River Engineering and Stream Restoration IIa- Watersheds

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Objectives

Brief overview of River Engineering and Stream Restoration with focus on:

1. Watershed Processes;
2. Sediment Yield;
3. Watershed Modeling.

Upper Basin: high-elevation snowpack; snowmelt runoff
Diverse Topography: highest mountains in Colorado - Elbert, Massive, Harvard, etc.
Objectives

1. Extend the applicability of the Model CASC2D-SED for simulating fate and transport of sediment and metals in surface waters

2. Field applications at the EPA Superfund site at California Gulch

Abandoned Mines, Mine Wastes, and Environmental Impacts

Impacts from wastes at inactive and abandoned mine (IAM) sites are widespread. Across the western US, contaminants from IAMs affect (USEPA, 1996):

1. More than 100,000 IAM sites;
2. More than 500,000 acres of land;
3. Thousands of miles of streams and surface waters.

Thousands of waste piles may be present at a single IAM site.
California Gulch - Historical mining site

Approximately 2000 waste piles across the site.

CASC2D-SED Modeling 2004

CASC2D-SED

- **Water**
  1. Rainfall
  2. Infiltration
  3. Overland and Channel Flow

- **Sediment**
  1. Upland Erosion and Deposition
  2. Channel Processes
  3. Sediment yield

- **Metals**
  1. Transport and Fate
  2. Phase Distribution
  3. Toxicity Levels
California Gulch Watershed

- EPA Superfund Site
- Location: Lake County (CO)
- Area: 30.6 km²
- 100-year flood: 2-h: 1.73 in

Input Data (DEM)

Digital Elevation Model

1. Channel Network
2. Terrain Slopes
Input data (soil type)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Soil Index</th>
<th>Bulk Density (g/cm³)</th>
<th>Bulk Density (mg/L)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>EC (mS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt Loam</td>
<td>1</td>
<td>1.25</td>
<td>1.35</td>
<td>0.25</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Loam</td>
<td>2</td>
<td>1.2</td>
<td>1.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
<td>1.1</td>
<td>1.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Calcareous</td>
<td>4</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Land Use Data

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Land Use Index</th>
<th>Manning n</th>
<th>Interception</th>
<th>C (DUF)</th>
<th>D (DUF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>1</td>
<td>0.25</td>
<td>0.25</td>
<td>0.005</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>2</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cultivated</td>
<td>3</td>
<td>0.1</td>
<td>0.8</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Pasture</td>
<td>4</td>
<td>0.2</td>
<td>1</td>
<td>0.09</td>
<td>2</td>
</tr>
</tbody>
</table>

Input data (land use)
Input data (rainfall)

10/17/81 event:
Duration: 3.5 hr.
Depth: 73 mm.

CASC2D-SED: Water Components

- Hortonian Runoff (infiltration excess)
- Rainfall: Raingages or Radar Data
- Interception, Surface Depression Storage
- Green/Ampt Infiltration
- 2-D Diffusive Wave Overland Flow Routing
- 1-D Diffusive Wave Channel Routing

Model Output:

- Infiltration
- Runoff
CASC2D-SED Hydrographs

- Observed
- Simulated

Erosion and Sediment Transport

... and Deposition
**Sediment Routing**

![Sediment Routing Diagram]

**Upland Erosion (2-D)**

Modified Kilinc and Richardson equation for sheet and rill erosion:

\[
q_s (\text{tons/m}^2\text{s}) = 23210 S^{1.66} W^{2.015} \left( \frac{Q}{W} \right)^{0.15} \]

**Sediment Modeling**

![Sediment Modeling Diagram]
Transport and Fate of Metals

AR3 (@ Confluence)

Metal Routing
Total Zinc, Copper and Cadmium

Available material

Advection
Re-suspension

Metal concentration within parent material

Outgoing Cell
Re-suspension

Suspension
Deposition
Parent material

Receiving Cell

Metal concentration

Settling

Receiving Cell

Model output in space and time

AVIRIS image reclassified to 7 minerals (Swayze et al., 2000)

ACIDC
High Lethality

NEUTRAL
Low Lethality

Pyro
Low pH water
Ankole
Ankole + Blackfield Acidics
Gravel
Inhibit 1
Inhibit 2

10
Chemical Transport and Fate

- The phase of a chemical determines its fate.
- Dissolved and bound chemicals follow water.
- Particulate chemicals follow sediments.
- Chemicals can change phase as environmental conditions change (pH, temperature, etc.)

- A chemical transport and fate module and other features are being added to CASC2D to permit analysis of mine waste transport across watersheds.

Metal Partitioning

Due to partitioning, metals mobilized in one phase may be transported in a different phase.

Include the effects of TSS, sediment/clay, pH, hardness, etc.

Example: Partitioning of Copper

Metal phase affects remediation strategy:
- Particulate -> revegetation/detention
- Dissolved -> capping
Model Output Example: Zinc Deposition

Metal Toxicity

Cumulative Criterion Unit (CCU)

\[ CCU = \sum_{i=1}^{N_{metals}} \frac{m_i}{C_i} \]

Where:
- \( m_i \) = measured concentration of the \( i^{th} \) metal
- \( C_i \) = toxic concentration for the \( i^{th} \) metal
Biodiversity Index (Clements 2002)

Relationship between metal levels and macroinvertebrate communities

Modeling Metal Toxicity

Maximum Toxicity
Contributions from different sources

Contribution at Outlet

Zone A
Zone B
Zone C
Other

Metals from Several Watersheds

Contribution at Downstream Reach

Gulch A
Gulch B
Gulch C
Gulch D

Conclusions

1. Tremendous developments in computer modeling of fate and transport of sediment and metals in surface waters.

2. Direct applications at the EPA Superfund site at California Gulch.
CASC2D-SED Web Page

- At Colorado State University
- Under direction of Dr. Pierre Julien

pierre@engr.colostate.edu

- Current manual, source code, example, MPEG movies

http://www.engr.colostate.edu/%7epierre/ce_old/projects/casc2d-Rosalia/index.htm

Thank You

Any Questions?
Pueblo Radar:
July 13, 2001 Storm

Arkansas River DEM
12,137 km² (4,686 mi²) watershed
High Relief: 2,800 m (9,200 ft)
lower slopes, exposed open watershed
downstream of Canon City