A linear scale is given on each sheet, because they were printed in a smaller format.

Chapter III includes a short statistical description of the lakes, diagrams of mean annual water stages over the study period till 1995 inclusive, together with their discussion, and an estimation of water resources of the lakes in particular catchments, with the percentage of lakes in each and their storage capacity. Maps of these last two features were also drawn for the whole region under analysis. Resources were summed up and general suggestions were presented as to the influence the lakes might have on the water cycle. *The Atlas* closes with an alphabetical index of the lakes.

One should stress the interdisciplinary character of *The Atlas*. It is intended not only for hydrologists, but also geographers, biologists, ecologists, and all those who are concerned with nature in the lakelands. Apart from scientists and students, *The Atlas* will also be of use to practitioners: planners, environmental protection officers, fishermen, tourists, schools and school superintendents' offices.

The lakes are presented in a hydrographic order, by catchment, in accordance with Poland's official hydrographic division. The first volume includes lakes situated in the Odra river basin, namely in the Wielkopolska Lake District and the southern part of Pomeranian Lake District. The second volume covers lakes located in Pomerania and in the lower Vistula river basin. The third will cover Masurian Lakes and those located in the southern part of Poland. The last volume will contain a review of the whole of Poland and also ice phenomena.

The basic statistical description of the lakes' features are listed in Tables 1. Chosen data of all lakes, catchments and lakelands are presented in Table 2. There are 121 subcatchments in Volume 1 and 169 subcatchments in Volume 2. An attempt was made not to distinguish too small catchments, but as this not always possible. However, where it was logically justified, some catchments distinguished in the *Hydrographic Division* [12] were combined to form larger areas.

Table 1. Statistical characteristics of the features

Parameter	Minimum		Maximum		Average		Variation Coefficient	
	Vol. 1	Vol. 2	Vol. 1	Vol. 2	Vol. 1	Vol. 2	Vol. 1	Vol. 2
Area (km^2)	0.08	0.09	35.27	71.40	0.73	0.84	2.46	3.48
Volume (mln m^3)	0.03	0.08	681.7	180.1	4.9	4.1	5.13	3.02
Maximum depth (m)	0.4	0.6	79.7	68.0	10.5	10.8	0.86	0.80
Mean depth (m)	0.2	0.5	20.2	18.7	4.3	4.3	0.70	0.63
Maximum length (km)	0.38	0.39	25.00	27.45	1.71	1.71	1.02	1.04
Maximum width (km)	0.12	0.12	4.90	7.60	0.51	0.53	0.76	0.88
Length of shoreline (km)	1.15	1.15	91.3	117.7	4.8	4.7	1.20	1.26
Development of shoreline	1.02	1.01	5.55	5.65	1.7	1.67	0.31	0.29
Exposure index	1	1	197	4462	19	30	2.01	5.53
Conductivity (μS/cm)	10	30	1000	4930	317	327	0.61	0.89
Oxidizability (mg O_2/dm^3)	1	0.8	64	66.5	10	9.3	0.50	0.61
Calcium (mg Ca/dm^3)	4	1	200	151	61	45	0.42	0.51
Sulphates (mg SO_4/dm^3)	2	2	181	280	42	31	0.71	0.82
Chlorides (mg Cl/dm^3)	1	4	544	1620	28	26	1.12	3.30
pH	7.0	4.5	9.4	9.5	8.1	7.7	0.04	0.09

Table 2. Water resources of lakes

Specification	Volume 1	Volume 2
Number of lakes	1104	1067
Area of lakes (km^2)	802	897
Volume of lakes (mln.m^3)	5389	4378
Area of catchment of lakes (km^2)	25220	20758
Area of lakelands (km^2)	45330	49444
Mean lake percentage of catchments (%)	3.2	4.3
Mean lake percentage of lakelands (%)	1.8	1.8
Mean lake storage capacity of catchments (mm)	214	211
Mean lake storage capacity of lakelands (mm)	119	88

At present Volume 3 is being prepared. The data of almost 700 lakes, with the total area of about 1050 km^2 and total volume of about 8300 mln. m^3, will be published.

A higher storage capacity in relation to the percentage indicates, that lakes in the catchments are small and deep. Conversely, a higher lake percentage than the storage capacity indicates, that the lakes predominating in the catchments are relatively large in area but shallower. It should be kept in mind that these are static water resources of lakes and only a part of them is in constant circulation. Still, remembering this, the index allows a direct comparison of concrete quantitative indicators of the balance. It seems that lakes can be expected to have a major influence on the water cycle in a given catchment at a storage capacity of more than 50 mm, while at more than 100 mm their influence should be very significant [6]. Naturally, in many catchments the role of lakes will not always increase in proportion to their growing storage capacity index. It will also crucially depend on the location of the lakes in the catchment and the morphometry of lake basins.

In the Institute of Meteorology and Water Management carriers out regular observations of water level fluctuation in chosen lakes. They provide basic information about their current water levels and how they change over time. The number of lakes whose water stages are registered is small, and additional problem is frequent changes of observation posts. The post are liquidated, and sometimes new ones are opened, for a variety of reasons, usually financial. Figures show mean annual variations, calculated from monthly means. It is generally assumed that mean annual stages reflect climatic change. However, they also depend on water cycle conditions in the particular lake basins and catchments. Disturbances in the natural water-level pattern may also due to human activity. Besides, water levels of some lakes are regulated by weirs; their influence on the mean annual stages, however, is rather limited.

An important issue is the tendency of change in the water levels of Polish lakes. In some lakes with longer observation series a negative tendency can be discerned more or less clearly. It is not sure if this is a permanent climatic or man-made tendency or one due to local variations connected with the water cycle in the given catchment [8,11].

Variations in the main water level are usually between 20 and 40 cm. There are lakes, however with longer or smaller amplitudes.

The lake water purity can be estimated generally on the basis of features that describe each lake. In Poland the evaluation system of lake water purity is based on determining over ten indices and calculating mean number of points. This evaluation system of three stages is recommended by the State Inspectorate of Environmental Protection. Some lakes located on the area of the first two Volumes scope have been explored more precisely than others and results of the exploration have been published [3,4,5]. So far, the 270 lakes inquiry has resulted in publishing the two volume Atlas. Only 6 lakes are in the first class of water purity, 116 ones are in the second, 97 ones are in the third and as many as 51 lakes are below the third class. As recent studies show [7] there are some lakes which change their classes even every year.

References

1. Choiński A. 1991 - 1992. Katalog Jezior Polski, cz. 1-3. Wyd. UAM T.1 i 2, Fund. „Warta" T. 3. Poznań.
2. Chojnowski S. 1984. Jeziora [w:] Atlas Hydrologiczny Polski [Red. J. Stachy]. T. 2. IMGW Warszawa.
3. Cydzik D., Soszka H. 1988. Atlas stanu czystoœci jezior Polski badanych w latach 1979-1983. Wyd. Geol. Warszawa.
4. Cydzik D., Kudelska D., Soszka H. 1992. Atlas stanu czystoœci jezior Polski badanych w latach 1984-1988. Bibl. Mon. Œrod. Warszawa.
5. Cydzik D., Kudelska D., Soszka H. 1995. Atlas stanu czystoœci jezior Polski badanych w latach 1989-1993. Bibl. Mon. Œrod. Warszawa.
6. Jańczak J. 1991. Fizycznogeograficzna typologia i ocena jezior na przyk³adzie Pojezierza Wielkopolskiego (Sum.: Physical-geographic typology and estimation of lakes on example of Wielkopolska Lake District). Mat. Bad. IMGW, Ser. Hydr. i Ocean. Nr 15. Warszawa.
7. Jańczak J. 1997. Zmiany jakoœci wody jezior na podstawie badań prowadzonych w monitoringu reperowym jezior polskich w latach 1991-1995 (Sum: Changes in the water quality of lakes on the bases of watermark monitoring studies of Polish lakes in the years 1991-1995). Bibl. Mon. Œrod. Warszawa.
8. Jańczak J., Choiński A. 1993. Zmiany wahań poziomu wody jezior w latach 1956-1985 (Changes in water level fluctuation in the lakes in 1956-1985). [w:] Przemiany stosunków wodnych wodnych w Polsce w wyniku procesów naturalnych i antropogenicznych. Red. I. Dynowska. Kraków.
9. Jańczak J., Sziwa R. 1984. Zwi¹zek miêdzy g³êbokoœciami najwiêkszymi a œrednimi jezior (Sum.: Relation between maximum and medium depths of lakes). Przegl. Geof. Nr 1.
10. Katalog Jezior Polski. 1954. [Red. S. Majdanowski]. Dok. Geogr. IG PAN. Warszawa.
11. Pas³awski Z. 1972. Wieloletnie wahania i tendencje zmian poziomu wody jezior odp³ywowych w Polsce pó³nocnej. (Many years oscillations and trends towards the changes of the water level outflowing lakes in northern Poland). Przegl. Geof. T. 17, z. 3-4.
12. Podzia³ Hydrograficzny Polski 1980. IMGW. Warszawa.

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Urban storm runoff assessment using hydrologic modeling technique: Its applicability and limitations (A case on Dhaka City, Bangladesh)

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The recent waterlogging problem of Dhaka Mega-City, which is the effect of human interference over natural system prompted us to realize the necessity of a management and monitoring tool based on Mathematical Models and combination of Geographic Information System (GIS) and Remote Sensing (RS) to analyze the complex hydraulic phenomenon of the Dhaka Mega-City drainage system.

The study result shows that the improved drainage system with retention pond, proper maintenance and operation, together with pump drainage facility the city can easily cope with the waterlogging problem in the near future. This kind of tool could form a better coordination among various service agencies. Further, it could be used to optimize the future expansion and management of the drainage system to cope with the city expansion and population growth challenge.

Introduction

United Nations (UN) in 1987 declared Dhaka as a "Mega-City" of the world (Islam, 1996). Dhaka the capital of Bangladesh is one of the fast growing cities in the world. This city is experiencing rapid and unplanned expansion along with vertical intensification due to population growth. The unplanned and rapid physical expansion is causing various physical and socio-economic problems. They were identified as increasing significant proportion of the impervious land, reducing the natural storage basin, disrupting the hydrologic link between the khals and main rivers by the flood protection embankment and different infrastructure. This is resulting in sever waterlogging problems in the monsoon season, which prompted us to realize the necessity of the tool based on Mathematical Model, GIS and RS for analyzing the complex hydraulic phenomenon of the Dhaka Mega-City's drainage system.

In this study the hydrologic modeling technique has been applied to analyze the effectiveness of the improved drainage system proposed and designed by JICA in 1990. In this research attempt has been made to develop a model and examine the requirement of the data/information, its present status, availability, quality etc.

Study area description

Dhaka Mega-City is located in the central part of the country and lies between 23°40'N-23°55'N latitude and 90°20'E-90°30'E longitude. The Burhiganga River in the south, Turag River in the west, Tongi khal in the north and the Balu River in the east bound it. Dhaka City and surrounding towns are situated mainly on alluvial terraces, known as the Madhupur Tract of the Pleistocene epoch. Topographically, Dhaka City is relatively flat, the surface elevation of the city ranges between 1.7 m and 14 m AMSL. The study area belongs to sub-tropical monsoon and humid climatic condition. Dhaka experiences about 2000-mm rainfall annually, of which about 80% take place during the monsoon. Dhaka Mega-City is about 265 sq. km with a population of 10 million.

Due to the limited time frame and data availability a small catchment area has been selected fordeveloping a prototype model, which is known as "Drainage Zone–H" or "Kallyanpur Catchment Area". The selected model area has an area of 17.6 sq. km. Based on JICA (1987 and 1990), drainage improvement proposal "Kallyanpur Pumping Station" with a capacity of 10 m^3 /sec has already been installed and made operational. A number of underground pipes and other improvement work have been completed in this drainage zone. This catchment area is having a 208 hectares large retention pond to store temporally the urban storm water runoff for pumping into the surrounding rivers. The model area has been embanked in the period of 1990-91.

Objectives

This research aims to examine the applicability of DUFLOW model to find the effectiveness of the JICA (1990), proposed drainage system for the Dhaka Mega-City during the monsoon season. The specific objectives of this research are as follows:

- to develop a pilot demonstrative mathematical model for a small part of the Dhaka Mega-City.
- to simulate the waterlogging condition under the design rainfall condition and the September 1996 real-time rainfall condition using DUFLOW Model;
- to identify the effectiveness of the JICA, 1990 designed and proposed drainage system for the Dhaka Mega-City; and
- to assess the data availability and examine the existing data quality for developing a detailed model for real time Decision Support System (DSS) for drainage monitoring in an optimum operation.

Methodology and materials

The methodology to be followed in this research covers the identification of the problem, available technology and their applicability and examining the limitation etc. The main focus of this research was, collection, evaluation and analysis of the existing data relevant to the model. Data analysis and manipulation will mainly involve the use of ARC/INFO, ILWIS and DUFLOW Modeling software.

The model parameter selection criterion was developed based on geometric and hydrologic characteristics of the terrain. Initial and boundary conditions for the model setup were identified based on design parameters.

Various sources of materials e.g. IRS-1C Pan image 1996, Topographic Map, Spot Elevation Map, Geomorphologic Map, Urban Expansion Map, Hydro-Climatic Data and JICA study reports were used to finalize this study.

Preparation of model input parameters using gis and rs

For setting up the hydrologic model one of the requirements is the space-related information, which can be easily obtained, using GIS/RS techniques. For this modeling exercise all nodal information (X,Y coordinate), percentage of impervious areas, catchment areas and height etc. were derived from various GIS/RS techniques.

Network schematization using duflow software

For this network schematization both geometric and hydrologic criteria were taken into consideration. The khal drainage system (node points, sections and cross-sections) was defined as a network for this model. Artificial drainage system was not taken into account because of the sensitive nature of the DUFLOW model. To derive the channel node point and bottom and end level of the channel, IRS-1C panchromatic Image (February 1997) and a DEM were used. Sections were selected based on the flow direction of the khals towards the outlet. The cross sections were chosen based on the JICA (1990) study, which were the estimated values for the khal improvement. The sub-catchment area as well as the percentage impervious areas were identified by visual interpretation of the IRS-1C PAN image. This estimation was based on local knowledge and the tone, texture and pattern information of the satellite image. The degree of imperviousness varies from 10% to 80% in this model area. Finally, 26 nodes, 25 sections and 24 sub-catchment area were identified to design the network for the DUFLOW Model.

Setup of the model

At this stage space and time variables were defined in **Flow Data Module** to calculate the flow. The output requirement was similarly defined in the **Calculation Definition Module**. During the model setup period, a number of headwater sections were modified and some new sections were added to achieve stable computations. For a final setup of the model, the initial and boundary conditions were defined as follows:

Initial Condition

- The constant water level of 4.5 m GTS in the retention pond;
- Storage in the retention pond was assuming of 5.0 m GTS storage level; and
- No initial flow was applied.

Boundary Condition

Rain: as a time series using the 5 years frequency and 2 days consecutive design rainfall and 4 days consecutive rainfall of the September 1996 were applied;
Level: 5.5 m GTS was assumed as bank height in node 27 as a constant function.

For the flow computation purpose de Chezy resistance formula was used.

Design of the model simulation run

Model simulation was designed and carried out considering the following criteria:

- Khals are having JICA (1990) proposed cross-sections;
- No land encroachment along the khal bank; and
- Regular cleaning and maintenance activities are conducted.

Based on the above mentioned criteria and available rainfall data two simulation run were designed to simulate the waterlogging conditions in the study area under full implementation of the on-going khal improvement plan (Table-1).

Table -1: Description of the Simulation Runs.

Simulation Run	Flow Type	Headwater Inflow	Rainfall	Output
1. Under Design Condition	Dynamic unsteady flow	Constant	2 days consecutive design rainfall	Water level, discharge and velocity.
2. Under September 16-19 1996 Rainfall Condition	Dynamic unsteady flow	Constant	4 days consecutive rainfall during 16-19 September 1996	Water level, discharge and velocity.

Result and discussion

The result of the two-simulation run indicated that under the improved drainage condition, waterlogging would not be a major problem in this catchment area. Result of the simulation run under the design condition indicates that water level varies from 4.98m GTS to 6.62m GTS in different khals in this catchment. And the generated runoff from design rainfall is discharged within 15 - 18 hours into the retention pond. On the other hand, the result of the simulation run under the 4 days consecutive rainfall of September 1996 illustrates that, it was causing waterlogging in the study area having differences in depth and duration. The 19^{th} September waterlogging is more severe compared to the previous 3 days. Water level varies from 4.98m GTS to 5.7m GTS in different parts of the study area. Water level rises within 2 hours and discharges rapidly within 6-8 hours into the retention pond. Model simulation for the September 1996 waterlogging was carried out with improved drainage condition. So the model result indicates that with the improved drainage system, the model area will face waterlogging for a short period only. Local road and ground level of the some houses will be inundated during the monsoon for a short while.

Limitations regarding software, data availability and data quality

Urban hydrologic modeling requires a huge amount of data to determine the flow behavior in the city. At present there is no agency involved in maintaining databases in an organized way. Due to the scarcity of the key data the model was setup based on the JICA (1990) proposed drainage improvement scheme. In this modeling exercise only the open channel flow was taken into consideration due to the limitation of the model and key data. So pressurized flow was not modeled in this study. Besides the model and data availability, it was found to be a difficult task to compute the cross sections from the DEM. At the first attempt the cross sections were derived from Q TIN DEM using ILWIS were found leading to computational instability. Due to the shallow height difference of the cross sections and in some cases large differences in gradient (more than 3 meters). At the last stage, cross sections were chosen based on the JICA (1990) study, which were estimated values for the khal improvement. At present there is no such information regarding bottom level of the khals and the elevation data for the built-up areas were available. Setback of the drainage modeling for the Dhaka Mega-City regarding the information/data were identified in this research as follows:

- Lack of detailed topographic information for the built-up areas;
- Unavailability of the updated and good quality landuse map;
- Soil map and lithological information are not available;
- Water level, discharge and velocity data for the Dhaka Mega-City drainage system (khal and storm drainage) are not measured at present;
- Bottom levels information, cross-sections and longitudinal profile of the khals are not provided in the "Drainage Network Map" and "Spot Elevation Map" of DWASA and SOB respectively; and
- No information available regarding the percentage of the impervious areas of the Dhaka Mega-City.

To carry out the study the calibration parameters such as percentage of the impervious areas were estimated from IRS-1C PAN image based on image signature together with local knowledge, which needs further verification against measured field data. No calibration and verification of the developed model could be possible due to the non-availability of the key data. Mainly ***runoff coefficient*** and the ***Chezy friction coefficient*** needs further verification for a real time solution.

Conclusion and recommendation

To come up with an effective solution of the waterlogging problem of Dhaka Mega-City, it is necessary to apply the hydrological modeling technique coupled with GIS & RS for analyzing the complex hydraulic phenomenon of the Dhaka Mega-City drainage system.

However in this research, an effort was made to analyze the applicability of the hydrologic modeling approach and drainage condition of Dhaka City under the JICA (1990) proposed drainage improvement scheme. This model result is only a first approximation. **Hence the model results of this research should be interpreted as indicative only.** From the model result it can be assumed that, under the JICA (1990) proposed drainage improvement scheme, waterlogging will not be a major problem in the study area. If the cross section of the khals are maintained properly and no further land encroachment occurs along the khals, no land development activities in the retention pond area and cleaning activities conducted regularly than the Dhaka Mega-City can easily cope with the waterlogging problem. More over, if the design ground level for the new urban expanded areas in the 'Drainage Zone - H' maintained at 5.5 m GTS, it can easily cope with the waterlogging problem in the future with this improved drainage system along with actual and proposed pump facilities (Khan. 1997).

From this model study it can be recommended that there is an urgent need for establishing and maintaining the digital databases and drainage monitoring (short and long term) network within the concern agencies. A topographic and landuse survey should be carried out for the built-up areas. Which is the vital input for the hydrologic model. Discharges, velocity, water level of the khals, storm sewer pipe and box culvert need to be measure for necessary modification and improvement of the Dhaka Mega-City drainage system Few more rain gauge should be install and measurement frequency need to be increase in 5 minute intervals during the rainstorms. The decision of the Government and concerned agencies in data acquisition is important, for the Dhaka City drainage monitoring in an optimum operation.

This model can provide an effective and consistent FLOOD MANAGEMENT tool to establish better coordination among the various agencies. Further, this model could be used to optimize the future expansion and management of the drainage system to cope with the city expansion and population growth challenge.

References

FAP-8A, 1991, "Master Plan for Greater Dhaka Protection Project (Study Area in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan", Main Report, Japan International Cooperation Agency.

FAP-8A, 1991, "Master Plan for Greater Dhaka Protection Project (Study Area in Dhaka Metropolitan Area) of Bangladesh Flood Action Plan", Supporting Report No. I & II, Japan International Cooperation Agency.

Geiger W. F., 1990, "Appropriate Technology for Urban Drainage in Developing Countries", In Hydrological Processes and

Water Management in Urban Areas, Edited by Massing Herbert, Packman J., and Zuidema F., IAHS Publication No. 198.

Islam N., 1996, "Dhaka from City to Megacity", Department of Geography, University of Dhaka.

JICA, 1990, "Updating Study on Storm Water Drainage Improvement Project in Dhaka City", Supporting Report, Japan International Cooperation.

JICA, 1990, "Study on Storm Drainage System Improvement Project in Dhaka City", Main Report, Japan International Cooperation.

JICA, 1987, "Study on Storm Drainage System Improvement Project in Dhaka City", Main Report, Japan International Cooperation.

Khan N. I., 1997, "Urban Storm Runoff Assessment Using A Combined Geomorphological and Hydrological Approach : A case Study on Greater Dhaka City", unpublished M.Sc Thesis, ITC, Enschede, The Netherlands.

Khondaker M. A. M. and Chowdhury J.U., 1992, "Effects of Dhaka City Flood Protection Embankment upon Surface Water Drainage System and Environment", IFCDR, BUET, Sponsored by United Nation Development Program Nagoga, Japan.

Lazaro R. Timothy, 1991, "Urban Hydrology, A Multi Disciplinary Perspective", Revised Edition, Technomic Publishing Co., Inc., Lancaster, Basel.

Richter K. G., Schultz G. A., 1988, "Aggravation of Flood Conditions Due to Increased Industrialization and Urbanization", In Urban Water 88, Proceedings of Hydrological Processes and Water Management In Urban Areas, Germany.

SWMC, 1997, "Storm Water Drainage Modeling For Dhaka City", A Pilot Study Report, SWMC and Danish Hydraulic Institute.

UNESCO, 1987, "Manual on Drainage in Urbanization", Planning and Design of Drainage Systems, Vol. I.

Management of data

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Issues of hydrological database management

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1. Introduction

This paper is one of six keynote papers to be presented at the *International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management, Koblenz, 22 – 26 March 1999.* With data collection, quality assurance and data availability covered in other keynote papers, this paper will address the application of hydrological database systems and the potential benefits of new and emerging technologies. Initially, the paper focuses on the situation in Europe but then considers issues of general interest.

2. Hydrological data management in Europe

Networks to observe hydrological and meteorological variables are well established in most European countries. According to WMO INFOHYDRO figures, Europe has over 38,000 river gauging stations, 48,000 precipitation stations and 84,000 groundwater observation boreholes (WMO, 1995). A survey of hydrometric monitoring practices in Europe (Rees *et al.*, 1996), conducted on behalf of the European Environment Agency (EEA), identified over 15,000 stations gauging river levels and flows in just 12 countries. It also found a high degree of commonality between the hydrometric monitoring programmes of different countries, with most countries having a programme that is coordinated, at national level, by a single body (the National Hydrological Service) which is responsible for the management of a national database. Data collection and the day-to-day management of the observation network, however, is largely the responsibility of local, regional or basin authorities who use the information for operational purposes within individual river basins. Some networks are operated by private organisations for a specific purpose, such as hydropower production or reservoir management. In most countries, hydrometric data from local/regional authorities are transferred periodically (on a daily, weekly or monthly basis) to the National Hydrological Service where the information is typically stored at 15 minute, 1 hour or daily intervals on a relational database management system.

With so many issues of common concern, considerable benefits could be gleaned through the formation of an international forum, or network, for the National Hydrological Services of Europe. In meteorology, such a network, called EUMETNET, has already been established. Involving 18 European National Meteorological Services, EUMETNET provides "a framework to organise co-operative programmes between the Members in the various fields of basic meteorological activities such as observing systems, data processing, basic forecasting products, research and training" (Pastre and Le Floch, 1998).

One objective of the proposed forum could be to integrate hydrometric data from the different national hydrometric programmes to provide an overview of the present-day hydrological status of European

rivers and other freshwater resources. This would complement the work of the EEA who are planning to implement the EURO-WATERNET, an European monitoring and observation network for inland waters, which "will draw upon existing national and international databases" to produce contemporary information on the state of the aquatic environment (Thyssen and Lack, 1998).
A pan-European observation network would be relevant to the WMO who, being concerned that the ability to provide adequate information on the status of water resources is declining in some parts of the world, are establishing a World Hydrological Cycle Observing System (WHYCOS). The first steps have been made through regional HYCOSs in the Mediterranean, Southern Africa and West and Central Africa (WMO, 1998). MED-HYCOS involves 13 Mediterranean countries and the transmission of real-time hydrometeorological data to a regional database in Montpellier, France.

Two notable examples of existing hydrological database facilities which have been established through international cooperation are the FRIEND European Water Archive and the WMO's Global Runoff Data Centre. Developed within the FRIEND (Flow Regimes from International Experimental and Network Data) project, the European Water Archive serves the research needs of project participants by providing long-term historical river flow data and catchment characteristics for some 5000 small catchments in 29 countries (Rees, 1999). The Global Runoff Data Centre, based in Koblenz, has assembled a database of historical flow data for over 3600 gauging stations world-wide to be used, primarily, for research and education (GRDC, 1998).

3. Evolution of database systems

Before computers, hydrological data were stored on manual filing systems. With the dawning of the "computer-age" in the late 1960's and 1970's, manual systems were replaced by computer file-based systems. Although an improvement on manual systems, file-based systems had serious limitations, such as the isolation of data in separate files, duplication of data, incompatible file formats and restrictions on the ability to query data. To overcome these limitations, database management systems (DBMS) emerged providing facilities for users to define, create and maintain data in a logically structured database. Problems in the so-called first-generation (network and hierarchical) DBMSs led to the relational data model (Codd, 1970) and the development of the (second generation) relational DBMS (RDBMS). Today there are several hundred RDBMSs commercially available including Oracle, Ingres and Informix, which provide multi-user access on mainframe and mini computers, and Microsoft Access, dBase IV and Paradox, for microcomputers. In Europe, most National Hydrological Services now store their data on an RDBMS.

In parallel with the evolution of database systems, there has been a massive increase in the volume and types of data stored. Initially, only simple time-series data, which were ideally suited to the relational model, were stored. Now, complex spatial data from geographical information systems (GIS) and computer aided design (CAD) software are required to optimise the overall infromation delivery of the database management system. Recognising the inadequacies of RDBMSs to deal with such data, third generation of DBMSs, Object Oriented DBMSs, have been developing in recent years. Research conducted by Cemagref (France), into the application OODBMSs in hydrology, has yielded some promising results (Lang and Manea (1994); Manea and Givone (1995); Manea et al. (1997)) although there is little evidence of such systems having been applied widely in practice.

4. Issues of Hydrological Database Management

Hydrological data may be used for a variety of purposes, such as (WMO,1998):

- assessing the country's water resources
- planning, designing and operating water projects;
- assessing the environmental, social and economic impacts of water resource management practices;
- assessing the impacts of other sectors' activities, e.g. urbanization or deforestation, on water resources;
- providing security against floods and droughts.

The data required can differ significantly from one application to the next. For example, in flood forecasting, real-time data at a fine temporal resolution is needed, whereas, for the planning of water resources, daily or monthly historical data would suffice. As well as meeting the disparate needs of the various users, the design and development of a hydrological database management system should carefully consider how to maximize information output from the data available.

To address the issues of hydrological database management, it is useful to view the flow of information in three consecutive elements: input; storage; and output. The input element involves the collection of the hydrometric data and its transfer onto an appropriate storage medium, the database. The storage element concerns the database, its design, management and maintenance. The output element involves the design of the user-interface and the application programs that are to process the data. It has been suggested, that the issues of data collection are largely independent of those of database management and that the actions of the end-users are generally outside the control of the database manager (Cahill *et al.*, 1994). However, the independence of these components has often been a major weakness in terms of information delivery. There is a need for greater connectivity and dialogue between data collectors and end-users. In this context, the database manager can assume a pivotal role. Consideration should also be given to the role and benefits of Annual Hydrometric Data Audits which can help to maximize the information content of the archived data by appraising network performance, improving data quality and meeting the information needs of users (Marsh, 1999).

Hydrometric data can be collected by a variety of means, including: paper charts, punched paper-tape, digital data loggers or via telemetry. The methods of translating the collected data into digital form and then transferring them onto the hydrological database will, to a limited extent, influence the design of the database. It is important that all the raw a data hydrological database receives is kept intact and that a record (audit-trail) be maintained of all actions subsequently performed on the data. Often, the raw data will be provided as a time-series of level, or stage, readings. To convert this information into a time-series of river flow requires the provision of a rating curve, or stage-discharge relationship, for the gauging station concerned. Again, it is most important that the equation of the rating curve is kept (if not the spot-gaugings to derive it) and a record be made of which curve was used to derive any given set of flow records. Equally important is the need to record any changes in the method of gauging, the relocation of the gauging station and any human induced changes in the catchment (e.g. land-use changes, river training). Further discussion on data quality measures is given in the keynote paper by Roald.

As has been described, many national databases are serviced with data from several regional offices. The organisational infrastructure within a country and the relationship between national and regional offices will effect the design of both regional and national databases. Charged with the operational management of local water resources, the regional offices will commonly be responsible for data collection, the derivation of rating curves, the conversion of river level to flows and all the quality control and assurance measures. Details of changes in the method of measurement or changes to the catchment would be stored at the regional office. Only the processed flow data, possibly aggregated to daily values, would be transferred to the national database. There is danger, when such a limited amount of "local" information is filtered upwards, that utility of national-level data is compromised. For example, a recent study of trends and variation in UK floods (Robson *et al.*, 1998) interestingly suggested that the non-stationarity of many of the flow records was a result of poor data quality, changes in the gauging, drainage diversion or urban growth. This observation has obvious connotations for those attempting to find evidence of climate change from national or international data.

The means of transferring data between organisations also has implications for data design and management. In the (not so distant) past, the only means of transferring hydrological data from one location to another was by sending the data on floppy disks, or magnetic tape, by post. Now, computer networks have developed that enable computers to be connected with thousands of other machines around the world. The existence of local area networks (LAN), wide area networks (WAN) and the Internet means that hydrological data can be transferred anywhere almost instantaneously. File transfers, however, continue to be a problem in hydrological database management with a seemingly countless number of different file formats in use. A standard data format for the transfer of hydrological data should be internationally agreed.

Although computer networks are used extensively for the transfer of data files, the ability to "network" the databases themselves has yet to be realised in hydrology . The new distributed database technology (viz. distributed database management systems (DDBMS)) lends itself well to the regionally distributed nature of hydrometric data collection in many countries. The use of DDBMSs would eradicate the need for conventional file transfers while maintaining nodes of local expertise.

Another problem in hydrology, which is noticed especially during data transfer and which could hinder the uptake of DDBMSs, is that of non-standard nomenclature. It is not uncommon for different names to be given to the same variable or the same name used to describe two different variables. Problems also occur when different units are used to quantify a variable (e.g. litres per second or cubic metres per second). Universal standards should be determined for the naming and definition of hydrological variables and the corresponding units of measure.

Relational database management systems are widely used in hydrology. The recommended steps for the proper design of a relational database are well documented elsewhere (e.g. Date, 1995). It has been suggested that the most active 20% of user queries account for 80% of the total data access (Wiederhold, 1983). In designing a database, special attention should be paid to those few applications having the greatest number of database transactions. In practice, few applications are written before the database design is complete. It is imperative, therefore, that the requirements specification for the application are available during database design. With DBMSs it is also common to "prototype" the database and certain applications before full system implementation. Prototyping allows a rapid assessment of the database or application, helping to identify features that work well or that are inadequate.

An application is a program or procedure that allows data on the database to be queried, processed and manipulated. Applications include both programs that load data onto the database as well as those that are used to abstract information it. RDBMSs provide a Data Manipulation Language (DML) which allows the user to build a statement to query the database and manipulate the data (e.g. SQL (structured query language)). They also feature fourth generation language (4GL) tools that enable forms, reports and application programs to be developed very quickly without the need for hundreds of line of 3GL code (e.g. FORTRAN). Applications written with 3GL code (e.g. a hydrological model) may access the database by embedding SQL statements in the software. The software, needing to be precompiled, is specific to the one vendor's RDBMS and cannot be used directly with any other type of RDBMS. Aware of the problem, Microsoft produced the Open Database Connectivity (ODBC) standard which provides a common interface for accessing SQL-based databases from different vendors. More recently, Microsoft have developed OLE DB (Object Linking and Embedding for Databases) which provides access to any data source including relational and non-relational databases. The development of such facilities could change the whole approach of developing hydrological software with models able to be applied to any data anywhere.
Hydrological database management systems can no longer be considered simply as a relational database comprising time-series of river levels and flows and associated gauging station information. The "system" includes spatial data derived from advanced database applications, such as, geographical information systems (GIS), computer aided design (CAD) software and remote sensing (RS). Rivers and catchment boundaries digitised from maps, or derived from digital elevation models (DEM), are now an important part of a modern hydrological database management system, as are digital maps of soil types, geology, hydrogeology and land-use. Remote sensing images, providing up-to-date information of land-cover, soil moisture and groundwater add another dimension. While many suppliers of RDBMS software now allow the storage of GIS/CAD/RS images as Binary Large Objects

(BLOBs), the DBMS has no information concerning the content or internal structure of the BLOB and can do little other than to display the object. The Object Oriented Databases emerged in response to the increasing complexity of database applications and the inadequacies of the relational model to reflect the "real world. Time will tell whether the object oriented approach will supersede RDBMSs in hydrology.

5. The Future?

Rapid advances in computer science and database technology make it very difficult to gauge what will be possible in 5, 10 or 20 years' time. As far as hydrological database management is concerned, it is clear that several new technologies could bring considerable benefits in the short to medium-term. Examples, such as, OODBMS and DDBMS have been mentioned previously, others may include:

- The World Wide Web (WWW) as a database application platform

  In January 1997 the Internet was estimated to have over 100 million users; one year later the estimate had risen to 270 million users: the Internet and the WWW especially will revolutionise society's view on data and data dissemination. Free, unrestricted, access to hydrological data over the WWW will encourage hydrological research and help improve our understanding of hydrology and water resources. A good example of a hydrological WWW database application in practice can be found with the Portuguese Water Resources Information System, SNIRH, at "http://www.inag.pt/snirh/index.html".

- Data Warehousing and Data Marts

  A new approach to database management, data warehousing provides a solution for accessing data held in non-relational databases. Large volumes of data are reorganised around major subjects rather than major applications, focusing on using the data to support decision making. Data marts are created from data warehouses to give users rapid access to data they analyse the most.

- On-line Analytical Processing (OLAP)

  On-line Analytical Processing is the dynamic synthesis and consolidation of large volumes of multi-dimensional data. OLAP would be useful for operational databases, by providing a rapid means of retrieving large number of records and summarising them dynamically. OLAP data servers provide facilities to aggregate (consolidate) data as simple "roll-ups" or complex expressions of inter related data (Connolly *et al.,* 1998). For example, data for many gauging stations may be rolled up into a region, regions could be rolled-up into countries. OLAP also allows data to be analysed from different viewpoints (pivoting), for example, to display the total runoff of catchments between 500 m and 1500 m .

- Data Mining

  Data mining is the process of extracting valid, previously unknown, information from large databases. There are four data mining techniques, each of which has the potential of being applied in hydrology: *predictive modelling* can be used to analyse existing data to determine some essential characteristics (model) about the data-set, the model is then tested against new data; *database segmentation,* the process of partitioning the database into an unknown number of homogeneous records, could be used to classify hydrologically homogeneous regions; *link analysis* aims to establish associations between records and could be used to detect trends in hydrological data; and, finally, *deviation detection*, a visualization technique that identifies outliers in data-sets.

Advocating the use of new technology when hydrological services are financially constrained in many countries may seem somewhat naive. However, it is important for hydrology that those in charge of data are aware of the tools and are able to maximise the utility of the data available. The application of the above technologies could bring many benefits, such as, more efficient data management, improved data accessibility, better information to decision makers, and the increased portability of hydrological applications. New technology can help improve our understanding of the hydrological cycle and, hence, improve our ability to properly manage the Earth's precious freshwater resources.

References

Cahill, B., Owens, K., Wallace, J. and O'Kane, J.P., 1994. "The EROS2000 environmental database", In: HYDROINFORMATICS '94 (Vol. 1), Proc. of First Int. Conf. on Hydroinformatics, Delft, Netherlands, 19-23 September 1994.

Codd, E.F., 1970. "A relational model of data for large shared databanks", Comm. ACM 13(6), 377-387.

Connolly, T.M. and Begg, C.E., 1998. "Database Systems: A practical approach to design, implementation and management", 2nd Edition, Addison Wesley (Pub.).

Date, C.J., 1995. "An Introduction to Database Systems", 6th Edition, Addison Wesley (Pub.).

GRDC, 1998. "Report No. 18 – GRDC Status Report 1997", Global Runoff Data Centre, Federal Institute of Hydrology, Germany, June 1998.

Lang, M. and Manea, A., 1994. "BRECHE project of hydrological data base for ERB: modelling of data series", In Proc. FRIEND: Flow Regimes from International Experimental and Network Data – Braunschweig Conference, October, 1993. IAHS Publ. No. 221, 1994.

Manea, A., Breil, P. and Desbos, E., 1997. "FRIEND-AMHY data base scheme", Seminaire international annuel du Groupe AMHY de FRIEND, Thessalonique – 1997. Rapport annuel AMHY No. 5, UNESCO.

Manea, A. and Givone, P., 1995. "Hydrological Information System Design: requirements, specifications and evaluation", In Proc. International Conference on Meteorological and Hydrological Technology and its Management, Geneva 22-26 May 1995.

Marsh, T.J., 1999. "Maximising the Utility of River Flow Data", In Herschy, R.W., 1999, "Hydrometry: Principles and Practices ", John Wiley & Sons Ltd. (Pub.).

Pastre, C. and Le Floch M., 1998. "EUMETNET – The Network of European Meteorological Services", (http://www.eumetnet.eu.org/) Météo-France, October 1998.

Rees, H.G., 1999. "The management of the FRIEND European Water Archive", In Proc. International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management, Koblenz, Germany, 22- 26 March 1999.

Rees, H.G., Cole, G.A. & Gustard, A. 1996. Surface Water Quantity Monitoring in Europe. European Environment Agency, Topic Report No. 3.

Robson, A.J., Jones, T.K., Reed, D.W. and Bayliss, A.C., 1998. "A study of national trend and variation in UK floods", In: International Journal of Climatology, Vol 18, 165-182, 1998.

Thyssen, N. and Lack, T., 1998. "EURO-WATERNET: A Water Resource Monitoring Information and Reporting Network for Europe", International Conference on Water and Sustainable Development, Paris, 18-21 March, 1998.

Wiederhold, G., 1983. "Database Design", 2nd Edition, New York. McGraw-Hill (Pub.).

WMO, 1995. "INFOHYDRO Manual", Operational Hydrology Report No. 28. World Meteorological Organization, Switzerland.

WMO, 1998. "WHYCOS: World Hydrological Cycle Observing System", (http://www.wmo.ch/web/homs/whycos.html), World Meteorological Organization, Switzerland.

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Data base management system implantation at the Mexican National Meteorological Service

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Introduction

The Mexican National Meteorological Service (NMS) has to manage, among other responsibilities, the climatological daily records measured at 5,575 ground stations. The digital information, which includes rainfall, evaporation, maximum, minimum, and observed temperature, sky condition, haze, hail, and electric storm, varies from January 1, 1921 to December 31, 1990.

Objective

The objective is to integrate a database with the climatological information, and to develop a system for managing, consulting and executing computations with the information, taking advantage of a Geographical Information System (GIS). The user should be able to consult the data using the system or by making direct queries or computations on the database.

Issues

The NMS needs an integrated system with a fast time of access and response to queries, to perform the climatological computations, and to provide security to the data, all with graphical user interface and with georreferenced information, easy to use.

The typical questions the NMS has to answer include the recorded value of a climatological variable at a certain station, the day in which the maximum or minimum value of variable occurred, the average value of a variable, the unconditional probability of rainfall, the map of isolines, the thematic map of the combination of variables, etcetera.

The developed system complies with the fast access restriction, provides security to the database, and constitutes a user-friendly platform to do climatological computations. The system have dialogue windows, on-line help, and links to databases, backed up by the data security and speed in solving queries that a relational data base management system can provide. The user can access the historical climatological data with out know how to manage Oracle® or another RDBM, is easy to use since was developed to be manage by persons with the minimum experience on manage an computer.

Methodology

- Select the Geographical Information System (GIS) in order to have a graphical interfaz. In this case we selected the ArcInfo® system, this system permit to connect to Oracle®, and have the utilities to make the interpolations, graphics, etcetera.
- Select the Relational Data Base Management System (RDBMS).
  The RDBMS had to manage a very large number of records, to provide security, and to run in a Silicon Graphics® (SGI) platform. For these reasons it was decided to use Oracle as the RDBMS.

- Communication between ArcInfo® and Oracle®: Was done through a connection. ArcInfo® connects to Oracle® and requests the information. Oracle makes the consults and sends the information back to ArcInfo®.

- Select the database design: The design considerations were:
  Daily records with 29,106,207 records
  Annual, records with 802,314 records
  Monthly records, with 8,641,908 records

  Since Oracle allows only 255 fields the annual design is not possible. Besides, the annual and monthly designs do not allow direct consults using queries.

  To make queries with and without the system the consults are easier with the daily design. Because the main use of the system is for making consults, it was decided to keep daily design.

- To minimize the response time while consulting .
  Response time was a big problem, and creating a table with monthly precomputed data averages solved the issue.

- To make the computes.
  Probability of rainfall, mean of a period, daily averages, monthly average, humidity index and boolean consults were computed using climatologic concepts.

Description of the Climatological Information System (SIC)
The system was developed in an Indigo Silicon Graphics® workstation, with operating system IRIX® 5.3., using the Oracle RDBMS and ArcInfo® as the SIG.

The database is integrated mainly by the following tables: climatological data, climatologic stations, states, hydrological regions, basins, dams, and precomputed data.

The main coverages used in the system are: country, hydrologic regions, basins and political division.

The following diagram is a general description of the system menu and its options.

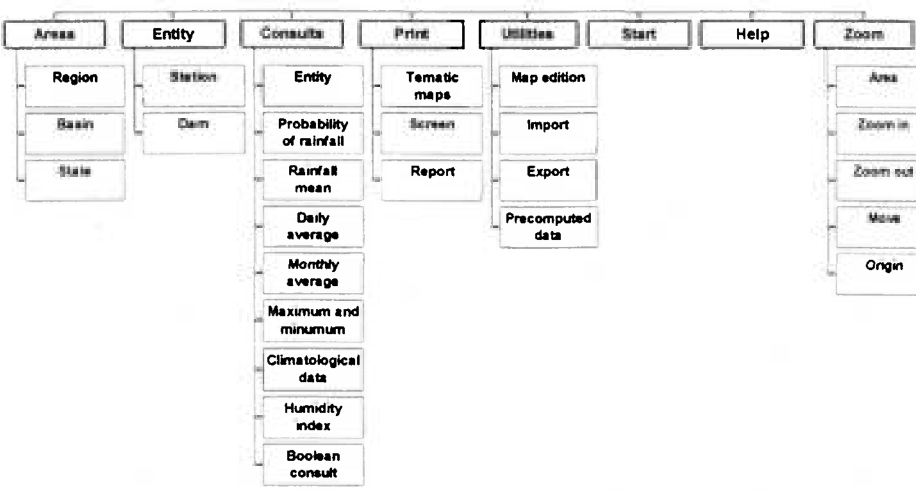

Figure: General description of the system menu and its options

Description of the system options:

- **Areas**: Allows to display the hydrological region, state, basin, irregular user-defined area or single climatological station covers on the Mexican Republic coverage.
- **Entities**: Displays inside the chosen area the climatologic stations and dams.
- **Consults**: This menu performs the following options:

  Entity: For making consults about an entity selected with the mouse or by typing a key or a name.

  Probability of rainfall: Allows to compute the empirical rainfall probability for a given day in a station, basin, hydrological region, state, or the whole country.

  Mean of a period: Computes the mean values of rainfall, evaporation, and observed, minimum, and maximum temperature for a given period in the selected area.

  Daily averages: For rainfall, evaporation, and temperature. This option computes the histogram of frequencies, the daily average value, and the climatological normal as the daily cumulative average. The output can be a graph or a daily average list.

  Monthly average: Computes the monthly averages of a climatological station, basin, hydrological region, state or irregular user-defined area. The user can list the data, generate a report, or a map of isolines.

  Maximum and Minimum: Computes the maximums and minimums values of data averages for a given period.

  Climatological data: Has two options:

  Consult by catalogue:
  The user can consult the climatological data of a given station, state, region or basin in a user-defined period.
  Consult by query:
  The user selects the fields that wants to see, define conditions to filter the data and send the output to a file or to the screen.

  Humidity index: Computes the humidity index as the ratio of the mean annual rainfall and the mean annual evaporation in every pixel, and generates the maps of isolines.

  Boolean consults: This option allows to identify in a thematic map the areas where several climatological variables satisfy a user-defined range of values over a period that could be a month, a year, or an arbitrarily user-defined period.

- **Print**: This option allows sending to printer a thematic map, a screen, or a report.
- **Utilities**: Has the following options:

  Map edition: Allows to change the text and lines attributes, to select the palette, etcetera.

  Import data: Imports INFO (ArcInfo®) and DBF data format. The data are imported to an Oracle table.

  Export data: Exports climatological data. The formats used for exporting are INFO, DBF, ASCII and binary.

  Generation of precomputed data: This option allows the system manager to update the table of precomputed data when there has been a change in the climatological data. The precomputed data are monthly averages.

- **Help**: Displays a window in the screen with a helping text related to the menu and option the user is in.
- **Zoom area**: Has the options of zoom in, zoom out, and move origin.

Conclusion

A system to handle, store, transmit, and perform climatological computations in a 29 million records database was developed using ArcInfo® as the user graphical interface and Oracle® as the relational data base management system. The SIC is able to make queries, boolean operations, computations, and updates on the climatological data without jeopardizing the data security. The developed system uses an entity-attribute relation, allows concurrent queries, and the users are able to make consults and computations not considered in the system via SQL language. The SIC system, developed at the Mexican Institute of Water Technology, is fully operational at the Mexican National Meteorological Service.

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Data collection in the Pöllau basin

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1. Introduction

With this report, the Institute of Hydraulics and Hydrology of the Technical University in Graz gives a description about its experiences in collection, analysis and management of data of the hydrological research basin of Pöllau. The possibilities of an economic collection of field data are pointed out as well as the suitable management of these data in a data base.

It was in 1991, that a new generation of data loggers for rain gauges (man. MATT&SOMMER) was introduced forming the basis for the development of a database. For this reason, there was an extreme increase of data, which had to be processed through suitable software and managed in a database to have as small loss of information as possible.

1.1. The Hydrological Research Basin of Pöllau

In the course of point-of-main-effort tasks of the International Hydrological Program (IHP) the installation of the hydrological research basin in Pöllau near Hartberg (Eastern Styria) was beginning in 1979. This measuring net with high density of gauges was especially equipped for scientific purposes and has been operated since then by the Institute of Hydraulics and Hydrology of the Technical University Graz together with the Hydrographical Service of the Styrian government.

The causes for the choice of this region for scientific purposes were on the one hand the general scientific objectives and on the other hand the practical demands as well as the location near Graz.

The research basin is situated in centre of the superior catchment area of the river Lafnitz. The catchment area comes to 58,3 km^2 at the basis gauge station „Pöllauer Saifenbach". The catchment area is divided into several subcatchment areas, two of them („Dürre Saifen", 22,9 km^2 and „Prätisbach" 21,1 km^2) are recorded with own gauge stations.

The climate of the Pöllau basin is characterised by its location at the SE-incline of the Alps. The basin is relatively well protected from W-NW weather influences and is susceptible for S-SE influences due to ist open location in SE only. The yearly precipitation amounts to 800 - 1000 mm (dependent on the altitude), the monthly maximums are concentrated in the summer months, which are partially characterised by heavy convective rainfalls.

The instrumental equipment of the hydrological research basin consits of self-registering measuring instruments in time-variable form of precipitation recording (BERGMANN&STUBENVOLL, 1986) as well as of gauge stations with recording of the water level at recording drums. At present, 7 rain gauges, 4 flowgauge stations as well as one meteorological station are available.

2. Analysis of field data

2.1. Collection of raw data

2.1.1. Runoff
As it was mentioned before, the hydrographs of water level are recorded at the recording drums of the flowgauge stations. Furthermore, these hydrographs are annually digitised with the software HEDA (man. HYDROCONSULT) to be able to manage them in electronic form.

To construct the stage-discharge relation in the flowgauges, liquid flow measurements with tracer are made in regular intervals, whereas for the purpose of control these measurements are completed in certain intervals with liquid flow measurements in using propeller-type current meters. The stage-discharge relation is checked every year for its plausibility and is corrected if necessary and is also available in digital form in the HEDA-software. Since HEDA is programmed in APL, the conversion of these data into ASCII-format is necessary to make possible its subsequent processing with the evaluation software of the Institute. For this purpose, a conversion software was developed, which is integrated in the HEDA-software.

2.1.2. Precipitation
Precipitation data are recorded in time variable and digital form with data loggers at the rain gauge stations, which are working on the basis of whips (0,1 mm and 0,2 mm precipitation). These data are available for further evaluations and analysis in ASCII-format.

2.1.3. Meteorological data
Meteorological data (direction and velocity of the wind, radiation, evaporation, air and soil temperature, air pressure and humidity of the air) are recorded in digital form at the so named central station in different time intervals and are available for further processing in ASCII-format as well.

2.2. Evaluation of raw data

2.2.1. Runoff
The evaluation of the hydrographs can be made in the APL-software HEDA as well as with the FORTRAN-program POENAB. In both programs there is the possibility to separate the hydrographs and to deal with single events.

The POENAB program allows furthermore to include the precipitation data into the evaluation as well..

2.2.2.Precipitation
In a first step the precipitation data recorded in digital form are compared with the values of the sumps situated in the rain gauges and data losses are commented. In the next step daily sums of precipitation are calculated from the corrected values and a file is made with the shifts of the whips per unit of time, which can be used for further calculations.

2.2.3. Meteorological data
The meteorological raw data are checked on its plausibility and losses are commented.

For further processing, a special program (UMW3) is available to calculate the daily means, to make charts and diagrams. A further evaluation is not planed because of the high density of data, but would be possible.

3. Management of data

3.1. Data base of Pöllau

The data base is built on the basis of ACCESS and includes the management of precipitation, runoff as well as meteorological data of the hydrological research basin of Pöllau.

The construction of the data base was done from the beginning without a storage of raw data, but deliberately it was set great store by an efficient management of data. Therefore, in the „data base of Pöllau“ there are no files but references, in which directories the requested data can be found and with which software and programs the necessary calculations and evaluations can be made. The scheme of the data base can be seen in fig. 1.

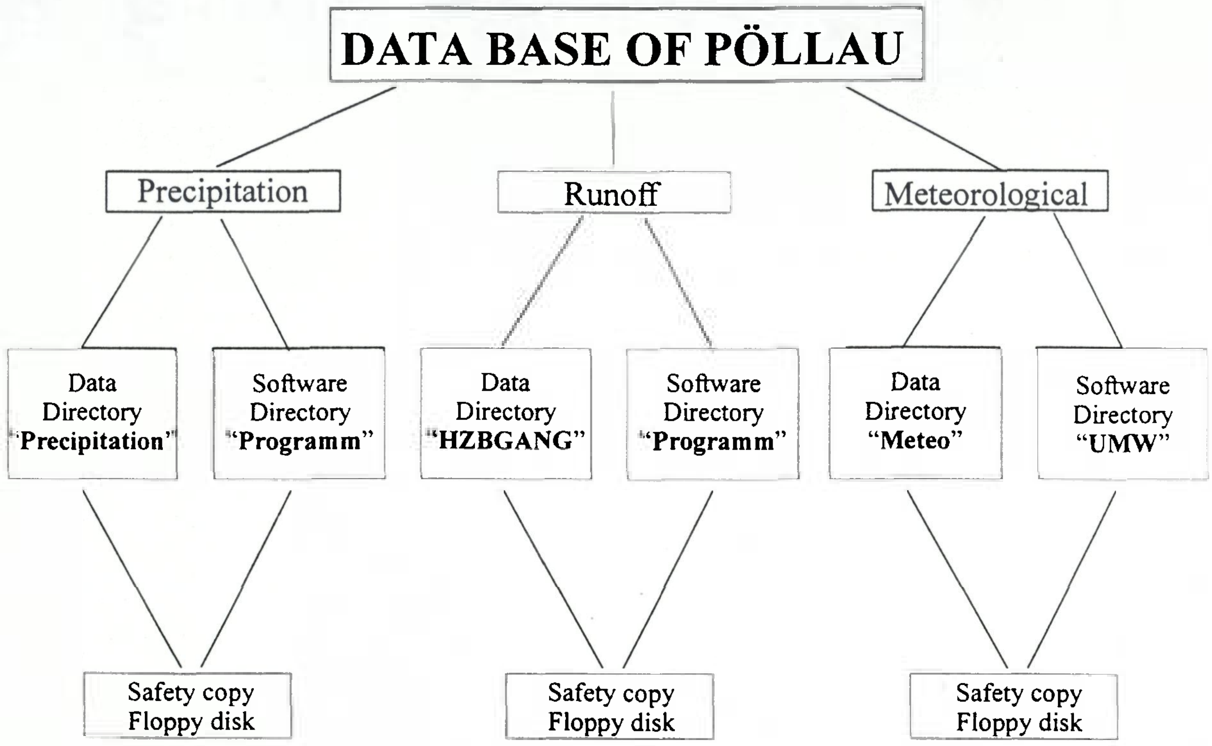

Fig.1: Scheme of the data base of Pöllau

After the evaluation of data mentioned in 2.2. the files are stored in the designated directories and a safety copy is made on a floppy disk, which is put into a box designated for this purpose.

The directories of the files are installed in the net of the Institute (own server) allowing thus a quick access to the data for the whole staff of the Institute and to reduce the required computing time to a minimum.

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Practical approach for rainfall data processing in Wadi Feiran, South Sinai, Egypt

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Abstract

Data quality and certainty is very important in wadi hydrology, especially, in utilization and protection works. Contradiction, homogeneity and availability are the key factors for data processing. This paper deals with processing short term rainfall data for wadi hydrology analysis. Moreover, rainfall having duration of 1 hour or less is of a great importance for water resources projects planning and design. Consistent relationships between t-minute rainfall duration and 1-hour rainfall duration have been derived. Most raingage stations verified the validity of the relationships in the study area. These ratios enable the estimation of the rainfall depth for any duration from 5-minute to 2-hour and any return period from 2-year to 100-year once the basic 10-year 1-hour value is known. The consistencies in the ratios were expressed mathematically by generalized depth-duration-frequency functions which have either the 2-year 1-hour, 5-year 1-hour, 10-year 1-hour rainfall as a basic value. Comparison between Depth-Duration Ratios with other countries have been done. This approach will reduce the labors of dissecting records, extrapolating to long return periods, and efficiently presenting the data to potential users. Results obtained show the importance of the topography and geology in this aspect. This approach can be applied in similar wadies in different regions

International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management

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Integrated Data Management in Operational Hydrology and Water Management

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Abstract:

Due to the progress in hydrological modeling and water management techniques the requirements for hydrological or ecological data in quantity and quality is improved in last years. Today the information technology represents a ideal base to implement a hydrologic information system. A hydrologic information system should deal with this data from the acquisition at the gauges up to verified data sets considering the aims of the user.

In this paper the development of the hydrological information system WISKI will be described. WISKI is a client/server system based on relational databases, which was designed under strong contact to water agencies and hydrologist. To realize the integrated data management the system consists of three parts, a data acquisition server for remote control and data fetch from the gauges, a central database server for data storage and management and window oriented client systems as a hydrological workbench.

At this workbench the hydrologist does all his work from the plausibility control of new data, their graphical and tabular visualization, error correction, statistics up to summary reports as documentation in hydrological yearbooks or internet publications. Also an alarm system for flood management can be maintained from this workbench. This alarm system can be configured for handling of different tasks like data collection for retention basin management or public information at alarm occurrence.

Different tools are integrated into the hydrological workbench to support the hydrologist in his work. There are configurable tabular and graphical data editors, automated procedures for standard tasks as plausibility checks, fill up of data gaps, main value calculation or transformation of measured water levels to discharge rates. Especially for discharge calculation a comfortable graphical rating curve editor was developed. This tool supports the hydrologist by the construction of rating curves from discharge measurements and the maintenance of the validity of the curves. Thereby numerous national and international standard procedures are supported. For navigation in the hydrological network the hydrologist is supported by a GIS, which provides a river basin map with geographical information as well as actual time series data from a remote data fetch or stored data from the database server.

Tools like WISKI are very helpful for data collection and data management in operational hydrology, because they support the hydrologist very effective in his daily work and ensure an unique, verified pool of data, which can be accessed by all other users.

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The Hydrological Research Division (HRD) and its HRD Flood Information Centre of the Ministry of Flanders (Belgium)

Jos Heylen
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Abstract

The global water management policy in Flanders (Belgium) and especially the management of the Flemish waterways network require a serious study of the water levels and discharges in the watercourses.

The HRD developed a performant hydrometrical network over the Flemish territory, continuously measuring and computing water levels and discharges.

In this network water levels are automatically registered by water level gauges in about 150 HRD hydrometrical stations. In about 100 of these stations the HRD computes discharges.

In times of threatening floods, the HRD Flood Information Centre is activated for a round-the-clock real time monitoring of water levels and is so continously supplying various authorities with flood risk related data. Also the HRD issues short-range water level forecasts, based on water level values, meteorological data as rain and cloud satellite pictures.

1. Introduction

As a low-lying and highly developed country, Belgium -and especially Flanders- is continuously facing a potential flooding disaster.

The several Flemish rivers may cause serious problems due to high water-levels, which happened as recently as 1993 and 1995. To many people, the fact that flooding and inundation could occur even in well-regulated rivers came as a surprise.

As early as the 1970s, some government investigations focused on protection from floods.

One of these investigations led to the establishment of the Hydrological Research Division.

It can be said in general that the Hydrological Research Division studies any specific problems related to the hydrology of the waterways of the Flemish Region, not subject to the tides.

This management led to thorough deliberations when taking the required measures in order to avoid catastrophic water levels.

A good knowledge of water quantities in waterways is also indispensable when designing hydraulic constructions, operating weirs and locks on a daily basis and distributing the water into the canals.

Nowadays, the water quality problem has also become a very topical matter and one cannot do without a profound knowledge of our waterways' water quantities within the framework of water purification programmes featuring adequate emission and immission measures.

A second network -managed by the HRD- is a pluviographic measuring network consisting of registering rain gauges.

2. Data monitoring and communications

2.1 The hydrometric network of the Hydrological Research Division

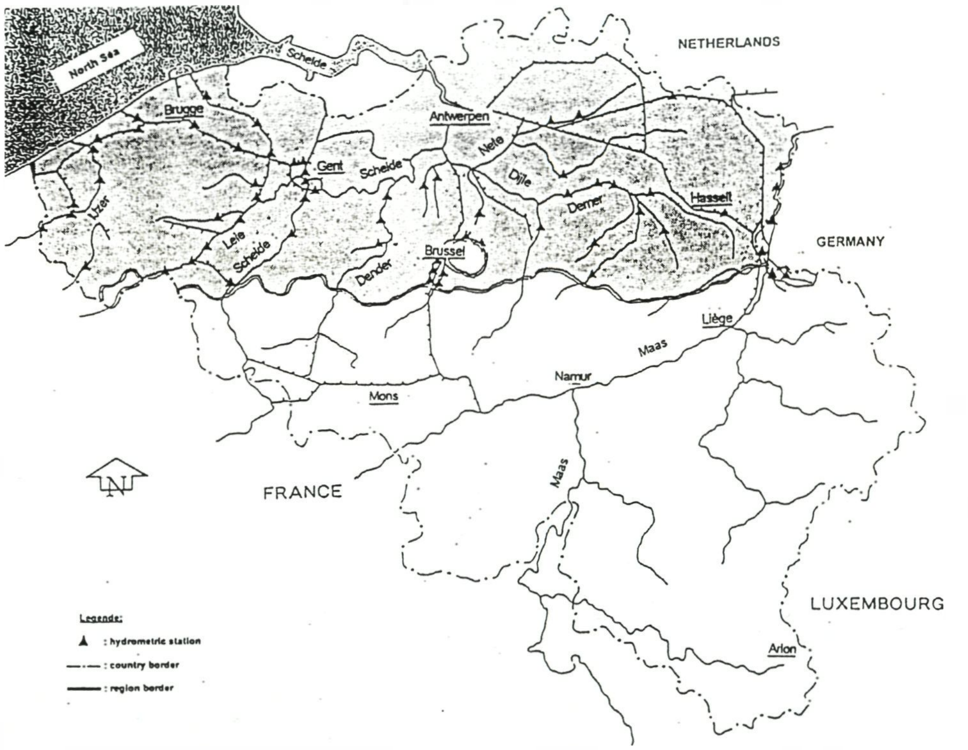

Fig. 1 Map of the Flemish Region waterways with the location of the most important hydrometric stations

Presently, the hydrometric network consists of 140 stations equipped with one or more water level recorders.
Most of these stations were established between 1960 and 1980.
Figure 1 shows the location of the most important stations along the waterways of the Flemish Region.
Most hydrometric stations were established in spots with an unambiguous water level-discharge relationship without adaptations to the waterway. Stations along navigable, canalized waterways were established on the movable weirs.
On the smaller waterways as well, the existing weirs were used when installing stations.
The Hydrological Research Division also determined the discharges at 90 hydrometric stations.
Momentary discharges are calculated by means of an acoustic flow meter in 2 stations.
12 additional acoustic flow meters are planned for the 1997 to 1999 period.
Annually and in principle, discharges are measured 5 to 8 times for each station and all over the water level interval.
Discharges are measured by means of the "sounding the velocity field" method. The wetted area of the watercourse is divided into a number of measuring verticals, in which the velocity is recorded in 1 top 6 different points, depending on the water depth.
When doing so, the applicable international standards -among other things the ISO standards- are respected.
The Hydrological Research Division (HRD) uses for the flow measurements propeller current meters and magnetic induction flow sensors.
The HRD has four measuring-vans equipped with electric winches for the cable-suspended current meters, this way restricting the interventions of the hydrographer to a minimum.
All these flow measuring data are directly fed into a PC/laptop.
This way, immediate verification of each measuring becomes possible.

The discharge data are processed into a water level-discharge curve.

2.2. The pluviographic measuring network of the Hydrological Research Division
This measurement network consists of 20 rain gauges, spread over the various hydrographic basins.

2.3. Transmitting and decoding the data of the stations
The stations' data are transmitted to the central computer of the Hydrological Research Division in Brussels either through the Belgacom public telephone network or through the Ministry's own network.
Each station is equipped with a memory unit for storing data and an automatic answering module connected to the above-mentioned central computer.
Two or three times a day, a call of the division in Brussels makes a link with the answering module of each station. In the form of frequencies, this call sends the momentary value(s) of the water level and/or the rain and also the average hourly values stored in the memory since the previous call to Brussels.
It can be said here that the above-mentioned hourly average is the average value of the thirty momentary measurings -carried out every 2 minutes- in one hour.
Subsequently, the calling unit sends the values to the collection-calculation module of the central computer; in that unit, the frequencies are decoded and converted into water level and/or rain data, recorded in the database of that computer.
One can also make manual calls in between the automatic calls any time.

3. Data management

3.1. Hardware
The Hydrological Research Division central computer is a COMPAQ PROLIANT 486 server with Novell Netware 3.12 (capacity 4 Gbytes) network software operated by means of the Advanced Revelation database management system.
All collaborators of the service use a PC workstation connected to the server.
Figure 2 lays out the data transmission and processing schedule.

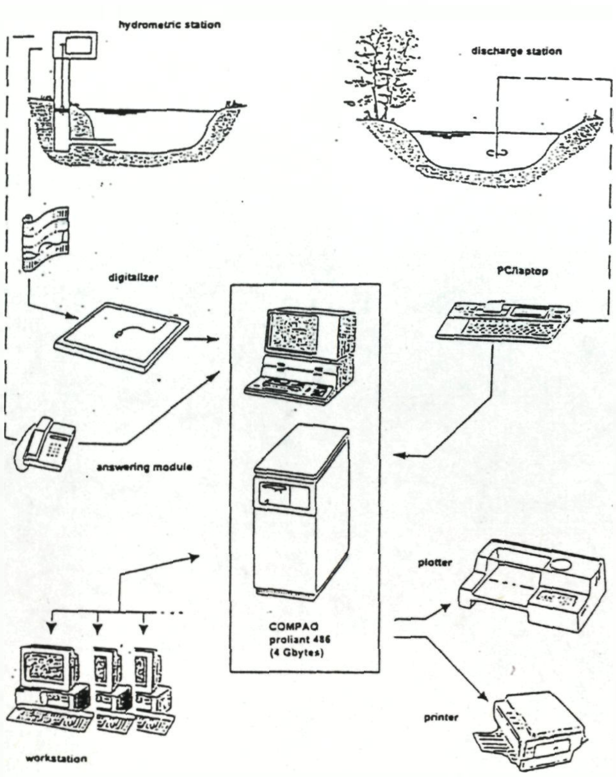

Fig. 2 Outline of the data monitoring, transmission and management

3.2. Software

The Hydrological Research Division gaurantees the processing and critical analysis of data, simulation and mathematical model construction of the hydrological processes and the solution to any other problems related to the hydrographic basins or parts of them.

Obviously, one of these problems is monitoring in real time and -if possible- forecasting water levels and discharges in flood periods.

The central computer database includes various blocks.

A first block includes all files with the general documentation regarding the hydrometric and pluviometric stations and also regarding the cross sections for the discharge measurements.

A second block contines the files of the executing discharge measurings and also of the calculated water level-discharge curves.

These curves consist of one or more parts (no more than 5); they are all of the 1st, 2nd or 3rd grade type and they are calculated by means of the linear regression technique (method), in which the sum of the square deviations is minimalized.

Decoding the hydrometric stations' data -as explained above- yields the average hourly water levels recorded in a third block.

By means of these blocks, the computer calculates the average hourly discharges, recorded in a fourth block.

Finally, the average water levels and discharges on a 24 hour basis are calculated and stored in separate blocks.

The pluviographic files contain the overall hourly rain data and the overall rain data calculated on a 24 hour basis.

3.3. Data analysis

In order to dispose of effective data, the Hydrological Research Division developed many systems in computing technology for data analysis.

This way, additional calculations yield a whole series of other basic data, such as:

- specific and classified discharges;
- average values for several years, including extreme values;
- annual and several years frequency of exceedance of discharge
- listing with maximum water levels and discharges during flood periods.

Recently, the division further developed graphic applications aiming at an even more efficient visualization of the various data types and at tracing and correcting mistakes.

Figure 3 shows a graphic application.

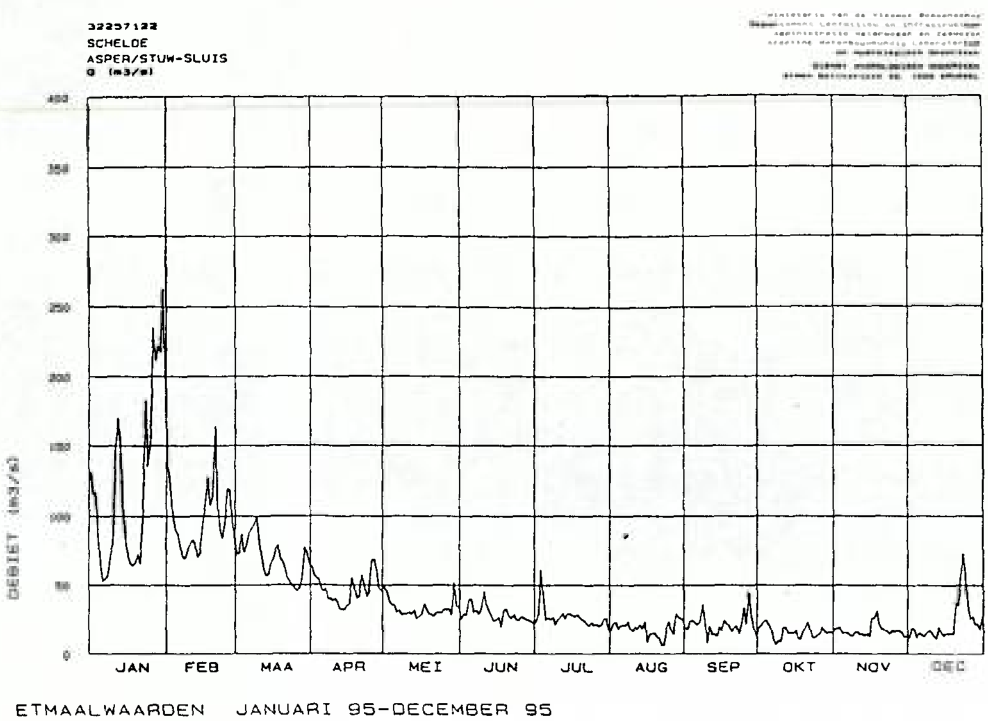

Fig. 3 Diagram with the average daily discharges 1995 of the Scheldt in Asper upstream Ghent

The actual data analysis offers a thorough knowledge of the hydrological and metereological situation -also in real time- and allows to make short-term forecasts in that context.
Now, also users can consult all the data of the last month by means of a modem link with a suitable software programme.

3.4. Flood forecasting and decision support systems
Due to the restricted length of the rivers in Flanders and also to a shortage of staff in the Hydrological Research Division, less attention was devoted to developing models up to now.
Right now, a programme is being developed that aims at creating the required combined flood forecasting/decision support systems by means of models for the main Flemish rivers in the medium term (5 years).
Up to now, the Hydrological Research Division developed two models.

3.4.1. The real-time flood forecasting model of the Belgian part of the river Meuse

During floods information about actual and expected water levels of the river Meuse is very important.

The basin of the river Meuse covers a surface area of about 33.000 km². The upper (French Meuse) and middle reach (Ardenese Meuse) of the basin cover 21.000 km² and are situated upstream of the level gauge Maaseik, which is on the Belgian-Dutch border (fig. 4).

Fig. 4 Basin of the river Meuse

For the occurrence of extreme discharges large amounts of rainfall over a large part of the basin are required. Furthermore the basin must have a large discharge potential, which means that the rain cannot be stored in the soil and is quickly discharged. This is for example the case if the subsoil is saturated or frozen. Both in 1993 and in 1995 these requirements were met. Preceding rainfall caused in large parts of the basin a saturated subsoil. In 1995 also snow played a role. Both in 1993 and 1995 extreme amounts of precipitation followed, of up to 35 mm in 24 hours and over 120 mm in seven days over the entire basin. Locally these amounts were much larger.

These huge amounts of rainfall caused high discharges in the entire Meuse basin. In 1993 there was only one peak (fig. 5). The extreme rainfall was concentrated in one period. The peaks from the tributaries in the Ardenese Meuse all came together. They did not fully coincide with the peak from the French Meuse. The maximum discharge at Maaseik was 2811 m³/s (fig. 5).

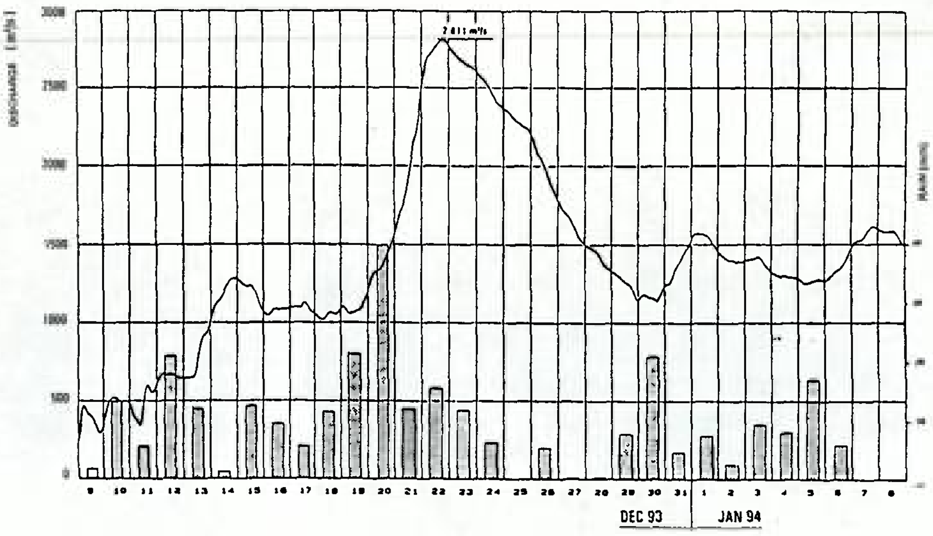

Fig. 5 Diagram with the river Meuse discharges of the flood period Dec 93 on the Belgian-Dutch border

The estimated recurrence period is 125 years. In 1995 there were three peaks, following three periods of extreme rainfall. In the first two peaks the contribution of the French Meuse is relatively small, but following the relatively slow but steady reaction of this part of the Meuse, the contribution to the ultimate third peak is large. This peak coincided with the peaks from the tributaries in the South of the Ardennes. Because the peaks from the Northerly tributaries were lower than in 1993, Maaseik was spared another record discharge. The maximum discharge was 2736 m^3/s with an estimated recurrence period of 65 years.
The peak flow of 1993 was higher than in 1995. However, the volume of the flood wave of 1995 was much larger.
Water levels and discharges can be predicted with a flood forecasting model, developped by the Hydrological Research Division in co-operation with the Laboratory of Hydrology and Water Management of the University of Ghent.
In 1990 the model has been implemented for data analysis and since then, when it was possible, the module is used to forecast flood events.
The flood forecasting moedel was developed in three phases. In a first phase rainfall-runoff models were calibrated for the main subcatchments of the river. These hydrological models forecast discharges at the outlet of the subcatchment, based on real-time measurements of rainfall and water level. A stochastic transfer function noise modelling approach was found to yield reliable operational forecast. In a second phase a hydraulic flood-routing model for the main branch of the river, between Chooz and Maaseik, was developed. In order to model part of the tributary river Sambre as well, a branched network was chosen for representation of the system. The implementation of the model on the computer system of the HRD took place during the third and last phase.
This forecasting model enables forecasts (up to 12 hours) of the discharge of the River Meuse and its tributaries.

3.4.2. *The Yser basin model*

An ID hydrodynamic model of the Yser basin was set up last year in co-operation with the "International Marine and Dredging Consultants" nv within the framework of the water management programm of this river.

The Yser basin in situated in northeastern France and northwestern Belgium and it has a surface of 1112 km^2.
The river is 75 km long and has its source in France at an altitude of about 35 m. The main Belgian part of the river and the downstream part of its tributaries are situated in polder areas (below 5 m altitude); they are drained by canals not connected to the Yser.
Although the Yser is only a small river with a width of about 12 m at the Belgian-French border and about 35 m downstream, considerable floods occur regularly. These floods are caused by a combination of factors.
The Yser is a typical lowland river with almost no topography except in the upper third of the basin. The bottom slope in the downstream part of the basin is very small (0.05 m per km), whereas the slope is higher (about 1 m per km) in the upstream part of the basin. Consequently, the water flows relatively fast in the upstream and relatively slow in the downstream part of the basin.
The discharge capacity of this part is not sufficient to drain all the water to the sea. Moreover, the river mouth at Nieuwpoort is connected to the Yser estuary and the Northsea by means of a lock and a sluice. The lock and sluice prevent the tides from entering the river. Therefore, discharges into the sea are possible (on average) only 5 to 7 hours per tide or 10 to 14 hours a day.
The model has been used to simulate the major December 1993-January 1994 flood and to investigate some planned measures aiming at reducing future floods.
The main reason for the large flood turned out to be the limited conveyance of the river and not the limited capacity of the downstream sluice. Actions to reduce the flooding area and to avoid flood catastrophies like in 1993-1994 come down to deepening the downstream part of the river or increasing the capacity of a tributary canal used as a bypass.
Figure 6 shows the measured (dotted line) and simulated (solid line) water level in four points along the Yser during the flood period 10 Dec 93 - 20 Jan 94. The normal water level is 3,14 m TAW.

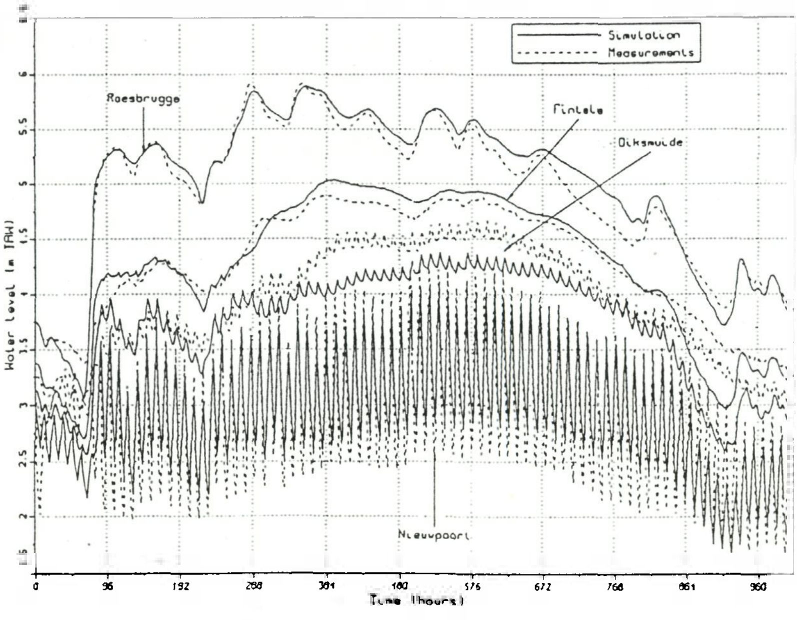

Fig. 6 Diagram with the measured and in model simulated water levels of the river Yser for the flood period Dec 93 -Jan 94

In a next phase, the model will be extended to the French part of the Yser with financial support by the EU-Interreg fund.
Simultaneously, research will focus on predicting rainfall and run-off aimed at better hydrological input data and at setting up a rainfall and water-level forecasting system.
Furthermore, the hydrodynamic flow model will be extended with a water quality to be used for developing an investment strategy for water treament in the Yser basin.

4.The HRD flood information centre

From the early 1980s on, the HRD Flood Information Centre has played the leading role in flood warning.

As soon as extreme high water levels with a possible flood risk occur in Flemish waterways, the Hydrological Research Division starts to monitor these water levels and the inherent discharges in real time through its data gathering.

For that purpose, a HRD Flood Information Centre (HRD-FIC) is established within the division for the flood period; if necessary, it functions round the clock.

Rain analysis is conducted by means of the data from the own pluviographic network, completed by additional data from the Walloon Region hydrological service, the Belgian Royal Metereological Institute -the division has a modem link with this institute for receiving cloud images and rain radar images-, the Meteowing of the Belgian Airforce and possibly the French metereological services.

Moreover, the evolution of the water levels of the own hydrometric station is closely monitored; possibly, the responsible service of the Walloon Region and France are requested to send any interesting data about the evolution of the rises in the Leie, Upper Scheldt, Dender and Meuse rivers. For the latter river, regular contact with the Dutch "Rijkswaterstaat" is also established.

In most cases, comparisons with historical data related to rain, water levels and discharges of earlier flood water periods allow for an interpretation of data and for drawing up prognoses for possible rises in the hydrographic basins or parts thereof.

The management and intervention bodies are presently kept posted all the time by fax message or telephone about the evolution of high water levels and possible flood risks.

All bodies must be mentioned here:

- the responsible services of the own department
- the Coordination and Crisis Centre of the federal government
- the civil protection services
- the local crisis centres (if they are established)
- the Walloon Region hydrological service
- the Dutch "Rijkswaterstaat" (for the Meuse river).

The different flood water periods clearly revealed that rises could be well-monitored, that the maximum water level and flow prognoses were as good as possible and that sufficiently accurate data could be transmitted to the responsible services.

When the river Meuse level rose spectacularly in January 1993, the HRD-FIC was able to forecast the maximum water level of Flemish part of the Meuse in a sufficiently accurate manner 12 hours in advance.

5. Conclusion

Data gathering through the own measuring networks -in co-operation with other services and institutes- enables the Hydrological Research Division to monitor the situation of waterways in the Flemish Region in real time, also in flood periods.

In recent years, our country obviously experienced that floods may cost the community dearly. That is why they must also be a continuous source of watchfulness and a permanent action stimulant.

Concerning flood management in Belgium, the importance of a more operational meteorological radar network and even better performing structures for flood forecasting and warning must be emphasized.

Enhanced GIS tools, integrated river basin models and flood risk assessment methodologies are required as well.

The Ministry of Flanders' Hydrological Research Division has been contributing to this for years and it will continue to do so.

References

Heylen, J. 1995. *Report floods Dec 93 and Jan-Feb 95 on the Belgian part of the river Meuse* (*in Dutch*).
Heylen, J. 1995. *Report flood Dec 93-Jan 94 on the river Yser (in Dutch and French).*
Heylen, J. 1996. *Frequency analysis for the maximum discharge of the river Yser (in Dutch).*
Parmet, B., Burgdorffer M. *Extreme discharges of the Meuse in the Netherlands: 1993, 1995 and 2100 - Operational forecasting and long term expectations.*
Sas, M., Fettweis, M., Van Erdeghem, D., Van Damme, L., Heylen, J. 1997. *A model of the Yser basin: Flooding in a lowland river basin.*
Van Erdeghem, D., Troch, P., De Troch F. 1992. *Real-time flood forecasting model of the Belgian part of the river Meuse (in Dutch).*

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Integration of precipitation data from various sources using a GIS

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Introduction

Nowadays, the hydrological community can rely on precipitation data from various sources: station observations, weather radar observations and predictions from meteorological models. Since each of these data sources has its own spatial and temporal scale and its own data format, it is not always easy to combine the information from the different sources and obtain a clear picture of the rainfall input to a catchment area.

Method

In this paper a Geographical Information System (GIS) is used to integrate precipitation data for the Netherlands from the following sources:

- a dense nation-wide network of rainfall stations measuring daily at 8 UT precipitation amounts accumulated over the previous 24-hour period,
- a network of automatic weather stations measuring precipitation continuously,
- a radar providing precipitation fields based on 5 minute samples,
- three meteorological models for which predictions of 24-hour accumulated precipitation in a grid were made available for this study.

All precipitation data were transformed to either point values or 500 m. mesh grid values in a common geographic projection in the GIS. This allowed for direct comparison of precipitation from each source.

Results

As an example, precipitation observations at 27 and 28 October 1998 were studied and compared with model predictions. These two days were chosen because of the unusual hydrometeorological event in the northern part of the Netherlands, where discharge was seriously hampered. This gave rise to economic losses due to damage to property and loss of crop.

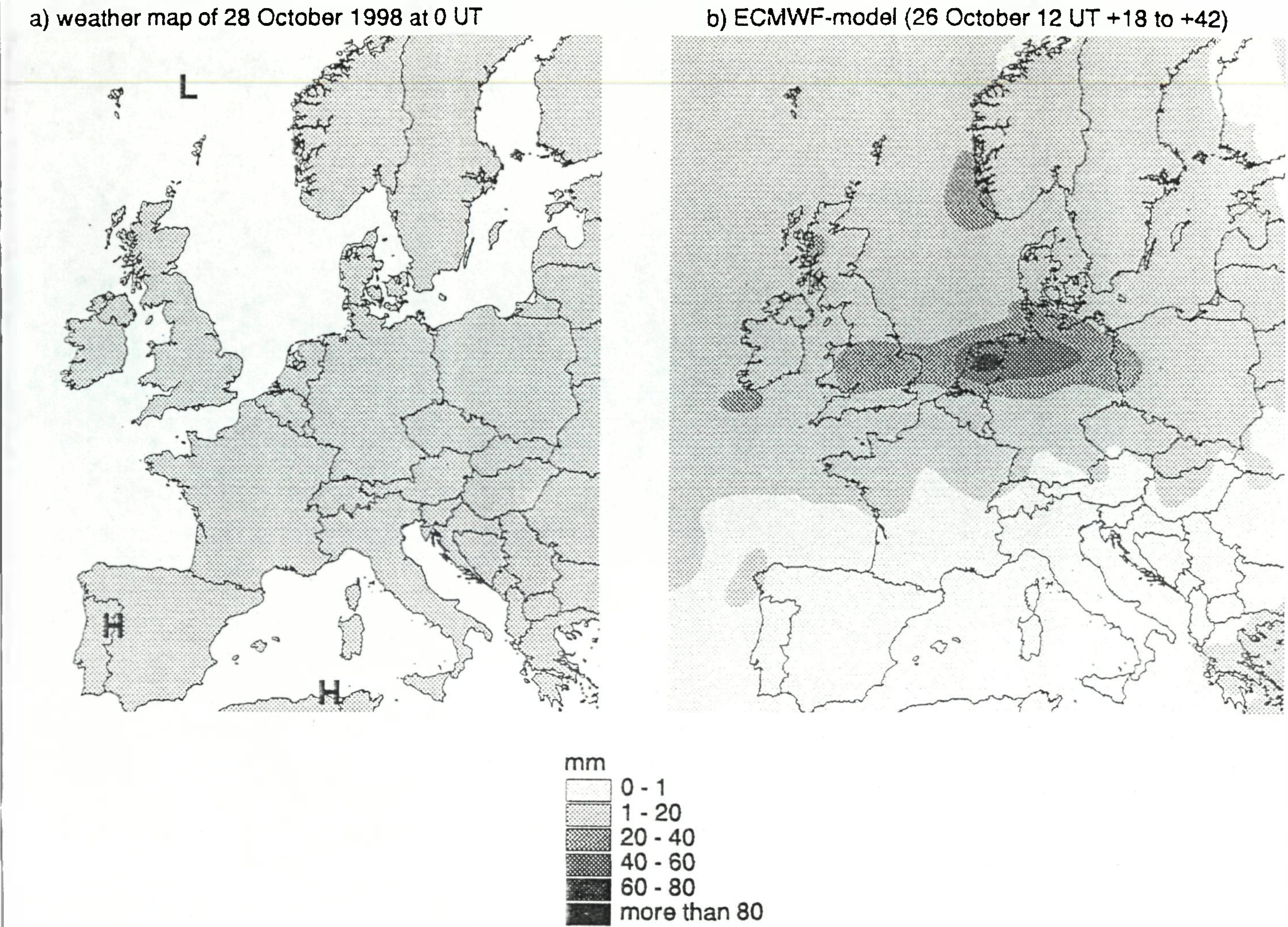
Figure 1 shows a map of the weather at 0 UT in the night of 27 to 28 October. The frontal system situated over the Netherlands is responsible for the high precipitation amounts observed in the 24-hour period between 27 October 8 UT and 28 October 8 UT. Heavy rainfall was also predicted for this period. **Figure 2** presents the station locations in the observational networks used to study actual precipitation in more detail, whereas **Figures 3** and **4** show predictions of precipitation produced up to 66 hours in advance by 3 meteorological models. **Figure 5** portrays observed 24-hour precipitation totals, and finally **Figure 6** shows an example of the use of the ratio between 24-hour precipitation observations from radar and precipitation stations for deriving time series of hourly precipitation at a particular location of interest. Here, a comparison is made between estimated and observed values at two automatic weather stations.

Conclusions

The GIS environment enables precipitation data from various sources to be presented consistently at a chosen spatial and temporal scale. Furthermore, composite precipitation fields can be made and statistical properties can be calculated. Transfer from one scale into another is allowed for and simple estimates of uncertainty are provided. As such, the GIS is a powerful tool for further analysis, validation and verification of precipitation observations and model predictions. Although we do not have the experience of operational use at our meteorological office, the widely accepted GIS format Arcview / Arc-Info used in this study is potentially also a comfortable standard for data exchange.

Acknowledgements

I would like to thank Erik van Meijgaard and Rudolf van Westrhenen for kindly providing model data and radar data, respectively. Valuable discussions with Frans van der Wel contributed to a more advanced use of the GIS.



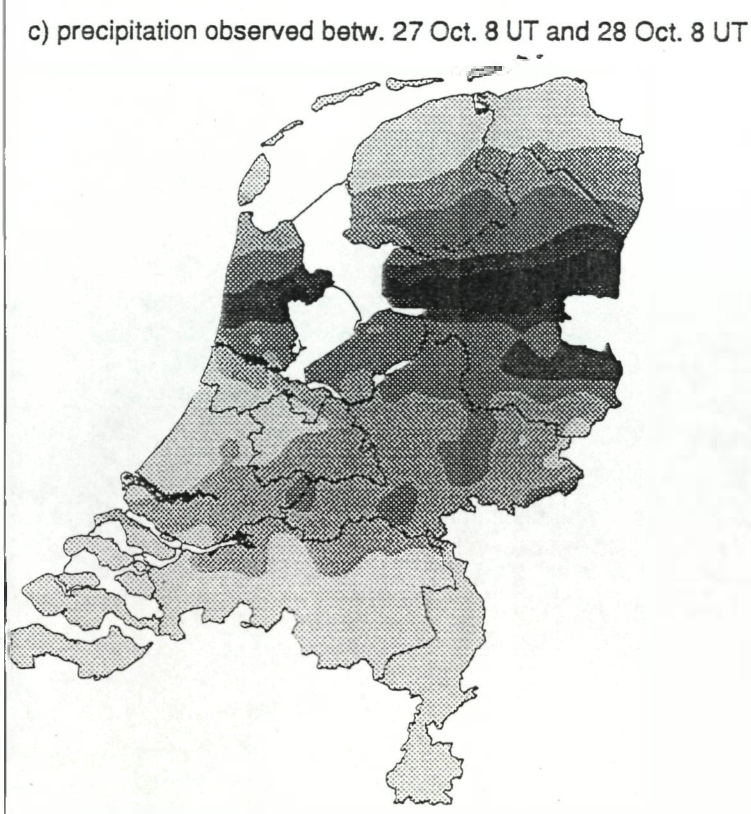
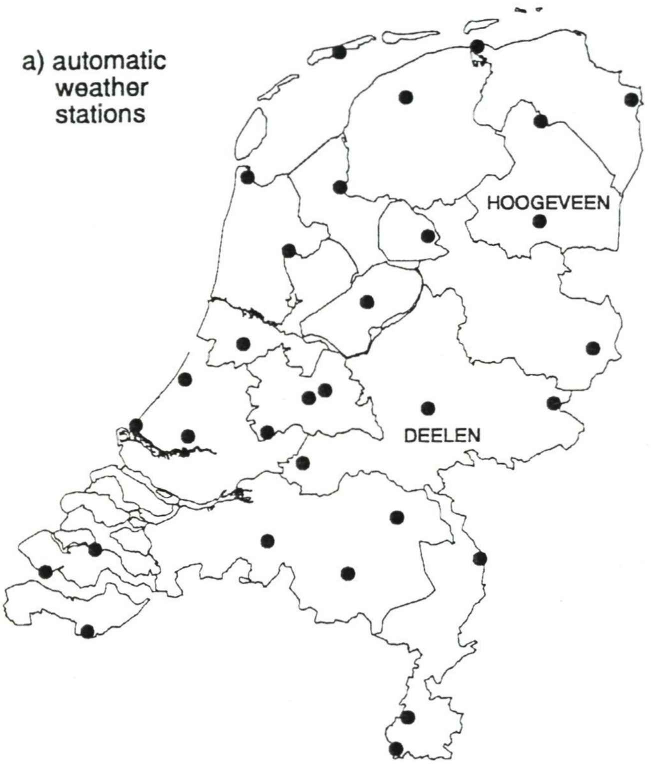
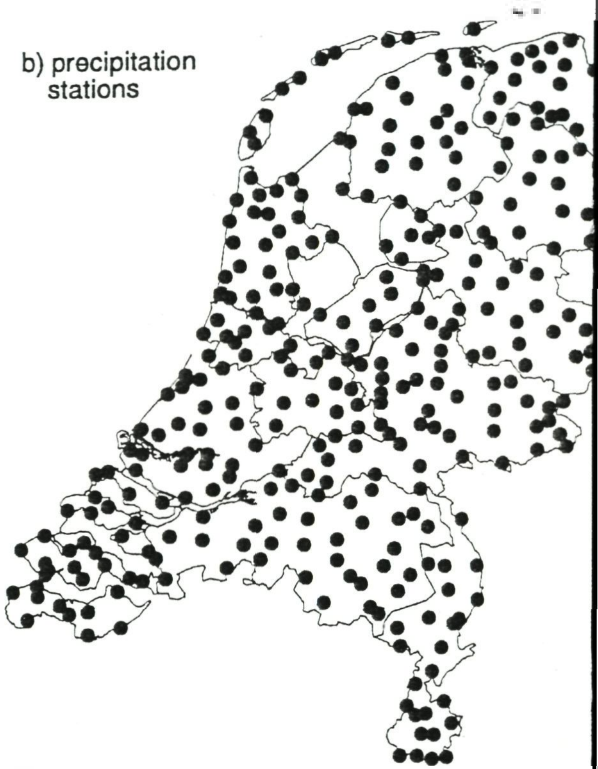


Figure 1. **a**) Weather map of 28 October 1998 0 UT, **b**) map of precipitation in the 24-hour period between 27 October 6 UT and 28 October 6 UT predicted at 26 October 12 UT by the meteorological model of the European Centre for Medium Range Weather Forecast (ECMWF) and **c**) map of precipitation observed in the Netherlands in the overlapping period from 8-8 UT (see also **Figure 5**).

The weather at 27 and 28 October 1998 was characterised by a deep depression west of the coast of Norway accompanied by a frontal system situated over the Netherlands. The position of the cold front changed very slowly, causing precipitation amounts up to 90 mm in 24 hours in a small band from west to east in the northern part of the Netherlands. These high precipitation amounts were remarkable well-predicted 18 hours in advance by the ECMWF model shown.





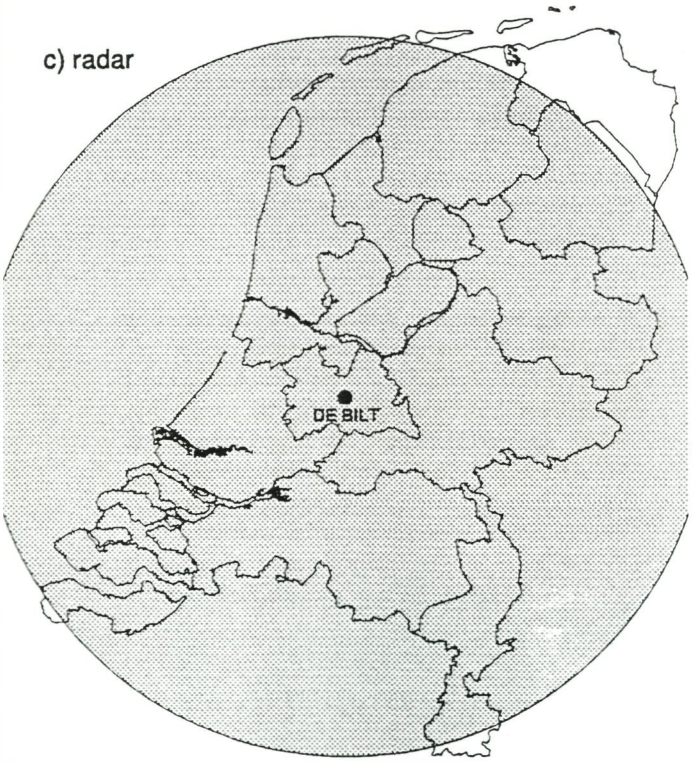
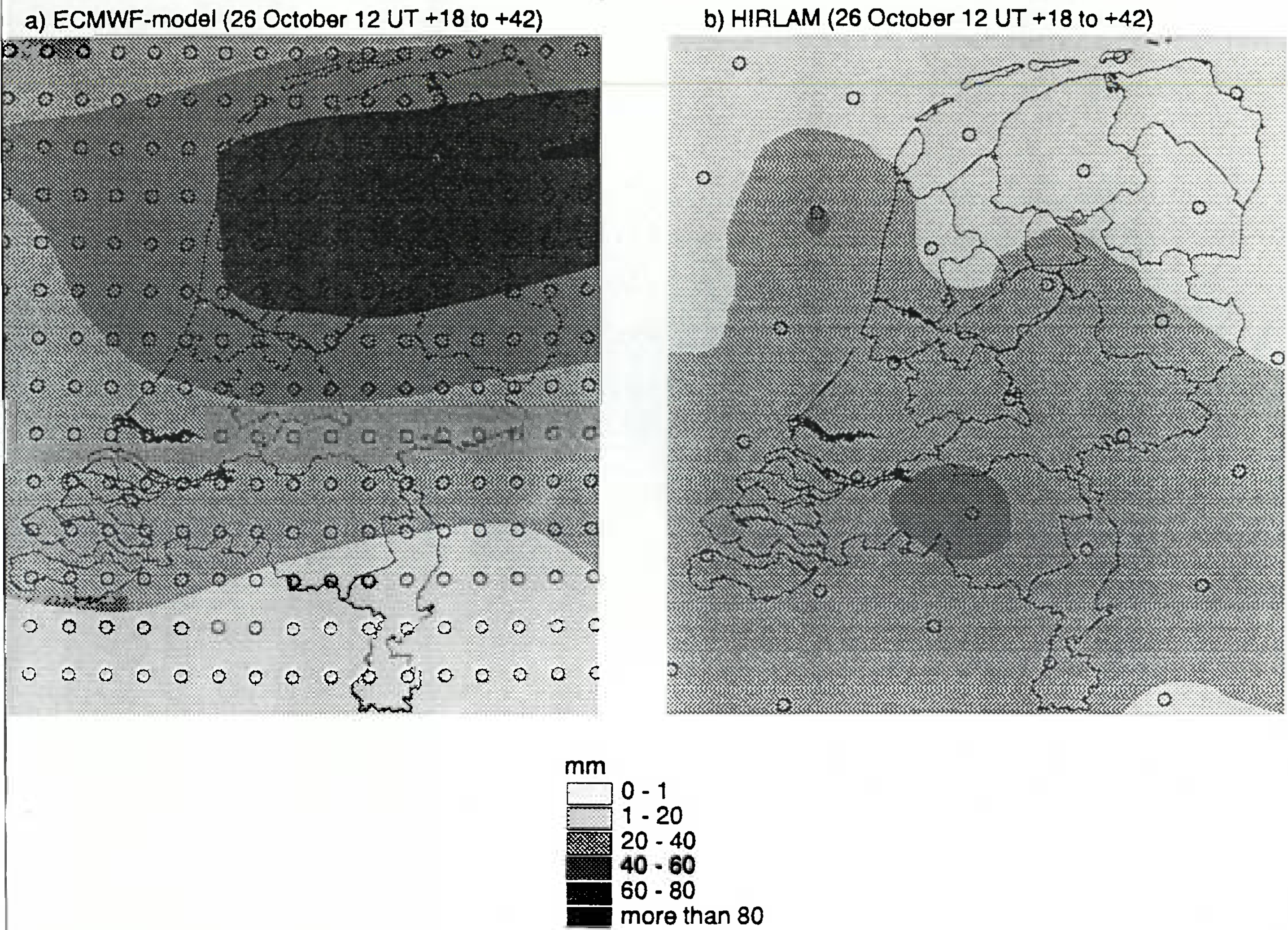


Figure 2. Observation network of
a) automatic weather stations with continuous precipitation registration
b) precipitation stations with 24-hour accumulated precipitation measured daily at 8 UT
c) radar providing 5-minute samples of precipitation intensity.

The circle in **c**) represents the valid domain of the radar situated in De Bilt. Although a second radar is situated in Den Helder, for this case study only data from the De Bilt radar were used. Spatial resolution of the radar is about 2.5 km and inter-station distance between automatic weather stations in **a**) and between precipitation stations in **b**) is on average 50 and 15 km, respectively.



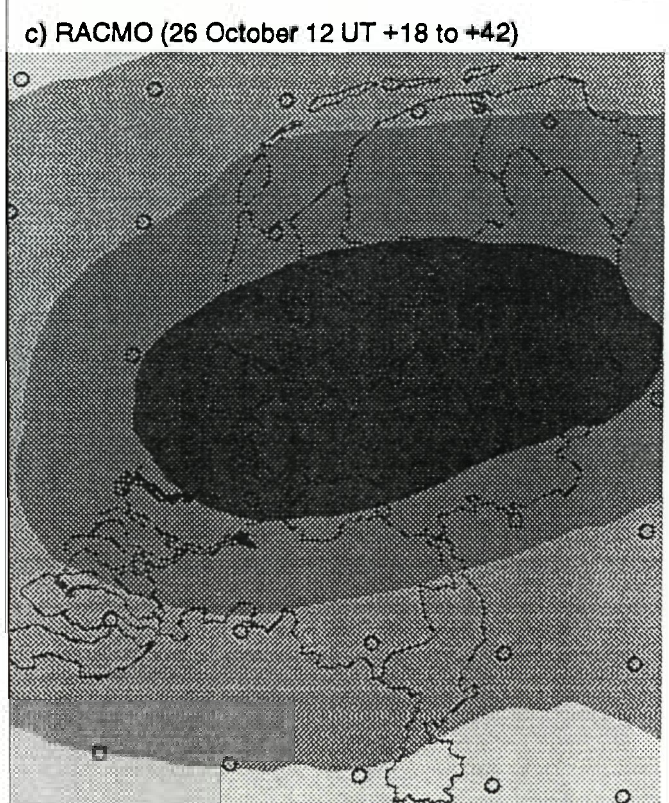


Figure 3 Precipitation in the 24-hour period between 27 October 6 UT and 28 October 6 UT as predicted at 26 October 12 UT by the

a) ECMWF-model (European Centre for Medium Range Weather Forecast)

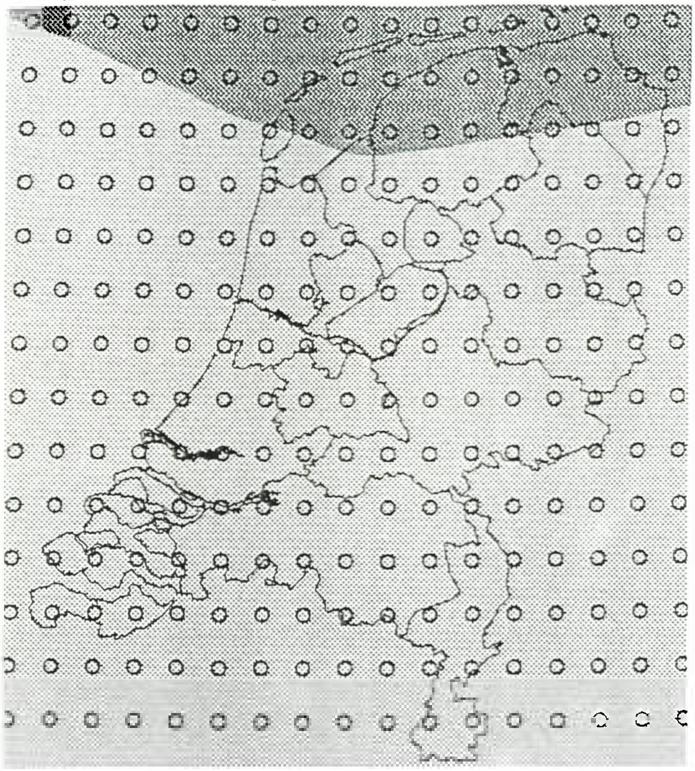
b) HIRLAM (High Resolution Limited Area Model) and

c) RACMO (Regional Atmospheric Climate Model)

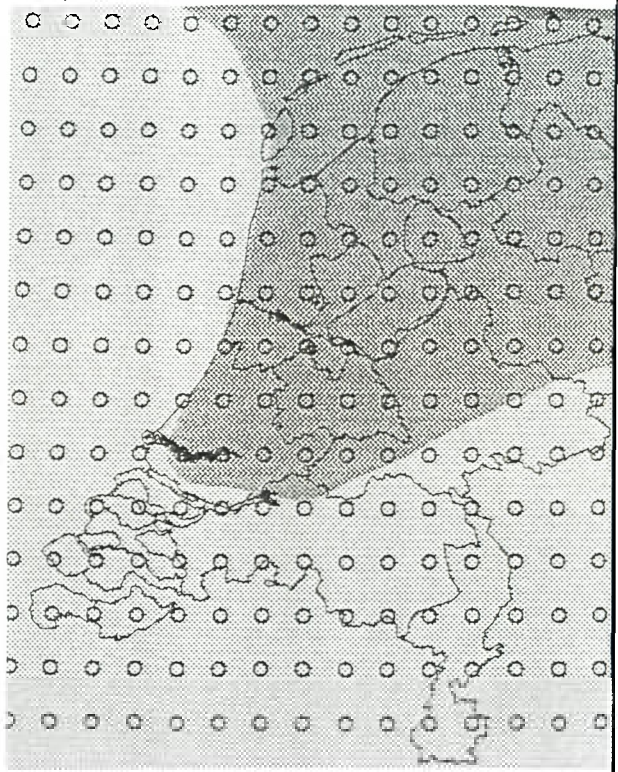
In each figure the open dots represent the gridpoints in the model. For interpolation a wider area (more gridpoints) was used than depicted in the figure to avoid edge effects.

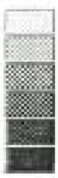
As seen, the precipitation predictions for the Netherlands from 18 hours in advance are very good, except for HIRLAM that predicts to little precipitation to far south.

d) ECMWF-model (24 October 12 UT +66 to +90)



e) ECMWF-model (25 October 12 UT +42 to +66)





f) RACMO (25 October 12 UT +42 to +66)

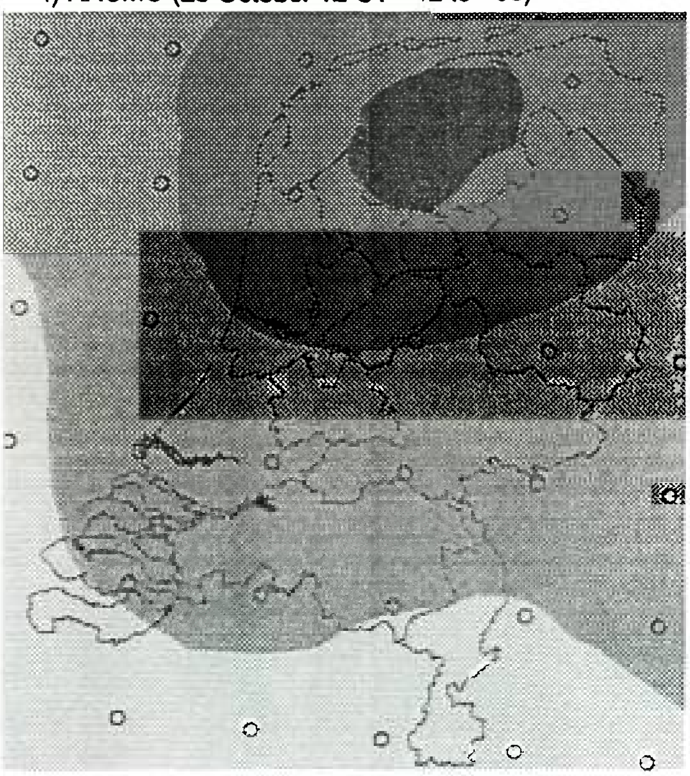
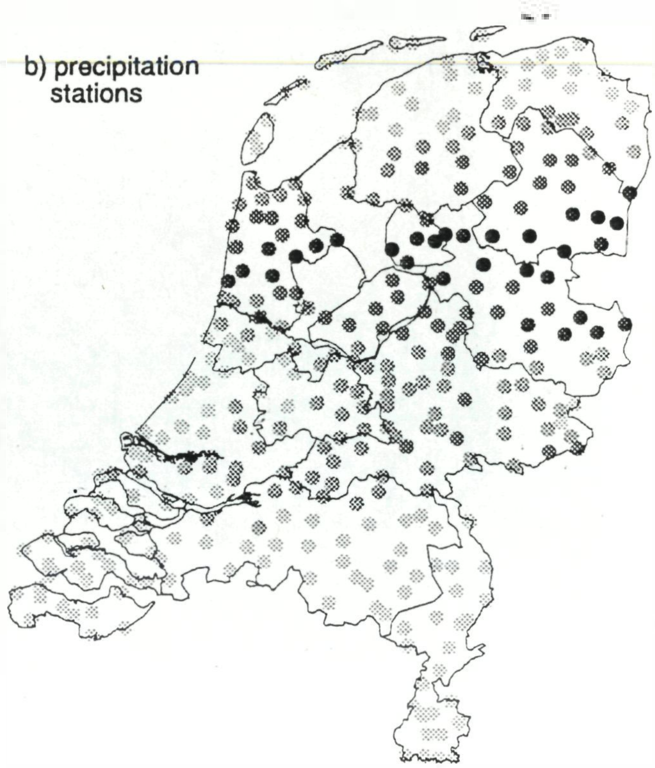
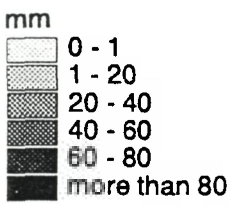


Figure 4. Precipitation in the same 24-hour period as in Figure 3 but now predicted by the ECMWF-model at **a**) 24 October 12 UT and **b**) 25 October 12 UT and **c**) predicted by RACMO at 25 October 12 UT instead of 26 October 12 UT as in **Figure 3**.

Only in the 26 October run of the ECMWF-model the predicted precipitation amounts over the Netherlands are realistic. In earlier runs far lower amounts are predicted for the Netherlands, with higher amounts shifted north (outside the window). Already at 25 October 12 UT, RACMO predicted amounts over the Netherlands close to those observed (earlier runs for RACMO were not available).





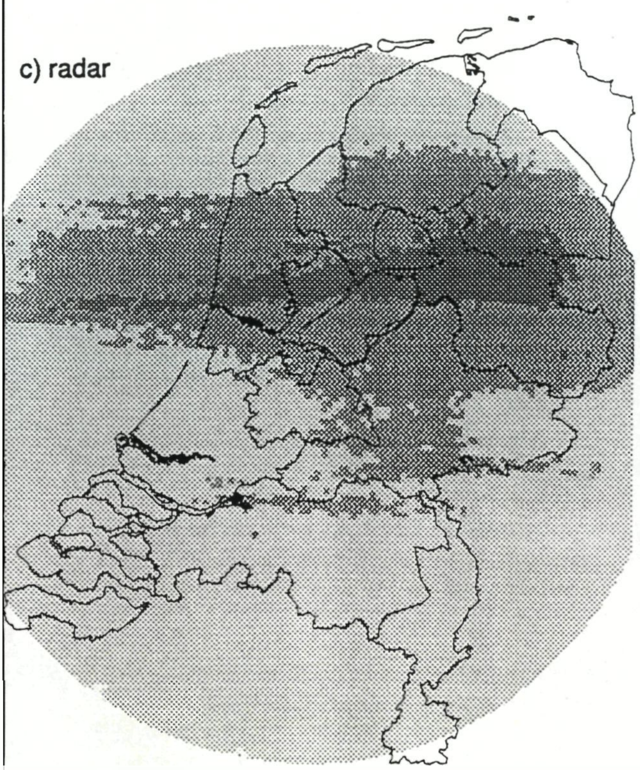
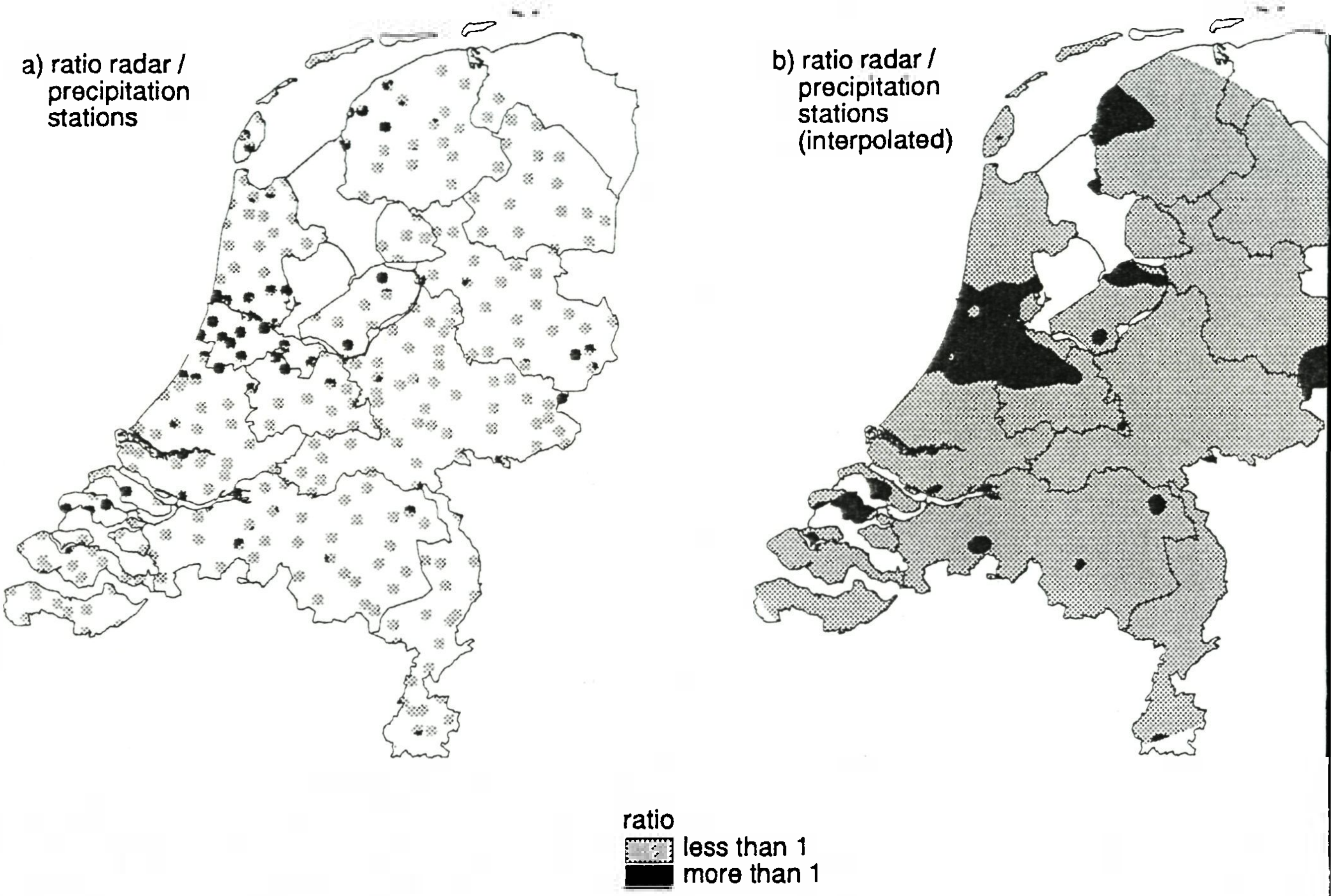


Figure 5. Precipitation in the 24-hour period between 27 October 8 UT and 28 October 8 UT as observed at
a) automatic weather stations
b) precipitation stations
and as derived from
c) radar (sum of 24x20 5-minute samples)

Based on the observations at precipitation stations in **b**) the precipitation map of **Figure 1 c**) was produced by interpolation.

Radar did not detect precipitation amounts over 60 mm as observed at stations in the small band in the northern part of the Netherlands. In the next figure it will be shown that this is in agreement with the fact that for the study period radar derived amounts are generally lower than the amounts observed at precipitation stations.

Note that the 6-6 UT period for which precipitation predictions are shown in **Figure 3** and **4** is slightly shifted relative to the precipitation totals in the 8-8 UT period in this figure. However, precipitation amounts in the non-overlapping 6-8 UT periods were rather low.



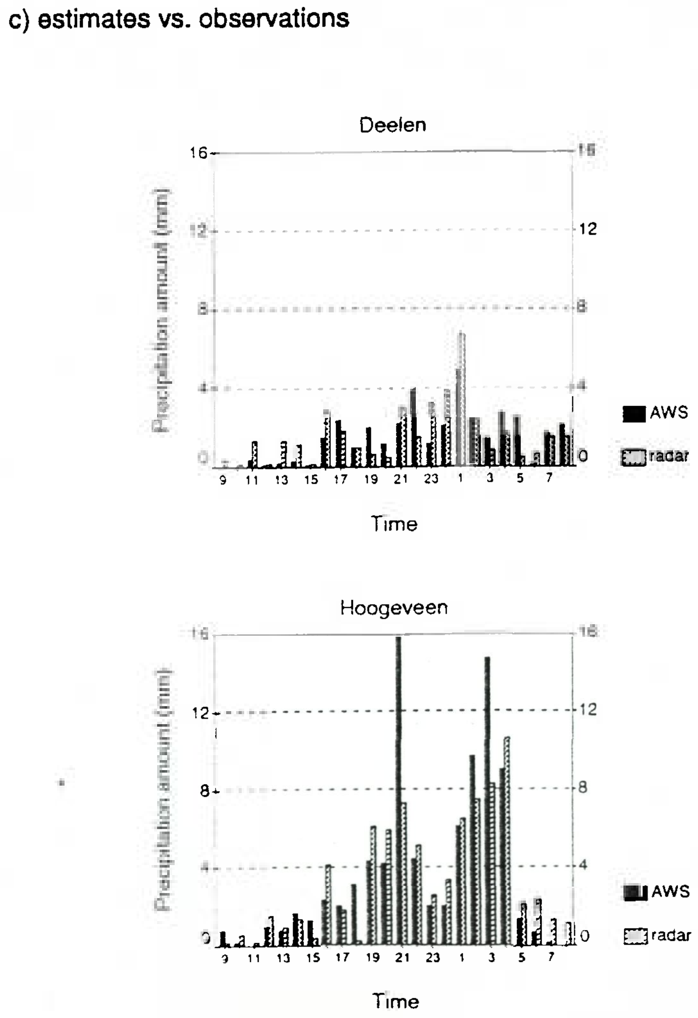


Figure 6 The use of the ratio between 24-hour precipitation observations from radar and precipitation stations for deriving time series of hourly precipitation at a particular location of interest. First, the ratio at precipitation stations is calculated (**a**), taking for radar the average of the values in a circle with 2.5-km radius centred on a precipitation station. This ratio is subsequently interpolated (**b**). Next, a multiplying factor derived from the ratio field is applied to the hourly sums of 5-minute radar precipitation values at the location of interest (again the average in a circle with 2.5 km radius is taken). In **c**) the estimates of hourly precipitation values between 27 October 8 UT and 28 October 8 UT at the location of two automatic weather stations (Deelen and Hoogeveen; see **Figure 2**) are compared with observed values at these stations. The multiplying factors at these sites are 0.60 and 0.51, respectively.

Since radar fields are continuous in space, in a similar way high resolution time series of areal average precipitation can be obtained.

International Conference on Quality, Management and Availability of Data for Hydrology
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Time series and their applications analysis and design of a data model

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Introduction

The subject of the following chapters is the analysis and application of Time Series, and a more detailed discussion of implementation on computers. Special attention is paid to the usage of time series in hydrological applications. The aim of this paper is to provide an understanding of the complexity of the problems in this area and to show some possible solutions. Whenever it seemed appropriate, excursions outside hydrology have been made, to show general concepts. We have paid special attention to the relevance of our functions and attributes to the subject matter.

Chapter 2 formally defines the term Time Series. The different Types of Time Series are defined, and the gap problem is discussed. The quality of a time series is introduced, which plays a central part in the rest of this paper.

Chapters 3 and 4 are concerned with the application of time series, firstly from the software point of view, and secondly from the point of view of the end user.

The two following chapters cover data storage. Apart from the mass data all information is kept in a relational database.

Finally, the last two chapters deal with the internal implementation details, such as object oriented class design, and algorithms.

Contents

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Combined application of United Kingdom national river flow and water quality databases for estimating river mass loads

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Abstract
The paper introduces the combined application of the UK national river flow and water quality databases for the systematic calculation of annual mass loads of materials transported by rivers towards estuaries and coastal waters.

Introduction
In recent years interest has grown in the contaminant loading of the North Sea (e.g. Andersen and Niilonen, 1995), and the scientific community has responded accordingly. One of the key objectives of the UK Land-Ocean Interaction Study (LOIS) was "To estimate the contemporary fluxes of momentum and materials (sediments, nutrients, contaminants) into and out of the coastal zone, including transfers via rivers ..." (Wilkinson *et al.*, 1997). LOIS has broadly similar objectives to (i) the European Land-Ocean Interaction Studies (ELOISE) being managed under the aegis of the European Commission (Cadée *et al.*, 1994) and (ii) the Land-Ocean Interactions in the Coastal Zone (LOICZ) programme being promoted as part of the International Geosphere-Biosphere Programme (IGBP) (Pernetta and Milliman, 1995). Clearly, any LOIS, ELOISE or LOICZ assessments of the fluvial transport of materials from land to coastal waters and beyond (and the modelling of such transfers) should be concerned with (i) the quality of river mass loads estimated from recorded flow and concentration data and (ii) improving our understanding of the processes which act as sources and sinks of material in non-tidal rivers, estuaries and coastal waters. Indeed, data quality and process understanding are highly complementary aspects of modelling the land-ocean material transfer system.
Whilst LOIS and similar projects may generate new data of great value they also stimulate reassessments of relevant information available from existing data. This paper is concerned with systematic calculation of annual river mass loads through the combined application of the UK National River Flow Archive (NRFA) and the Harmonised Monitoring Scheme (HMS) river quality database.

The databases
Most of the data held in the HMS database and the NRFA have been derived from measurements by the Environment Agency (EA) for England and Wales and the Scottish Environmental Protection Agency (SEPA). The NRFA, maintained by the Institute of Hydrology (IH), includes essentially unbroken time series of daily mean flows for over 1100 sites throughout the UK, with an average record length (in 1999) of about 27 years. Information about the NRFA and the availability of its data is published in a Register of Gauging Stations which is updated every five years (e.g. Marsh and Lees, 1998) and in Yearbooks (until 1995) (e.g. IH, 1996). Post-1995 Yearbooks are published electronically[1]. The NRFA plays a major role as a source of hydrometric data and information to

[1] http://www.nwl.ac.uk/~nrfadata/nwa/web/nwa.htm

assist with water resources management in the UK. A short history of river water surveying in the UK (until the 1980s) is given by Lees (1987).

The HMS database holds mainly river water quality data from 1974 onwards. In 1998 responsibility for the management and maintenance of the HMS database was transferred from the Department of the Environment, Transport and the Regions (DETR) to the EA. There are over 200 HMS sites throughout Great Britain, most of which are near the tidal limits of major rivers and at, or near, an NRFA river gauging station (but in some cases the HMS and NRFA sites are several kilometres apart). For each sample taken, more than 100 determinands can be accommodated in the HMS database. Usually, however, about 25 determinands are recorded at a particular HMS site, many of which are 'standard' (e.g. temperature, suspended solids, nitrate) with the rest deemed to be important locally. The assemblage of determinands recorded at an HMS site can vary with time. Although sampling frequency at some sites might be nominally weekly, monthly, etc., in practice HMS concentrations are typically spaced irregularly in time (i.e. aperiodic), with the time between samples varying typically from about four to 60 days. To enable estimation of river mass loads without recourse to any other source of data or information, the HMS database also records river flow corresponding to the time (or day) of the samples.

Whilst the NRFA and the HMS database are the best-organised UK national datasets for river flow and river water quality respectively, additional river flow and more comprehensive quality data exist (e.g. sub-daily river flows and non-HMS river quality data held by the EA and SEPA). The HMS commenced in 1974, and one of its founding aims (Simpson, 1978; 1980) was to provide a coherent source of data to assist with estimating river pollutant loads discharged to UK coastal waters. Another key founding aim of the HMS was to identify long-term trends. Since 1990, estimates of annual river mass loads have been supplied annually by the DETR to the Oslo[2] and Paris[3] Commission (OSPAR) who collate such information from countries bordering the North Sea.

Previous work (e.g. Rodda and Jones, 1983) has employed the HMS database for estimating river mass loads carried towards the sea but, with the computing resources which were available at the time, the calculation methodologies employed were limited compared to those which can be applied systematically today. It is now possible to handle and manipulate very large databases in ways which were not a practical option previously. Indeed, large databases like the NRFA and HMS can now be accessed simultaneously, enabling the implementation of methodologies for river mass load estimation which yield better results than those which can be derived solely from the HMS database (given the limited amount of HMS river flow data). The two databases applied together can lead to a synergy of information, e.g. improved precision in river mass load estimates.

Estimates of annual river mass loads

In a recent study (Littlewood, *et al.*, 1997; 1998) annual mass load time series, from 1975 to 1994, for the aggregation of all HMS catchments[4] near the tidal limits of major rivers in Great Britain (HMS_{GB}), were estimated for 12 determinands; total nitrogen (NH_3-N + NO_2-N + NO_3-N), orthophosphate, suspended solids, zinc, copper, lead, cadmium, nickel, mercury, lindane, arsenic and total phosphorus (dissolved and suspended). Special software (Watts and Littlewood, 1998) was devised to assist with this work. Annual river mass loads derived independently for the years 1990 to 1994 have been supplied by DETR to OSPAR and, where there is good agreement between these and the corresponding HMS_{GB} values, it is considered (Littlewood *et al.*, 1998) that the longer time series (HMS_{GB}) give a reasonable indication of the variation of annual river mass loads since 1975. Figure 1 shows the data for total nitrogen, orthophosphate, suspended solids and zinc; for many of the other determinands the agreement between HMS_{GB} and OSPAR values is not as good as shown in Fig. 1 (see the corresponding Conference Proceedings paper for further details).

[2] The (Oslo) Convention for the Prevention of Marine Pollution from Ships and Aircraft.

[3] The (Paris) Convention for the Prevention of Marine Pollution from Land-Based sources, 1974 (implemented 1978). The Oslo and Paris Commissions combined in 1994 (OSPAR).

[4] In this paper, aggregations or groupings of catchments exclude HMS basins which are nested within other HMS catchments.

Concluding remarks

An effective merger of the river flow and quality data in the NRFA and the HMS database respectively has yielded new information in the form of annual mass load time series from 1975 to 1994. Improved precision in river mass load estimates has been achieved by applying the NRFA and the HMS database together rather than the latter in isolation. Further harmonisation of the UK river flow and quality monitoring networks, and their databases, is required. The provision of good-quality river mass load estimates (for selected determinands) should be placed high on the list of required outputs from the combined monitoring network.

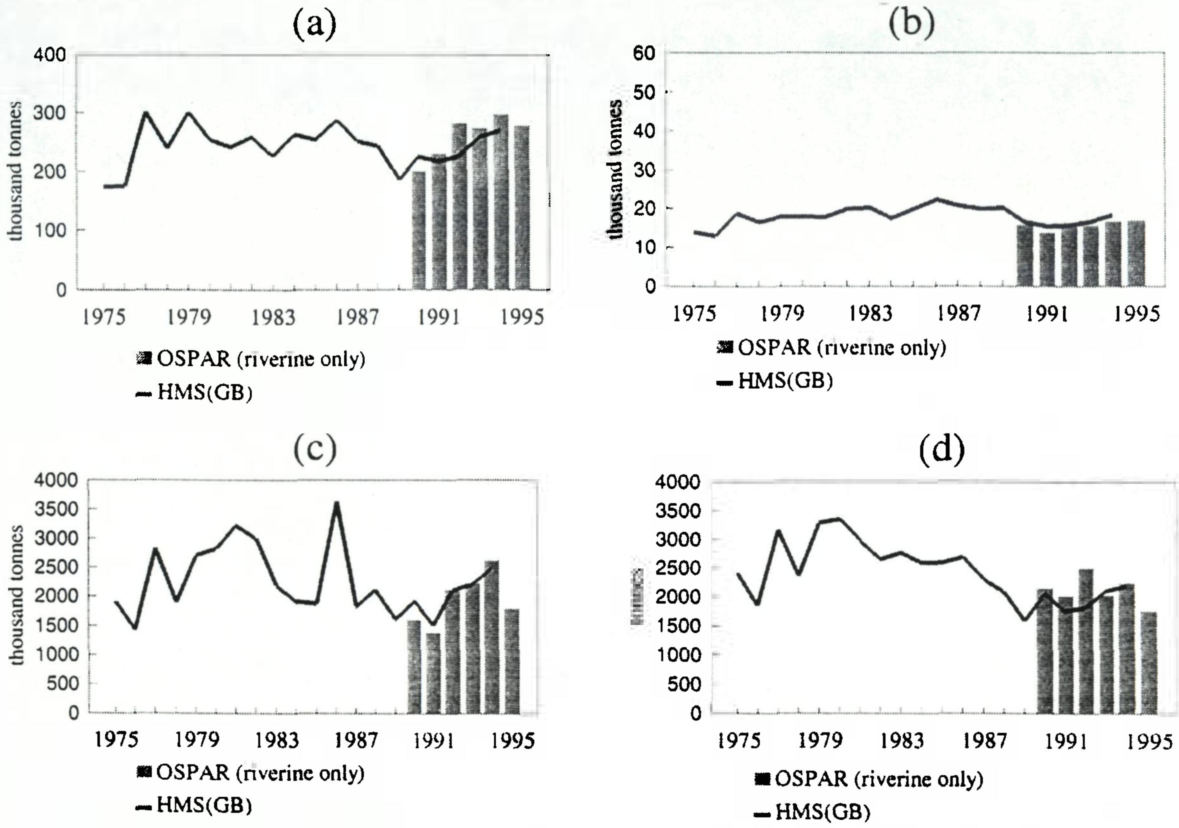

Figure 1 **(a) total nitrogen, (b) orthophospate, (c) suspended solids, (d) zinc**

References

Andersen, J. and Niilonen, T. (eds.), 1995. Progress Report: 4th International Conference on the Protection of the North Sea, Esbjerg, Denmark, 8-9 June 1995. Ministry of the Environment and Energy, Danish Environmental Protection Agency, Strandgade 29, DK-1401, Copenhagen, Denmark. 247 pp.

Cadée, N., Dronkers, J., Heip, C., Martin, J-M. and Nolan, C. (eds.) , 1994. European Land-Ocean Interaction Studies (ELOISE): Science Plan. European Commission, Directorate-General XIII, Luxembourg, 52pp.

IH (Institute of Hydrology), 1996. Hydrological data UK - 1995 Yearbook. Institute of Hydrology, Wallingford, 176pp.

Lees, M.L., 1987. Inland water surveying in the United Kingdom — a short history. Hydrological Data UK: 1985 Yearbook. Institute of Hydrology, Wallingford, UK.

Littlewood, I.G., Watts, C.D., Green, S., Marsh, T.J. and Leeks, G.J.L., 1997. Aggregated river mass loads for Harmonised Monitoring Scheme catchments grouped by PARCOM coastal zones around Great Britain. Institute of Hydrology contract report to the Department of the Environment, 91pp + Appendices.

Littlewood, I.G., Watts, C.D. and Custance, J.M., 1998. Systematic application of United Kingdom river flow and quantity databases for estimating annual river mass loads (1975-1994). The Science of the Total Environment, 210/211, 21-40.

Marsh, T.J. and Lees, M.L. (eds.), 1998. Hydrological data United Kingdom: Hydrometric Register and Statistics 1991-95. Institute of Hydrology, Wallingford, 208pp.

Pernetta, J.C. and Milliman, J.D. (eds.), 1995. Land-Ocean Interactions in the Coastal Zone (LOICZ). International Geosphere-Biosphere Programme, Global Change Report No. 33, Stokholm, 215pp.

Rodda, J.C. and Jones, G.N., 1983. Preliminary estimates of loads carried by rivers to estuaries and coastal waters around Great Britain derived from the Harmonized Monitoring Scheme. Journal of the Institution of Water Engineers and Scientists, 37, 529-539.

Simpson, E.A. 1978. The harmonization of the monitoring of the quality of inland fresh water. Journal of the Institution of Water Engineers and Scientists, 32, 57-66.

Simpson, E.A. 1980. The harmonization of the monitoring of the quality of rivers in the United Kingdom. Hydrological Sciences Bulletin, 25, 13-23.

Watts, C.D. and Littlewood, I.G. (1998). CORAL: a system for the calculation of river mass loads from UK databases. In: Wheater, H.S. and Kirby, C, (eds.) Hydrology in a Changing Environment. British Hydrological Society International Symposium, Exeter, 6-10 July 1998, John Wiley & Sons, 559-571.

Wilkinson, W.B., Leeks, G.J.L., Morris, A. and Walling, D.E. (1997). Rivers and coastal research in the Land Ocean Interaction Study. The Science of the Total Environment, 194/195, 5-14.

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Collection and Management of hydrological related Data in a Danish nation wide Area Information System

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Introduction

This paper describes the constraints, possibilities and thoughts behind the development, collection and management of nation wide geographical related data sets specifically in order to improve operational water management on a regional and nation wide scale (4).

The major collection of georelated data in Denmark is carried out by several, different institutes and companies: The Ministry of Environment and Energy, The National Survey and Cadastre, The Ministry of Food, Agriculture and Fisheries, gas and telephone companies, the counties and municipalities. These georelated information data sets are used for research, monitoring and administration.

Each of the administrative units has its own individual responsibilities and tasks, both depending on and influencing the land use. The primary goals of the various administrations are different and include commercial activities, protection of historical heritage, urban development, recreational interests, nature and environmental protection, tourism, traffic planning, and the estimation of the consequences for the landscape and environment. Lack of co-ordination between the various authorities implies that the collecting institutes use tools and data structures developed primarily according to their own requirements, without taking other user needs into consideration.

The lack of a common base map and data structure is a major barrier for the co-operation across county boundaries and institutional boundaries in, for instance, research and the undertaking of multidisciplinary tasks. Thus, the establishment of a unitary data base and data structure is indispensable for many national and international research projects.

Therefore, in 1996 The Danish National Environmental Research Institute together with other institutes in The Ministry of Energy and Environment initiated a collaboration with a number of other data collecting institutes with the aim of establishing a nation wide Area Information System (AIS) as a multi-disciplinary tool for research and administrative purposes.

The system is based on existing available topographical maps from the National Survey and Cadastre and supplemented with other relevant data. A unitary land cover map of Denmark status 1996 on scale 1:25,000, supplementary databases (amongst others water courses, lakes, wetlands, vegetation, geology) and a satellite archive are established. Moreover, continued collaboration with the data collecting institutes and development of updating methods are considered of major importance in the project.

Collection of data - and the thoughts behind

At the National Environmental Research Institute nation wide databases containing runoff, lake properties and water quality information are stored. The databases are mainly used for national environmental monitoring and for research purposes. To perform this work, there is a need for combining the above mentioned data with geographical information on stream networks, lakes and wetlands and other hydrology related data sets.

Within the hydrological field there is an improved acknowledgement of the need for exploring the most useful data in order to collect the relevant data at different scale of application for hydrological modelling purposes. On the other hand collecting data sets has constraints in what is possible and what can be gathered. Some examples will be given.

Land use

The unitary land cover map in AIS is based on merging of information from mappings of The National Survey and Cadastre, Agricultural Subsidy areas, The counties registration of protected nature types and a land cover satellite classification based on Landsat TM. The origin of these mappings are a mixture of land cover and land use resulting in unitary mapping consisting of extracts of both information types in order to get as accurate and detailed information as possible.

Geology

The existing soil mapping is based on agricultural mapping of soil type mainly based on soil samples collected in the very upper root zone. Investigations (2,3) have shown that irrigation need depends on the whole soilprofile covering the rootzone and that subsurface geology has to be taken into acount, especially is information of soil types underneath sandy top-soils. Modelling of evaporation, surface runoff and discarge can be expected to be similarly sensitive. The surface geological maps in scale 1:25.000 and 1:200.000 are based on detailed mappings at 1 meter depth are therefore digitized in order to improve modelling background.

Stream networks

All streams and lakes are captured from the National Survey and Cadastre maps and supplemented with data from the counties. As the purpose of cadastral mappings are to show human pathways of crossing these water courses, the streams are disconnected whenever they are covered by bridges or artificially buried (piped). Furthermore, in case of large streams, the streams are shown as areas (polygons). There remains therefore a need for both computerisation and manual processing to bring the streams and lakes into a proper stream network which can be used for various purposes e.g. simulation modelling. When the basic network has been established, associated data (e.g. flow direction, limit or target values etc.) will be connected to the stream network and lakes.

Catchment Boundaries

The existing stream catchment boundary database contains nation wide catchment boundaries up to 4th grade. The database is use-able for drawing figures, but it is not updated and complex to use it for analytical purposes, which is necessary for nutrient transport monitoring purposes. A national gauging station catchment boundary database are established, as the catchment boundaries normally are used together with the very stationary gauging and nutrient transport stations.

It is possible, via GIS, to establish the catchment boundaries for arbitrary chosen points on the stream networks based on a DEM, but the resulting boundaries will not be adequate due to smooth terrain and man made drainage. In Denmark the landscape is so influenced by manmade activities, that it pays to elaborate the database manually. The lowest possible catchment units will be stored together with amongst others the information of a hydrological id-number. A sequential file with the catchment numbers will be kept for the catchment analyses, making it possible to link sub-catchments within bigger catchment areas.

Wetlands
Mapping and information of the changes in wetland areas have great importance for water balance, nutrient reduction in the water environment and vegetation (development of potential nature areas). This information is even more important as it has shown not to be possible to gain any digital information on drained areas and the efficiency of the drainage. In connection to the AIS project a mapping of existing and potential wetlands are established. The actual wetland mapping is based on information on wet areas from the maps of The National Survey and Cadastre and the counties nature type registration. The mapping of potential wetlands is supplements the existing wethlands with digital information from geological maps (organic soil types) and old mappings of wetlands.

Use of data for management - research needs
The collected data clearly will improve the possibilities of management. In modelling, knowledge of topography and hydraulic soil properties normally are used for estimation of drainage conditions. It has been demonstrated how insufficient topographical information influents the modelling of the sinks and leads to erroneous water balance estimates (1). Enhanced knowledge of land cover, stream network, surface geology and actual and potential wetness conditions will improve the estimates. Examples will be given.

Another aspect of the earlier mentioned difficulties in collecting proper data is that data are often used as "are". Few investigations and thoughts exist on the resulting quality of the use of data. It is expected that the collected data in AIS will be an excellent background for research and analyses of sensitivity and adequacy of collected data.

AIS after 1999
As soon as the maps generated within the framework of the AIS project have been finished, enabling availability and updating will be a crucial task, and it is carefully considered how to manage these.

Co-ordination and agreements between data producers play a very important issue for the availability of the AIS-data.

Three important technical aspects will enforce the success criteria of updating. First of all, the data producers within the ministry will approve the use of the unitary maps defined within the AIS-project, in their contribution to the mapping. Second, data should be stored with detailed information of origin and history, allowing for partial updating. And finally, new and more efficient methods for creating information should be taken into account. In the case of, for instance, land cover mapping and nature type registration, experiments with integration of satellite image based methods for hot spot change detection have shown promising results for a more frequent and homogeneous updating than would be possible with old mapping methods.

References

1. Andersen, J. 1996. Application of GIS in hydrological models. Msc. thesis, Department of Geography, University of Copenhagen.
2. Holst, K. A., Madsen, H. B. 1988: Modelling the irrigation need . - The influence of climate and soil water content on the irrigation for barley and grass. *Acta Agric. Scand. No. 38,3: 261-269*
3. Madsen, H.B. Holst, K. A.. 1987: Potentielle marginaljorder - Landsdækkende kortlægning af jordbundsfysiske og -kemiske forhold, der har indflydelse på jordens dyrkningsværdi. *Skov- og Naturstyrelsen/Miljøstyrelsen, København pp. 113 + bilag. ISBN nr. 87-503-6611-4.*
4. Mielby, S., Platou, S.W., Müller-Wohlfeil, D.I. 1997. Land and Runoff Data in a Danish nation wide Area Information System. In *Refsgaard J.C. and Karalis, E.A (eds.): Operational Water Management. Proceedings of the European Water resources Association Conference, Coopenhagen Denmark 3-6 September 1997, pp. 271-276*

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The Land Ocean Interaction Study. Data management problems and solutions for a very large multidisciplinary Project

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Introduction

The Land Ocean Interaction Study (LOIS) is a Natural Environmental Research Council (NERC) Community Research Programme. It is a £30 million seven year project in which both the Institutes within NERC and United Kingdom (UK) Higher Education Institutes are participating. Its aim is to increase our understanding of how the land, rivers, coastal waters, deep ocean and atmosphere interact in order that the coastal zone may be managed in a way that is sustainable During the programme, immense volumes of data on many topics have been assembled. The paper describes some interesting data management issues raised and how they were resolved.

Background

The UK lies on a wide Continental shelf bordering the North Sea and the Atlantic Ocean. It is an island with enormous physical and ecological diversity that is changing rapidly as a result of interactions between man and the environment. Human activities not only affect the physical character of the land but have an especially strong impact on its ecosystems. Over the last 200 years, the range and quantity of substances applied to the land, and subsequently making their way via the river system to the coastal zone, has dramatically increased. These changes are the result of the growth of urban areas, the development of trade and industry and the intensity of agricultural practices and have affected both freshwater and marine ecosystems. The LOIS programme was devised as a means of studying these impacts in an integrated and all-embracing manner in a way and on a scale not previously attempted.

LOIS has as its main aim, an increased understanding of environmental processes and their interactions. A secondary objective is to encapsulate this understanding in models which can then be incorporated into decision support systems. These, it is hoped, will help to identify sustainable management strategies. To date, most research in the coastal zone has been carried out within the boundaries of the traditional scientific disciplines of hydrology, geology, oceanography and so on. Relatively little attention has be given to the study of processes that cross the boundaries.

Not surprisingly, therefore, the related datasets and database systems have also grown up in isolation. Even where the different disciplines collect and use the same data, there has been little commonality in their approach or terminology. However, for a project such as LOIS to succeed, a common understanding of what each item of data describes is vital. Without it, how can, say, a modeller, model an estuary where the input data are drawn from river, marine, geological and atmospheric data sources. Further, to explore relationships that cross the traditional scientific boundaries requires data types to be harmonised that have not previously been brought together. Different collection and storage strategies must be reconciled. For example, river water quality data are collected at fixed points over long periods, but marine and atmospheric data are collected intensively over short cruises and flights. New technologies are introducing new ways of measuring variables. For instance, remote sensing has the potential to generate immense volumes of time series water quality data, that have a high resolution both in space and time and cross all the traditional boundaries.

The assembly of such large and diverse datasets (of the order 50 -100 Gbytes) is itself a major problem. Because it is a scientifically unglamorous task, little attention has been given to it in the past. However, the resource implications of the current 'ad hoc' approaches to data gathering were so great for LOIS that a generic solution had to be found. Today the problem of data gathering is compounded not only by the fact that data come from many sources, but also by the fact that many sources are commercial and therefore covered by licence conditions which have to be respected. Knowledge of who owns what and for what purposes it may be used is important. The introduction of some very simple automated quality assurance (QA) has been the first attempt to address this problem.

The aim of the paper is to expand on these points and to explain how they have been handled in LOIS and are continuing to be addressed in succeeding projects.

Issues

Clearly a project of the size and complexity of LOIS faces many data management problems. Many will be familiar to most data managers, but four are interesting for the novelty of either the problem or the solution. They are;

- spatial time-series (data that vary in x, y, z and t)
- data load
- QA
- access to specialist data by users from other disciplines

spatial time-series (data that vary in x, y, z and t)

A distinguishing feature of LOIS has been the high proportion of the database for which it has been necessary to label each individual value with its co-ordinates in 3-D space and time. Nearly all LOIS data have the potential to change with time, though the time scale varies from millennia for geological change to seconds for some marine observations. The LOIS database mainly comprises traditional time-series data. For the land based components of LOIS, these arise from manual sampling at fixed points, while at sea and in the air they come from continuous sampling during cruises and airborne campaigns. However, while these methods are likely to continue for the foreseeable future, a new source of time-series data is emerging. During LOIS, a pilot exercise was mounted in which a plane was repeatedly flown over the same area with a Compact Airborne Spectral Imager on board for a period of four hours. The resulting images were classified to produce a series of high resolution (1m x 1m) maps of chlorophyll in the Humber estuary. As well as raising exciting possibilities, this also raises many practical data handling problems that must be solved. Each image is a picture of a body of water that is moving. Each image relates not to a moment in time, but to the period of time it took the plane to cover the area. Thus, a pixel on one side of the image relates to a different moment in time to a pixel on the other side and during that time the body of water represented by the first pixel will have moved and may be dispersed. Clearly the advantages of such data are that they give complete aerial coverage and that by 'drilling' down through the successive images, a time-series can be constructed for any point on the map. Some of the above problems have already been considered by the remote sensing community, but the implications for databases have yet to be identified. The solutions section of the paper explains how these data were held for LOIS and the issues that remain to be addressed.

The location of most land based data are adequately described by an X,Y co-ordinate. In the geological, marine and atmospheric worlds Z is equally important. In the marine and atmospheric worlds, the concept of fixed observation points has not been adopted to the same extent as it has in the terrestrial sciences. The ships and planes used as observation platforms at sea and in the air move. Current GIS systems, however, have very limited facilities for recording positional change with time.

The paper will explain how positional information whether point, line, or raster, have all been treated as time-series data in LOIS.

data load

LOIS has had to accept data on many subjects from many suppliers in many formats. For a variety of reasons it was not possible to dictate the format in which data were supplied, which left the data centres with the problem of translation. At the outset the unavoidable solution was to write separate programs to read, validate, translate and load each format. The cost was high and the resulting maintenance problem unmanageable.

From the repetitious production of conversion programs, most of which were variations on a common theme, a generic solution emerged that allows a single program to recognise, validate and load tabular data in a wide variety of configurations. It also handles the conversion of identifying codes and units of measurement. Provision has been made for the future automatic recording of QA information.

quality assurance

One of the problems facing the users and managers of LOIS data has been to know for what purposes the data are fit, how and for what they may legally be used and when, why and by whom changes to the data in the database have been made. It is quite possible to conceive of a database design that could record all of this information. However, it is almost certainly not economically feasible at present to produce a system that could store and utilise the information, without degrading its performance to the point of being unusable. In an ideal world, users would like to be able to ask all the above questions of each individual item of data. In the context of a research project with finite funds that is managing a constantly changing database whose size is measured in ten's of Gbytes, it is clearly impractical to label every individual value with its history. The section that follows sets out what has been achieved and direction that future work will follow.

access to specialist data by users from other disciplines

In any project where a wide range of disciplines are brought together, it is inevitable that many users will be working with data and systems that are new to them and whose terminology is unfamiliar. LOIS has explored the development of a database capable of handling the whole range of data collected and used within the study. There are several aims in so doing. One is to bring together similar information that is collected by many or all of the different components of LOIS and create a single harmonised dataset, for example, water quality data. The database used to do this has been the Water Information System (WIS). WIS is a generic system where users describe the data to be stored via a system of dictionaries. In common with most systems, it doesn't allow for multiple descriptions of the same data items and it is therefore necessary adopt one discipline's terminology or generate a new one. This clearly leaves the other users with a problem and one that can be serious where the different disciplines use the same terms to mean different things or where important qualifying information is assumed. 'Nitrate' is a good example of a widely used term with many interpretations. Another is 'dissolved' for which a filter size is frequently assumed but not stated and for which the assumption will vary from one determinand to another and from one environmental medium to another.

A further objective in marshalling all data into a single database is make the exploration of relationships between data of different types easier. It is in this context that users are most likely to be browsing and using data, systems and terminologies with which they are unfamiliar. For example, the LOIS database contains data about nutrient concentrations in rivers. In the dictionary, each nutrient is described by its chemical name. A biologist coming to the system for the first time may well not know what nutrient data are recorded nor the type of location or feature against which they are recorded. From his point of view, the natural thing to do would be to ask about 'nutrients', however, at present, most database systems have no way of getting from 'nutrients' to the sites and variables against which such data are held. If multidisciplinary science is the way forward, then this problem needs addressing and in the section that follows a description is given of the approach being adopted following LOIS.

Solutions

spatial time-series (data that vary in x, y, z and t)
In the database design adopted for LOIS, the 'peg' upon which everything is hung is the *object* (or in GIS terminology, the *feature*). Everything describing the object is recorded as an attribute. No attribute is regarded as any more or less important than any other attribute. Grid references, names, site ID's, water levels are, from the system's point of view, equally valuable. No distinction is made between spatial or other data. All data are assumed to have the potential to change with time and may change at fixed or random intervals in time. The system has a wide range of data types that includes not only conventional types such as numbers, dates and text but also images, grids, lines, points, arrays, periods of a year and relationships to other objects. Hence the system has the ability to record time-series of grids and images which can be replayed as animations or the paths of ships and aeroplanes which can be displayed as lines on maps. The paper will elaborate on the physical data model that accommodates the data.

data load
The needs of different situations and users personal preferences mean that even different sets of data about the same subject will be captured or required in a whole variety of different arrangements. However, many of these arrangements have a common underlying structure of an optional header block followed by a block of data arranged in columns and rows. The WIS-CSV format exploits this to make it possible for a single program to read and recognise data in a great variety of tabular arrangements. It does so by the addition of a small number of rows and columns that enable a program to identify the contents of each cell in the table and map them to their storage location in the database, transforming identifying codes and making unit conversions in the process. These can usually be added to existing data using a spreadsheet, word processor or text editor. Figure 1 shows the main components of a WIS-CSV file.

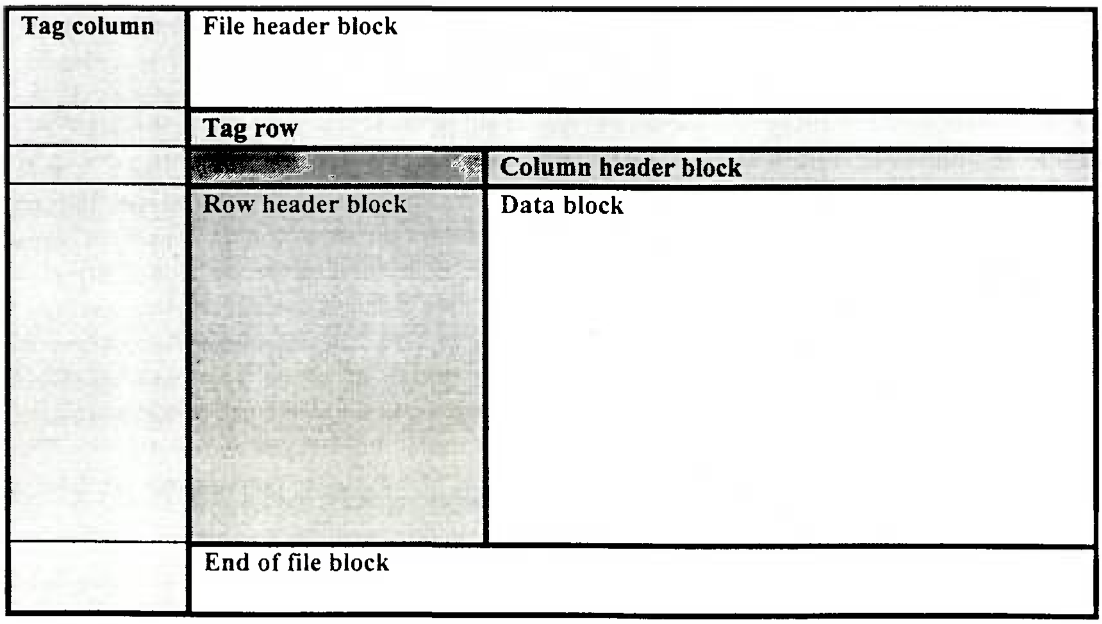


Figure 1 The main components of a WIS-CSV file

The purpose of the file header block is to convey information about the data set as a whole. Typically, it will contain descriptive information covering the nature of the data; who sent it, when and any conditions relating to its use. It can also be used to pass items of data that only need to be specified once in the file, for example, a site identifier, the date to which the data all relate, or the units of measurement.

The data values will be in the data block. The other parts of the file explain to the users and programs what each value in the data block describes i.e.:

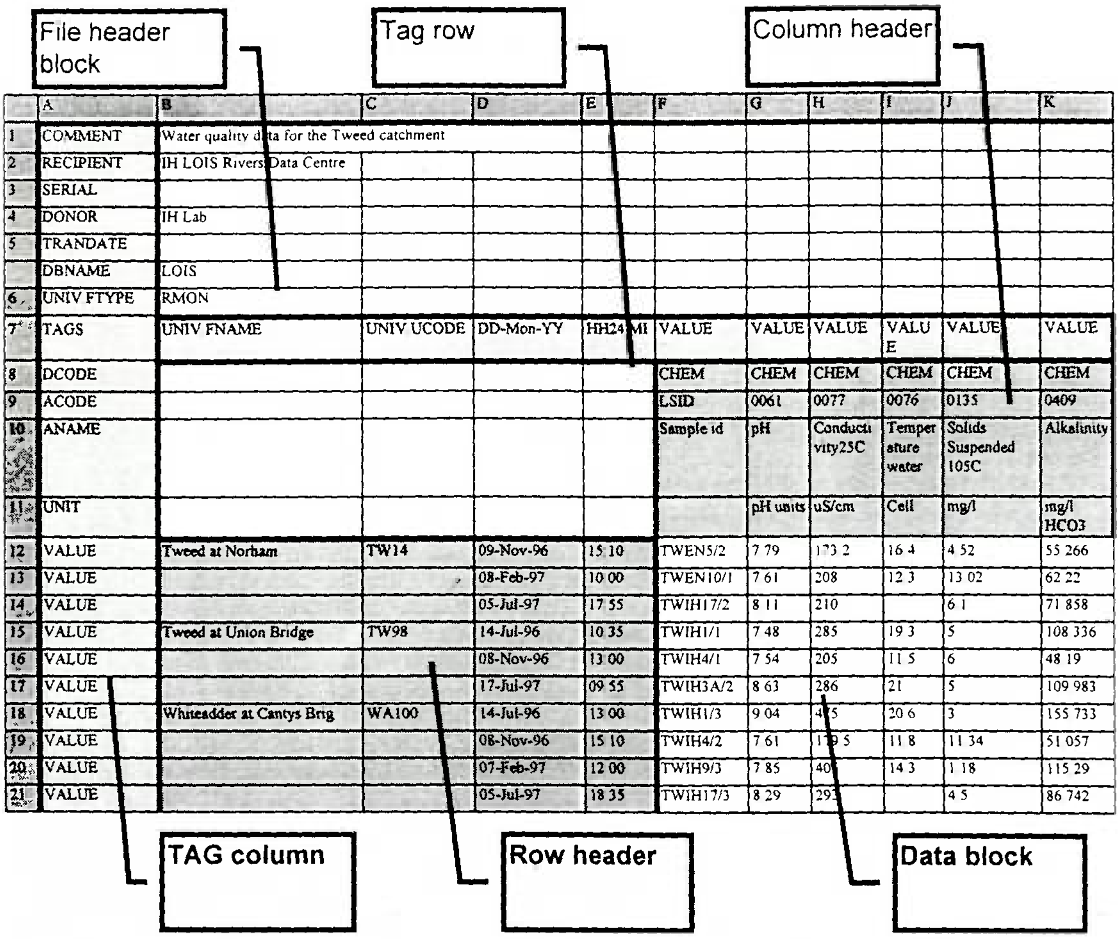
- the column header block indicates the attribute for which it is a value e.g. water temperature
- the row header block indicates the feature to which it belongs e.g. river monitoring site TW14 (Tweed at Norham)
- the tag row indicates the moment or period in time to which it relates e.g. 09-Nov-96 at 15:10
- if it is a replicate (not illustrated)

Figure 2 shows some water quality data as it would be displayed in a simple text editor. All the elements of a WIS-CSV file are displayed, but are not easy to see and therefore edit.

```
COMMENT, Water quality data for the Tweed catchment, , , , , , , , ,
RECIPIENT, IH LOIS Rivers Data Centre, , , , , , , , ,
SERIAL, , , , , , , , , ,
DONOR, IH Lab, , , , , , , , ,
TRANDATE, , , , , , , , , , ,
DBNAME, LOIS, , , , , , , , ,
UNIV FTYPE, RMON, , , , , , , , ,
TAGS, UNIV FNAME
UNIV UCODE, DD-Mon-YY, HH24 MI, VALUE, VALUE, VALUE, VALUE, VALUE, VALUE
DCODE, , , , , CHEM, CHEM, CHEM, CHEM, CHEM, CHEM
ACODE, , , , , LSID, 0061, 0077, 0076, 0135, 0409
ANAME, , , , , Sample id, pH, Conductivity25C, Temperature water, Solids Suspended 105C, Alkalinity
UNIT, , , , , , pH units, uS/cm, Cell, mg/l, mg/l HCO3
VALUE, Tweed at Norham, TW14, 09-Nov-96 , 15 10 , TWEN5/2, 7 79, 173 2, 16 4, 4 52, 55 266
VALUE, , , 08-Feb-97 , 10 00 , TWEN10/1, 7 61, 208, 12 3, 13 02, 62 22
VALUE, , , 05-Jul-97 , 17 55 , TWIH17/2, 8 11, 210, , 6 1, 71 858
VALUE, Tweed at Union Bridge, TW98, 14-Jul-96 , 10 35 , TWIH1/1, 7 48, 285, 19 3, 5, 108 336
VALUE, , , 08-Nov-96 , 13 00 , TWIH4/1, 7 54, 205, 11 5, 6, 48 19
VALUE, , , 17-Jul-97 , 09 55 , TWIH3A/2, 8 63, 286, 21 , 5, 109 983
VALUE, Whiteadder at Cantys Brig, WA100, 14-Jul-96 , 13 00 , TWIH1/3, 9 04, 475, 20 6, 3, 155 733
VALUE, , , 08-Nov-96 , 15 10 , TWIH4/2, 7 61, 179 5, 11 8, 11 34, 51 057
VALUE, , , 07-Feb-97 , 12 00 , TWIH9/3, 7 85, 405, 14 3, 1 18, 115 29
VALUE, , , 05-Jul-97 , 18 35 , TWIH17/3, 8 29, 293, , 4 5, 86 742
```

Figure 2 WIS CSV data file displayed in a simple text editor

Figure 3 shows the same water quality data file laid out neatly as it would appear displayed i spreadsheet. The data block records the concentrations of various chemicals (attributes) for seve sites (features) over time. In this case there is a column for each chemical and each row contains data for a particular site at a given date and time.



	A	B	C	D	E	F	G	H	I	J	K
1	COMMENT	Water quality data for the Tweed catchment									
2	RECIPIENT	IH LOIS Rivers Data Centre									
3	SERIAL										
4	DONOR	IH Lab									
5	TRANDATE										
	DBNAME	LOIS									
6	UNIV FTYPE	RMON									
7	TAGS	UNIV FNAME	UNIV UCODE	DD-Mon-YY	HH24 MI	VALUE	VALUE	VALUE	VALU E	VALUE	VALUE
8	DCODE					CHEM	CHEM	CHEM	CHEM	CHEM	CHEM
9	ACODE					LSID	0061	0077	0076	0135	0409
10	ANAME					Sample id	pH	Conductivity25C	Temperature water	Solids Suspended 105C	Alkalinity
11	UNIT						pH units	uS/cm	Cell	mg/l	mg/l HCO3
12	VALUE	Tweed at Norham	TW14	09-Nov-96	15 10	TWEN5/2	7 79	173 2	16 4	4 52	55 266
13	VALUE			08-Feb-97	10 00	TWEN10/1	7 61	208	12 3	13 02	62 22
14	VALUE			05-Jul-97	17 55	TWIH17/2	8 11	210		6 1	71 858
15	VALUE	Tweed at Union Bridge	TW98	14-Jul-96	10 35	TWIH1/1	7 48	285	19 3	5	108 336
16	VALUE			08-Nov-96	13 00	TWIH4/1	7 54	205	11 5	6	48 19
17	VALUE			17-Jul-97	09 55	TWIH3A/2	8 63	286	21	5	109 983
18	VALUE	Whiteadder at Cantys Brig	WA100	14-Jul-96	13 00	TWIH1/3	9 04	4[illegible]5	20 6	3	155 733
19	VALUE			08-Nov-96	15 10	TWIH4/2	7 61	1[illegible]9 5	11 8	11 34	51 057
20	VALUE			07-Feb-97	12 00	TWIH9/3	7 85	40[illegible]	14 3	1 18	115 29
21	VALUE			05-Jul-97	18 35	TWIH17/3	8 29	29[illegible]		4 5	86 742

Figure 3 WIS CSV data file displayed in a spreadsheet

The tag column and tag row each contain codes which, taken together, tell a program reading the file what to expect in each cell of the file. Thus in Figure 3, cell J11, the program knows to expect a unit of measurement, here, 'mg/l' because the tag column and tag row contain VALUE and UNIT respectively.

The file, column and row header blocks provide information identifying the attribute, feature and time that the value describes. Thus, in Figure 3, the column and row headers show that the second cell in the data block (G12) contains a value of pH of 7.79 in pH units, on 09-Nov-96 at 15:10 hrs for the Tweed at Norham.

The end of file block tells the user and program that the end of the data has been reached. It is optional but its use is recommended as it provides a positive end to the file.

The paper will expand on the design of the format, the program that reads it and how the first elements of automated QA are being built into it.

quality assurance

It has been the human factor and limited resources that has defeated most attempts to introduce QA into data collection. With respect to data QA has two key objectives; one is to enable future users to know for what purposes the data are fitted and may be used and the other to ensure that the history of important changes to the database is traceable. Both tasks require a high level of sustained commitment and care. Not surprisingly, they are the first casualties when resources become strained.

Therefore, in the first small step towards the introduction of QA, it was decided to automate as far as possible the recording of information and, where it could not be automated, make its capture unavoidable. The first issue addressed was recording the provenance of all datasets going into the database. A small extension to the user interface was written for the data load software that asks the user some simple questions about the data being loaded:

- who supplied the data?
- to whom was it being supplied?
- who was loading it?
- what was subject matter of the data?
- who owned the copyright?
- what restrictions were placed on its use?
- the name of the input file?
- the date and time of loading?
- the type of sites to which the data were to be attached?

The purpose of this information is to enable future users of the data to establish whether or not the data are fit for, and may legitimately be used for, whatever application they had in mind. This may be different to the original purpose for which the data were collected. However, recording 'fitness-for-purpose' difficult when the purpose is unknown.. Ideally, numerical information should be recorded about the data's accuracy. To do this though, would require repeat sampling. In almost every area, this is not economically feasible. The approach adopted has therefore been to make provision in the database to record the method of derivation beside every data value, since most methods have an associated reliability. However, at present, the effort required to enter and maintain the information exceeds the available resources. This situation may be about to change. As more data capture procedures become automated, it should become relatively simple to ensure that every value is labelled with its method of derivation.

Recording in detail the change history for a database the size of LOIS is not a practical proposition at present. The amount of additional work generated would exceed the available resources. It will only become feasible when the process can be largely automated and it can be made impossible to by-pass the recording system. This last point is difficult to achieve, since most databases can be edited by a variety routes. In principle, the solution is simple. Each time an item of data is added, updated or deleted, the change is recorded and the author and reason for the change recorded. The challenge is to prevent this process degrading performance to the point where the system is inoperable. While it is quite possible this can be done now for conventional time-series data such as water levels, recording change to high frequency, high resolution spatial time-series is more challenging. The performance problem is compounded by increasing demands to be able to set selective access rights at the individual data item level. The implication of this is that to any question or instruction that the user poses to the database, must be added additional criteria to check whether the user can perform the required action on the data involved. This can only be performed at run time since the restrictions are at the data item level. The paper will discuss a possible solution.

access to specialist data by users from other disciplines

The LOIS database contains much specialist data to which people from other disciplines will require access. The problem is that they are probably not familiar with the terms used to describe the data and therefore find it difficult to locate the data they require in the database. The solution to this problem, being implemented at present, is to introduce a dictionary of terms and a thesaurus. At the user level, the system should appear simple. He enters a term with which he is familiar, say, 'nutrients' and is then shown synonymous and related terms that lead him to data in the database. Technically, the solution is more complex, since there are a wide range of things to which any given term might lead. This is only part of a much larger problem which covers not only helping users to find data but also to find models and then link the models to the data. The paper will explain the solution.

Conclusions

The paper will have identified some key issues that faced the managers of a very large multidisciplinary project and the steps they took to resolve them. The conclusion will discuss the degree to which the solutions were successful and the direction of current research.

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The management of the FRIEND European Water Archive

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Extended abstract

1. Introduction

FRIEND - Flow Regimes from International Experimental and Network Data - is a collaborative study of regional hydrology. Instigated in 1985, the FRIEND project in northern Europe now actively involves over 50 organisations in 23 countries. The primary objective of the project is to develop a better understanding of hydrological variability and similarity across time and space in order to progress hydrological science and improve practical design methods. FRIEND is a major contribution to UNESCO's current International Hydrological Programme featuring as Project 1.1 of IHP V. The FRIEND research programme is, essentially, a coordinated collection of individual projects undertaken by five scientific project groups:

- Database
- Low Flows
- Large Scale Variations in River Flow Characteristics
- Techniques for Extreme Rainfall and Runoff Estimation
- Processes of Streamflow Generation in Small Basins

A central feature of the FRIEND project is the European Water Archive, a database comprising spatial data and time-series data for over 5,200 river gauging stations in 30 European countries. The Archive, located at the Institute of Hydrology, has two distinct elements: an ARC/INFO geographical information system (GIS), and an ORACLE relational database management system (RDBMS). The ARC/INFO component currently includes the following data coverages:

- digitised catchment boundaries for over 2,500 gauging stations;
- hydrometric region and area boundaries;
- a soils map of the European Communities;
- gridded maps of land-use, rainfall and potential evaporation;
- rivers, coastlines and national boundaries for European countries.

The relational database component of the Archive includes the following:

- 130,000 station-years of daily and monthly flow data for 4,400 gauging stations;
- 38,000 station-years of annual instantaneous maxima for over 2,100 gauging stations;
- gauging station details (e.g. station number, river name, site name, location, altitude etc.);
- catchment characteristics (e.g. area, average annual rainfall, altitude, %urban, forest or lake)
- derived statistics (mean flow, BFI, Q95, etc.).

The following sections of this extended abstract will address issues concerning the management of the Archive, the problems encountered and the steps taken to overcome them. It will also consider the future of the Archive and its role in international hydrological research.

2. Historical Background

The European Water Archive (EWA), as did the FRIEND project itself, evolved from a project undertaken on behalf of the Commission of European Communities entitled, "The European Flood Study" (Beran *et al.*, 1984). The project collated long-term river flow data (annual maxima and daily flows) and catchment characteristics from over 1000 gauging stations in 8 eight countries in northern and western Europe. A station numbering scheme was devised during the Study in order to uniquely identify each gauging station and its associated data. The scheme was based on a division of the study area into 98 hydrometric areas, each of about 10,000 km^2, and 6 hydrometric regions, typically containing 10 – 15 hydrometric areas. The same scheme, albeit extended to the whole of continental Europe, is still employed in the FRIEND EWA today.

Gauging stations were selected, first, according to length of record (generally, all those with at least 10 years of data were included), and, secondly, on the basis of a station grading reflecting the quality of the hydrometric measurements, especially at high flows. Various drainage basin properties (morphometric, climatic, land-cover) were derived using an automated procedure of overlaying digitised catchment boundaries onto grids of thematic data (Wiltshire, 1983).

Data collated during the European Flood Study were originally stored on an IH devised index-sequential file system on an IBM mainframe. This continued to be the data platform for the database as it developed in the early years of the FRIEND project. Then, in 1992, following a change in the Institute's computer strategy, the database migrated onto the present, UNIX based, ORACLE RDBMS.

3. Database Design and Operation

In an RDBMS, data are stored on user-defined database tables in rows and columns. The Archive currently comprises twenty-nine tables that are related to each other, as shown in Figure 1. The MASTER table contains primary station details, catchment characteristics and derived statistics for each of the gauging stations. Views, such as MASTER_LIST, CATCHMENT_CHAR, DERIVED_STATS, help database queries by providing windows onto selected rows and columns. Each gauging station on the Archive is allocated a unique, 7- digit FRIEND station number (FID). The FID is the key field (or column) of the MASTER table, which relates its data to the data on most other tables. For instance, all time-series data is referenced by the FID. Time-series data are stored on a number of FUT_FREM tables. Every single data value (e.g. a daily flow value) occupies one row of a FUT_FREM tables and is uniquely identified by three key fields: the FID, the date and the data-type. Although the data-type allows for any type of time-series data to be stored on the tables, in practice, only two exist: one for gauged daily flow data, the other for gauged monthly flow data. Annual instantaneous maxima are stored on a separate table, ANNMAX. Various other tables (REGIONS, COUNTRIES, REGION_COUNTRY, etc.) ensure the relational integrity of the database.

In terms of storage, the database tables alone occupy approximately 1.2 Gbytes of disk space. Indexes, used to speed-up data retrieval, currently occupy over 950 Mbytes. ORACLE's structured query language (SQL) is used as the primary method of analysing and reporting on the data stored on the Archive. For complex analysis of the data, PRO*FORTRAN is used, where SQL is embedded in FORTRAN.

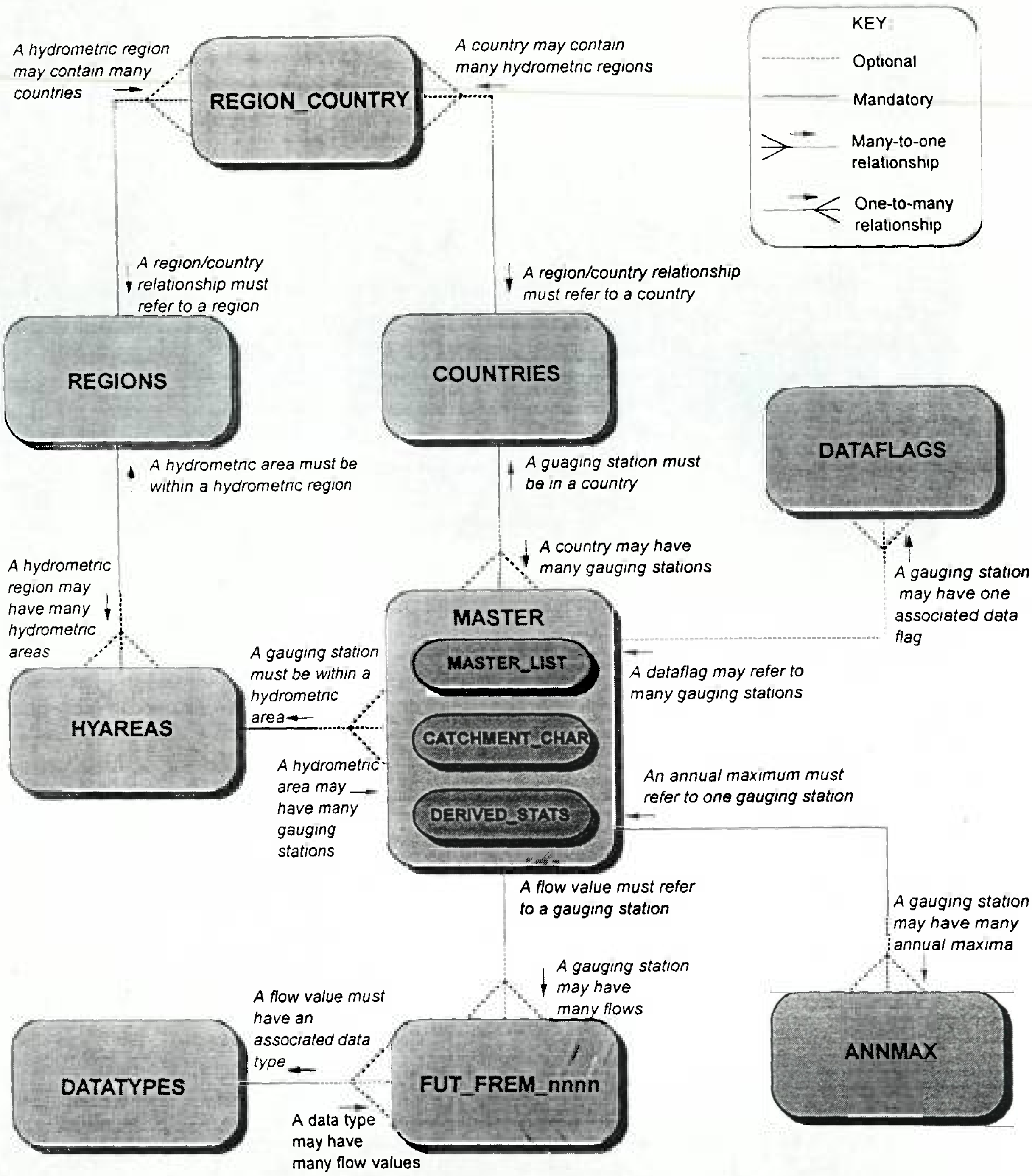

Figure 1 Entity Relationship Diagram for the FRIEND European Water Archive

Data transfer
The development and maintenance of the Archive is coordinated by IH. To assist, four Regional Dat Centres have been established: in Koblenz at the Global Runoff Data Centre; in Cemagref, Lyon; a the Norwegian Water and Energy Administration (NVE), Oslo; and at the State Hydrological Institute St. Petersburg. Each Centre has responsibility for obtaining data within a specified region. Originall it was planned that each Regional Data Centre would possess a copy of the Archive. However, this idea was shelved following problems in maintaining consistency between the central database and the databases of the satellite centres.

Data for the FRIEND project is provided voluntarily by many hydrometric agencies across Europe. As FRIEND is in no position to demand data, or impose deadlines on its transfer, data is received sporadically. Despite having a prescribed standard format for the data, the data is frequently received in a non-standard format. The ad-hoc development of software, to deal with varying data formats, has proved to be a significant drain on IH resources. A further problem is the lack of documentation to describe the contents of files. Often clarification must be obtained from the data provider before loading can proceed. This, again, uses up valuable time and resources.

Although data can be received on a variety of media (e.g. 9-track "" magnetic tape (1600 or 6250 bpi), DAT (5mm) tape cartridges, Exabyte (8mm) tape cartridges, diskettes (3.5" floppy)) transfers over the Internet, and e-mail especially, are becoming the norm.

4. Quality Control

It is assumed that the data has been quality controlled before it is forwarded to the FRIEND project. Despite this, further checks are carried out before data are loaded onto the Archive. The most effective technique, which is used before any time-series data is loaded, is the visual checking of hydrographs. Common problems include unexpected peaks, steppy profiles, negative values, missing values and inconsistencies between old and new data.

The incorrect allocation of FRIEND station numbers also gives rise to difficulties when data for one station are mistakenly attributed to another. It is most useful, therefore, for gauging station details, such as station number, river name, site name and exact coordinates, to be provided along with time-series data. Checking whether new data is consistent with older data by means of hydrograph analysis will, in most cases, reveal a problem with station numbering. Another useful check is a comparison of the mean annual runoff with the catchment average annual rainfall.

Even when the correct station number has been assigned, errors in data consistency still occur. These errors are mostly because values have been expressed in different units of measure. For example, it is not uncommon for flow to be expressed in litres or deci-litres per second instead of cubic metres per second. At times, however, there has been no mistake and the inconsistency is due to a revision of the rating curve. Whether the revision applies to the all data as well as the new, should always be clarified with the data provider. In general, all errors discovered during quality control are referred back to the relevant hydrometric agency and rectified before the data are loaded onto the Archive.

Following the successful loading of any data, a record is made of the tables and records that have been updated, the location of the source data, the names and location of any programs or procedures that were developed, the date of the update and the name of the responsible individual. Ironically, this information is recorded on a paper-based system!

5. Dissemination of Data

The dissemination of data held on the European Water Archive is a sensitive issue because several data providers insist that the data they have freely contributed should not be used for any purpose other than FRIEND. Accordingly, IH is obliged to always follow one simple guideline: that data are freely available to participants of the FRIEND project on the condition they are used solely for research within one of the five FRIEND research projects.

Legitimate requests from FRIEND participants are responded to as quickly as possible, with each given equal priority and dealt with on a first come, first serve basis. A metadata catalogue, listing the contents of the Archive, is available on request. Data can be supplied on tape, floppy disks, or via Internet. All data is supplied free-of-charge. While quality control procedures are employed on the data, no guarantee is provided on its validity or accuracy. Recipients are asked to report any errors detected to IH.

While every effort is made to ensure compliance with the conditions of data release, policing the subsequent use of distributed data is almost impossible. As yet, there have been no serious infringements of the conditions and there has been no need to sanction abusers.

As the hydrological research community becomes increasingly aware of the existence of the Archive and value of its data then the number of requests and queries from non-FRIEND participants continues to grow. Each is told that data can only provided after written approval is obtained from both the relevant national IHP committee and the hydrometric agency that provided the data. Alternatively, they could become a participant of the FRIEND project by submitting a research proposal to be approved by the relevant project co-ordinator.

The procedure for data distribution, even to FRIEND participants, is very labour intensive. More automated approaches to data dissemination, such as remote access via the world-wide-web (WWW), are being considered.

6. Conclusions: what future for the Archive?

There is still considerable scope to improve the management and operation of the FRIEND European Water Archive, such as:

revision of the station numbering scheme
- review of the database (table) design
- application of more rigourous quality control procedures
- development of a user-friendly man-machine interface for general queries and updates
- improved dissemination by allowing remote access via the Internet (e.g. WWW or Telnet) to FRIEND participants

However, before implementing such changes it is worthwhile to consider a long-term strategy for the Archive. These are four areas of concern, none of which are mutually exclusive:

- database updates
- dissemination of data to FRIEND participants
- links with other international scientific programmes
- funding

Concerning the database updates, one should remember that the European Water Archive is not an operational database but a facility to support the research needs of the FRIEND project in northern Europe. It is debatable, therefore, whether the Archive needs to be continually updated, as it is at present. Perhaps the data already held is sufficient to meet the objectives of the FRIEND project. The *ad-hoc* approach of updating is certainly a significant drain on resources, so why not "freeze" database development and updates in the short to medium-term? The extent of the Archive's future use will influence the answer to this question. Despite having a highly valuable data-set at their disposal, relatively few researchers within the FRIEND project have realised the potential of the Archive. Given the present use of the data, a freeze would have little impact on the FRIEND project in Northern Europe.

This leads to the second key issue: should FRIEND be looking to improve the dissemination of t data? The first step would be to increase the awareness of FRIEND participants to the availability a benefits of the Archive. Then, improved methods and procedures for the distribution of data should considered. Whatever steps are taken to encourage greater use of the Archive may, ultimately, pro detrimental. As more and more researchers become aware of the benefits, there is concern that t Archive could become a victim of its own success. The resources available at IH may not be sufficie to cope with the increased demand. Even if a remote access facility were to be provided, there danger that the number of queries concerning the data will become excessive.

Thirdly, the future role of FRIEND and the European Water Archive in other internation programmes needs to be addressed. Work conducted within projects such as GEWEX (Global energ and Water Cycle Experiment), WHYCOS (World Hydrological Cycle Observation System) an GEMS/Water (Global Environment Monitoring System), has relevance to FRIEND. There woul certainly be benefits in establishing closer collaboration with these programmes and the data centre they use, for example, the GRDC (Global Runoff Data Centre) and the GPCC (Global Precipitatio Climatology Centre). To overcome the constraints of data release, joint research projects could b established within the framework of FRIEND.

Whatever action is taken will depend largely on the financial resources available. With the exceptio of the money provided from IH core funds, the FRIEND European Water Archive has received no direct funding for its development. With the core funding reducing year on year and with the emphasis more on research than tools, the development of the Archive has, in recent years, relied heavily on indirect funding, through commissioned research projects on behalf of the UK Department for International Development, the European Commission and others. However, this is a volatile situation, which is, by no means, ideal. Projects rarely last more than three years and where database activity is normally only a small proportion of the total project allocation. The European Water Archive is, undoubtedly, a valuable resource, not only for FRIEND participants but also to hydrological sciences in general. Every effort should be made, therefore, to obtain reliable long-term funding to secure its future.

References

Beran, M., Wiltshire, S. and Gustard, A., 1984. Report of the European Flood Study. Institute of Hydrology report to the Commission of the European Communities – Climatology Research Programme.

Wiltshire, S.E., 1983. Flood Estimation in Europe – A Case Study of Applied Digital Cartography. Proceedings of the Auto Carto Six Symposium, Ottowa.

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Hydra II – a comprehensive hydrological data base system

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Introduction

The Hydrology Department of the Norwegian Water Resources and Energy Administration (NVE) is responsible for operating the national monitoring networks of hydrometry, snow, glaciology, groundwater, soil moisture, sediment transport, ice and water temperature. A small amount of meteorological data is also collected by NVE. Collecting, controlling and storing 15-20 million single observations every year require efficient computer systems. A limited system, yet advanced for its time, was replaced by a completely redesigned computer system in the spring of 1994. The system, which consists of a data base kernel and extensive software for control, analysis and presentation, was developed from scratch at the Hydrology department, NVE.

Basic conceptual model

The central concept in the database is the *station*. A station represents a unique geographical location. Each station may have one or more time series of optional parameters. The data can be observed or derived from other series. All data series have to be linked to a station. The system is optimised to handle long time series with variable resolution in space and time. This feature facilitates homogeneous handling of all kinds of time series data. We have experienced that this flexible system architecture makes it possible to include new parameters, e.g. water quality data, without extra adjustment of the software.

Specially designed techniques are used to store time series data of varying size and nature with fixed or variable time resolution in BLOB-fields (Binary Large Objects) in the database. Two structures have been implemented for these objects:

- Two-dimensional structure. (e.g. single time series with variable time resolution):

  time1 value1
  time2 value2. . .

- three-dimensional structure.(e.g. series with one variable observed at several depths with variable time resolution):

  time1 depth1 value(1,1)
  time1 depth2 value(1,2) . . .
  time2 depth1 value(2,1)
  time2 depth2 value(2,2) ...

Since all data are stored in the same database and handled through common software, is it easy to combine data from different gauging networks in analysis and presentations.

Derived series

On the basis of a predefined mathematical algorithm, time series can be derived from one or more other series. Derived series can be defined at a geographical point with or without observations. Examples of derived series are (1) discharge derived from water stage data using the rating curve, and (2) sum of multiple discharge series including scaling factors used to compute the total runoff to a defined coastal zone. Derived time series are not stored in the database. Instead the mathematical algorithm generating the derived series is stored and applied whenever derived series are requested. This ensures the derived series always to be based on the most updated version of the underlying time series. It is even possible to build hierarchical dynamic connections for derived series which uses other derived series.

Data flow and control routines

NVE receives data from a wide range of sources and data collecting systems. All systems produce data in different formats, which may necessitate considerable software development when new systems/modules are put in operation. In order to reduce this problem Hydra II converts all data to a standard format for data exchange before they are preprocessed and stored in the database. The original time series are stored in a transaction archive called HYTRAN (HYdrological TRANsaction archive) after being collected and preprocessed (Roald, 1999).

The data are copied to the archive HYKVAL (HYdrological quality controlled archive) after the primary data control. The observed series are stored at HYKVAL with variable time resolution. Discharge data will subsequently go through a secondary control including correction for backwater effects due to ice or vegetation and be stored in HYDAG (HYdrological DAily data archive) where time series are stored with daily mean values. This correction is done in an interactive program, which utilises adjacent stations and meteorological data as background information.

Each data point has a flag describing whether the data has been corrected and, in case of correction, by which method the correction is done. The original data observations are never changed because the data are copied to different archives when controls and corrections are performed. This makes it possible to repeat control and correction at any time.

Additional information and modules

The system also includes information about drainage basin characteristics, rating curves, reservoir volumes etc.

New modules have been added with functions such as:

- Detailed information about employed measuring equipment.
- Operational rules for regulated rivers and reservoirs as well as control software .
- System for calculating and storing naturalised flows corrected for operation in hydropower systems.
- Information about observers, their reporting routines, wages etc.
- Separate tables and software for processing and storing temporary project data.
- System for calculating and storing statistical characteristics of time series from selected periods.
- Receiving and storing real time data from telemetry stations used in flood forecast services.

Development of the system and computer technical aspects

During the process of designing the database, data modelling has been performed by formal methods implemented in software which generates SQL-scripts (Structured Query Language) for automatic database creation. The database consists of more than 100 tables.

The data model is implemented in a relational database system, Sybase DBMS (DataBase Management System), running on UNIX- computers (NVE uses SUN and Silicon Graphics). A database library (locally developed in C++) serves as a consistent and efficient API (Application Programming Interface) for storing and fetching from Sybase. Windows applications are developed using an object oriented Motif library (locally developed in C++). All graphics are based on GPGS (General Purpose Graphic System) which is a commercial Norwegian package.

Application systems Usoft Developer and PowerBuilder are used in development of applications for maintaining information not containing time series. These packages are commercial 4. GL running under Windows and Unix.

Application programs are written in C++ and Fortran, and are mainly running on UNIX-computers. Some applications have been written in JAVA with the use of either JDBC (Java Database Connectivity) or a locally developed socket server as data base connection. JAVA makes it possible to develop cross-platform applications runable also in a web-browser. JAVA will probably be a preferred programming language in further extensions of Hydra II. About 60 application programs are currently available for the hydrologists at NVE.

Conclusion

- An integrated system combining metered data and administrative information gives significant advantages for the users. Knowledge of the instrumentation and reports of problems at the station contributes to the interpretation of the data, and to evaluating the actual data quality.
- Be careful with ”big bang” projects – utilise old well tested software code and gradually rewrite with modern technics.
- Thorough work to get a well designed basic data model is extremely important for future expansion of the system.
- The development of such systems are very time consuming.
- Data should be continuously corrected as errors are detected. Whenever data is extracted from Hydra II, the system ensures that the most recent data is obtained. This is not generally the case for many databases comprising data from a host of primary data sources, and can lead to incorrect conclusions in studies based on the data

References

ROALD, L.A. (1999) Quality Control of Discharge Data. Submitted to the conference ”International conference on quality, management and availability of data for hydrology and water resource management”. Koblenz, March 1999.

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Lake watershed GIS data base for lake water quality management

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Introduction

Reduction of point and non point source pollutants flowing into the lake is the essential measure to improve lake water quality. It should be noted that various stake holders in the watershed should have common understanding on the pollutants source : the distribution and the course to flow into the lake, in order to build consensus among the people in the watershed on the purpose, effect and importance of various pollutants reduction measures. Integrated approach based on the cooperation between administrative organizations with the consensus among the people in the watershed might be often time consuming, but would be a shorter way to effectively achieve a goal for a better management of lake water quality.

The data and information concerning hydrological cycle in the watershed is distributed over a wide range, which include ?(1) geographic data such as topography, geology, surface soil, land use, administrative boundary and population? (2) meteorological data such as precipitation, temperature, wind speed and sunshine (3) hydrological data such as river discharge and water quality and (4) operational data related to man-made facilities such as water resources development facilities, water supply facilities for municipal, agricultural and industrial use and wastewater treatment facilities. There are many administrative organizations in the national, prefectural and municipal level. For example, in Japan, in the national government level, Ministry of Construction is in charge of geographical mapping data and hydrological data, while Meteorological Agency is in meteorological data. Water resources development facilities and waste water treatment facilities are within jurisdiction of the Ministry of Construction, while municipal, agricultural and industrial water supply facilities are each within the jurisdiction of the Ministry of Health and Welfare, Ministry of Agriculture and Ministry of International Trade and Industry.

For the integrated watershed management based on the understanding of watershed conditions as a whole, it is often necessary to display and/or analyze the related data collected by the different organizations. GIS data base would serve as an effective tool for compiling various data related to watershed aquatic environment using location as index.

This paper is on the development and utilization of the GIS data base for Lake Kasumigaura basin (lake area = 168km^2, basin area = 2,157km^2), which aims at applying for lake water quality management.

GIS data base for Lake Kasumigaura watershed

GIS data base for Lake Kasumigaura basin has been developed, as a research project, aiming at sharing data among related national, prefectural and municipal administrative organizations. The system was designed so that users can retrieve various information concerning quantity and quality of water by clicking the point on the map shown on the monitor display, which would be useful for consensus building and/or decision making by providing an overview of present watershed circumstances.

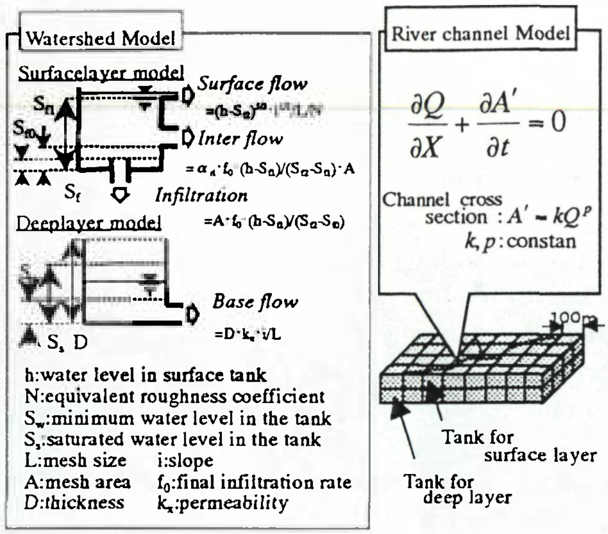
Mesh geographic data for a base map is based on the digital map prepared by Geographical Survey Institute, which covers the area with 50 m mesh for elevation, 100 m for land use and 1 km for surface soil and geology. Point data such as hydrological data are input with location of the observation point, while the areal data such as amount of municipal water supply in each municipality are input with municipal area as location.

For constructing the framework of GIS data base, we adopted EXCEL (Microsoft) as a popular and simple data base software and ArcView3 (ESRI) as a GIS software with rich presentation function, both of which can be run on WINDOWS PC. The reason is that we attached greater importance to easiness of operation and data updating rather than highly advanced analyzing ability. In order for disseminating the contents of data base through Internet Homepage, the data would be transformed into HTML format.

Example of application of GIS data base for lake watershed modeling

GIS data base for lake watershed can be applied for constructing and evaluating a model to simulate water and pollutants movement in the watershed, which is to be a useful tool to estimate the impact of land use change in the basin on lake water quality and to compare the effects of various measures for reducing pollutants load from the basin.

The concept of a distributed parameter model for simulating rain water runoff and consequent pollutant load runoff is as follows. Rainfall input for each mesh is first separated, through a combination of conceptual tanks having several outlet, into 3 components including surface flow, interflow and base flow, which is then flowing down along flow line based on the digital elevation model and produces channel flow. The channel flow is to be routed by kinematic wave method. In the process of identifying the model parameters, it was assumed that each parameter is a function of land use, soil type and surface geology of each mesh, which are stored in the GIS data base. Pollutants load model is based on the assumption that accumulated load on the land surface would be washed away by rain water and flow down through each component of runoff. The another assumption is that the pollutant load rate exponentially increases with river discharge, which is expressed in LQ formula. The structure of the model is shown in Fig. 1.



SurfaceLoadModel	SurfacelayerLoadModel	UndergroundLoadModel
$L_1 = K \cdot S^m \cdot Q_1^n$	$L_2 = K \cdot D^m \cdot Q_2^n$	$L_3 = C_3 \cdot Q_3$
$S = S_0 - L_1 \cdot \Delta t$	$D = D_0 - L_2 \cdot \Delta t$	
$S_0 = S_u \cdot (1 - e^{-K_s T})$	$D_0 = D_u \cdot (1 - e^{-K_d T})$	
Q_1 : SurfaceFlow Discharge	Q_2 : InterFlow Discharge	Q_3 : Base Flow Discharge

Fig.1. Structure of the model

Upper Koise River basin (Basin area = 15.5km^2) was taken as a case study area for constructing 100 m mesh distributed parameter model. 64% of the basin is covered by forest and the other land use include paddy field (14%), farm land (13%), urbanized area (4%). Figure 2 shows a bird's eye view of the basin with land use information and generated stream lines based on GIS data base. Example of simulated results in the case of a small rainfall event in 1997 was compared with the actual observed data in Fig. 3. Simulated results could produce the whole shape of pollutant load runoff relatively well. The model would be applied to different rainfall events for checking the reliability of parameters and is to be expanded to cover whole Kasumigaura Lake basin in the future.

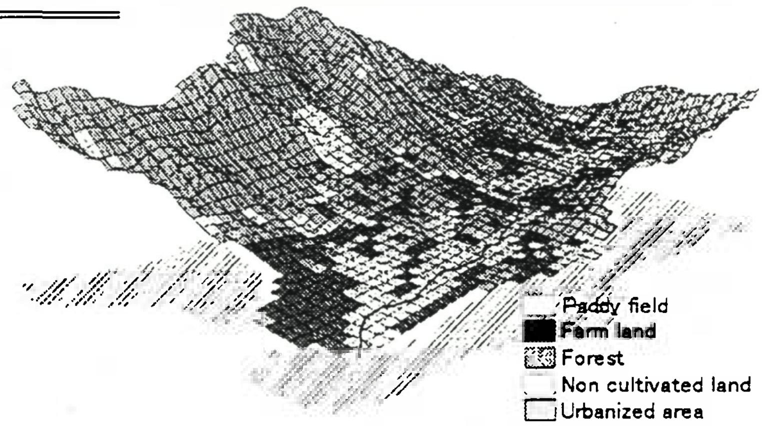


Fig.2. Bird's eye view of Upper Koise River basin

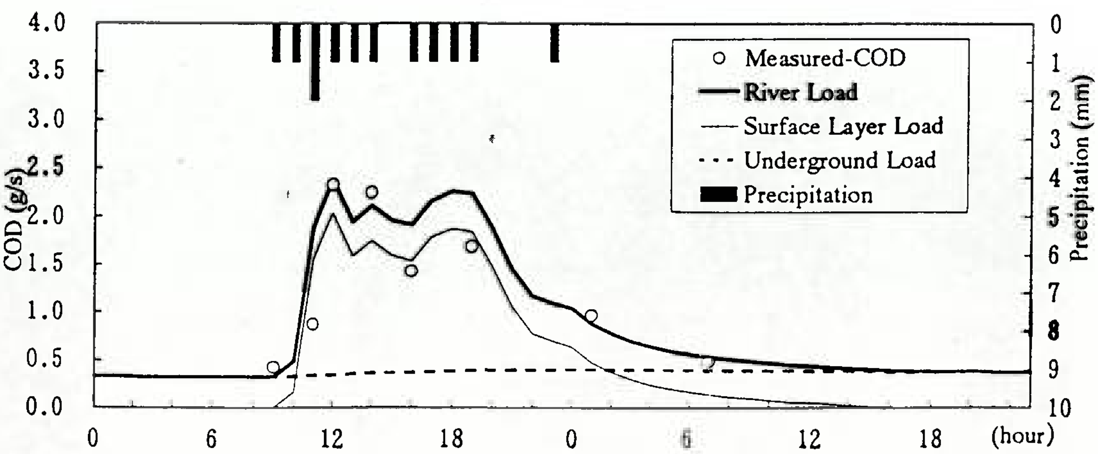


Fig.3. Comparison of simulated result with observed data

Conclusion

Framework of GIS data base for Lake Kasumigaura basin was constructed aiming at providing a tool for comprehensive lake water quality management. Various kinds of data including geographic, meteorological, hydrological and administrative data were stored in the data base, which would be disseminated to public through Internet in near future.

The GIS data base would contribute to build the consensus among various stake holders in the watershed by providing a common information about the present situation and problems to be solved. It also can be used for constructing/evaluating a distributed parameter watershed model, which would serve as a tool to estimate the impact of land use change in the watershed and of various measures for pollutant load reduction on lake water quality.

Reference

Abe, K., Wada, K., Sugimori, H. and Terakawa, A. : Development of a simulation system for lake watershed management. (in Japanese) Civil Engineering Journal, Vol. 40, No. 8, 1998.

Suzuki, T. Terakawa, A. and Matsuura, T. : Development of a distributed parameter runoff model for flood forecasting. (in Japanese) Civil Engineering Journal, Vol. 38, No. 10, 1996.

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AFRI and CERA: A flexible storage and retrieval system for spatial data

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1. Introduction

The exploration of the earth has lead to a worldwide exponential increase of spatial data. Data collection by satellites, global change investigation, and measurements all over the planet result in amounts of data that require modern techniques for handling and storage. As the different data are highly inhomogenious, it seems to be impossible to build-up a consistent common data model. So there is vital necessity for a coordinated construction of a network accessible meta database (MDB) to store information about the available data. Moreover, scientists shall be able to retrieve the underlying data directly, no matter where it is stored physically.

For this purpose at Potsdam Institute for Climate Impact Research (Potsdam-Institut für Klimafolgenforschung e.V., PIK) a meta database (Climate and Environmantal Data Retrieval and Archiving System, CERA) was developed and implemented in cooperation with several German geoscience institutes. The aim of that collaboration was not only to save time and money by a common development, but also to make the MDBs of the institutes mutually accessible.

Additionally, A Flexible Retrieval Interface (AFRI) for spatial data has been developed. It is platform independent and capable for data retrieval in the Internet as well as locally without the need to set up an internet server. Furthermore, it can easily be adapted to any in-house database in geosciences.

2. The CERA Meta Data Structure

Some years ago, several German geoscience institutes have joined for a collaboration on development, implementation, and linkage of the meta databases at their sites to give their meta data a common structure and to make it mutually accessible. Besides PIK, in this project the Deutsches Klimarechenzentrum (DKRZ, Hamburg) and the Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI, Bremerhaven) are involved, in the first phase, Forschungszentrum Karlsruhe (FZK), too.

The main aims of the common MDB are:

- to make accessible all geographical and other global change relevant data held inhouse to all employees and collaborators of the institute,
- to make accessible the corresponding data of the other involved institutes, together with quality information about it, by online-linkage of the databases,
- to enable the investigator to survey all available data and to assess its quality and reliability,
- to coordinate the storage of data and to avoid redundancies,
- to enable meta data interchange with national and international institutions by means of a distributed MDB.

So a common, transparent access to all data is as important as the highest possible flexibility. Furthermore, the structure has to meet the main exchange standards for spatial meta data (NASA-DIF, FGDC-CSDGM etc.) as well as functional standards (IEEE).

In 1996 and 1997 the common data structure of the MDB was developed and realeased as CERA 2.3.

The CERA database concept is highly flexible, as the necessary relational schemes (CERA Core) are separated from those, only used by few institutes. The latter are contained in modules that can be attached to the CERA Core table group, if they are applicable for the respective institute. The module table groups contain detailed information on, e.g., the way to access the data or the order in that the data are stored.
Institute specific tables can be supplemented at any site, but in a way, that does not interfere with the basic CERA structures and definitions.

The core Table group of CERA consists of 58 tables, 22 of which are value lists. They are divided into eight blocks, containing the information of a certain theme each, such as coverage or distribution information.

A variety of SQL tools and user interfaces, that are running on CERA, are available by download from the internet.

3. The AFRI Retrieval Interface

AFRI, A Flexible Retrieval Interface for spatial data written in Java, has been being developed at PIK since 1997 to provide intuitive retrieval of different (meta-) databases as well as vivid presentation of query results. Features of AFRI are network ability, platform independence, and flexible configuration abilities, as well as a comfortable and dynamic graphical user interface including an Interactive Digital Atlas (IDA).

3.1 Flexibility

One of the key aspects of AFRI is the demand to maximize usage bandwidth and to minimize porting costs and maintenance burden. AFRI is designed to be both platform independent and network enabled to allow the system to run on different hardware and operating systems in a location independent manner. Being World Wide Web (WWW) enabled, AFRI takes advantage from this wide-spread net infrastructure and provides scaleable access from world wide use (Internet) to inhouse use (Intranet). Alternatively, AFRI can be run locally, thus avoiding the need for an internet server.

The flexible configuration abilities of AFRI at server side allow to include different databases, to change database structures and to set up individual user interfaces without any need for reprogramming. A database table containing information about databases to be queried, relevant attributes, and about desired query components is used to set up AFRI's appearance and behaviour. The system dynamically looks up all relevant structural information and provides an appropriate graphical user interface.

3.2 Comfortable and Dynamic Graphical User Interface

Since a software's acceptance highly depends on its human-computer interface, AFRI provides an intuitive graphical user interface to relieve the user from entering retrieval requests in order to specify his/her queries.
The system offers a collection of comfortable query components, including - among others - thematic, temporal, spatial, and textual aspects, allowing the use of well known graphical input components like checkboxes, buttons, menus, sliders or textfields. Spatial queries are also supported by IDA, an interactive digital atlas (see below). The different query components' input can flexibly be combined to construct the desired queries, supported by input controls and user guidance.

To provide a consistent user interface, AFRI dynamically reflects the state of the underlying databases. The supplied database attributes are directly read from the relevant database, ensuring that changes in the database structure will also be present in the user interface. Furthermore, the thematic query component provides a n-staged hierarchy of selectable keywords, which - depending on selections made on higher stages - are looked up directly in the current state of the database.

Query results can be presented in different ways including (i) textual representation by using interactive viewers for tables and datasets as well as (ii) visualisation of spatial data and other data.

3.3 Interactive Digital Atlas (IDA)

AFRI makes an Interactive Digital Atlas (IDA) available for highly intuitive spatial queries and for the representation of spatial query results. IDA allows intuitive and flexible usage through complete mouse control and interactively displays area names and geographic coordinates. Furthermore, it allows to include different map hierarchies, i.e., administrative and river basin hierarchies. The user is able to navigate towards higher level and more detailed maps as well as to zoom into a map. Geographical areas can be selected simply by clicking or by freely defining an area using a rubber band. The bounding coordinates of a selected area are automatically transferred to AFRI's spatial query component.

IDA also provides interactive visualisation of query results that have a spatial representation as well as an interface for data visualisation. For example, a query resulting in a set of measurement stations can be represented on the appropriate map using different graphic symbols for different kinds of measurement stations. Different station types can be shown or hidden interactively, and moving the mouse over a station's symbol displays further information. A number of stations can be selected on the map to visualize their measurement data, using web enabled serverside visualisation tools.

4. Conclusions

Currently, the development and installation of the first stage of AFRI and CERA at PIK have come to an end and the practical inhouse usage has started. The coupling of the different MDBs is proceeding. The development of better display facilities for numerical data is planned as well as automatted control of data integrity, as most data are spread over the different working groups of the institute. In the Future, flexible tools will enable us to access and survey better the increasing amounts of data. Coming Versions of AFRI and CERA will go on this way.

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BEVER, a system based on agreements of standardised managing of data

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Introduction

Water quantity and water quality management in the Netherlands have been delegated to many authorities and institutions, each having its own procedures and standards for storage and management of data. Different kinds of data-models and databases are used, causing a lot of problems with data exchange between national and local levels. Time consuming conversions of data-sets are always required, causing undesired loss of data quality.

In recent years, however, national and local institutes involved in water management have reached agreements on a standardised approach for data management. A common data-model has been designed and is supported by the networks of authorities and institutes involved. New information systems will be based on these agreements as much as possible. Also, an attempt has been made to standardise the exchange of measurement-data. Based on the agreed common data-set, a common definition has been made of a standard interface file. Even when the databases are not the same, it should still be possible to exchange data in an easy way.

Standardised managing of data

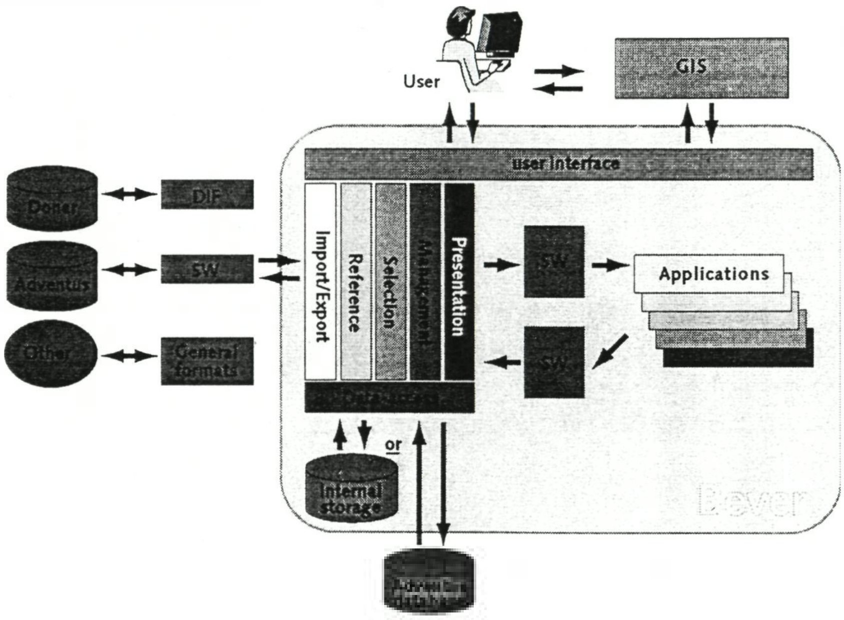
In the autumn of 1998, RIZA will finish the first information system based on the agreements on the common data-set and the common interface file, called BEVER. It will be capable of managing different data from the various databases from the participating institutes.

The fact that many institutes and commercial parties have already made clear their interest in building (commercial) modules within the BEVER system, confirms that the idea behind BEVER was and is a good one.

Description Bever

Examples of possibilities of BEVER are the selection and presentation of data. An active interaction with geographic information systems is also realised and last, but not least, this system has the possibility to start specific and customised functions to analyse and manipulate data, enabling it to evaluate water-quality, statistics and load calculations. Furthermore, because of the carefully considered system-concept, completely new functions can be added very easily, the idea being that the parent-system BEVER manages the data in a standard manner. Interaction with analysis-modules is done through the agreed common interface format. All analysis-modules can manage this interface file. This way users can add customised functions without worrying about importing, selecting and managing data, as this is done by the parent system, BEVER. The only condition for an analysis-module is that it can handle the common interface. Through that, only the core-business of the wanted functions has to be built. The specialised functions can therefore be built very easily and relatively cheaply.

System architecture of Bever



Donar	the existing central database of the Directorate-General for Public Works and Water Management (Rijkswaterstaat)
DIF	the type of data-input before DONAR
Adventus	the standardised common datamodel, used by national and local water authorities.
SW	the agreed common interface format used in Bever

Possibilities Bever

The following are a number of possibilities with BEVER

- importing and exporting data from several large Dutch databases with data on water-quantity and water-quality. These (series of) measurements can vary in x,y,z and time.
- importing and exporting 'standard' data from common data-files (e.g. Dbase, CSV and TXT files)
- 'direct access' to relational databases

- consulting, selection of representing data. Choices can be made on
    - locations or groups of locations
    - parameters or groups op parameters
    - water-systems
    - selections made within a GIS-system; if a geographical choice is made, all the measurements with co-ordinates within that choice are selected in Bever.
    - time and date
    - several administrative attributes of date.
    - if the choices do not suffice, selections can be made by SQL. A custom query builder is provided in BEVER.
- After a (sub)selection of data is made, the desired analyses can be started. BEVER exports the data to the common interface which is used by the desired function. Calculated results can be restored in the same way in the BEVER-database where post-processing can take place, e.g. presenting in graphics or exporting time-series to a word-processor or spreadsheet.

Technical issues

Bever is a PC-system built in Microsoft Visual Basic 5.0. It will run under Windows95 and WindowsNT. The internal database of Bever is designed in Ms-Access. However, a separate installation of MS-Access is not required to use the system. Only when manually editing of system tables is desired, will MS-Access be necessary.

Bever can run stand-alone, but in a multi-user environment, databases can also be shared.

Bever does not have its own GIS-interface. The use of a separate GIS-system is optionally. When the GIS system ArcView is installed it is notified and can be used by the system. The necessary ArcView scripts are supplied by the Bever system and can be customised and expanded by every user if desired. This way, all the possibilities of the GIS can be used. However, with a minimum of customising, other GIS-systems can be used..

BEVER has its own internet-site (albeit in Dutch). Beside a detailed explanation of the system, several examples of the system are shown. When there are new developments they are mentioned on this site. The address of the BEVER homepage is
"http://www.minvenw.nl/rws/riza/bcm/projecten/bever/bever.html", but it can also be reached via the RIZA-homepage "www.riza.nl".

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System of primary cartometric information records, providing computation of different basins hydrographical characteristics to any Section

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Catchments landscapes and characteristics of rivers hydrological regime are greatly various. However, revealation of their relationships is not a trivial problem. Some signs, such as slopes and streams gradients, influence on flow seems evident. But in many cases flow regime characteristics have no considerable deviations from their regional norms, though their basins have considerable differences by such signs. And on contrary, sometimes we can not explain peculiarities of hydrological regime of some basin using all its standard hydrographical characteristics. The latter is small wander because system of usually used hydrographical characteristics is primitive by content and do not reflect peculiarities of such complex geographic systems as river catchments. However, it is hardly possible to propose characteristics system suitable to all users. And so, it is expedient to create such base of primary cartometric data, which will allow to compute different characteristics for any section of any basin.

Hydrographical characteristics in hydrological computations are used only in empirical statistical relationships. Dimension principles make no sense for them and therefore it is more important to know relation of the given basin hydrographical characteristic to its mean value for all the same order rivers in the given region, than its absolute value. Possibility of quick computation of any complex hydrographical characteristic for the set of the given order rivers is an important request to such data base. The best hydrographical characteristics presentation as hydrological regime factors may be received by means of their values replacement with their cumulative probabilities. Relationships linearisation and graphic presentation are achieved in this case.

If all catchments of all great and small inflows (different orders subsystems), included in any river (or lake) basin directly, are excluded from its catchment, a lot of the rest unstructured segments of the catchment surface, having a piece of the stream bank line as a chord, represent primary elements of a basin structure. Such elements we have named as the 0-order elements. The chord as a piece of the stream bank line is the attribute of the 0-order element. By analogy we may subdivide a catchment of every inflow. Using this method in turn, we receive full decomposition of the entire basin on the 0-order elements. The most simple unstructured small catchments consist of two such elements separated with a stream, prolonged up to the watershed. Any characteristic of entire basin may be computed with the help of some uniformly operations with data, received by means of measurements on maps inside contours of such primary elements.

Composition of hydrographical characteristics necessary for basins in different natural zones is not constant. So, such important for river basins in Russia characteristics as forestation and swampness have no sense for many other regions of the world. For other territory, for instance, it is very important to take into account catchments urbanization or karst availability. It is expedient to record such characteristics in the special files with conditioned names. Data processing programs have to take them into account depending on the result of search of appropriate files. By analogy with it special data which we have only for some basins (such as fractions of catchment with different soil types or fragments of cartographic situation in vector format) may be considered.

In our system, the necessary data for all elements of all catchments are presented with two files. The first of them contains codes of all elements and subsystems of the basin structure in their hydrographical consequence. The code points position of the given element in the hydrographical system of a basin. The code consists of the number of all primary (the 0-order) elements inside the basin subsystem and of the consequence of all subsystems numbers with greater orders, including the given subsystem directly. Code numbers of the 0-order elements may be from 0 to 127. Code numbers of the I - IX-order catchments may be from 1 to 15. So, the code of an element in whole always has dimension of 5 bytes. The name of the data file and the file with additional information contains the code of the given catchment belonging to rivers systems of greater orders. If some order basin in the subsystems consequence, including this element, is absent, it is signed by 0 in the proper code position. This makes coding system supple and allows to represent incompletion of river system development. This compact coding system provides the detailed structure description even of a great river basin, represented at the 1:25 000 or 1:10 000 scales maps.

The code of a catchment element and its distance from the offing of the first catchment, which includes this element directly, exactly determine the element position in the basin. This values may be considered as its coordinates in the hydrographical space. These codes contain sufficient information for construction of such important basins characteristics as indices of the level of their structure organization [1, 2]. As a result of the latest works the author makes the conclusion, that it is inexpedient to prolong stream line up to watershed. Instead it is proposed to determine systematically catchments areas to the river head. It is proposed the part of a basin up to the river head to consider as the 0-order element with number 0. The attribute of the given part of a basin is the single point of the stream line (the river head itself). However the real experience of this proposal use is not sufficient for the present.

The second file contains the consequence of records of the basic chartometric data for every 0-order element of a basin structure. These data are sufficient for computation of various characteristics for any order catchments, including these elements. Structure and dimension of fields for all records are equal, but content of the data in these records are somewhat different depending on the type of the hydrographical system element. We make out 5 types of such elements:

1. Primary unstructured segment of the catchment area which has the stream bank line of a river or a small stream as the chord.
2. Segment of a catchment area, presented with the part of a drainage lake basin slope, which has the stream bank line of the lake as the chord.
3. The water plane of a drainage lake.
4. The island, the hydrographical structure of which is not taken into account.
5. The element of a catchment area at the large island or the part of a basin, included between adjacent river arms.

Only the 3-th and the 4-th types have principle differences in composition of the necessary information. For the rest types some difficulties appear during computation of elements distances from the offing and as well the length of the main stream, using the length of stream pieces, measured inside of every element. Additional principles have been worked out to form records in such cases. Except the number which marks the element type, information composition for the I, II and IV types includes:

1. the distance from offing (for the lake basins slopes it is measured across the water plane of a lake with the straight line);
2. the length of the stream bank line which is the chord of a segment;
3. area of a basin segment;
4. the number of points of the stream bank line intersection with horizontals;
5. the number of different horizontals in a segment;
6. summary length of all horizontals inside a segment;
7. the median altitude of a segment surface;
8. the greatest order of the stream, including the channel piece of the given segment;
9. the number (1 byte), which points to a presence of the different additional information.

As an additional information we used:
- fraction of catchment covered by forests and bogs;
- water plane area of drainless lakes;
- the share of segment drainless area, including drainless lakes catchments;
- coding signs of the relief morphogenetical type of the given catchment part;
- detailed data about horizontals length.

All characteristics, received by length measurements on maps, are given as whole numbers (mm), their dimensions are 1 or 2 bytes. Areas characteristics are given as whole numbers with dimensions of 2 bytes after their multiplication by 100.

Method of slopes average gradient determination by sum of horizontals length is greatly perfect. This fact allows to propose that the horizontal length data themselves contain a lot of possibilities to construct highly informative integral characteristics of basin relief topology as the important factor of flow formation. As well it is necessary to take into account that data of relief morphogenetical type contain considerable information about soil composition. We studied diagrams of summary length of the same value horizontals $L_H=f_2(H)$ for different elements of basin structure. These diagrams are somewhat analogous to hypsographic curves $F_H=f_1(H)$, well-known in hydrography, but do not duplicate their information. Combined examination of the both types diagrams is the most useful. Moreover, it is especially useful to draw additional diagrams $n_H=f_3(H)$ of the number of the same value horizontals contours. They allow to identify relief small forms (especially englacial ones), which considerably influence on flow formation processes.

Data for computation diagrams L_H and n_H are recorded for every element of basin structure as a string of textual file, containing such consequence: horizontal value H, the number of its contours n and the appropriate number of contours length (in mm) records. Classification of diagrams forms $L_H=f_2(H)$ with marking out 4 types, as it is shown at the figure 1, was used as a base of their interpretation. In fact, the choice of diagram type for a catchment element is relative.

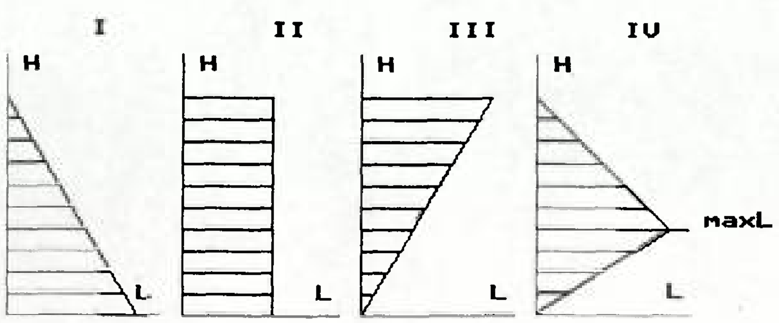

Fig.1 Diagrams types of horizontals summary length at different altitudes.

The type may be expressed more objectively with two numerical characteristics: relative height of position of maximum of horizontals length and ratio of average horizontals length to maxi mal one.

This data interpretation problems do not connected with the theme of this conference directly and therefore are not considered there in detail.

References

1. Kokorev A. V. (1992) Some representations of information about river basins structure and determination of their representativity. in the book "Landscape-hydrologic analysis of territory", "Nauka" (in Russian)

2. Kokorev A. V. (1992) Landscape-hydrographical similarity, representativity and hydrologic analogy of river basins. Trudy GGI, 357, pp. 32-45(in Russian)

International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management

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Characterization of piezometric temporal patterns using non-parametric statistical and factorial analysis techniques

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In order to recognise piezometric temporal patterns in Silves-Querença aquifer system, a karstic unit situated in Algarve region, Portugal (Fig.1), a methodology was developed articulating 2 different techniques: Non-Parametric Statistics and Multivariate Data Analysis.

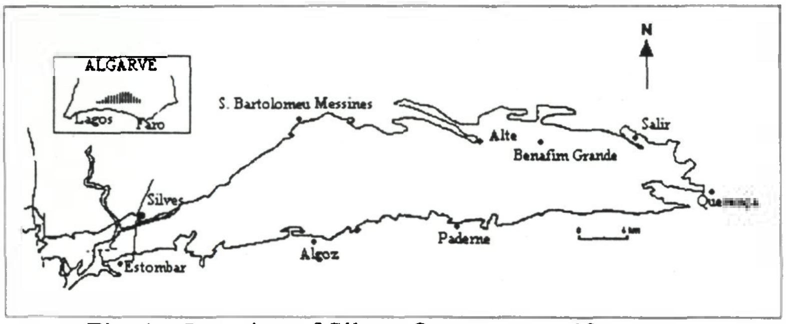

Fig. 1 – Location of Silves-Querença aquifer system

The monitoring network consists in 22 observation points, evenly distributed in theaquifer (Fig. 2). Groundwater levels have been measured from 1982 to 1993 with an irregular sampling frequency - 6 stations recording continuously, 10 monthly and 6 half-yearly.

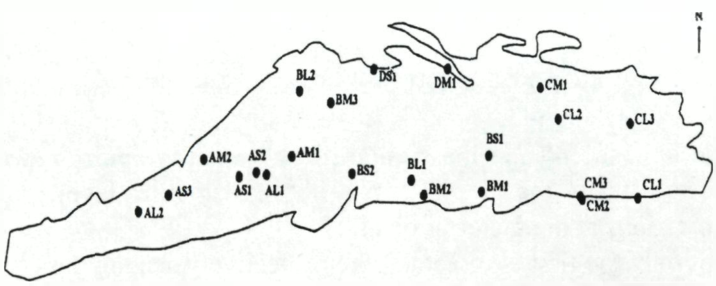

Fig. 2 – Piezometric network in Silves-Querença aquifer

In a first step Mann-Kendall statistical test was used in order to detect the magnitude of upwards or downwards trend in each piezometric observation time series taking into account the seasonality (Fig.3).

Also, in order to estimate the rates of change per unit time, an unbiased estimator due to Thiel and Sen was calculated for the trend slope.

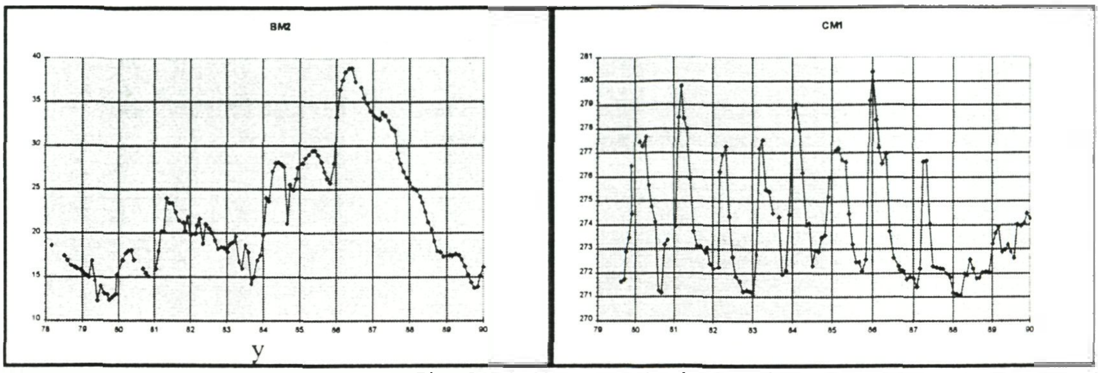

Fig. 3 - 2 piezometric time series

Principal Component Analysis (PCA) is a factorial technique that provides the visualisation and reduction of the data contained in tables of great dimension composed by sample stations (rows) and variables (columns). The method finds the factors which explains the opposition or similarity between the atributes by reducing the dimension of the initial cloud and minimizing the loss of information.

PCA was applied to a matrix of seasonal piezometric slope trends. Figure 4 displays the 1st factorial plan that represents 75.63% of existing information in the initial matrix.
According with Figure 4, the monthly and the continuously piezometers are associated with the first axis while the half-yearly piezometers are associated with the second axis. The results show that the first factor establishes a decrease gradation in the piezometers slope trends: the higher ones are located in positive side and the zero trends are situated in the negative side.

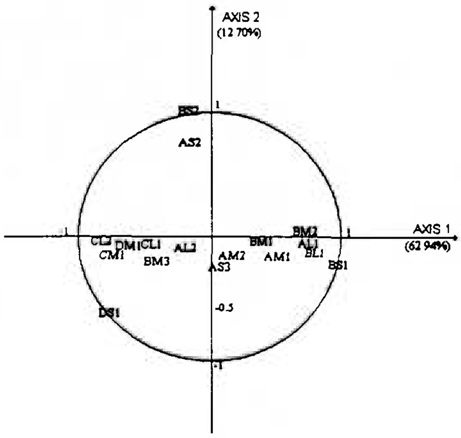

Fig. 4 – Projection of piezometers in the 1st factorial plan

After analysing the oppositions and the similarities between the piezometers slope trends a Cluster Analysis was used to classify the piezometers with similar water level profiles and according with their respective projections at the factorial plan.
Taking into account only the first two factors, the respectively dendogram (or branching diagram) was determined (see Figure 5).

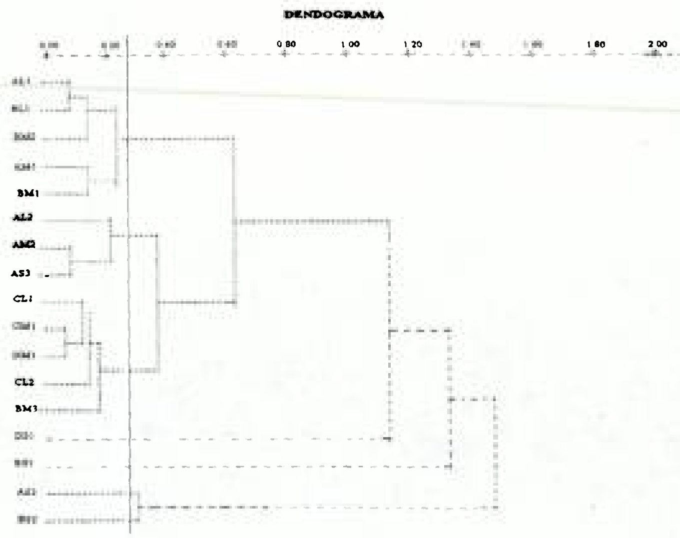

Fig. 5 - Dendogram of classes of piezometers

Figure 5 shows that is possible to individualise, considering a cut-off coefficient of 0.25, three piezometers groups of different characteristics:

Group I: AL1, BL1, BM2, AM1, BM1;
Group II: AL2, AM2, AS3;
Group III: CL1, CM1, DM1, CL2, BM3.igure 6 displays distribution of these groups in the aquifer, within each one a unique piezometer can be elected for future monitoring.

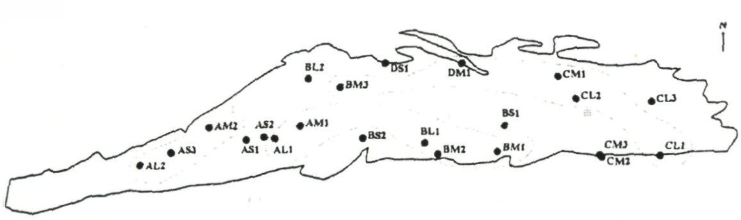

Figure 6 - Piezometers groups distribution in the aquifer

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Modelling of the relation between water flow rate and mean concentration of suspended-load at extreme discharges

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The authors propose an empirical model to extend the previously developed regression function between water flow rate and the profile mean of suspended-load concentration to extreme values of the flow rate. Such model should be valid in all gauging stations of the Czeck Hydro-Meteorological Institute.

The original regression function - Eq.(1) - was computed using extended sets of field data comming from both alluvial [1, 3] and canalized [2, 3] rivers. All data especially the concentrations, showed such partion of variability that it was impossible to treat them by the methods of one-dimensional regression. Thus concentrations were reorganized to subsets over uneven class intervals of flow rates [1, 2] and it was found that their probability density functions could be represented by the logarithmico-normal distribution. This was verified by statistical tests [2]. The means of these distributions in the subtests appeared to be a plausible function of flow rate while their standard deviations were of the flow rate independent. With this result, the authors were able to compute a regression function between those mean values and flow rates represented by a three-parameter logarithmic function as follows

$$\lg c = X + Y(\lg(Q + Z)) \tag{1}$$

where X, Y and Z are constants determined by the methods of non-linear regression.

A good fit of this relation was found in canalized sections of rivers or in those sections in which the river channel was provided by the banks designed for many-year flood protection and the bottom reinforced by heavy gravel.

On the contrary, smaller rivers of more alluvial character and higher variability of flow rates show, paradoxically, relatively high values of concentrations at minimum water flow rates while, at extreme high flow rates, the gauging stations record lower concentrations. An example of this may be seen in Fig. 1 where the logarithmic regression was applied to two different gauging stations. Nìmèice is located on the Labe (Elbe) river between two canalizeed sections. Its channel is provided with high anti-flood banks and most of the bottom is covered by gravel. Variability of the flow rate is relatively low due to the canalized section up the river. The logarithmic regression fits in Němčice well.

Station Kroměříž on Morava (March) river is located in the section of more alluvial character. The slope is mild since the landscape is flat and the variability of flow rates is high. The logarithmic regression does not fit both at low and high flow rates.
As concerns low values, we tried to explain this phenomenon by the relative in crease of concentration of fine fraction of suspended load caused by effluents of the sewage treatment plants which is constant all over the year and contributes much to the fine fraction < 10 μm of the suspended load.
As far high flow rates, concentration decreases faster than flow rates as it was regularly observed during flood events. At extreme flood flows, river inundates and thus sedimentation occurs out of the main river channel where the concentration decreases.

The authors were not able to explain these phenomena theoretically. Moreover, the higher concentrations at low flow rates may be explained by the increase of transport ability of the flow under the ice cover in winter. Such information is not, sorry to say, available together with the pertinent data.

Under these conditions, the authors were able to present an empirical solution only. They proposed a fitting formula

$$\lg(c/c_0) = k\left((Q/Q_0)^\beta - 1\right) / \left((Q/Q_0)^\beta + 1\right) \qquad (2)$$

which, in fact, is a hyperbolical tangent. For computation of constants c_0, Q_0, k and β, the same treatment of data as for the logarithmic regression was used. Among the constants, c_0 and Q_0 are the co-ordinates of the inflection point of the fitting curve. The actual points in both Figs represent the mean values of logaritmico-normal distributed concentrations computed in uneven class intervals limited by flow rates of the same probability of exceedance. The tests proved a good fit of Eq. (2) with the actual points even in the cases where the logarithmic regression failed. So the model according to Eq. (2) fits well in all stations measuring the suspended load.

The theoretical explanation of the phenomenon just described is very difficult and it could be done in co-operation of the research in fluid mechanics, hydrology and stochastic methods.

Conclusion : Logarithmic regression between suspended-load concentrations and the flow rate developed by methods of 2-dimensional statistics was extended empirically to both low and high values of the flow rate. The presented relation fits well to all gauging stations of the Czeck Hydrometeorological Institute but, sorry to say, the authors are not able, up to this time, to develop it theoretically.

Reference:

[1] Rudiš, M., Machek J.: An Estimate of Total Amount of Suspended Load which Settles in a Reservoir. ACTA TECHNICA ÈSAV, vol. 8, N°1, p. 80 - 100, 1963

[2] Rudiš, M., Trejtnar, K. und andere: Transport und Belastung von Schwebstoffen und Sedimenten in der tschechischen Elbe. Projekt 523 KfK 9404, Zwischenbericht für 1996, Výzkumný ústav vodohospodáøský T. G. Masaryka a Povodí Labe, Praha - Hradec Králové, März 1997

[3] Petrůjová T., Rudiš M., Haléøová J.: Sledování plavenin a sedimentù v povodí Labe, Moravy a Odry (Observation of Scespended-Load and Sediments in River Basins of Elbe, March and Oder). Grant Project of the Czeck Ministry of Enviroment N° 510/3/98, Annual Report 1998, Brno, November 1998.

Fig. 1 Application of logarithmic regression - Eq. (1) - - to two different gauging stations

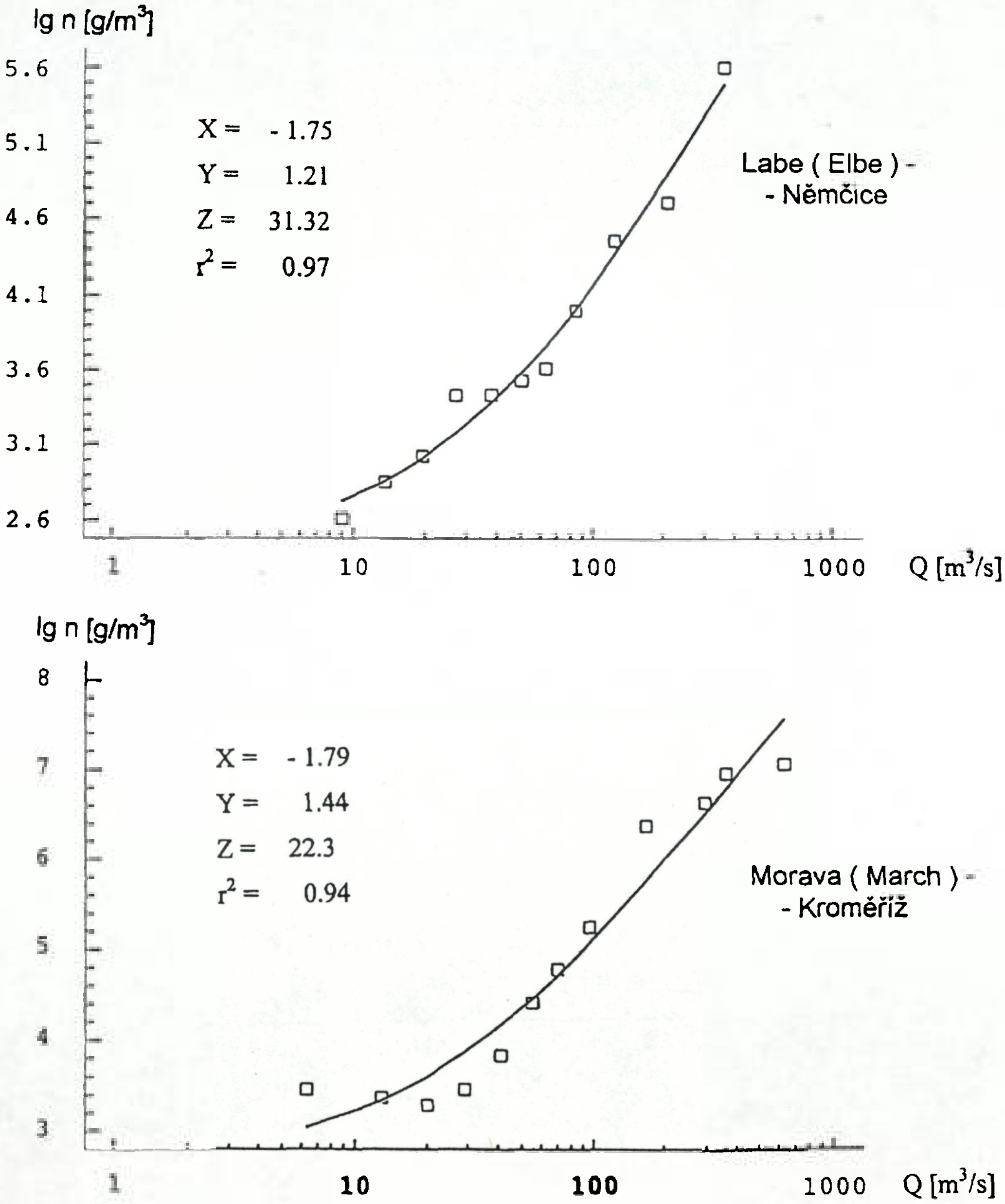
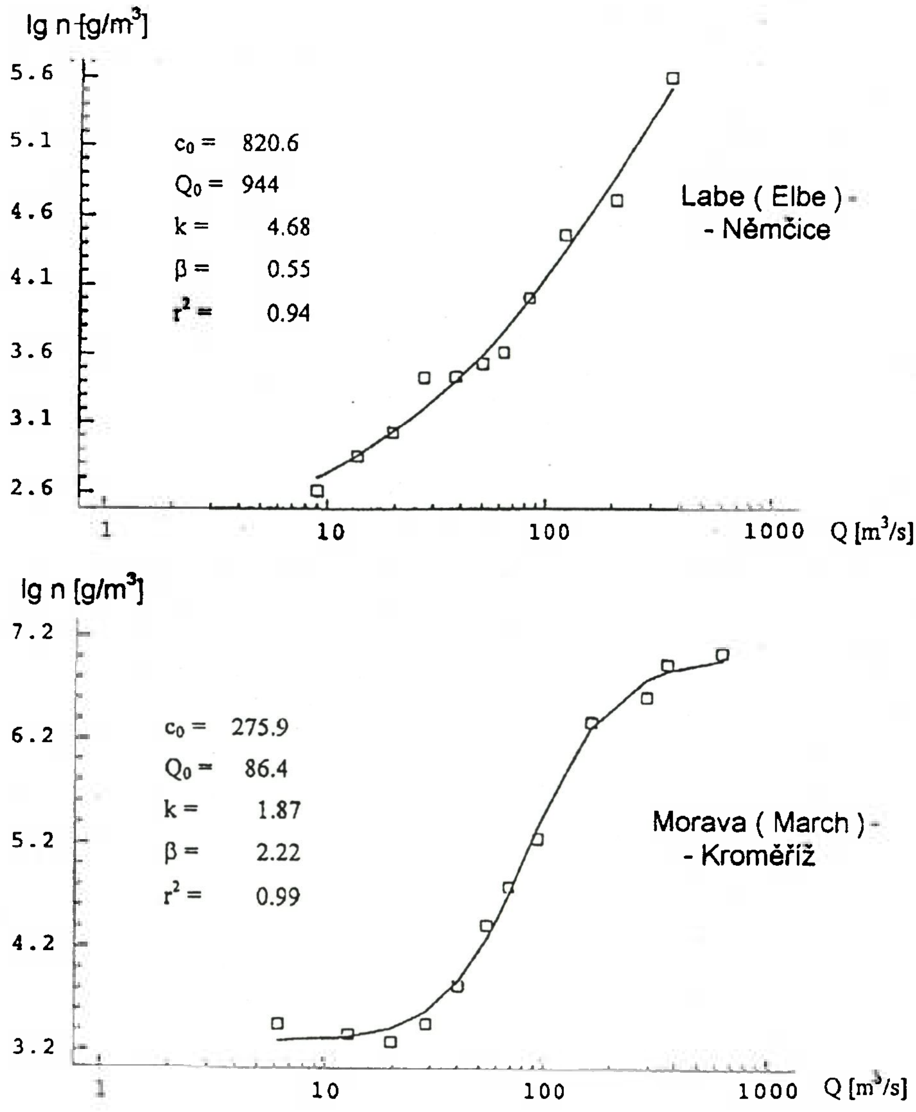


Fig. 2 Application of the proposed empirical model - Eq. (2) - - to two different gauging stations



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Data bases to meet new demands in hydrological information

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An increase of demand in water resources, growing antropogenic loads on water objects and climate change make it necessary to expand the composition and to modify forms of presentation of information to be delivered to users.

In Russia it is possible to combine basic requirement to presentation of information in the following groups:

- complex character;
- differentiation with respect to geographical or administrative territories;
- illustrative capability of representation;
- increasing expedience of delivery;
- possibility to be used for analysis of changes and forecasting.

Complex character is attained through the use along with traditional hydrological information (runoff, level, water temperature) of data related to water resources utilisation, water quality variation, ecological conditions of water objects and their basins.

Differentiation is caused by difference in conditions of formation and utilisation of water resources on the territories of the Subjects of Federation and by local peculiarities in maintaining complex territorial cadasters of natural resources.

To meet demands for information current status of water resources, water supply organisations, who are basic users of hydrological information, develop the integral system of information support in the field of nature use and management. The system is developed and operated on the basis of the following principles: the system is interagency in character; the system is opened for interaction and information exchange with foreign and natural information systems; elements of the system are compatible due to unification of its organisationai-legal, linguistic, software-hardware support; confidentiality and protection of the system information resources from non-approved access, damage, loss and destruction; consideration of interest of the Russian Federation in general and its elements, territories as well as the system owners and users in particular.

The system consist of four non-hierarchical levels: local (objective), territorial (administrative territories), regional (basin) and federal (central).

The local level is presented by information systems of direct observers, owners of hydrological and water supply information and it provides data of observations for the territorial level.

The territorial level insures collection, control, processing, generalisation, accumulation, storage, dissemination of information, and formation and maintenance of territorial data banks.

The regional level unsures generalisation of information for specific water system basins as well as basin data bank maintenance and basin information dissemination.

The federal level is responsible for generalisation of regional level data, formation and maintenance of central data banks “Underground Water” and “Use of Water”, creation of interagency integral data bank, information support of publications containing generalised information, international exchange of information.

Similar scheme is used by Federal Service of Hydrometeorology and Environmental Monitoring (Roshydromet) for collection, accumulation and dissemination of hydrometeorological information by Committee on Protection of Environment for information related to protection of environment.

Hydrological and hydrochemical information is accumulated and disseminated by network divisions of Roshydromet and through State Water Cadaster long-term observational reference data banks "Rivers and Channels", "Lakes and Reservoirs", "Land Water Quality", "Glaciers". Information related to protection of environment is collected through the system of ecological monitoring and accumulated in territorial ecological data banks and in Federal Centre of Geoecological System (FCGS "Ecology").

The aforementioned agency data banks and automated systems, used to update them serve as the basis for creation of territorial basin and central integral data banks.

Integral data banks besides usual hydrological and hydrochemical information include information about sources of water object pollution, limits of permissible concentration of waste materials disposed into water objects, sanitary-hygienic conditions of fresh water sources and water sources used for recreation, depletion of water resources and degradation of water ecosystems.

To provide integral representation and visualisation of hydrological, water supply and hydrology-ecological information the system of state Water Cadaster maintenance is being created on the unified geoinformation basis.

To increase availability and expedience of information required for water supply management and water-ecological system protection it is planned to use telecommunication networks which allow combination of territorial and regional levels with federal information centres and data banks.

Considering climate impact on water resources to Federal data bank "Rivers and Channels" besides complex hydrological and ecological information contains data on climate parameters such as monthly totals of atmospheric precipitation, mean air temperature and generalised indicators describing atmospheric phenomena occurred over territory of Russia.

Hydrological data for climate studies are held in a separate set with due consideration of requirement of their representativeness.

Those data are considered to be representative, i.e. with minimum impact of local conditions, which are obtained at rivers with either natural hydrological regime or with hydrological regime only slightly affected by industrial activities. To study local peculiarities of climate change impact on Water objects rivers having basin area from 1000 to 5000 sq. km are used.

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Hydrological Monitoring and Structure of Information Security of Nature-Technical Systems Models

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Introduction

Systems created for reaching of the economic purposes (hydroreclamating; hydrjtechnical; hydropower etc.), influencing on water objects, render inevitable influence to an environment. Because of presence of complicated chains direct and inverse connections between various systems and processes, flowing past in them, and also inconsistency of interests of various natural and engineering systems competing for consumption of water resources, this influence not always positive. In these conditions systems creation and control should be carried out in view of necessity of sufficing by them for two purposes simultaneously: maximization of an economic efficiency, and minimization of negative influence on an environment. Thus for models of any stage of systems studyness: 1. Ascertainings of a condition and comparison of systems among themselves; 2. The prognosis of their operation in the future; 3. Systems optimization using decisionmaking systems support required data obtained on the base of monitoring realization.

In work the conceptual problems of hydrological monitoring organization both creations of an effective system of storage and use of data obtained at it realization are considered.

That the hydrological monitoring met the requirements of efficiency (exceeding of the incomes from more point decision making above costs on realization), it should be for information maintenance for maximum large number of soluble problems: for various above-stated stages ofsystems learning, their various type and hierarchical level of a scale (interstate, interbranch, within the limits of branch, water catchment, separate object. In this connection the data of hydrological monitoring will be used on a set of the tasks (models) of a various type, each of which has the requirements to a data structure. It is obvious, that in these conditions task's shaping of a data structure is completely unproductive, as reduces in necessity of a multiple gang of the same data calculated in hundreds of thousands and millions of figures, but with various modification of their structure appropriating for each concrete task. Alternative to this is the data storage of the invariantly rather soluble tasks, i.e. with use of data bases ideology. For want of it the observations data are introduced once, and their concrete subsets (structures), necessary for the various solved tasks, are formed, using the language of a manipulation by data.

The solution of an above-stated problem requires realization of choice of observable parameters for want of monitoring of their space and temporary organization, their storage.

The operation of any system is defined(determined) by a modification of a vector of its indexes in time in three-dimensional space. In an assotiation from characteristic time of proceeding these indexes are divided on processes: unguided entering actions $\xi(t)$, controls $U(t)$, variable condition $Z(t)$, output actions y(t) and on supposed constant (and actually also evolutive, but with large characteristic time of courses) governed parameters P and not governed parameters N of a system. For example, for hydroreclamative systems it: $\xi(t)$ - meteorological factors: u (t) - expenditures of waters which are pumped out from channel, z (t) - levels, expenditures, evaporations formed in channels and ground, y (t) - formed crop of agricultural cultures and indexes of the environment condition, P - parameters of channels, drains, N - factors of a filtration, water returning, channels roughness of canals etc.

Choice of a concrete kind of observable indexes (the degree of their aggregativeness), which storage should ensure the data base, is determined by a level of a deciding task hierarchy. For want of it for each problem there are alternate variants of models on the degree of description aggregativeness, of the used mathematical means, kind of observations, necessary for their identification described by difference in possibility and accuracy of their realization, and also costs of realization, including information maintenance. The choice of an optimum model up to an extremity not formalized basically, i.e. is carried out heuristic methods.

As the all set forth above indexes are represented by time series, the basic; in essence difference from a point of view of a database structure represents only organization of their spatially - temporarily tracings: the periodicity of fixing and method of realization of monitoring or in the fixed network of points of the system, that is most distributed (for example, measurement of levels of ground waters on slits, costs and levels on water posts); or tracing of a site of the system (its boundaries) in time. Some singularities are brought in also by a scales of a measurement of observable indexes subdivided on: a) quantitatively measurable (level, volume, expenditure, concentration etc.), expressed by numerical indexes (whole and real);

b) qualitatively measurablereflecting as a rule more aggregated performances of systems: a structure, type etc., for example, type of ground (turfen, sandy, peat etc.), type of organisms (animals, plant with this or that detaling).

The full performance of the process has a place, if the investigated variable is fixed continuously in time in three-dimensional space. However it is obvious that the observations to be observed and furthermore to be stored in the computer must have discrete temporal and space steps. Steps magnitude is determined by a lot of the reasons: by a resolving power of measuring instruments, financial and manpower, desirable detail and exactitude of reviewing of a problem, requirements to security of used computing methods stability, possibility of the assembled information storage. At the end choice of space and temporal pitches, as well as of set of observable indexes, is based on heuristic reasons.

In view of that the people basic purposes depend on processes having characteristic times of a course, commensurable with day, and also in connection with convenience (naturalness) of information input and effectiveness of consequent use, for a basis for data storage of all observable hydrological indexes (time series) it is expedient to accept a universal format of daily data representing an annual table (12 months*31 days). Thus the data set appropriate to each year is univalently identified by a key (cap of a table), including the name of an aspect of an observable index (ground water level, precipitation, evaporation, flow) with an improvement of their categories (average, maximum, minimum, with the increasing total and for what period); an item, where the observation is carried out (name, coordinate X; Y; Z, height (depth) installation above (below) ground), year of observations.

For indexes, which values are observed and should be stored with an interval more often 1 time per day, the separate copy of an annual table of a standard format with the indication of time of observation can be integrated.

The universal kind of the initial tables of daily data allows effectively to realize their transformation and creation of structures of data for diverse models, using a small set of operations. On character of data structures, obtained in an outcome of initial tables all operations is possible to subdivide on:

1) Operations directed on the elementary transformations of initial data tables with an entry of outcomes in a table of a similar format (recalculation of levels from conditional marks in absolute, velocities and squares of a stream in expenditures, corrective action on wetting of precipitation-meter

etc.), sold(realizabled) with the help of operations of an algebraic data conversion of a table, linear combination of a series of tables, interpolation (restoring of passed observations), smoothing, average, toting on n-days periods.

2) Operation of data aggregating in time: count on daily data tables of tables of decade, monthly, seasonal, annual, long-term data . At aggregating at each new temporal level from input data the various variants can be obtained: average, maxima, minimum, dispersion, sum with the increasing total for a phase etc.

3) The operations on shaping data structures required by various models, basic of which are: a choice of an observable index on an indicated gang of items on the given date (temporal slice), choice on an indicated transmitter (transmitters) for an indicated phase (time series), choice of characteristic dates.

4) Operation on shaping structures of data for the reports (visual tables of the various form, graphs of time series etc.).

The indicated conceptual approach is realized at data base creation for storage of outcomes of natural medium basic performances monitoring of a: water (flow and level condition in channels, evaporation, levels of ground waters, humidity of ground etc., prcipitation and others metefactors), thermal, chemical, radiating conditions in ground, channels, atmosphere (all more than 40 indexes). Monitoring was carried out on the Pruzhansky stationary on two compared catchments common square about 50 000 ha. One of them is the catchment of the river Yaselda (the pool of the Black sea) reclamated also is in heavily agricultural use. Other is near located catchment of the river Narev (the pool of the Baltic sea) is in natural waterlogged state on territory of national park "Belovezhskaya Puscha".

The convenient interface of the database with various models (statistical, stochastic, determined, neural networks etc.) has allowed to decide effectively a number of hydrological problems: forecasting of high waters, creation of levels of ground waters and number other. It allows to suppose it to be the basis of decision support systems for want of water problems solutions.

International Conference on Quality, Management and Availability of Data for Hydrology and Water Resources Management

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Management of hydrological data of the rivers Belarus

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The economic crisis connected to disorder of Soviet Union, has coincided on time with rough development of computer technologies. Therefore, for today, there was a paradoxical situation: on the one hand, the wide circulation was received with personal computers with a large spectrum of possibilities, with other - was failed of measures on translation of the information from old machines on new media. In result, there was a danger of loss already accumulated data of hydrological observations on electronic media. The situation is aggravated onetime output out of operation machines of old generation and absence of the uniform standard on information interchange, that strongly complicates transmission and data exchange between the interested sides.

In 1950 - 1990 in support of State committee on a Hydrometeorology was present from 200 up to 250 posts.

Now observations behind a hydrological condition will be carried spent only on 134 posts (120 - river and 14 - on lakes and reservoirs, including 134 - behind a level of water, 107 - behind a drain of water, 8 - behind a rigid drain, 51 - behind a meteorological condition, 133 - behind atmospheric precipitation).

The state committee on a hydrometeorology of Republic Belarus continues to support a close contact with a Federal service of Russia on a hydrometeorology and it by subdividings: by state hydrological institute (S.Peterburg), Gidrometeocentre of Russia (Moscow), World data center (Obninsk), introduces working techniques and programs of operation work.

Despite of complicated economic conditions, the State committee on a hydrometeorology for last years stabilized a situation and has saved a republican hydrometeorological web without further essential modifications.

Except Russia, the State committee on a hydrometeorology supports close contacts with national hydrological services of the states of Ukraine, Poland, Lithuania and Latvia, is the permanent member of a World meteorological service.

In a real economic situation, actual the task of preservation of an old information on a hydrology and constant supplement by its new information is.

It is necessary to mark that fact, that along with development of the old software the main attention was given to computing operations, while the concept technological of operation with the computing system practically was not developed.

Nowadays, we develop the software packages allowing, on the one hand to analyze and to restore, with other - to predict a number of the hydrological characteristics. For a support of effective operation of these packages, the subsystem of handle of bases by data is offered which provides input and upgrade real and restored characteristics.

The considered tasks are realized by us as the application package "Hydrobroad Gully" connected with account annual, monthly and characteristic expenditures of water (spring high water, summer-autumn raining of high waters, minimum winter and summer, etc.).

In a context of their solution is analyzed homogenates with the help of criterion's Gnedenko - Koroljuk, Kolmogorov - Smirnov, Students and Fisher. The independence of units a number with the help of a criterion Valda - Volfovic is estimated, the auto correlation functions and number are investigated, the type of allocation etc. is defined.

In the total, the choice of designed period is carried out, if necessary, number of the hydrological characteristics with use of a method of hydrological analogies is prolonged.

Then, to be made estimation empirical and various asymptotic curve allocations.

In case of absence of data, the program complex allows to select the rivers - analogues or to use a cartographic material for account of the required hydrological characteristic.

Thus, using a program complex, it is possible to solve the tasks of an engineering hydrology for conditions Belarus.

The developed complex distinguishes universality, and after small adjustment it can be adapted to other regions.

The experience of maintenance of the given system, together with the analysis of development of tools of computer facilities for the last 5 years, has shown, that the database management system is necessary for upgrading for more full satisfactions of inquiries and necessities of the modern user by the database. The process of modernizing mentions the following function boxes:

1 Subsystem of limitation of the rights allowing eliminating unauthorized access to base and change of the information, taking place in it.

2 Subsystem of registration of brought in changes, which except registration of the fact of change or addition of data should store the items of information on the operator that has carried out change.

3 Subsystem of synchronization of the information in various versions of base, especially urgent, when in addition of data some subjects carried are engaged simultaneously is territorial, that eliminates possibility of use of the local computer network for share access of the users to the information stored in the database.

4 Subsystem of automated restoring of absent data and checks of their correctness, proceeding from the statistical analysis of behavior of available data on standard and - or by the developed user to techniques of restoring, with mandatory saving of the information about the used technique in each concrete case.

5 Subsystem of forecasting of hydrological values on the basis of standard and - or of the techniques, developed by the user.

6 Subsystem of creation of multiple inquiry of the information on the criterions, accepted in a concrete case, of selection, with possibility of the consequent transmission of results external or firmware's.

7 Subsystem of the visual analysis of obtained results with possibility of the output of the graphics information on a printing station.

8 Subsystem of archiving of the database on the external medium and it of the consequent restoring, in case of necessity.

9 Subsystem ensuring information interchange through the global computer Internet network, including obtaining of the necessary information from the database and addition of base by the authorized faces.

10 Subsystem of storage standard and - or of the techniques, developed by the user, (algorithms) as connected DLL - units, which use allows considerably to lower the cost price of development of specialized software and their modernizing in case of change of state standards earlier created of programs.

11 A subsystem of automatic upgrade of appropriate units of the database allowing, according to inquiry of the user, automatically update the software of the database from the delivered floppy medium or through the global computer network Internet.

The analysis of the existing software, proceeding from necessity of implementation of the above-stated subsystems, has allowed us to select for the given project the Microsoft Access system with development program units by Visual Basic 5.0. The described system is proposed on operation under the control of a user environment Windows'95.

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Processing hydrometeorological data from lakes and reservoirs of Russia

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Standard hydrometeorological observations were made at about 250 lakes and reservoirs of Russia during different periods (see Table). Since early 1930-s the observations have been carried out according to standard methods, instruments and equipment.

TABLE Dynamics of gauging sites on lakes and reservoirs of Russia

Year	1940	1950	1960	1970	1980	1986	1991	1996
Total number of gauges	125	193	387	447	532	543	447	377
including lakes	116	176	233	239	261	270	198	170

In 1986 a specialized database of lakes and reservoirs to be used for an automatic data processing was put into the operation.

The database keeps the following information :
- physiographic characteristics of water bodies;
- detailed description of the gauging site on lakes and reservoirs;
- annually replenished data of hydrometeorological observations near shore and/or on lake water area;
- annual data generalization in the form of hydrological yearbooks.

The database is used to solve several problems:
- archiving and keeping of inquiry data and data of annual generalization; characteristics of water bodies and gauging sites ;
- up-dating of physiographic characteristics of water bodies and gauging sites ;
- input and control of current data in the mode of dialogue and their load into the database;
- management of the database;
- processing with outputs in the form of tables of hydrological yearbook and annual generalization to up-date long-term data series in the automatic regime and the mode of dialogue;
- issue of data on request;
- water balance calculations.

The database is used on request. The spatial and temporal range of the information issue is wide. The requests should be implemented for a gauge, a reservoir or a lake as a whole, administrative and physiographical regions as well as for an hour, day, month, year and any time intervals.

A preparation of the hydrological yearbooks on the regime of lakes and reservoirs grouped by the territories of the regional departments of the Russian Hydrometeorological Service is one of the most important functions of this database. Another task of the database is a periodic publication of reference books summarizing long-term national data on lakes and reservoirs for different economic needs.

The following information on lakes and reservoirs is presented in the hydrological yearbooks:

- list of gauges on lakes and reservoirs, the information on which is placed in a yearbook;
- water level at gauging sites and mean lake level of lakes and reservoirs;
- surface water temperature near shore and on the lakes surface area;
- water temperature at different depth;
- heat content of the lake water mass;
- ice cover duration at gauging site;
- ice thickness and snow depth on ice at coastal zone and on ice profiles;
- recurrence of different wind speeds and wind directions;
- water balance;
- waves;
- currents.

Nowadays reference book "Long-term data on inflow to the reservoirs of the largest hydroelectric plants of Russia" is prepared at the State Hydrological Institute on the basis of the data base on lakes and reservoirs. This reference book contains information on monthly, quarterly and yearly inflow of different probabilities to the reservoirs and lakes with dams, synchronous occurrence of wet and dry periods on the cascades of reservoirs(for example, Volga, Angara, Yenisei, and etc.) generalized for the XX century.

Transboundary networks

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Transboundary networks

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Dealing with transboundary networks means looking after their bases in transboundary water management, transboundary co-operation, shared water uses, transboundary impacts, common issues and agreed problems.

The UN Convention on Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992) is an example of an international treaty dealing with this issue. Other examples are the existence of many bi- and multi-lateral agreements and conventions between countries and the existence of transboundary commissions and river commissions.

Transboundary issues can be numerous, e.g. floods, droughts, ice problems, water quality problems, pollution loads, river deterioration. They have impacts on safety, water uses, ecosystem functioning and economic activities. "Information is needed", but this statement has to be specified! It is certain that the issues of transboundary states include the access to information, agreements on data exchange etc., but first there should be the recognition of and agreement on (shared) problems and management priorities.

Even if problems are identified, the information needed cannot be provided by monitoring networks only. It depends on the character of the problem whether research or inventories, surveys, field assessment, trend monitoring, compliance testing or early warning are needed.

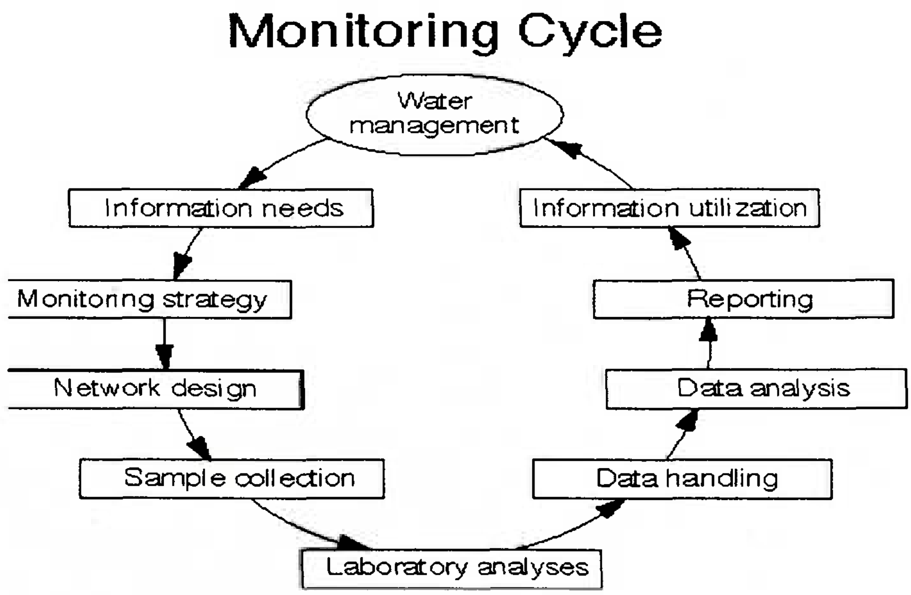
Do we just need a figure or do we need the message behind it? The message is found in the relation of the figures with references, target values, criteria and standards for water uses. Risk assessment plays an important role in finding criteria for water uses and for the identification of problems, e.g. in the assessment of flood hazards, assessment of hot spots and priority pollutants. This may even lead to priority setting in information needs.

According to the above, information needs in the context of a transboundary watercourse can only be specified on the basis of a water management analysis, in which the functions and uses of the transboundary watercourse are recognised, the problems and threats are identified and policies and measures are defined.

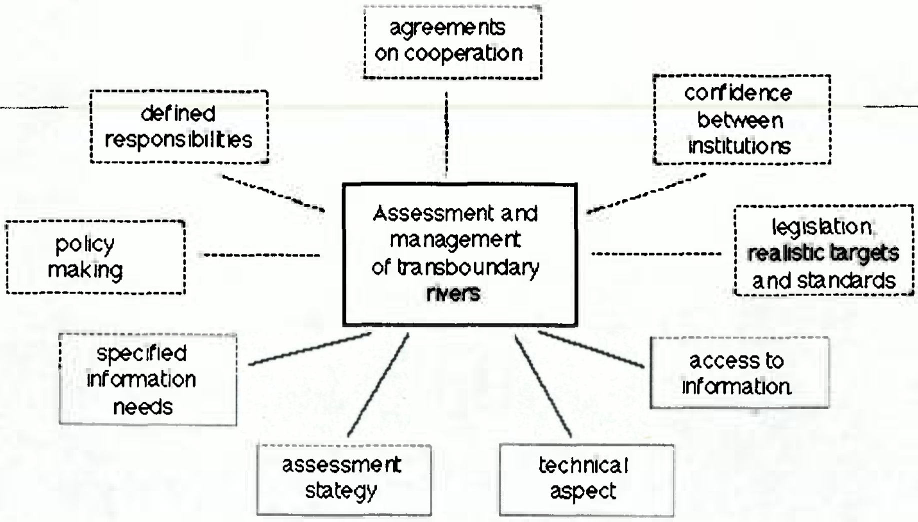
Five elements can be recognised in the establishment of a transboundary network:

1. A thorough analysis of the water management of countries riparian to a watercourse should make clear what the information needs in the national as well as in the transboundary context are.

2. The assessment of the state and problems of the water course requires inventories of available information (on water uses, pollution sources, etc.) and specific surveys and assessments to get the insight which is missing in relevant characteristics and processes.
3. Strategies on assessment and monitoring should be developed to fully meet the information needs and monitoring objectives. These strategies include the careful distinction between and selection of a routine monitoring programme, surveys or surveillance, with a view to detection of trends or compliance testing, in-depth investigations or early warning. They also include the selection of indicators, sampling/measurement locations, agreements on common measurements, protocols for data handling etc.
4. The quality assurance of monitoring and assessment concerns a chain of activities which should be paid attention to, starting with the specification of information needs and ending with the utilisation of information for management decisions. Successive steps set design criteria for the next steps in the monitoring process.



5. The successful monitoring and assessment of a transboundary watercourse not only depends on technical aspects. Institutional aspects play a major role as well, i.e. the institutional arrangements on the national scale in the countries (clear responsibilities, existence of policy plans, well established and up to date legislative system), as well as the arrangements between countries (access to information, agreement on co-operation). The experiences of international river commissions show that confidence between institutions is an elementary factor which can grow over time.



References:

[1] ECE, Guidelines on Water-quality Monitoring and Assessment of Transboundary Rivers. In: Protection of Transboundary Waters, Water Series No. 3, ECE/CEP/II, New York and Geneva, 1996.

[2] Adriaanse, M., Tailor-made guidelines: a contradiction in terms? In: Proceedings of the International Workshop Monitoring Tailor-made II, Nunspeet, the Netherlands, 1997.

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WHYCOS - Facilitating the availability and management of hydrological data

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The pressure on global freshwater resources has increased considerably in recent years and this trend will most certainly continue as the demand for water grows to meet the needs for socio-economic development and for maintaining the health of aquatic ecosystems. Further, refinement of climate prediction models , to detect both climate variability and climate change and to reduce uncertainties in climate prediction with the framework of such international initiatives as WCRP and GEWEX call for improved knowledge of the hydrological cycle at the appropriate scales.

However, a number of recent international conferences and regional and global surveys have confirmed that current knowledge and information on water resources in many parts of the world are grossly inadequate to address the many issues relating to water. Accordingly, governments have been urged to develop or to strengthen their water related information systems.

In response to this call the World Meteorological Organization (WMO) in association with the World Bank, has developed the concept of the World Hydrological Cycle Observing System (WHYCOS). Further development of the programme has been supported by the Government of France and the European Commission. The programme was launched in 1993 as a global initiative aimed at: (i) building the capacity of national Hydrological or Hydrometeorological Services to carry out water resources assessment on a continuing basis; and (ii) promoting the development and/or improvement of consistent and reliable water data information systems at the river basin, regional and global levels in support of sustainable development. It consists of two components: a support component which strengthens the co-operative links among participating countries and an operational components, which achieves the "on the ground" implementation of regional/sub-regional HYCOS projects.

WHYCOS is being modelled on the WMO's World Weather Watch (WWW) system. It makes use of state-of-the-art technologies, such as real-time, satellite-based and remotely controlled observation networks for the collection data on river flow, water quality and certain climatic variables, as well as the internet for dissemination of information from distributed data bases The whole of the African continent is covered by HYCOS projects either being implemented or at various stages of development. A number of projects are also being developed for other regions of the world. The activities of the various projects are co-ordinated within a common WHYCOS framework by a WHYCOS co-ordination mechanism established by WMO in 1998.

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MED-HYCOS : a tool for water resources assessment and managementin the Mediterranean

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Introduction

The countries of the Mediterranean Basin experience varying conditions regarding availability of water resources and needs, highly increased by irrigation, development of tourism and improvement in living standards.

The Mediterranean climate is characterised by a yearly precipitation, comprised of between more than 1000 mm for the northern countries and less than 400 mm for some of the southern countries and by a potential evapotranspiration often higher than 1200 mm implying a hydric deficit which is often high. The hydrological regimes are marked by strong inter-season irregularity. The available soft water resources are often difficult to accede, being fragile and poorly distributed.

This can result in conflicts of interest and difficulties in sharing the available resources and in preserving the environment for any length of time.

More than 200 million people live on the area drained by the Mediterranean, 150 million of whom live on the coast. This situation is reinforced by a seasonal, tourist and migratory flow of more than 100 million people.

Agriculture often requires water provisions in order to irrigate the crops. Presently, more than 16 million hectares are irrigated with a growth rate of 200 000 hectares/year. The global water consumption is about 16 times higher than the urban consumption. Thus, if on the global level, 70% of water mobilised resources are destined to the irrigation, this ratio already reached 90% in certain countries of the South and the East of the Mediterranean basin.

Besides, the urban discharges in the Mediterranean estimated around 2.5 billion m^3 per year whose 1.5 of which are linked to tourist activities endanger the quality of water resources in the coastal area and represent the main source of pollution in the sea.

The exploitation index proposed by Jean Margat (1997, Blue Plan) is the ratio between the quantity of mobilised water and the quantity of renewable water. This is an indicator of the pressure on water resources and of the difficulties that face the countries to satisfy their water needs. Five countries, or territories, have an index that approaches or exceeds 100% : Egypt, Israel, Malta, Palestinian territories, and Libya. It means that these countries use no renewable resources and/or non conventional resources as desalinisation or reused water.

The present and future problems and tensions depend on the evolution of the quantity of available water per inhabitant. 2000 m^3/year/inhabitant is the threshold under which a worrying situation may occur. The state of complete shortage is defined as being underneath 1000 m^3/year/inhabitant. Now, several southern countries are already facing this situation such as Malta, Libya, Israel, Tunisia and Algeria . Cyprus, Lebanon, Syria, Egypt and Morocco might join them in 2025.

In many cases, to face these issues, new resources should be identified locally (ground water exploitation, desalinisation, waste water reuse) and transfers of water are considered from one productive region to another less supplied. In any cases, it is generally admitted that the management of the water demand will be one of the mains keys to solve the issues concerning the balance between the water resources availability and the satisfactory of the needs. However, in this context of scarcity, a better assessment of the qualitative and quantitative evolution of natural and usable resources both in space and time is more and more required.

In fact, water assessment, monitoring and management is dependant on the existence of reliable water resources information systems at national and regional levels, covering not only the collection and analysis of data but also the exchange and dissemination of these data and related information to the users, ranking from the general public to the decision makers. Regional data are also needed for water cycle models considering the global change effects and local physical impacts (deforestation, cultivating new land, construction of large-scale works, irrigation, etc).

Besides, there are many important shared rivers and groundwater basins which require regional co-operation for adaptation and integration of water "information systems" favouring the use of drainage basin simulation and management models.

Considering these facts, in the Mediterranean area more than elsewhere, having an excellent knowledge of hydro-meteorological phenomena and hydrodynamic processes of water supply in the different stages of the hydrological cycle is necessary to assess the variability of available resources in space and in time, to measure the impact of human activities and/or climate change on water availability and to favour co-operation between the border countries. To reach this target, the World Meteorological Organisation (WMO), in association with the World Bank, launched in 1995 the Mediterranean Hydrological Cycle Observing System (MED-HYCOS), based on a global network of reference stations with real-time satellite data transmission, to contribute to the development of consistent, high-quality and constantly updated distributed national, regional and international data bases on river flow, water quality and certain climatic variables.

The MED-HYCOS Project

The MED-HYCOS project proposes the development of a regional approach by encouraging the co-operation between hydrologists through the development of common activities. The participating countries will therefore consider their national problems in a regional context, this is particularly valid in the case of border region resource areas. The promotion of using modern technology is not an end in itself, it is a way of re-enforcing the capacities of the management services from the observation networks and to ease the setting-up of a high quality, operational, regional data base. Water resources management and assessment are based on a coherent analysis of series of observations over a long period and the providing of information in real time or slightly later. The MED-HYCOS hydrometeorological Data Collecting Platforms network (DCPN) would be considered as a reference for other national hydrological network.

The MED-HYCOS project (Mediterranean Hydrological Cycle Observing System) concerns the Mediterranean ; the Black Sea countries are involved in co-operation activities :

Mediterranean Sea Basin : Albania, Algeria, Bosnia-Herzegovina, Bulgaria, Cyprus, Croatia, Egypt, France, Greece, Israel, Italy, Jordan, Lebanon, FYR Macedonia, Malta, Morocco, Palestinian Territories, Portugal, Slovenia, Spain, Syria, Tunisia, Turkey, Yugoslavia (24).

Black Sea Basin : Georgia, Moldova, Romania, Russia, Ukraine (5).

The initial phase (May 1995 - May 1999) is being executed by the countries partners with the help of WMO and with the financial support of World Bank.

Presently, twenty five countries are collaborating and participating in the MED-HYCOS project at different levels of commitment.

The Regional Co-operating Group (RCG) is composed of officially designated representatives of the participating countries, regional organisations concerned, funding agencies and donors, as well as the World Bank and WMO. RCG is responsible for defining strategies, making technical choices and implementing the project.

The implementation strategy has been set up for the initial phase of the project (May 1995 - December 1999) to fulfil the 3 immediate objectives of the project:

Objective 1 : Installation of a network of key stations of multisensor-equipped Data Collecting Platforms (DCPs) storing and transmitting hydrometeorological data.

Objective 2: Development and implementation of the MED-HYCOS Information System.

Objective 3: Improvement of national hydrological services and networks notably through provision of new equipment and development of related training programmes.

Objective 4 : Creation of an Information and Co-operation Infrastructure

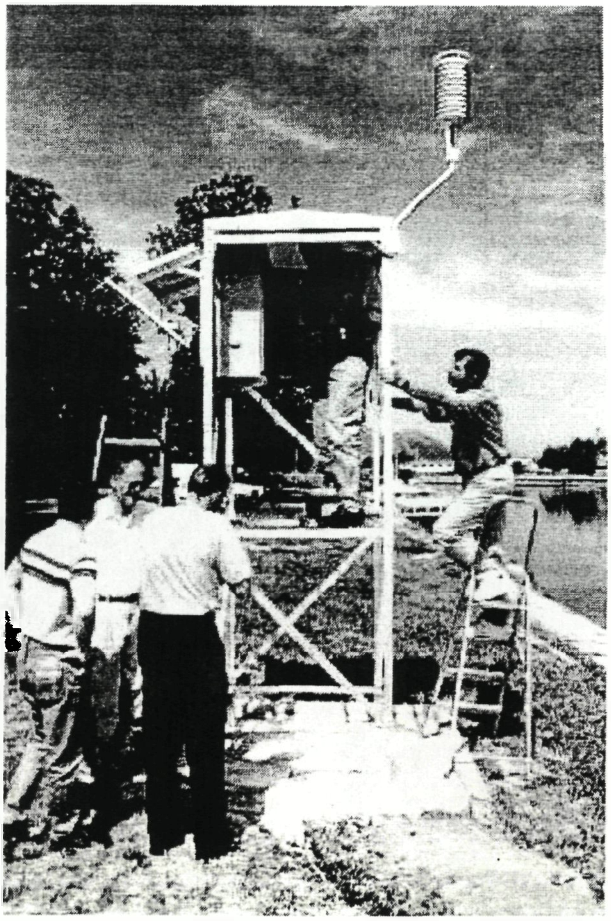
The Research Institute for Development (RID ex ORSTOM) is hosting in Montpellier (France) the MED-HYCOS Pilot Regional Centre (PRC) in charge of co-ordinating and leading the project with the support of Regional Task Forces with experts from participating countries. The Pilot Regional Centre acts under the authority of the Regional Co-operation Group. The host country for the PRC provide : office space and part of the furniture for the PRC, a scientific and technical team and its salaries, and part of the recurrent costs. Other costs are supported partly by the project, partly by the participating countries .

The Initial Co-ordinating Group (ICG) helps the PRC in the conduct of the project. ICG is presently composed by Bulgaria, Cyprus, France, Italy, Malta, Romania, Slovenia, Spain, Tunisia, regional organisations concerned (FRIEND-AMHY, MEDIAS-France, RID, VERSEAU) and funding agencies and donors.

The first immediate objective of the project to collect hydrometeorological data in order to follow the evolution of resources on main Mediterranean rivers, to face the International and transboundary water issues, to evaluate the terrestrial pollution flows from the catchments to the coastal zones of the Mediterranean sea, to evaluate certain terms of the hydrological cycle at different watershed scales (runoff, evapotranspiration), to monitor the management of dams and the transfer of water between different areas, etc.

The designation of the sites to be equipped with the MED-HYCOS Data Collecting Platforms (DCP) is the responsibility of the countries according their own interest. However, it is recommended the MED-HYCOS DCPs are chosen amongst the existing stations of national networks according to the stability of their gauging and the length of their observation series.

Twenty Data Collecting Platforms (DCP) are functioning in the following countries : Albania, Bulgaria, Croatia, Cyprus, Jordan, Lebanon, F.Y.R. Macedonia, Malta, Morocco, Slovenia, Tunisia, and Turkey. Every three hours, the DCPs are transmitting hourly data on water level, water temperature, air temperature and rainfall. These DCP are manufactured by CEIS-TM (Toulouse France) according with the specifications requested by MED-HYCOS project, especially for remote monitoring.



The main characteristics of these DCPs are : METEOSAT transmission (or GOES/GMS, ARGOS, INMARSAT, modem), Self power supply with solar panels and battery, Additional capacities for meteorology or water quality monitoring (17 sensors), Easy installation and maintenance, etc.

Certain countries like Italy, France, Romania, Slovenia, Spain and Romania transmit to the Pilot Regional Center near real time data from about thirty hydrological stations.
The MED-HYCOS Information System (MHIS) is constituted by all information related to the National Hydrological Services and to the MED-HYCOS activities and by the Regional Data Base.
The Regional Data Base is composed by the data collected in real time from DCPs, data coming from near real time sites and historical data (especially daily and monthly discharges) from other sites chosen by the countries representatives. The Regional Data Base is managed by the Data Base Management System ORACLE interfaced with Internet. Thus, the MED-HYCOS Web site presents hydrological data on more than sixty stations ; for about two third of them, data are updated every week.
Above all, several useful tools available in free access on the Web Site have been developed in order to check, to examine and to visualise the hydrometeorological data. Data managed on the server are transferred to CD-ROM while preserving their organisation. Thus, the MH tools are used to process data through the Web Site or on CD-ROMs or on hard disk. So, the MH tools can be applied to process national data outside MED-HYCOS regional context.

Conclusion
By promoting the use of modern technologies for data acquisition, transmission and information processing and dissemination, by promoting the exchange of information, data and skills among the countries participating in the project and by strengthening the capacities of their National Hydrological Services, MED-HYCOS is one of the initiative which contributes to water resources assessment and management in the Mediterranean region.

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Data-base of physical characteristics of small catchments in Slovakia: Methodological aspects of its creation

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Hydrological characteristics estimated for ungauged catchments are reliable only if the hydrologically homogeneous regions or regional types are sufficiently exactly identified. Regional-typifying methods are first applied to a set of gauged catchments, which are clustered on the basis of their physical-geographical characteristics to larger in geographical space not contiguous spatial units - regional types. Hydrological homogeneity within a regional types or heterogeneity between them with regard to selected hydrological characteristics is then tested by mathematical and statistical methods. The rest of ungauged catchments in a study area are included in the hydrologically homogenous identified regional types according to their physical characteristics and their hydrological characteristic are expressed by regional value.

Creation of a network of small catchments in study area functioning as a classified objects along with the data-base of their physical-geographical characteristics is then a basic prerequisite for application of regional-typifying procedures as a tool for the estimate of the values of hydrological characteristics for the ungauged catchments.

The contribution outlines the basic methodological procedures of creation of a network of small catchments in Slovak Republic (49 000 km^2) and the database of their physical characteristics.

Digital Network of Small Catchments

Small catchments were identified in such a way as to fulfil besides the formal requirements (spatial continuity of the units of approximately the same size without any two of them overlapping and all together covering the area of interest) also the request of natural closeness of hydrological cycle and autochthony of their hydrological response. It means that there is only one input to the catchment (precipitations) and only one output (discharge in the final profile), and the hydrological response is the product of physical-geographical attributes of a particular catchment. A network of small catchments in the territory of Slovakia fulfilling the above quoted was created by an extensive adaptation (generalisation, re-digitising) of the digital network of even smaller or detailed catchments made by the Slovak Environmental Agency by digitising the water divides of such detailed catchments drawn on hydrological maps in scale 1:50 000. Generalisation and re-digitising of the original network of detailed catchments removed its biggest drawback, i.e. presence of catchments with allochthonous hydrological response. Both procedures were carried out in GIS Arc View environment.

The hydrological numbering of streams in Hydrologické pomery ČSSR (1965) refers to the catchments of the Danube and Vistula as the 1st order catchments. Their direct tributaries: the Morava, Váh, Hron, Ipeľ, Slaná, Bodva, Hornád, Bodrog, Poprad, and Dunajec are the 2nd order catchments. The direct tributaries to the 2nd order catchments are the 3rd order catchments and in the tributaries of the last quoted catchments are the 4th order catchments. Our generalisation observed the following rule: the catchments of the basic network were identified so as to: **1)** fulfil the condition of closeness of the natural hydrological cycle in the framework of hierarchic 3rd, 4th, 5th, or any following order, **2**) their heterogeneity from the point of view of physical attributes was not too high and **3**) the area of catchment not exceeding the size of about 100 km^2. Allochthony of hydrological response of catchments which was not removed by generalisation was cleared out by their re-digitising by use of digital layers of contour lines and river network created from the topographic maps in scale 1:50 000. About 4 600 small catchments with autochtonous hydrological response were identified in Slovak Republic.

Database of Physical Characteristics of Small Catchment Network

The physical-geographical characteristics of catchments can be classified into four basic groups representing: **a**) relief morphometry, **b**) climate, **c**) substrate and soil, and **d**) land cover.

Morphometric characteristics of relief

The set of morphometric characteristics of relief was computed from digital model of relief (DMR). The input data necessary for computation of DMR at medium and small scales are usually derived applying vector digitisation of contour lines. Selection of interpolation methods is very important both from the theoretical and methodological point of view. To provide data for environmental analyses the group of interpolation methods called global base splines is one of the best ones. These are characterised by properties (for instance, differentiability, flexibility, local behaviour, and segmentation processing) by which top quality of interpolation and processing of unlimited number of input data can be obtained. This was the reason why we used a regularised spline with tension controlled by the tension parameters and smoothing with a possibility of direct calculation of morphometric characteristics of relief (Mitášová and Mitáš 1993). The method was implemented in GIS GRASS.

The DMR of the whole territory of Slovakia in a form and quality complying also with the most demanding criteria of all its users was not processed as yet. In spite of the fact that there exist at least three all-national DMRs in raster formats with a pixel resolution 100 metres, their low quality, inconsistency of input data, and the used methods make them useless for our needs (see Šúri et al. 1997). This was why it was decided to create a new generation DMR with pixel resolution 50 m (DMR50-SK). DMR50-SK was processed by GeoModel Ltd company that provided it for the purpose of derivation of database characteristics.

The input data set for the calculation consists of about 16 million points derived from vectorised contour lines of 137 topographic maps at scale 1:50 000 covering the whole of the Slovak territory. DMR50-SK consists of rasters of elevation, slope, aspect, normal and tangential curvature of relief (the last two characteristics define the shape of relief in a given point). Using DMR50-SK for each small catchment we have computed the following morphometric characteristics: *mean, maximum and minimum elevation* (in metres above sea level), *mean slope* (in degrees), and *aspect* (percentage of area extent for 8 intervals).

Climatic characteristics

Out of climatic characteristics we have used mean annual precipitation total as one of the most important indices characterising the input into hydrological cycle. The input data were derived from isohyets vectorised from 1:750 000 map. The raster data layer with pixel resolution 100 metres was computed in a similar way as DMR by method of regularised spline with tension. The *mean annual precipitation totals* (in millimetres) were derived for each catchment of the database.

Substrate and soil characteristics

Influence of geological substrate and soil on the character of hydrological response of catchment is expressed by means of transmissivity. Transmissivity or discharge is a property of acquiferous layer to transmit water. Co-efficient of transmissivity T ($m^2 . s^{-1}$) is a result of two directly stipulated values: co-efficient of filtration k ($m.s^{-1}$) and thickness of acquiferous layer M (metres). The basic information source used for the creation of digital map of transmissivity (Grešková 1997) was the hydrogeological map of ČSSR in scale 1:200 000 which still provides the most complete information on geological and hydrogeological attributes of the whole territory of Slovakia. In the given scale and distinguishing level areas sized up to 0.5 km^2 are reflected. The *transmissivity* of each selected small catchment is expressed by weighed arithmetic mean.

Characteristics of land cover

Characteristics of land cover for each catchment were derived from the CORINE Land Cover database. The Project CORINE Land Cover is a part of the EU programme and it was carried out in Slovakia in the years 1994-1996 (Feranec et al. 1996). Its aim was to create a consistent and compatible database concerning land cover of Europe in scale 1:100 000. Methodologically the project is based on visual interpretation of satellite image maps created from the Landsat TM data. Digital spatial database of Slovakia represents the actual state of land cover in the years 1989-1992. In the sense of the defined legend (Heyman et al. 1994) it contains in total 44 classes (31 out of them were identified in Slovakia) hierarchically arranged to three levels. There are 5 basic classes at the first level: artificial areas, agricultural areas, forest and semi-natural areas, wetlands and waters. For our purposes several of the classes were amalgamated at the third level and using GIS we computed the percentage of their area extent within the catchments.

Conclusion

The creation of digital network of small catchments together with development of digital thematic layers of landscape enables to gain new and more precise knowledge on physical characteristics of catchments and to improve regional typification of study area.

Literature

1. FERANEC, J. OŤAHEĽ, J. PRAVDA, J. (1996). Krajinná pokrývka Slovenska identifikovaná metódou CORINE Land Cover. *Geographia Slovaca*, 11, 95 s.
2. GREŠKOVÁ, A. (1997). Digitálna mapa transmisivity. *Geografický časopis,* 49, 223-229.
3. HEYMANN, Y., STEENMANS, CH., CROISILLE, G., BOSSARD, M. (1994). *CORINE Land Cover - Technical Guide*. Office for Official Publications of the European Communities (Luxembourg), 136
4. HYDROLOGICKÉ POMERY ČSSR (1965). *I.Díl*. Hydrometeorologický ústav, Praha
5. ŠÚRI, M., CEBECAUER, T., HOFIERKA, J. (1997). Tvorba digitálneho modelu reliéfu Slovenskej republiky. *Geodetický a kartografický obzor*, 43, 257-262
6. MITÁŠOVÁ , H., MITÁŠ, L. (1993). Interpolation by regularized spline with tension I. Theory and implementation. *Mathematical Geology,* 25, 641 - 657.

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„Digital Waterway Vechte": Set up and implementation of a transboundary geohydrological information system between Germany and The Netherlands for the catchment of the river Vechte.

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Introduction

Digital Waterway Vechte is a transboundary cooperation project initiated and supported by the federal German states Niedersachsen and Nordrhein Westfalen (North-Rhine/Westphalia) and the Ministry of Transport, Public Works and Water Management, the province Overijssel and some Water Boards in the Netherlands. The project is subsidised by Euregio Gronau in the framework of the Operational Programme for the Euregio 1994-1999 of INTERREG-II. After a long preparation period of about 3 years the project started finally in June 1998 and the duration of the project will be approximately 2 1/2 year. The province of Overijssel at the Dutch side of the border is the official applicant of the project and consequently functions as the principal towards the executing agency The Netherlands Institute of Applied Geoscience TNO. The project is executed in close cooperation with several German institutes and authorities which are responsible for the collection, processing and storage of geohydrological data at the German side of the border.

The transboundary catchment of the river Vechte covers parts of the federal states Niedersachsen and Nordrhein Westfalen on the German side of the international border and of the provinces Overijssel, Gelderland and Drenthe on the Dutch side of the border. The total area covers approximately 4000 km2.

Project objectives

The aim of the project is to set up a system of data storage, data processing, data exchange and information access with respect to the transboundary aspects of groundwater resources in the region of the catchment of the transboundary river Vechte. The system should provide the responsible water managing authorities in the region with the needed information about transboundary groundwater flow in quantitative as well as in qualitative sense and through this for the possible evaluation of the transboundary impact of the human activities on the availability and sustainabilty of the groundwater resources. The project will establish contacts between the various institutions that may endorse and realize transboundary integral water management.

Contents of presentation

The paper to be presented will contain the results of the first phases of the project which will include the results of the inventory of the data sources, the design of a data exchange directory and a data conversion protocol and the first results of data collection and processing. The difficulties met in organizational and technical sense which can be attributed to transboundary aspects of the project will be discussed. Further it will address the differences in type of data, the availability of data and the definitions used. Based on the first results of the collected data, some transboundary aspects of the groundwater system will be discussed and presented with the information system applied.

The information system applied to this region is the Regional Geohydrological Information System REGIS which has been set up for the storage and processing of geohydrological data in The Netherlands. REGIS is the central digital data base system on groundwater which has been built and is maintained by The Netherlands Institute of Applied Geoscience TNO for the Directorate-General of Public Works and Water Management (Rijkswaterstaat) and the provinces. The Data Base of this system, which is linked to a GIS, contains non-spatial data (attributes) and spatial data (points, lines, polygons and surfaces) on groundwater. It contains groundwater quantity and quality data, relevant surface water data and geohydrological subsurface layer models. The layer models which have been applied in the province of Overijssel have to be extended to the German side and adapted to the local geohydrological situation.