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SPECIAL SECTION ON IMPROVING GREAT LAKES WATER LEVEL STATISTICS

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INTRODUCTION TO THE SPECIAL SECTION ON IMPROVING GREAT LAKES WATER LEVEL STATISTICS

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ABSTRACT. The water levels of the Great Lakes achieved record high levels in 1985 and 1986 followed by a significant decline in 1987 and 1988. Neither the rise nor decrease in levels were forecasted, leading to public demand for improved water level information to be used for planning and water resource management. The development of improved water level statistics must address the user's needs and should consider the physical aspect of the water fluctuations being modeled (annual fluctuations, seasonal fluctuations, storm rises, etc.), matching the type of statistic to the type of risk evaluation and the planning horizon. In order to develop new water level statistics, the experts must reach a consensus on the statistical model, incorporate conditionality, and properly adjust recorded data to reflect the existing hydraulic and hydrologic regimes. The effective use of the new statistics will depend upon the development of decision-making techniques for each interest and their communication to the user in non-technical terms.
INDEX WORDS: Lake level statistics, resource management, extreme events, frequency analysis, duration, decision making.

INTRODUCTION

The water levels of the Great Lakes achieved record high levels in 1985 and 1986 followed by a significant decline in 1987 and 1988. Neither the rise nor decrease in levels were forecasted, leading to public demand for improved water level information to be used for planning and water resource management (IJC 1989). This issue was addressed in a symposium on Great Lakes water level forecasting and statistics held in conjunction with the 1990 International Association for Great Lakes Research conference in Windsor, Ontario (Hartmann and Donahue 1990). A major thrust of the symposium was to explore innovative approaches for developing water level statistics that would best serve the wide range of user groups in the Great Lakes basin. The accompanying papers presented in this journal are from five authors who comprised a panel asked to address water level data analysis and interpretation. Subsequent to the symposium, the authors were requested to do additional analysis to develop a coherent set of papers describing the present state of knowledge of Great Lakes water level statistics. The rich variety of responses to this charge demonstrated that past analyses have not fully exploited the existing information contained within recorded Great Lakes water levels. Victor Privalsky and Geoffrey Kite approached the task from a time series analysis point of view. Lynn Herche and Holly Hartmann applied a variation of the "Bootstrap" technique, conditioned on initial starting elevation, planning horizon, and climatic regime. Ken Potter's work combined elements of these approaches by deriving statistics based on time series models of monthly mean levels and storm surges, conditioned on the planning horizon. The method of statistical analysis presented by Harold Kubik provided a method by which statistics could be derived for locations with a short period of record by incorporating information from longer records of other recorded lake levels. This report serves as an introduction to these papers, and summarizes the various aspects of developing improved water level statistics.

One of the recommendations which resulted from this panel's work was that a consensus among the experts be established regarding statistical methods, addressing such issues as methods, assumptions, data, and products (Reinartz 1990). Another recommendation was that the statistics be communicated in contexts understandable to the layman (Moulton 1990). Thus, these recommendations constitute two broad goals for improving Great Lakes water level information. To accomplish these goals, three questions remain to be addressed:

1) What statistics should be generated?
2) How should they be generated?
3) How should the statistics be used for decision making?

While these three questions appear to be obvious and rather simple, the issues and the answers required are more complex.

WHAT STATISTICS SHOULD BE GENERATED?

The answer to this first question should address explicit ways of recognizing users' needs. For example, shoreline property owners may be most interested in the frequency of instantaneous peak levels, since the resulting flooding or associated erosion could cause significant damages. A utility company designing a water intake may be concerned with the duration of specific extreme events, such as severe low levels. A large shoreline structure may be designed with a life span of 50 years or more, but water level fluctuations over a short initial period of time (6 months-2 years) may be critical to the financial success of a new marina. Therefore, the answer to this question must consider the physical aspect of water fluctuations being modeled (instantaneous maximums or minimums, seasonal fluctuations, annual fluctuations, storm rises, etc.), matching the type of statistic to the type of risk evaluation, and the planning horizon.

Since the ultimate goal is to improve the usefulness of water level statistics, alternatives to the traditional statistics using annual maxima and minima need to be investigated. From a planning perspective, the duration of the highs or lows may be more critical than a single occurrence of the extreme. Some examples of possible "alternative statistics" that may be more revealing to the decision maker include: distribution of time to exceedance of various levels, distribution of duration of exceedance of various levels, and distribution of number of occurrences of exceedance.

HOW SHOULD THESE STATISTICS BE GENERATED?

The answer to this second question must address the assumptions and technical procedures used in the development of the statistics. Some aspects of this question are outlined below.

Statistical Model Selection

While the desire to incorporate various aspects of water level fluctuations has resulted in a diversity of methods, an agreement should be reached as to which aspects can be successfully modeled, find the commonalities within the methods, and strive for "one" method. Assumptions, models, and verification should be clearly and explicitly presented.

Conditionality

Due to the lakes' large surface areas, relatively small outflow capacities, tremendous heat storage, and the basins' moisture storage capacities, their levels are highly serially correlated. The levels have well-defined seasonal cycles, and evidence suggests that specific climate regimes occur, resulting in persistent high or low level conditions. Therefore any statistics developed should explicitly consider the initial lake level for short planning horizons, the impact of the beginning season or month on expected probabilities of levels over a short planning horizon, and the impact of the climatic regime(s) expected to occur over the planning horizon on the expected probabilities of levels (Herche and Hartmann 1990).

Data Adjustments

The impacts of man on the Great Lakes hydraulic and hydrologic regimes, and crustal movement over the Great Lakes basin, are reflected in the recorded Great Lakes water levels. The data must be adjusted to reflect present conditions for meaningful statistics. Other factors such as different period of records from gage to gage, and gage location must also be considered. Specifically, data must be adjusted for impacts of diversions, changes in connecting channel hydraulics, lake outflow regulation, crustal movement, consumptive use, different periods of record, and site location.

Credibility

The results should be clear, understandable, and explainable to the users for whom the statistics are intended. O'Grady and Shabman (1990) indicate that the users' trust (or lack of) in the source may be the most significant factor in the communication of lake level information and its incorporation in decision making.

HOW SHOULD THE GENERATED STATISTICS BE USED?

The answer to the third question must address how the engineer, resource manager, shore property owner, etc. can use the statistics. Decision-making techniques, perhaps based on risk concepts, must be explored. This information must be conveyed in non-technical terms, as well as technical terms, as required by each user. The mechanisms for communicating this information must also be established.

Finding the answers to these questions will indeed be a challenge. However, the papers presented here and those included in the symposium proceedings (Hartmann and Donahue 1990) have prepared the backdrop for future work.

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