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A probabilistic model of sediment delivery risk using joint density functions

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Abstract: Water resource managers are often concerned about the *risk* of particular constituents exceeding some threshold concentration within the hydrologic system. For example, treatment and supply infrastructure typically have threshold concentrations above which systems become inoperable. Aquatic ecological systems may also have thresholds, beyond which the state of the system shifts to some new state. Typical questions include "What is the probability the sediment delivery rate will exceed *x* for more than *t* period of time?" or "How much has the chance of exceeding a threshold sediment delivery rate *x* been increased by my land management action ?" However water quality models are rarely able to provide this kind of probabilistic output, except via resource intensive numerical modeling at fine temporal scales. In this paper we explore a new probabilistic approach to this problem via the use of transfer functions between joint input random variables based on rainfall intensity-duration distributions, and the joint output random variables of sediment delivery rate and duration.

In this analysis the arrival of discrete erosion events is viewed as a time-homogeneous Poisson process. In many systems erosion events (periods of relatively high stream sediment delivery) arrive as discrete events, interspersed with periods of non-flow, or baseflow that is characterized by a low sediment delivery rate. Examples include storm-driven water quality events in temperate forests following fire, and runoff events from unsealed roads into forest streams. The sediment delivery rate X and event duration Y for each event *i* are treated as independent and identically distributed random vectors. Each event can be visualized as a non-overlapping rectangular "pulse" along a time-line, with the horizontal dimensions of the rectangle representing the event duration, and the vertical dimension representing the time-averaged event delivery rate.

Rainfall variability in time can also be represented in a similar manner, with the storm visualized as a non-overlapping rectangular "pulse" along a time-line, with the horizontal dimensions of the rectangle representing the event duration, and the vertical dimension representing the time-averaged event delivery rate. This representation is often used in rainfall frequency analysis. The challenge then is to define and parameterize a suitable analytical transfer function for the system (ie catchment) in question to operate on the input rainfall joint density function , and convert it into the output water quality joint density function.

The joint density transfer function approach was evaluated using field rainfall and erosion data collected at two different scales. At the small catchment scale we analysed data from 3 post-fire years from two (136 & 244 ha) steep *Eucalyptus sp*. forested SE Australian catchments. Analysis of the 596 defined erosion events confirmed that the event inter-arrival times were exponentially distributed (with rate λ= 0.26), supporting the application of a Poisson process. Event durations were log-normally distributed with parameters μ=2.2 and σ^2=0.44, while the distribution for the sediment delivery rate for the event varied as a continuous function of the event duration. At the hillslope scale 10 plot years of data was collected from road segments 100-200 m long and is currently being analysed.

This new analytic probabilistic approach to water quality risk shows considerable promise as a practical planning-level water quality management prediction tool because the input-joint density functions are easily available, while the probabilistic outputs satisfy a management need that is currently poorly serviced by existing modeling approaches.

Keywords: *probabilistic, erosion, water quality, Australia, model*

Abstract only