Climate Variability and Uncertainty in Flood Hazard Planning in Colorado

Extended Abstract
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Background and Project Goals

Extreme storms create serious flood hazards in Colorado, making flood risk an important aspect of state and local planning. Flood probabilities derived from historical flood and precipitation frequency information are used in developing floodplain maps, determining flood insurance rates, and designing storm drainage systems, flood control structures, roads, and bridges. However, in areas of steep topography such as Colorado, estimates of local flood probabilities are highly uncertain because of the sparsity of data and the high spatial and temporal variability in precipitation. Recent multidisciplinary research has raised serious questions about the accuracy of precipitation frequency estimates currently used for flood hazard planning in Colorado and other Rocky Mountain states.

This project focuses on the uncertainty in analyses of flood and precipitation frequency in Colorado. A primary goal is to find ways of improving estimates of annual exceedance probabilities and confidence intervals for the extreme warm season rainfall that causes severe floods in the Colorado Front Range (CFR). To be useful, the information must be accepted within the regulatory process and tailored to the needs of policy makers, floodplain managers, and technical experts. Therefore the project has two major components: (1) to learn how scientific information and uncertainty are incorporated into flood-related decision making and regulation, and (2) to develop improved methods of estimating precipitation frequencies through meteorological analysis and use of extreme value statistics.

Current Participants

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Description

Flood hazards result from combined effects of local climate, topography and land uses, therefore decisions and actions to reduce flood damage must be made at the local level. However, in the U.S. much of the impetus for flood hazard mitigation has come from the federal level, stimulated by a desire to curb the enormous federal expenditures for disaster assistance. This has resulted in a complex system of floodplain management, in which responsibilities are divided between federal, state, and local governments. Regulatory policies are established by the Federal Emergency Management Agency (FEMA), subject to requirements of the National Flood Insurance Program. FEMA relies on other federal agencies for much of the necessary scientific data and methods; thus, approved methods of hydrologic analysis are determined primarily at the federal level.

To understand how scientific information is obtained and used and attitudes about the available information, we conducted semi-structured interviews and discussions with floodplain managers, agency personnel, engineers, and scientists. Further insights were derived from attendance at meetings of the Association of State Flood Plain Managers (ASFPM) and the Colorado Association of Stormwater and Floodplain Managers (CASFM). We also reviewed federal and state guidelines for flood hazard management and local flood studies.

For ungaged streams and urban watersheds, floodplain maps often are constructed using a "design rainfall" standard, usually the estimated 100-year (or 1% annual chance) precipitation. The design rainfall is entered into a rainfall-runoff model to generate estimates of the “design flood” discharge.

Precipitation uncertainty is only one of many physical and economic uncertainties affecting the accuracy of floodplain maps. Currently, it is common practice to allow for uncertainties by building a “margin of safety” into regulations and design of flood control structures by applying somewhat arbitrary safety factors or freeboard requirements. Recently, the Army Corps of Engineers has moved to “risk-based analysis” techniques, which incorporate estimates of uncertainty, and has eliminated freeboard requirements. Effective use of the risk-based approach requires that all major sources of uncertainty be identified and estimates of uncertainty provided.

We have identified several areas in which improvements in precipitation information and the representation of uncertainty are needed:

(1) The NOAA Precipitation Frequency Atlas for Colorado (Atlas 2), published in 1973, is the main source of precipitation frequency information for Colorado. It is based on very limited data (mainly 1949-70). Approximately 30 years of additional data are now available. The NWS has recently developed new atlases (entitled Atlas 14) for parts of the U.S., which include estimates of uncertainty. Unfortunately, the NWS has been unable to find funding to update the atlases for the Rocky Mountain region. An updated atlas is greatly needed in Colorado.

(2) A large proportion of U.S. floodplain maps are over 10 years old and no longer provide an adequate representation of flood risk. FEMA is now attempting to remedy this through the Map Modernization Program initiated in 2003. The program focuses on upgrading representations of land use and topography, and converting floodplain maps to digital form. Restudies of hydrology are not encouraged except in special circumstances. In Colorado, older floodplain maps were based on very limited precipitation and streamflow data, and flood frequency estimates have been disputed in a number of locations. Restudies of hydrology are needed using improved data sets and analysis methods.

(3) Hydrologic studies (particularly those based on rainfall-runoff models) often require expert judgment. Experts sometimes disagree, and techniques are needed to estimate the associated judgment-based uncertainty.

As a result of the identified need for improved precipitation frequency atlases in mountainous areas, scientists in the Assessment Initiative (from the Geophysical Statistics Project) are currently developing methods for spatial analysis of daily and hourly precipitation data using methods of extreme value statistics. Estimation of the uncertainty in calculations of precipitation frequency and return level is a particular focus. A goal is to develop prototype methods that could assist the NWS in developing a new precipitation frequency atlas for the Rocky Mountain region. We expect that this work will provide a basis for further study in FY05 of local climate factors that influence severe flooding in Colorado.

Project results

The following papers are currently in preparation:

(1) "Flood risk, uncertainty, and scientific information for decision-making: Lessons from an interdisciplinary project", by R.E. Morss, O.V. Wilhelmi, M.W. Downton, and E. Gruntfest, recently submitted to *AMS Bulletin*. (See Appendix.)

(2) "Flood-related decisions and scientific uncertainty: Estimates of extreme precipitation in Colorado", by M.W. Downton, R.E. Morss, O.V. Wilhelmi, E. Gruntfest, and M. Crandell, for submission to *Environmental Hazards*.

Mary Downton gave presentations about the project at the Colorado Association of Stormwater and Floodplain Managers (CASFM) conference in September 2002 and at the American Meteorological Society conference in February 2003. The latter presentation, "Problems of climate variability and uncertainty in flood hazard planning for the Colorado Front Range", is available at http://www.assessment.ucar.edu/new/flood/research.html.

The project website (http://www.assessment.ucar.edu/new/flood/index.html) includes descriptions of Colorado floods and flood damage, maps, photographs, and links to sources of additional data on Colorado climate and floods. Future plans include expanding the website as a repository for Colorado precipitation data.