Cambridge University Press
978-0-521-03673-3 - New Uncertainty Concepts in Hydrology and Water Resources
Edited by Zbigniew W. Kundzewicz
Excerpt
More information

I

Introduction

1 Hydrological uncertainty in perspective

Z. W. KUNDZEWICZ

Research Centre of Agricultural and Forest Environment Studies, Polish Academy of Sciences, Poznań, Poland

ABSTRACT Different aspects and meanings of uncertainty are reviewed. This introductory review forms a basis for putting recent developments in hydrological and water resources applications of uncertainty concepts into perspective. The understanding of the term uncertainty followed herein is a logical sum of all the notions discussed. An attempt is made to justify the structure of the present volume and to sketch the areas of particular contributions in the volume and to point out their connections to different facets of uncertainty.

INTRODUCTION

It seems that there is no consensus within the profession about the very term of uncertainty, which is conceived with differing degrees of generality. Moreover, the word has several meanings and connotations in different areas, that are not always consistent with the colloquial understanding.

In the following section the notions and concepts of uncertainty both beyond and within the water resources research are discussed. Further, particular contributions in this volume are reviewed in the context of their connections to different facets of uncertainty. This is done in the systematic way, following the structure of the book.

NOTIONS OF UNCERTAINTY

Let us take recourse to established dictionaries and see how the words 'uncertain' and 'uncertainty' are explained. Among the meanings of the word 'uncertain', given by Hornby (1974) and Webster's (1987) dictionaries, are the following: not certain to occur, problematical, not certainly knowing or known, doubtful or dubious, not reliable, untrustworthy, not clearly identified or defined, indefinite, indeterminate, changeable, variable (not constant).

The noun uncertainty results from the above concepts and can be summarized as the state (quality) of being uncertain, with the word uncertain attaining one of meanings listed above.

There is a plethora of single words that are synonymous of the word uncertainty. The meaning of the term uncertainty partly overlaps with the contents of such words as doubt, dubiety, skepticism, suspicion, mistrust, inconstancy.

Uncertainty is obviously opposed to certainty, where the complete information is available. One sometimes makes a distinction between risk and uncertainty. In the former case, i.e. when talking of risk, one tacitly assumes that a probability distribution of outcomes exists, made on a meaningful basis (i.e. agreed upon by a set of relevant experts). In the latter case, if there is an absence of information on prior probabilities, i.e. nothing (or little) is known as to the likelihood of particular outcomes (or a consensus among experts cannot be achieved), one can talk about uncertainty. In other convention of risk and uncertainty, risk embraces both uncertainty and the results of uncertainty, and means lack of predictability about outcomes, structure etc.

Sometimes authors distinguish between uncertainty and randomness. In this context, uncertainty results from insufficient information and may be reduced if more information is available. This is to be distinguished from the concept of randomness related to quantities fluctuating in a non-controllable way.

There are several practical approaches to dealing with some forms of uncertainty. One possibility is the Laplacean postulate, called also principle of insufficient reason. It states that if the probabilities of an event are not known, they should be assumed equal. A simple, though typically non-satisfactory method is – to replace the uncertain quantities with the worst case values (most pessimistic scenario) or with some measures of central tendency (expected value, median). By a sensitivity analysis the importance of uncertainties can be traced. The other simple way of coping with some types of uncertainty is by interval analysis, i.e. assuming ranges of parameters rather than a number. In a more advanced approach that is commonly used, uncertainty can be encoded with probability methods or with fuzzy sets methods. The former approach is most useful if the estimating functions have a statistical form, i.e. if standard deviations, standard errors of forecasts etc. are available. The measures of uncertainty are typically – probabilities, approximated by frequencies or via the geometric definition. The fuzzy sets approach is a powerful tool where insufficient data exist, or where it is difficult or even impossible to attribute probabilities. That is, the areas of dominance of concepts of randomness and fuzziness can be defined as follows. The former apparatus is used if the event is clearly defined but its occurrence is uncertain. In the latter approach the very event may not be strictly defined and no additivity property is present.

There are two basis attitudes to uncertainty in hydrological and water resources research. Either the world is considered as being basically indeterministic (i.e. must be modelled in terms of stochastic systems) or the stochasticity is a necessary evil (i.e. cannot be avoided at present, when the understanding is not sufficient, but would give floor to increasingly deterministic descriptions when our understanding improves).

It is not only uncertainty about numbers (e.g. inaccuracy of measurements). If one does not know whether some variable attains the value of 1.03 or 1.05, it is a very trivial lack of certainty, though it may be quite critical in some cases. The uncertainties in hydrology are much stronger and pertain to the directions of change, dominating mechanisms, and understanding of processes. Moreover, it follows from the theory of chaotic systems, that the time series of hydrological variables are inpredictable over a longer time horizon, hitherto inherently uncertain, unknown.

Uncertainty in hydrology results from natural complexity and variability of hydrological systems and processes and from deficiency in our knowledge. The uncertainty may pertain to magnitudes and space-time (i.e areal location and temporal frequency) attributes of signals and states of hydrological systems (storages).

Yet more uncertain (unexpected and unforeseeable) are the variables of relevance to water resources management. One may identify, among others, the following uncertainties:

- uncertainty in knowledge of the external environment (structure of the world, future changes of the environment);
- uncertainty as to future intentions in the related fields of choices;
- uncertainty as to appropriate value judgments of consequences.

Consider the water demands as an example. They depend on several demographical, economical, technological, social, political, and regional development factors, each of which is itself uncertain and non-predictable (e.g. forecast of future population, water use rates, priorities, irrigation patterns). On top of this there is also an uncertainty on the side of available water supply, whose natural variations have been typically considered known. The main uncertainty there falls in the category known under the collective name of the climate change.

There were numerous attempts in the water related literature to distinguish different types of uncertainty. Plate & Duckstein (1987) identified the groups of uncertainties in a hydraulic design. They distinguished hydrological uncertainties, embracing data uncertainties (e.g. measurements), sample uncertainties (e.g. number of data) and model uncertainty (density function). Further they identified hydraulic uncertainties in the process of hydraulic transformation of hydrological data, embracing parameter uncertainties (Manning's n), model uncertainty (empirical equations) and scaling laws (physical models). Finally, structural uncertainties were associated with the material, design models, external effects, etc. However, in another convention, structural uncertainty is understood as considerable lack of sureness about the formulation of the problem in terms of structure and assumptions.

Bernier (1987) distinguished natural uncertainty related to a random nature of physical processes and technological uncertainties embracing sampling errors and the model uncertainties. Uncertainty of the former category is linked with the total duration of the period of records, whereas the latter category may result from the model choice or imprecise identification of parameters.

Beck (1983) distinguished uncertainty and error in the field data, inadequate amount of data, uncertainty in relationships between variables, and uncertainty in model parameters estimation. After a successful calibration exercise it would be expected that the degree of uncertainty in a parameter estimate would be less than the uncertainty associated with the prior estimate before calibration. Reduction of uncertainty is the measure of relevance of a parameter. However, the uncertainty of parameter estimates is inversely related to the amount of field observations and to errors associated with these observations. Posterior estimates are also uncertain (fingerprint of the calibration method that can propagate forward).

Klir (1989) considered uncertainty versus complexity. Both categories are in conflict: if complexity decreases, the uncertainty grows. Uncertainty is related to information, being reduced by an act of acquiring information (observation, performing an experiment, receiving a message). The amount of information received quantifies the reduction of uncertainty. Klir (1989) considered the principle of maximum uncertainty – use all, but no more, information than available. Our ignorance should be fully recognized when we try to enlarge our claims beyond the given premises. At the same time – all information contained in premises should be fully utilized. Another aspect is the principle of minimum uncertainty, actual when simplifying a system. The loss of relevant information should be minimized at any desirable level of complexity.

The understanding of the word uncertainty in the present volume will follow the logical sum of all the uncertainty aspects discussed above.

FACETS OF UNCERTAINTY

Although the Workshop was primarily method-oriented, some contributions were rather problem-oriented. It is worth mentioning a couple of examples, starting from contributions pertaining to the very timely area of hydrological consequences of climatic change.

Moss (1995) studied the concept of Bayesian relative information measure, applied to evaluate the outputs of general circulation models (GCM). The relative information was understood as the ratio of information contents of the model and of the data, e.g. of the model-based histogram and the data-based histogram). The approach allows the complexity connected with disparate temporal and spatial scales of outputs of GCM simulations and the actual observations to be resolved. The methodology devised by Moss (1995) is capable of giving preliminary answers to several practical questions connected with comparisons of models, effects of the grid size and evaluation of the soundness of disaggregation.

Bardossy (1995) extended the classical hydrological perspective of transformation of rainfall into runoff by treating the atmospheric circulation pattern as the primary input signal. He confirmed that daily precipitation depths and mean temperatures are strongly linked to the atmospheric circulation patterns and developed relevant mathematical models. As GCMs produce air pressure maps with relatively good credibility, the model lends itself well to applications in stochastic simulation studies of climate change.

Another example of problem-oriented research was the contribution of Kotwicki & Kundzewicz (1995), studying the process of floods of Lake Eyre. This is quite a convincing manifestation of hydrological uncertainty. The available observational records are not long. Therefore one is forced to use a model and proxy data in order to reconstruct river flows.

Strupczewski & Mitosek (1995) showed that the hydrological uncertainty influencing a design in the stationary case, will significantly increase in the non-stationary case. One can only hypothetize the mechanism and structure of non-stationarity. Strupczewski & Mitosek (1995) developed a method of estimation of time dependent parameters of a distribution from the available non-stationary data set. The uncertainty in the design process is magnified due to the necessity of identification of additional parameters. This is likely to lead to the increase of the quantile estimation error, growing with the length of the time horizon of extrapolation.

Guo (1995) devised and examined a new plotting position rule. The new formula is applicable for the presented case, where flood records obtained in two different ways (i.e. of different accuracies) should be blended. In addition to the systematically recorded data (observation period) there may exist also historical data and palaeologic information related to flows over some threshold of perception.

NOVEL APPROACHES TO UNCERTAINTY

There is a number of novel methodological approaches to uncertainty, originating in areas outside hydrology (typically – applied mathematics, systems theory, physics) but relevant to water sciences. Although the origin and applicability of these approaches largely differ, they are treated collectively in one part of this volume.

The concept of fractals, as developed by Mandelbrot (1977), has found a strong resonance in hydrological sciences. This methodology made it possible to analytically describe complicated natural objects, without the need to approximate them via the constructs of the classical geometry.

Kemblowski & Wen (1995) tested the assumption of fractal permeability distribution in their study of infiltration soils. This represents one of the challenging avenues of application of fractal framework, gaining increasing recent interest in the theory of flow in porous media, groundwater and petroleum engineering. Kemblowski & Wen (1995) postulated that the fractal nature of the permeability distribution strongly influences the mixing processes in groundwater, with major impact on the value of asymptotic macrodispersivity. A higher fractal dimension results in higher vertical mixing and less longitudinal spreading of the plume, while for the fractal dimension approaching two the horizontal spreading disappears. It was also indicated that the travel distance necessary to reach the asymptotic conditions was scale-dependent and related to the thickness of the plume and to the pore-level transverse dispersivity. These findings of Kemblowski & Wen (1995) are believed to narrow the gap in the understanding of subsurface transport processes, and in particular of the process of mixing of soluble plumes with surrounding groundwater.

The contribution of Lovejoy & Schertzer (1995) differs considerably from the rest of the volume. It is a solicited extensive review paper reaching much further than the oral presentation at the Workshop. It summarizes the research work that has been done in the area of multifractal analysis of rain. The bulk of the material stems from the original research of the authors. Lovejoy & Schertzer (1995) established and tested the scaling ideas of description of the process of rain. The concept of continuous turbulent cascades is thoroughly discussed. Different applications of the concepts of multifractals at the interface between meteorology and hydrology are reviewed. The contribution by Lovejoy & Schertzer (1995) is possibly the most extensive lumped coverage of the problem available in the literature.

Zawadzki (1995) studied scaling properties of the spatial distribution of rainfall rate, for a broad spectrum of scales ranging from the radar coverage area down to individual rain drops. The results show that no scaling or multiscaling properties could be detected for scales exceeding the size of a mature precipitating cumulus. Preferential scales were found in the range of a few tens of kilometers. Within the scales of the order of a cumulus size some multiscaling properties were found.

Hubert *et al.* (1995) reported the evidence of a multifractal structure of temporal occurrence of rainfalls at particular locations of the Soudano-Sahelian region for a range of temporal scales of two orders of magnitude, ranging from days to months. Fractal dimensions of the data analyzed, varying between zero and one, were estimated with the help of the functional box counting method. As can be expected, fractal dimensions of rainfall occurrence depended strongly on the chosen rainfall intensity threshold, decreasing with the rise of the threshold. Attempts to find regional patterns and trends were also undertaken.

It seems that the fractal concepts are of permanent value in hydrological sciences, as they provide a new insight into the nature of processes, describing apparently irregular natural forms in a straightforward, novel way.

The contribution by Georgakakos *et al.* (1995) dealt with the area of chaotic dynamics that has risen considerable general interest. They reported on their analysis of very fine increment point rainfall data. High-resolution rainfall data recorded by a fast-responding optical raingauge was analyzed via classical statistical and recent fractal and chaotic dynamics methods. The analysis showed the evidence of scaling and chaotic dynamics.

An assemblage of four papers presented in Madralin, two of which are published in the present volume, dealt with the problem of applications of the fuzzy theory in hydrology.

Mizumura (1995) presented a model of snowmelt runoff based on the theory of fuzzy sets. The contribution shows that the combined approach using the conceptual tank model and a fuzzy logic model yields satisfactory results. The effect of different membership functions on the prediction is tested.

Kindler & Tyszewski (1995) objectively studied the applicability of the fuzzy sets theory to hydrological and water resources problems. They elucidated why the practical applications of the methodology in the water field are so rare. The fundamental problems are – how to identify membership functions, and how to interpret fuzzy results. According to Kindler & Tyszewski (1995), the theory seems more applicable for diagnostic problems rather than in the context of decision making.

Another novelty that has attracted much interest of hydrologists was the concept of pattern recognition, belonging to the area called artificial intelligence (AI).

Mizumura (1995) used a technique originating from pattern recognition methodology to forecast the ranges of runoff values likely to occur. The forecast made use of the values of rainfall and runoff recorded in former time steps. The Bayesian methodology used does not require the detailed physical information on the watershed. Use of the tanks model, and prediction of runoff by the pattern recognition method, from the past observed data and the past errors of the tank models improves the accuracy of forecasts.

Ranjithan *et al.* (1995) devised a method potentially useful for hydraulic gradient control design of plume migration. The neural network technique was used, i.e. a branch of the artificial intelligence (AI) framework. This method can capture information that is imprecise, complex, vague and inexpressable by mathematical or symbolic means. Pessimistic realizations of the uncertain field of hydrogeologic parameters that would influence the final design were identified. Although the process of training the neural network (pattern association task, i.e. learning the links between each spatial distributions of hydraulic conductivity values and the impact upon the final groundwater remediation design) was found difficult, a trained network screens a set of realizations with little computational effort.

One of the promising techniques raising recent interest in hydrology has been the non-parametric approach. This could help in objectivization of the design procedures. Non-parametric methods allow the bulk of information present in the data to be extracted, without forcing it to fit a tight uniform. They let the data speak for themselves, so to say, thus decreasing the degree of subjectivity. The non-parametric estimation methods enable one to estimate an unknown p.d.f. without a prior assumption of the underlying parent distribution (that is, in fact, never known in hydrology). This is particularly important for extreme value statistics used in the hydrological design that typically dwelt on a number of standard distributions. As the values used in design were obtained via extrapolation (e.g. assessment of the 100-years flood), they do heavily depend on the type of distribution used. The non-parametric methods are capable of inferring complicated densities or relationships. They allow, for instance, a bimodal form to be approximated, what can occur in hydrological data forming a superposition of two distinct mechanisms of generation.

Feluch (1995) applied the non-parametric estimation methods to two classes of practical hydrological problems. He presented the multivariate estimation of annual low flow and high flow characteristics (understood as: maximum flow and volume of the flood wave; or minimum flow and low flow period, respectively). He also used the non-parametric regression to establish the linkage between the river discharge and the water stage, and to find the relationships between concurrent time series of runoff and groundwater level. Variable kernel estimator was found better when the sample skewness was greater than one. Simulation showed that quantiles estimated by a non-parametric method compare favourably to the parametric estimator. In extrapolating exercises the non-parametric method places a stronger weight on a few large observations. Thus the problem of the tails of parameters distribution fitted to the whole sample is weakened.

Guo (1995) studied non-parametric methods of flood frequency analysis (FFA). He compared application of fixed and variable kernel estimators (FKE and VKE, respectively) for analysis of a design flood with pre-gauging data and information. He gave also the guidelines on the choice of the kernel type, depending on the sample skewness.

RANDOM FIELDS

The era of univariates in hydrology has been passing. It gives room to the era of random fields, where hydrological variables are treated as functions of location (in one, two, or three dimensions) or both location and time (spatial-temporal fields). Random fields approach better represents the nature of processes. Examples of typical applications of random fields in hydrology range from rainfall, through distributed runoff, to groundwater and water quality.

Krasovskaia & Gottschalk (1995) analyzed regional drought characteristics (deficit and extent). They used empirical orthogonal functions (EOF) in their quantification of regional meteorological droughts. It is again a type of technique that draws much information from the data, without the need to dwell on assumptions.

Georgakakos & Krajewski (1995) analyzed the worth of radar data in a real time prediction of areal rainfall. The methodology used was the covariance analysis of a linear, physically based model. The improvement of estimators due to the presence of radar data was quantitively evaluated.

Krajewski & Smith (1995) addressed the problem of rainfall estimation via radar, and in particular adjusting radar rainfall estimates to raingauge estimates.

Meyer *et al.* (1995) considered the risk of exposure to contaminated groundwater caused by leakage from a municipal solid waste landfill. In order to reduce this risk by early detection of the contaminant and appropriate prevention action, a groundwater quality monitoring network is to be designed. The methodology used contains numerical modelling of groundwater flow and contaminant transport and optimization. The main uncertainties pertain to the contaminant source location and variations in hydraulic conductivity. The issue of strong practical flavour reads – find the well locations in the neighbourhood of the landfill, that maximize the probability, that an unknown (here randomly generated) plume is detected.

Romanowicz *et al.* (1995) studied the effect of the spatial variation of the initial soil moisture contents on the distribution of the soil moisture and on the evaporation rate from the land surface. They used a lumped nonlinear model based on thermodynamics and evaluated distributions, means and variances of the soil moisture contents, time to desaturation and actual evapotranspiration. The case of lognormal distribution is considered in more details.

Gottschalk *et al.* (1995) addressed the problem of determining outliers in the data on floods in Norwegian rivers. Point kriging, i.e. the methodology belonging to the geostatistical framework, was exploited.

TIME SERIES AND STOCHASTIC PROCESSES

Several contributions presented at the Workshop can be clustered around the heading of time series and stochastic processes, although typically in a non-classical context.

Rasmussen & Rosbjerg (1995) analyzed the applicability of seasonal models for representation of extreme hydrological events. In the case of a prediction task it may well be that a simplified non-seasonal model performs superior to a seasonal model due to parsimony in parameters. Rasmussen & Rosbjerg (1995) recommended that in case of weak seasonalities the available data should be pooled. If the seasonality is pronounced, the most dominant season should be selected for the non-seasonal approach, and the data on the other seasons discarded. In the cases analyzed by Rasmussen & Rosbjerg (1995) optimal estimates of T-year events were always obtained with the non-seasonal approach.

Jakubowski (1995) presented analytical derivations of the general form of distribution of the l-day total precipitation. This has been achieved within the framework of the alternating renewal methodology. The assumptions made in the development are – dependence of total precipitation of the wet days sequence on the length of this sequence and independence of successive dry and wet spells.

Konecny & Nachtnebel (1995) presented a stochastic differential equation model, based on the mass balance of a linear reservoir, to describe daily streamflow series. The jump process for the input was based on the concept of intensity function randomly alternating between two levels. The model applied to an Austrian river yielded a good reproduction of the observed characteristics.

Weglarczyk (1995) performed extensive analysis of the impact of temporal discretization on the analysis of different stochastic characteristics of the point rainfall. The material used is a continuous record of precipitation depth at a gauge in Kraków, covering the time span of 25 years. The range of time intervals from five minutes to one day, i.e. over two orders of magnitude were considered. The modelling of distribution of particular characteristics and study of interrelations between them was made.

Gottschalk & Kundzewicz (1995) analyzed the series of maximum annual flows with respect to outlying values.

Tsakiris & Manoliadis (1995) modelled the hydrants operation in irrigation networks, using alternating renewal process in continuous time. It seems that the renewal theory is a good basis to assess the probability of hydrant operation and to aid in design of pressurized irrigation systems.

Kowalski (1995) compared the correlation time of hydroclimatical processes (flow of few European rivers, temperature and precipitation in Poznań). The correlation time was considered as a measure of the order or disorder of geophysical processes.

Napiórkowski & Strupczewski (1995) incorporated physical structure into the study of stochastic processes of river flow. They used a rapid flow model originating from a physically sound hydrodynamic description of the process of open channel flow.

RISK, RELIABILITY AND RELATED CRITERIA

This part of the book groups six contributions covering a broad spectrum of topics.

Plate (1995) sketched the outline of a gigantic research project into non-point pollution of surface waters in agricultural landscape (Weiherbach project). The models consist of four parts, each of which contains uncertainty elements. The input model provides the pollutant outflow along the river for a given rainfall and pollutant input. The process describes the transport of pollutants in a river. Finally, the decision model quantifies the consequences of excess pollution of the river. Plate (1995) discussed also risk as a figure of merit and uncertainty in the decision model.

Karbowski (1995) dwelt upon the idea of application of statistically safe sets and optimal operation of water storage reservoirs. The methodology seems to be quite a general tool for solving storage management problems under risk. Inflows are assumed to be independent random variables of known distribution or the Markovian chain. A set of constraints (chance-constraint or expected value-constraints) need to be fulfilled. The approach separated two basic elements of a control problem, i.e.

(a) optimization of a performance index (P1); and
(b) fulfillment of reliability constraints.

Applicability of different variants of dynamic programming is discussed.

Kozłowski & Łodziński (1995) proposed a method of risk assessment in the problem of management of a system of storage reservoirs in Poland. The risk was estimated on the basis of probability distributions of inflows, conceptualized as a non-stationary Markovian chain. Kozłowski & Łodziński (1995) advocated that two indices related to risk, i.e. the probability of failure and the magnitude of loss should be considered in the decision making process.

Kundzewicz & Łaski (1995) reported on a subset of criteria of evaluation of performance of water supply systems, embracing different notions of reliability and related concepts. The analysis was presented for two case studies in Poland, for which system simulation for historical series of flows and hypothetical assessments of future water demands were performed. The criteria studied were related to frequency, duration, and severity of non-satisfactory system performance (reliability, resilience, vulnerability). Straightforward results and links between criteria are due to the application of the renewal theory, where exponential distribution of periods of nonsatisfactory and satisfactory system performance were assumed.

Bogardi & Verhoef (1995) analyzed a number of performance indices describing the operational behaviour of the multi-unit multipurpose reservoir system situated on the Mahaweli River, Sri Lanka. They formulated several conclusions on the relative importance of particular performance indices. It was shown, for example, that maximum vulnerability and frequency of failures are more important characteristics of municipal water supply systems than mean vulnerability or duration.

Sowinski & Yusuf (1995) addressed another problem of risk analysis in hydraulic engineering. They studied a composite risk model of the Ogee type spillway.

CONCLUSIONS

Uncertainty means lack of sureness about something (or somebody). It may range from the complete lack of definite knowledge (about facts, mechanisms, processes, results) to small doubts (falling short of certainty, imprecision). The very term of uncertainty has quite fuzzy borders.

Uncertainty is inherent in water resources research as observations, measurements, theories, assumptions, models, equations, predictions, estimators, parameters do not closely reproduce the reality. And sometimes no observations, measurements, theories and models exist at all.

It is shown in the present volume that the problems of uncertainty are by no means simple. Therefore much effort must be directed to this problem area. The importance of the topic can be illustrated by an excerpt of rare beauty, formulated by an ancient Chinese philosopher – Tsu, and quoted by Klir (1989): *Knowing ignorance is strength. Ignoring knowledge is sickness.*

The coverage of uncertainty problems in the book is by no means complete, nor uniform. Some areas are presented in detail, the others, though undoubtedly important, remain untouched.

The contributions gathered in this volume range from rigorous analytical developments, where under some simplifying assumptions a closed-form formula can be obtained, through mixed analytical-numerical approaches to numerical studies, where a large number of variants are calculated.

In all contributions quantitative methods, i.e. various classes of mathematical models are explored.

The apparent side effect of the Workshop was also putting different methods into perspective. It possibly helped assessing methodologies and answering the question whether the apparent attractivity of particular methods is based on permanent values or it is just a band-wagon effect and the methods are likely to pass as a short-lasting fashion.

As an example of promising methodologies the renewal theory can be mentioned. It is being increasingly applied in hydrology and water resources. This has been proved in the present volume in three distinct areas; i.e. precipitation totals; reliability properties of irrigation systems; and water supply systems by Jakubowski (1995), Tsakiris & Manoliadis (1995) and Kundzewicz & Łaski (1995), respectively.

The Workshop was primarily devoted to recent methods of representation of uncertainty in hydrology and water resources. This embraces newly introduced methods and approaches that, albeit not new, have raised considerable recent interest. In the menu of topics tackled at the Workshop were, among others, such diverse items as fractals, risk and reliability related criteria, fuzzy sets, pattern recognition, random fields, time series, outliers detection, non-parametric methods, etc.

Hydrologists claim to have mastered uncertainty. This statement may be relatively valid in the sense that hydrologists have always had to deal with uncertainty and they have developed some tools (e.g. flood frequency studies). The numbers for design (e.g. 100-years flood) are produced. The critical question may occur – how uncertain are these numbers? This rhymes with Klemes's rhetoric – unreliability of reliability estimates.

It is believed that the material presented in the Workshop and contained in the present volume is an important contribution to our knowledge of uncertainty in hydrology and water resources, showing us how to deal with uncertainty.

REFERENCES

Bardossy, A. (1995) Stochastic weather generator using atmospheric circulation patterns and its use to evaluate climate change effects, present volume.

Beck, M. B. (1983) Uncertainty, system identification and prediction of water quality. In: Beck, M. B. & van Straten, G. (Eds.), *Uncertainty and Forecasting in Water Quality*, Springer, Berlin.

Bernier, J. M. (1987) Elements of Bayesian analysis of uncertainty in hydrological reliability and risk models. In: Duckstein, L. & Plate, E. J. (Eds.), *Engineering Reliability and Risk in Water Resources, NATO ASI Series, Series E: Applied Sci.*, No. 124, Nijhoff, Dordrecht.

Bogardi, J. J. & Verhoef, A. (1995) Reliability analysis of reservoir operation, present volume.

Feluch, W. (1995) Nonparametric estimation of multivariate density and nonparametric regression, present volume.

Georgakakos, K. P. & Krajewski, W. F. (1995) Worth of radar data in real time prediction of areal rainfall, present volume.

Georgakakos, K. P., Sharifi, M. B. & Sturdevant, P. (1995) Analysis of fine increment point rainfall, present volume.

Gottschalk, L., Krasovskaia, I. & Kundzewicz, Z. W. (1995) Detection of outliers in flood data with geostatistics, present volume.

Gottschalk, L. & Kundzewicz, Z. W. (1995) Outliers in Norwegian flood data, present volume.

Guo Sheng Lian (1995) Non-parametric approach for design flood estimation with pre-gauging data and information, present volume.

Guo Sheng Lian (1995) New plotting position rule for flood records considering historical data and paleologic information, present volume.

Hornby, A. S. (1974) *Oxford Advanced Learner's Dictionary of Current English*, Oxford Univ. Press, Third Ed.

Hubert, P., Friggit, F. & Carbonnel, J. P. (1995) Multifractal structure of rainfall occurence in West Africa, present volume.

Jakubowski, W. (1995) The distribution of the l-day total precipitation amount – a renewal model, present volume.

Karbowski, A. (1995) Statistically safe sets methodology for optimal management of reservoirs in risk situations, present volume.

Kemblowski, M. W. & Jet-Chau Wen (1995) Dispersion in stratified soils with fractal permeability distribution, present volume.

Kindler, J. & Tyszewski, S. (1995) On the value of fuzzy concepts in hydrology and water resources management, present volume.

Klir, G. J. (1989) Methodological principles of uncertainty in inductive modelling: a new perspective. In Erickson, G. J. & Smith, C. R. (Eds.) *Maximum-Entropy and Bayesian Methods in Science and Engineering*, Vol I.

Konecny, F. & Nachtnebel, H. P. (1995) A daily streamflow model based on a jump-diffusion process, present volume.

Kotwicki, W. & Kundzewicz, Z. W. (1995) Hydrological uncertainty – floods of Lake Eyre, present volume.

Kowalski, K. (1995) Order and disorder in hydroclimatological processes, present volume.

Kozłowski, A. & Łodziński, A. (1995) The risk evaluation in water system control, present volume.

Krajewski, W. F. & Smith, J. A. (1995) Estimation of the mean field bias of radar rainfall estimates, present volume.

Krasovskaia, I. & Gottschalk, L. (1995) Analysis of regional drought characteristic with empirical orthogonal functions, present volume.

Kundzewicz, Z. W. & Łaski, A. (1995) Reliability-related criteria in water supply system studies, present volume.

Cambridge University Press
978-0-521-03673-3 - New Uncertainty Concepts in Hydrology and Water Resources
Edited by Zbigniew W. Kundzewicz
Excerpt
More information

Lovejoy, S. & Schertzer, D. (1995) Multifractals and rain, present volume.

Mandelbrot, B. B. (1977) *Fractal Geometry of Nature*, Freeman, New York.

Meyer, P. D., Eheart, J. W., Ranjithan, R. S. & Valocchi, A. J. (1995) Design of groundwater monitoring networks for landfills, present volume.

Mizumura, K. (1995) Application of fuzzy theory to snowmelt-runoff, present volume.

Mizumura, K. (1995) Application of pattern recognition to rainfall-runoff analysis, present volume.

Moss, M. E. (1995) Bayesian relative information measure – a tool for analyzing the outputs of general circulation models, present volume.

Napiórkowski, J. J. & Strupczewski, W. G. (1995) Towards the physical structure of river flow stochastic process, present volume.

Plate, E. J. (1995) Stochastic approach to non-point pollution of surface waters, present volume.

Plate, E. J. & Duckstein, L. (1987) Reliability in hydraulic design. In: Duckstein, L. & Plate E. J. (Eds.), *Engineering Reliability and Risk in Water Resources, NATO ASI Series, Series E: Applied Sci.*, No. 124, Nijhoff, Dordrecht.

Ranjithan, R. S., Eheart, J. W. & Garrett, J. H. Jr. (1995) Application of neural network in groundwater remediation under conditions of uncertainty, present volume.

Rasmussen, P. F. & Rosbjerg, D. (1995) Prediction uncertainty in seasonal partial duration series, present volume.

Romanowicz, R. J., Dooge, J. C. I. & O'Kane, P. (1995) The spatial variability of the evaporation from the land surface, present volume.

Sowiński, M. & Yusuf, M. I. (1995) Composite risk model of Ogee type spillway, present volume.

Strupczewski, W. G. & Mitosek, T. M. (1995) Some aspects of hydrological design under non-stationarity, present volume.

Tsakiris, G. & Manoliadis, O. (1995) Stochastic modelling of the operation of hydrants in an irrigation network, present volume.

Webster's Ninth New Collegiate Dictionary (1987) Merriam-Webster Inc., Springfield, Massachusetts, USA.

Węglarczyk, S. (1995) The influence of time discretization on inferred stochastic properties of point rainfall, present volume.

Zawadzki, I. (1995) Is rain fractal?, present volume.

Cambridge University Press
978-0-521-03673-3 - New Uncertainty Concepts in Hydrology and Water Resources
Edited by Zbigniew W. Kundzewicz
Excerpt
More information

II

Facets of uncertainty