ENCYCLOPEDIA OF EARTH SCIENCES SERIES

# ENCYCLOPEDIA *of* NATURAL HAZARDS

*edited by*

**PETER T. BOBROWSKY**
*Simon Fraser University*
*Canada*

Springer Reference

# Encyclopedia of Earth Sciences Series

## ENCYCLOPEDIA OF NATURAL HAZARDS

### Volume Editor

Peter Bobrowsky is an Adjunct Professor at the Center for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada (ptbobrow@sfu.ca). With over 30 years of professional experience as an environmental and engineering geologist he has worked in Africa, China, India, North America, Middle East and South America. He has published extensively on a variety of subjects and has served/serves on a number of bodies and organizations: Secretary General of IUGS, President of the Geological Association of Canada, President of the Canadian Quaternary Association, Vice President of the International Consortium on Landslides, editorial board for Landslides Quaternary International and several others. The project to compile and publish this volume was completed during his tenure as SG of IUGS.

### Editorial Board



### Aims of the Series

The *Encyclopedia of Earth Sciences Series* provides comprehensive and authoritative coverage of all the main areas in the Earth Sciences. Each volume comprises a focused and carefully chosen collection of contributions from leading names in the subject, with copious illustrations and reference lists.

These books represent one of the world's leading resources for the Earth Sciences community. Previous volumes are being updated and new works published so that the volumes will continue to be essential reading for all professional earth scientists, geologists, geophysicists, climatologists, and oceanographers as well as for teachers and students. See the back of this volume for a current list of titles in the *Encyclopedia of Earth Sciences Series*. Go to http://www.springerlink.com/reference-works/ to visit the "Earth Sciences Series" online.

### About the Series Editor

Professor Charles W. Finkl has edited and/or contributed to more than eight volumes in the Encyclopedia of Earth Sciences Series. For the past 28 years he has been the Executive Director of the Coastal Education & Research Foundation and Editor-in-Chief of the international *Journal of Coastal Research*. In addition to these duties, he is Professor Emeritus at Florida Atlantic University in Boca Raton, Florida, USA. He is a graduate of the University of Western Australia (Perth) and previously worked for a wholly owned Australian subsidiary of the International Nickel Company of Canada (INCO). During his career, he acquired field experience in Australia; the Caribbean; South America; SW Pacific islands; southern Africa; Western Europe; and the Pacific Northwest, Midwest, and Southeast USA.

### Founding Series Editor

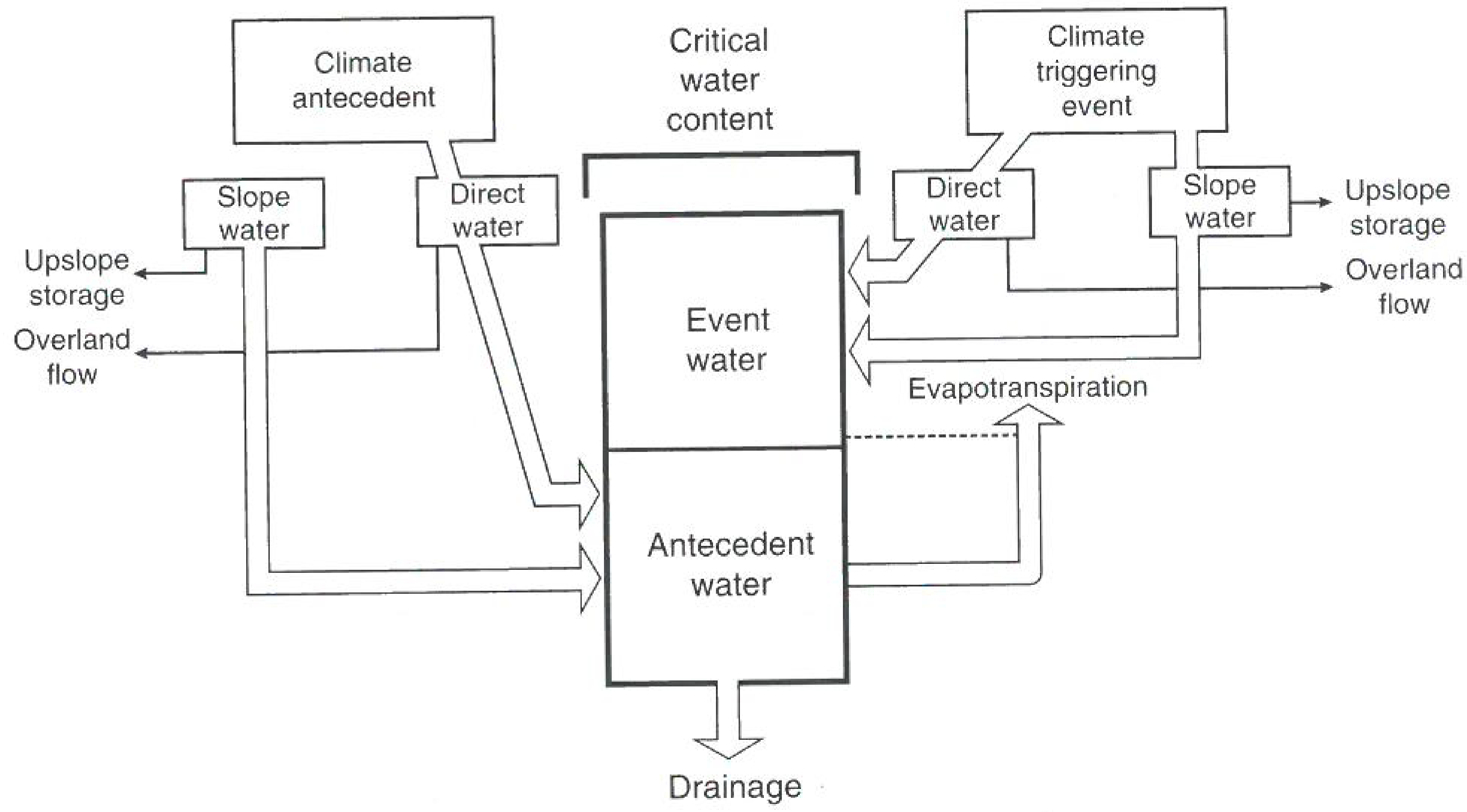
Professor Rhodes W. Fairbridge (deceased) has edited more than 24 Encyclopedias in the Earth Sciences Series. During his career he has worked as a petroleum geologist in the Middle East, been a WW II intelligence officer in the SW Pacific and led expeditions to the Sahara, Arctic Canada, Arctic Scandinavia, Brazil and New Guinea. He was Emeritus Professor of Geology at Columbia University and was affiliated with the Goddard Institute for Space Studies.

## ANTECEDENT CONDITIONS

Michael James Crozier[1], Nick Preston[1], Thomas Glade[2]
[1]Victoria University of Wellington, Wellington, New Zealand
[2]University of Vienna, Vienna, Austria

### Synonyms

Preceding event




**Antecedent Conditions, Figure 1** Conceptual climatic-hydrological model for shallow rainfall-triggered landslides.

## Definition

Antecedent conditions represent a temporary state within dynamic natural and social systems that precedes and influences the onset and magnitude of a hazard and its consequences. They are distinct from, but influenced by, what are commonly referred to as preconditions (preexisting conditions). Preconditions are generally static or slow changing and influence the inherent (as opposed to temporary) susceptibility of an area. For example, in natural systems, rock type, soil structure, and topographic geometry are common preconditions that affect susceptibility to landslide occurrence, whereas groundwater level, soil moisture content, and under certain circumstances, vegetation cover are dynamic factors representing influential antecedent conditions for landsliding. In social systems, coping capacities such as the presence of emergency response organizations or availability of insurance schemes are preconditions whereas time of occurrence (e.g., day/night; workday/weekend; holiday, etc.) is a dynamic factor strongly influencing the consequences of a triggering event.

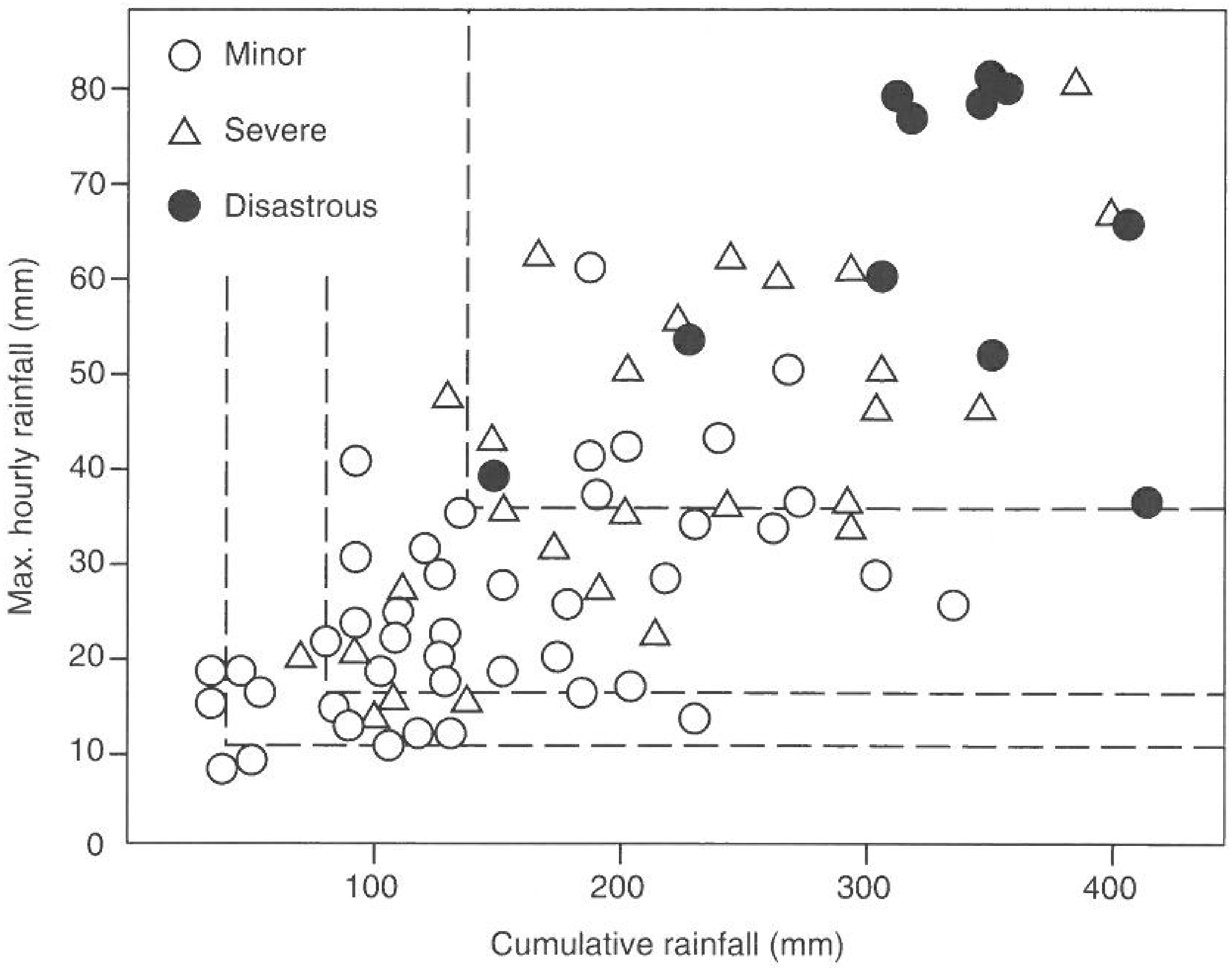
Examples of antecedent conditions for specific hazards include tidal phase (tsunami and storm surge), vegetation moisture levels (forest fire), humidity (heat waves), groundwater level (liquefaction and flooding), wind direction and strength (volcanic eruption), temperature and freeze/thaw history of snow packs (snow avalanching), and amount of debris accumulated in source areas (debris flow). Antecedent conditions can also be represented by hazard history. For instance, forest fires can induce hydrophobic conditions in soils that favor the development of debris flows during heavy rainfall, and foreshocks may weaken natural and man-made structures causing amplified damage in subsequent earthquakes.

An example of rainfall-triggered landslides illustrates the rationale and methods for assessing antecedent conditions. Antecedent conditions are represented in this case by the *antecedent soil water* (water accumulated in the slope over a period preceding landslide occurrence) which, along with *event water* (water accumulated on the day of landslide occurrence), forms the *critical water content* (CWC) within a slope, that is, the amount of water required to initiate landslide movement (Figure 1). Rainfall thresholds for landslide initiation established by historical observation essentially represent an approximation of the CWC (Crozier, 1989; Glade et al., 2000; Guzzetti et al., 2008). In a location where CWC for landsliding is known, real-time monitoring of the antecedent soil water, allows a continuous estimate of the amount of event water required to reach critical conditions. This in turn has been used to derive a probability of landslide occurrence based on frequency–magnitude distributions of rainfall conditions derived from the historical climate record (Crozier, 1999).

Water within the slope reduces stability by either decreasing cohesion or increasing buoyancy through the development of positive porewater pressures, to the point where strength of slope material is lowered below the prevailing shear stress and consequently failure occurs.

In practical terms, the *event water* component of the CWC can be represented by some parameter of rainfall at the time of landslide occurrence whereas *antecedent soil water* is represented by the *antecedent soil water status*. The value of the *antecedent soil water status* can be determined at any one point in time given knowledge of past precipitation and evapotranspiration rates, the regolith storage capacity (porosity and depth), and the drainage rate of *excess precipitation* (i.e., rainfall in excess of storage and evapotranspiration requirements).

In short, the *antecedent soil water status* is an index of the water content of the soil based on the climatic water balance, and provides a scale with negative values




**Antecedent Conditions, Figure 2** Landslide event thresholds defined by intensity and 2-day antecedent rainfall, Korea (Source Kim et al., 1992).

representing soil storage below field capacity, held in the form of capillary or hygroscopic water, and positive values representing gravitational water that accumulates as groundwater in certain slope locations (Crozier, 1999).

Landsliding is usually (but not always) associated with positive values of the *antecedent soil water status index* calculated from *excess rainfall,* that is, rainfall exceeding potential evapotranspiration and soil storage requirements.

In the calculation of the *antecedent soil water status index* (Crozier, 1999), *excess rainfall* is decayed on a daily basis and accumulated over a given period (often about 10 days) to represent antecedent excess rainfall values. These constitute the positive values of the *antecedent soil water status index.*

$$\mathrm{EPa}_0 = k\mathrm{EP}_1 + k^2\mathrm{EP}_2 + \cdots + k^n\mathrm{EP}^n$$

where $\mathrm{EPa}_0$ = antecedent excess rainfall on day 0 (mm), $\mathrm{EP}^n$ = excess rainfall on the nth day before day 0 (mm), and $k$ = constant decay factor.

The decay factor represents the rate of drainage from the soil and in some cases can be determined from the exponential decline of the recessional limb of flood hydrographs for streams within the locality under study (Glade et al., 2000). The use of stream hydrographs to indicate antecedent water status assumes that flow regimes have not been artificially modified by structures such as reservoirs or other drainage works.

Kim et al. (1992) (Figure 2), Glade (2000), and Garland and Olivier (1993) have demonstrated that, in certain regions, antecedent conditions have a major influence on the initiation of landslides, whereas in other regions, storm event characteristics appear to dominate (Caine, 1980; Wilson and Wieczorek, 1995). Similar findings for debris flows have been summarized by Wieczorek and Glade (2005).

Although critical preconditions and triggering factors can be established for a number of different hazards, the temporal variability of antecedent conditions provides a significant level of uncertainty to hazard assessments. The investigation of antecedent conditions is a critical component for both the prediction and explanation of hazard occurrence.

## Bibliography

Caine, N., 1980. The rainfall intensity-duration control of shallow landslides and debris flows. *Geografiska Annaler*, **62A**(1–2), 23–27.

Crozier, M. J., 1989. *Landslides: Causes, Consequences and Environment*. London: Routledge.

Crozier, M. J., 1999. Prediction of climatically-triggered landslides – a test of the antecedent water status model. *Earth Surface Processes and Landforms*, **24**(9), 825–833.

Garland, G. G., and Olivier, M. J., 1993. Predicting landslides from rainfall in a humid sub-tropical region. *Geomorphology*, **8**(2–3), 165–174.

Glade, T., 2000. Modelling landslide-triggering rainfalls in different regions in New Zealand – the soil water status model. *Zeitschrift für Geomorphologie*, **122**, 63–84.

Glade, T., Crozier, M. J., and Smith, P., 2000. Establishing landslide-triggering rainfall thresholds using an empirical antecedent daily rainfall model. *Journal of Pure and Applied Geophysics*, **157**, 1059–1079.

Guzzetti, F., Peruccacci, S., Rossi, M., and Stark, C. P., 2008. The rainfall intensity-duration control of shallow landslides and debris flows: an update. *Landslides*, **5**(1), 3–18.

Kim, S. K., Hong, W. P., and Kim, Y. M., 1992. Prediction of rainfall-triggered landslides in Korea. In Bell, D. H. (ed.), *Landslides*. Rotterdam: Balkema, Vol. 2, pp. 989–994.

Wieczorek, G. F., and Glade, T., 2005. Climatic factors influencing triggering of debris flows. In Jakob, M., and Hungr, O. (eds.), *Debris flow hazards and related phenomena*. Heidelberg: Springer, pp. 325–362.

Wilson, R. C., and Wieczorek, G. F., 1995. Rainfall thresholds for the initiation of debris flows at La Honda, California. *Environmental and Engineering Geoscience*, **1**(1), 11–27.

## Cross-references

Early Warning Systems
Exposure to Natural Disasters
Hazards
Uncertainty
Vulnerability