KINEROS2
A DISTRIBUTED KINEMATIC RUNOFF AND EROSION MODEL

USDA-ARS Southwest Watershed Research Center, Tucson, AZ
OVERVIEW

• Background
• Model Features
• Sensitivity
• Flood Forecasting
• Model Limitations
• Conclusions
Kinematic Runoff and Erosion Model (KINEROS2)

- Event-based (< minute time steps)
- Distributed: physically-based model with dynamic routing – both for overland flow and erosion
- Has been used in urban environments
- Hydrology, erosion, sediment transport (plus N&P with OPUS version)
- Usually applied to smaller watersheds (< 100-200 km²)
K2 FEATURES

- Approx. watershed by cascade of overland flow elements, channels, impoundments
- Space-time rainfall intensity interpolation
K2 Model Element Types

- Overland Flow Element
  - Planar or curvilinear
  - Multiple - cascading

- Channel - Trapezoidal
  - Simple or compound

- Urban Element
  - Flow & Channel (1/2 street)

- Pond Element
  - Geometry +
  - Outflow rating

- Injection Element
  - Introduce a known discharge
Representative Slope Profile and Flow Length

\[ S_i = \frac{\sum_{p=1}^{n} s_{pi} \cdot k_p}{\sum_{p=1}^{n} k_p}, \quad k_p = a_p \cdot l_p \]

- Calculate a weight grid for every cell on the hillslope
- Calculate a weighted slope for each cell - \( S_i \)

\[ L_r = \frac{\sum_{p=1}^{n} l_p \cdot a_p}{\sum_{p=1}^{n} a_p} \]

- Calculate a weighted length for each flow path
- \( L_r \) is the representative flow length

(Flanagan et al. 2011)
Hillslope profiles from DEM at NRI point

- Hillslope profile based on ArcGIS through NRI plot
  - Flow Length = 45 m

- Profile based on the weighted flow length method
  (Flanagan et al. 2011)

- Representative profile
  - Representative Flow Length = 75 m

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Tucson - Tombstone, AZ
K2 Model Element Types (Cont.)

- Diversion Element - allows simulation of wetlands
  - Modify channel length to represent sinuosity
  - Modify channel width as surrogate for braided channels
  - Modify channel slope to affect stream energy
  - Modify channel roughness to affect stream velocity
  - Modify channel KS to increase infiltration capacity
Flexible Element Configurations

Walnut Gulch Subwatershed No. 11 showing the watershed boundary and primary channel network (the pond catchment is a noncontributing area).

The minimum representation required to support the channel network.

Model system consisting of rectangular overland flow planes contributing to a network of trapezoidal open channel segments.
Interactive Infiltration

- Coupled Infiltration – Routing (Runoff – Runon)
Spatial Variability of Infiltration

- Small scale spatial variability of infiltration represented in distribution sense and parameterized for numerical efficiently
- Microtopography represented

![Graphs showing infiltration rate and relative surface coverage](image-url)
Two Layer Infiltration

- Infiltration with two-layer soil profile
- Soil moisture re-distribution during storm hiatus
Compound Channel Routing

- Compound channel routing with distinct main and overbank channel infiltration
Urban Element

• Simplifies urban modeling

• Is an abstraction representing contributing areas along one side of a street, and one half of the street itself
**Erosion – Sediment Transport**

- Multiple particle class size sediment routing (non-interactive)
- Entrainment by rainsdrop impact and hydraulic shear
- WEPP and RHEM (stream power) erosion models are also being incorporated
KINEROS2 Parameters

- Geometric (position, length, slope, width)
  - From DEM and watershed discretization
- Hydraulic Roughness, microtopo, and interception
  - From soils and cover (literature)
- Infiltration (Ksat, porosity, suction term, rock, residual and maximum fillable porosity)
  - Soils data modified by cover (literature and experimental data)
- Erosion Parameters (splash, cohesion, pave, sediment fractions)
  - Soils data (literature and experimental data)
- Channel Parameters (and culverts)
- Pond/Detentions Structures
- Urban Elements
### Parameters based on soil texture

<table>
<thead>
<tr>
<th>Texture</th>
<th>Ksat</th>
<th>Suction</th>
<th>Porosity</th>
<th>Smax</th>
<th>CV</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Dist</th>
<th>Kff</th>
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<tbody>
<tr>
<td>Clay</td>
<td>0.6</td>
<td>407.0</td>
<td>0.475</td>
<td>0.81</td>
<td>0.50</td>
<td>27</td>
<td>23</td>
<td>50</td>
<td>0.16</td>
<td>0.34</td>
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<tr>
<td>Fractured Bedrock</td>
<td>0.6</td>
<td>407.0</td>
<td>0.475</td>
<td>0.81</td>
<td>0.50</td>
<td>27</td>
<td>23</td>
<td>50</td>
<td>0.16</td>
<td>0.05</td>
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<tr>
<td>Clay Loam</td>
<td>2.3</td>
<td>259.0</td>
<td>0.464</td>
<td>0.84</td>
<td>0.94</td>
<td>32</td>
<td>34</td>
<td>34</td>
<td>0.24</td>
<td>0.39</td>
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<tr>
<td>Sandy Clay Loam</td>
<td>4.3</td>
<td>263.0</td>
<td>0.398</td>
<td>0.83</td>
<td>0.60</td>
<td>59</td>
<td>11</td>
<td>30</td>
<td>0.40</td>
<td>0.36</td>
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<tr>
<td>Silt</td>
<td>6.8</td>
<td>203.0</td>
<td>0.501</td>
<td>0.97</td>
<td>0.50</td>
<td>23</td>
<td>61</td>
<td>16</td>
<td>0.23</td>
<td>0.49</td>
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<tr>
<td>Loam</td>
<td>13.0</td>
<td>108.0</td>
<td>0.463</td>
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<td>42</td>
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<tr>
<td>Sandy Loam</td>
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<td>1.90</td>
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<td>0.32</td>
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<td>Gravel</td>
<td>210.0</td>
<td>46.0</td>
<td>0.437</td>
<td>0.95</td>
<td>0.69</td>
<td>27</td>
<td>23</td>
<td>50</td>
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<td>0.15</td>
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</table>

### Parameters based on land cover classification (NALC)

<table>
<thead>
<tr>
<th>Land Cover Type</th>
<th>Interception (mm/hr)</th>
<th>Canopy (%)</th>
<th>Manning's n</th>
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<tbody>
<tr>
<td>Forest</td>
<td>1.15</td>
<td>30</td>
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<tr>
<td>Oak Woodland</td>
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<td>0.040</td>
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<tr>
<td>Mesquite Woodland</td>
<td>1.15</td>
<td>20</td>
<td>0.040</td>
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<tr>
<td>Grassland</td>
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<td>0.050</td>
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<td>Desertscrub</td>
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<td>0.055</td>
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<td>Riparian</td>
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<td>Agriculture</td>
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<tr>
<td>Urban</td>
<td>0.0</td>
<td>0.0</td>
<td>0.010</td>
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</table>
Hydrologic Modeling & AGWA

GIS Data

Assumptions

Runoff Erosion

Rainfall

Runoff
Flash Flood Forecasting

- Real time, using Doppler weather radar
  - Can include predicted rainfall (QPF)
  - Multiple Z-R relationships simultaneously
- Spatially distributed model, using short (3-5 min) time steps, ideal for fast-responding basins
- Can be calibrated using archived radar data and discharge data at forecast points

AGWA Parameterization Intersected with Polarimetric Radar Grid

Doppler Weather Radar

Predicted Rainfall

KINEROS2

Graphical User Interface
K2 SENSITIVITY

- Relative ranking of most sensitive inputs and parameters
  - Rainfall Inputs (emphasis in arid and semi-arid areas)
  - Saturated Hydraulic Conductivity
  - Hydraulic Roughness
- All a function of watershed geometric complexity
Small Scale Rainfall Variability

Lucky Hills-104

- 4.4 hectare area
- 48 non-recording gauges (30 x 30 m grid)
- 9 recording gauges
- Total Event Depth Contours (Aug 12, 1990)
  - Aver. – 52.9 mm
  - Range – 10.6 mm

Goodrich et al., 1995 – J Hyd.
Small scale spatial variability of rainfall (on the order of ~150 m)

Walnut Gulch – Lucky Hills #104 (4.4 ha)
Small test basin setup: Walnut Gulch Flume 11 (WG11)

- 6.5 km² area
- Almost spatially homogenous parameters (from AGWA)

Model run setup

- Monte-Carlo simulations (~100,000)
- 23 parameter modifiers (Hillslope, Channel & Initial conditions)
- Successful forecasts: ‘behavioral envelope’
  - e.g. van Straten and Keesman, 1991
Relative Influence of Radar Rain Depth Bias

Influence on uncertainty in peak magnitude

July 29, 2006 storm
Model/parameter & rain uncertainty

July 29, 2006 storm
90% confidence interval

Model/parameter uncertainty
Model/parameter + rain uncertainty

Discharge in cms

Radar Time Steps
Additional Limitation – Cannot model backwater or presurized culvert flow
What Could Possibly Go Wrong??

PLENTY

**SYSTEMIC ERRORS**

These are “hidden” & include:

- Poor conceptual model
- Programming errors
  - AGWA, SWAT, KINEROS2
- Poor process representation
- Errors in GIS data
  - Land cover, soils
- Assumptions in the look-up tables

**PROCESSING ERRORS**

These are “visible” & include:

- Errors in GIS data
  - DEM
- Lack of input data
  - GIS, rainfall
- AGWA fails to characterize watershed
KINEROS2 Strengths

- Readily available inputs
- Physical-based model
- High resolution both spatial and temporal
- Can simulate detailed flood routing
- Can simulate detailed sediment budget

Weaknesses

- More parameters to estimate
- Currently not continuous in the current AGWA release
- Subsurface flow component weak, works better in streams with negligible base flow
- Currently improving snow melt component
- Will not model “small events” where the runoff to rainfall ratios are small (most any model)
CONCLUSIONS - Cautions

• KINEROS2 – Evolved from a research model to one gaining wider applicability

• K2 most sensitive to rainfall input and Infil. Par.

• In a water limited area with small runoff to rainfall ratios, runoff modeling is difficult and highly dependent of the quality of model input

• The model representation of the watershed must keep up with changes in the watershed characteristics due to land use changes (i.e. urbanization, change in agriculture, fires, etc.)