Abstract

CASC2D is a two-dimensional, physically-based, event watershed model that can simulate rainfall, runoff and sediment transport. Researchers at Colorado State University and the Bureau of Reclamation have added several features and made modifications in order to apply the model for two different problems: extreme floods for dam safety on large watersheds (>1,000 km²); and chemical transport at the watershed scale to assess the impact of wastes from inactive and abandoned mine (IAM) sites. To meet this need, the Two-Dimensional, Runoff, Erosion, and Export (TREX) watershed model was developed based on CASC2D and the WASP/IPX series of water quality models. New channel automation tools have been developed so that TREX can be applied to large watersheds. Floodplain interaction, upland soils and channel sediment layering, channel bed erosion, and chemical fate and transport routines are added to the model. A new storm model is coupled with stochastic storm transposition, so that TREX can be used for flood frequency analysis. One feature of the model is its ability to track the movement of particles from upland sources to downstream areas. Model results can be used to assess the contribution of individual contaminated areas (waste piles) to overall site impairments. Such information is useful to establish cleanup priorities and provide an improved understanding and illustration of metals transport and fate in mine waste impacted streams.

The model and results are demonstrated for two case studies: estimating extreme floods and flood frequency curves for dam safety on the 12,000 km² Arkansas River watershed above Pueblo, Colorado; and metals transport from the historical mine waste site California Gulch, a 30 km² watershed near Leadville, Colorado. The TREX model provides a unique physically-based method for determining flood frequency curves under varied scenarios of antecedent moisture conditions, space and time variability of rainfall and watershed characteristics, and storm center locations. It can now be used to assess the impact of wastes from inactive and abandoned mine sites.

TREX: Two-Dimensional Runoff Erosion and Export Model

TREX: a Spatially Distributed Model to Assess Watershed Hydrology, Sediment Transport, and Contaminant Transport and Fate

Model Development

The starting point for TREX development was CASC2D (Julien and Saghaian, 1991). The basic framework is an event-based model that simulates overland flow, surface soil erosion and deposition, channel flow and sediment transport through stream channels. As part of TREX development, the hydrologic and sediment transport components of CASC2D were significantly expanded and enhanced to support addition of chemical transport features. Chemical transport and fate components were formulated based on those in the USEPA WASP/IPX series of stream water quality models (Velleux et al. 2001) to create a fully distributed model to simulate chemical transport and fate at the watershed scale. Conceptual diagrams of chemical model processes and model hierarchy are presented below. Model input and output requires a GIS.

Modeled Processes

Hydrologic Processes:
1. rainfall, interception, surface storage; and
2. overland and channel flow.

Sediment Transport Processes:
1. advection and dispersion; and
2. erosion and deposition; and
3. bed elevation adjustment.

Chemical Transport and Fate Processes:
1. chemical partitioning and phase distribution; and
2. advection-diffusion; and
3. erosion and deposition;
4. infiltration and transmission loss; and
5. mass transfer and transformation processes.

Model state variables are water depth in the overland plane and stream channels. Rainfall can be uniform or distributed in both time and space. When spatially distributed rainfall is simulated, areal rainfall estimates are interpolated from point rain gage data using an inverse distance weighting approach. Interception and surface storage are simulated as equivalent depths. All processes occur in both the overland plane and stream channels. Any number of particle sizes and chemicals can be simulated. Advection is computed from flow and concentration. Erosion and deposition rates are calculated as a function of the hydraulic properties of the flow, the physical properties of the soils and sediments such as particle grain size and surface characteristics such as slope. Partitioning can be simulated on a concentration or organic carbon normalized basis.

Extreme Floods

Arkansas River at Pueblo, CO (12,000 km²)

- Pueblo Dam overtopping risk
- Snowmelt runoff upstream
- Extreme rainstorms downstream – June 1921
- TREX flood frequency
- Stochastic Storm Transposition
- Comparison with paleoflood data

Metals Transport

California Gulch near Leadville, CO (30 km²)

- Historical mining district
- Mining, ore milling, and smelting
- Extensive contamination by mine wastes
- Includes waste rock, tailings, and slag
- Metals of concern: Cu, Cd, and Zn