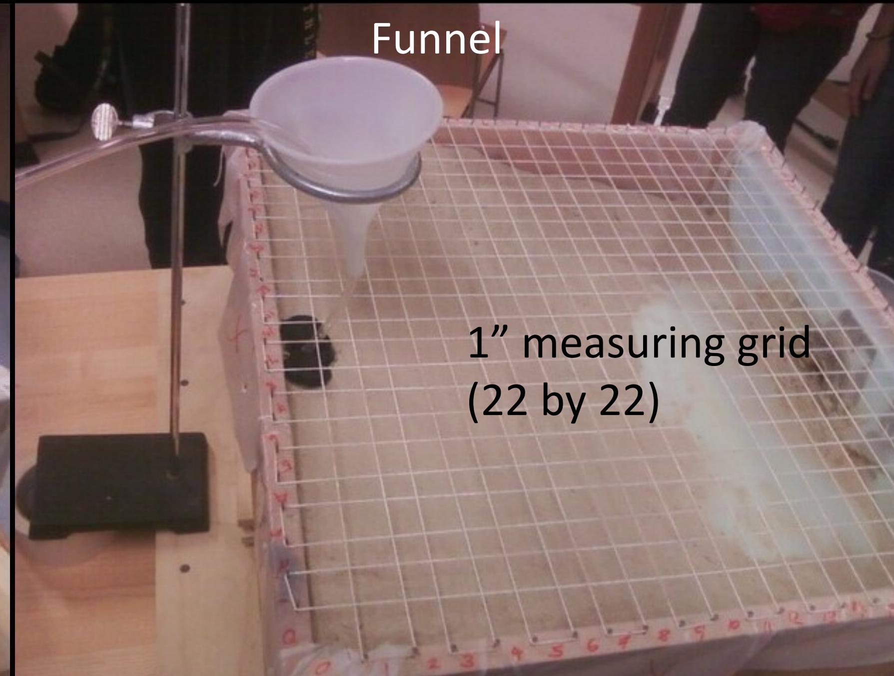
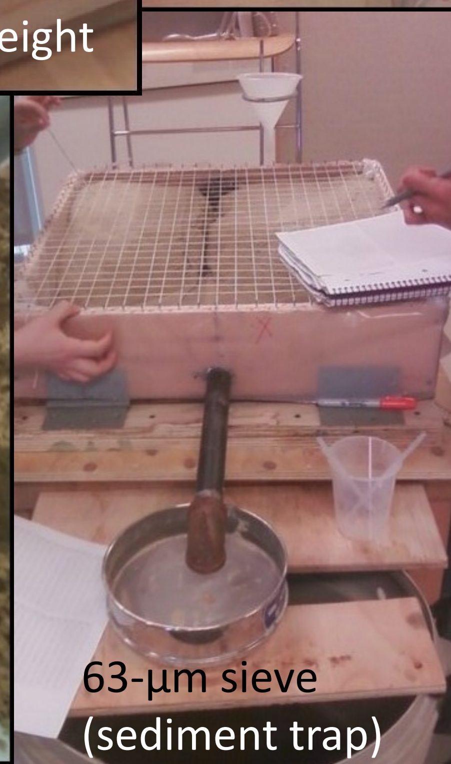
The "Sandbox" Project

SETUP:


5 lbs of fine sand
22” by 22” by 5” box
adjustable “hinterland” height

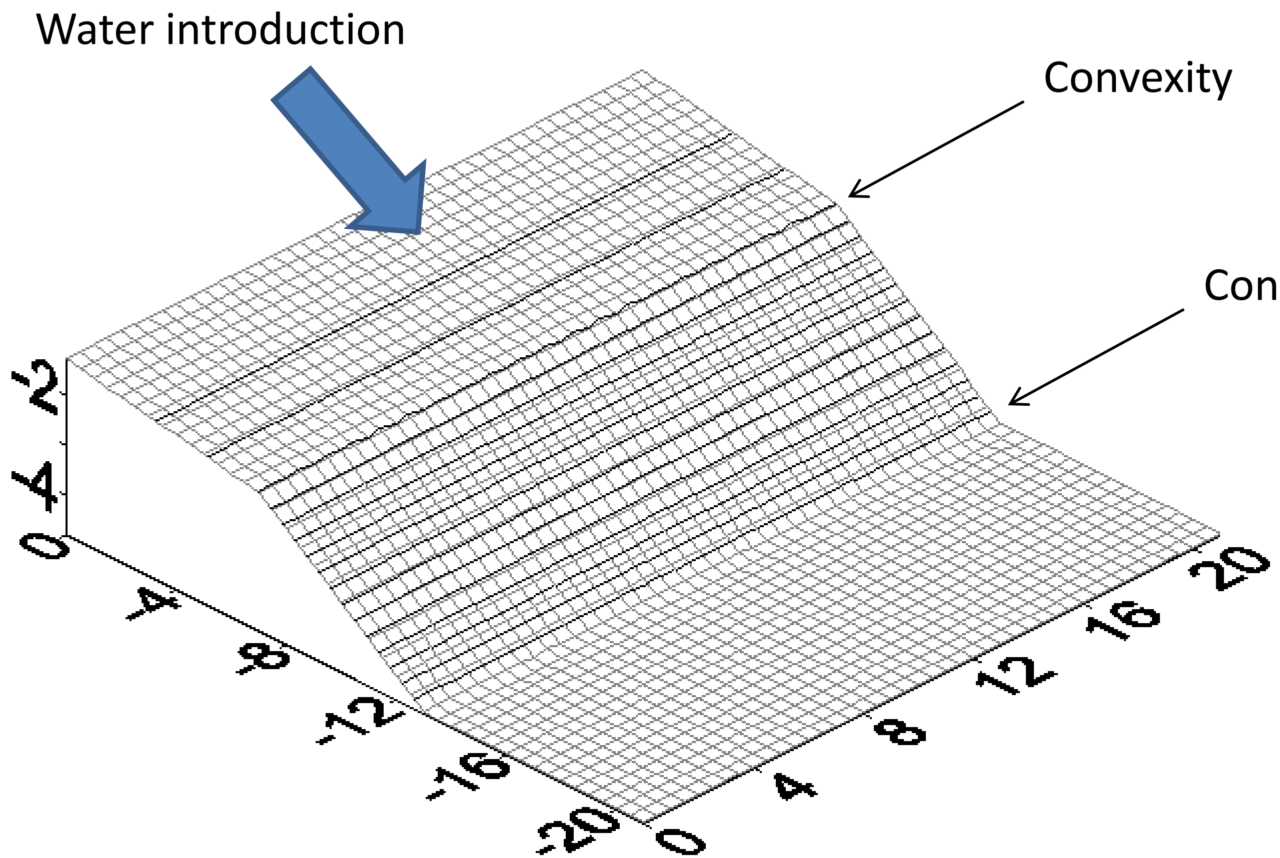

Funnel
1” measuring grid
(22 by 22)


½” foam +
plastic liner


63-µm sieve
(sediment trap)


outflow pipe
trash barrel

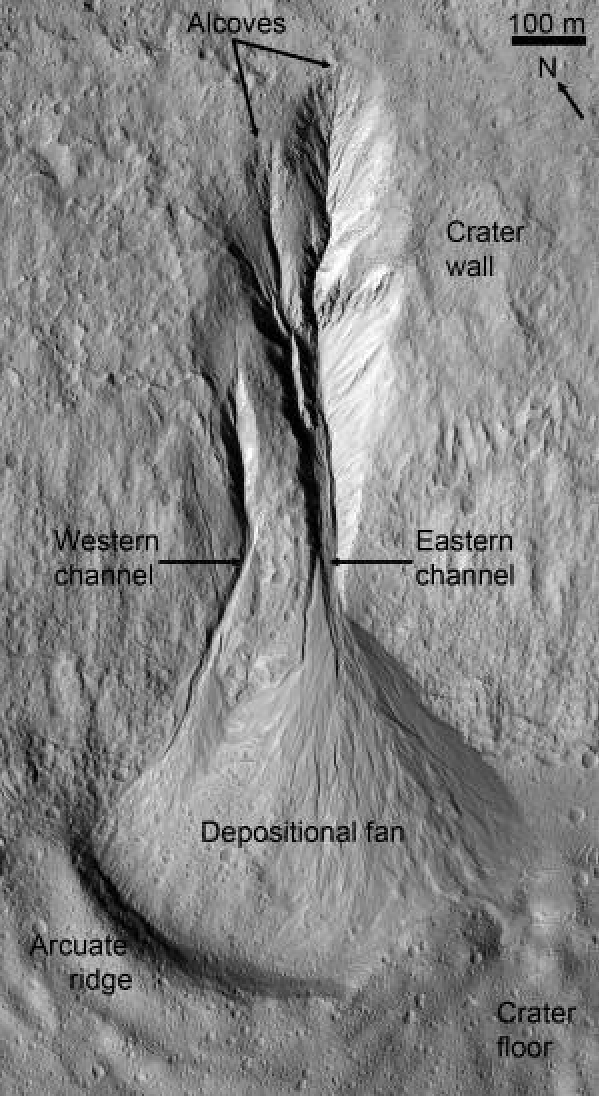
Modeling knickpoint erosion, sediment transport, and fan/delta formation



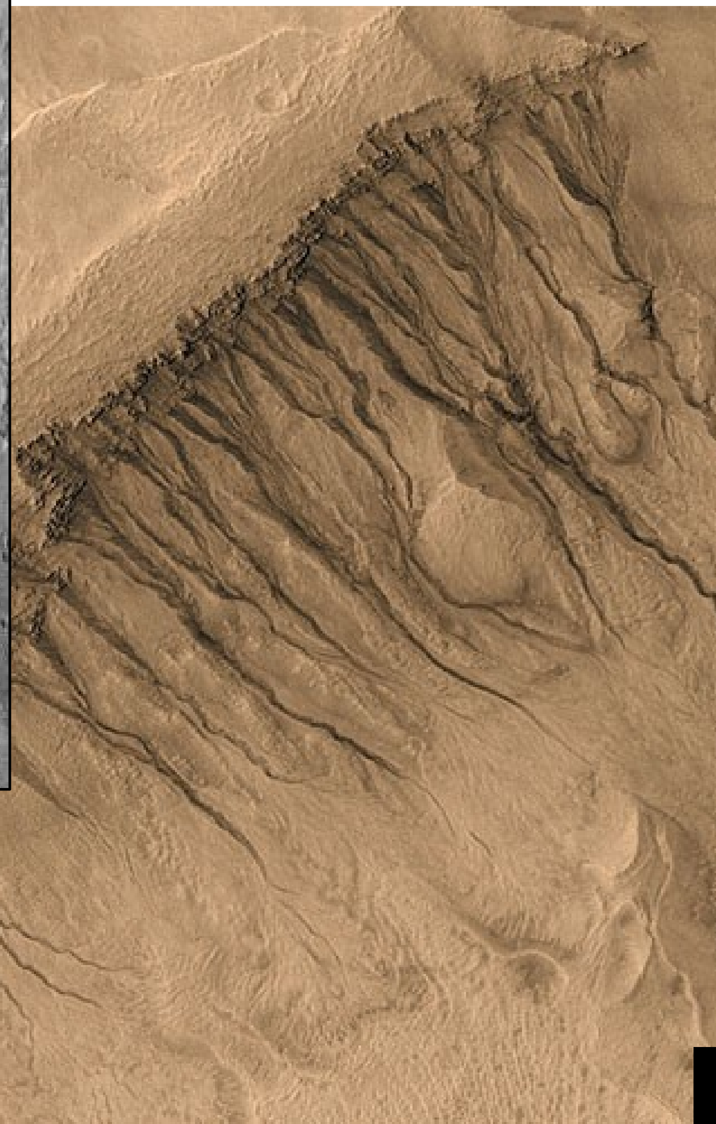
Analogues

Holden Mining Site - USDA

Gullies on Mars

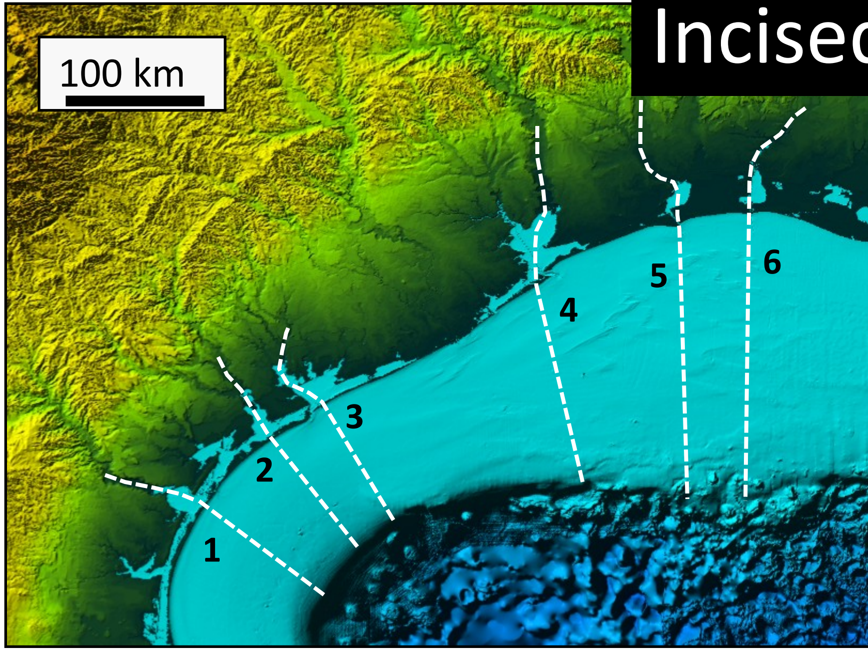


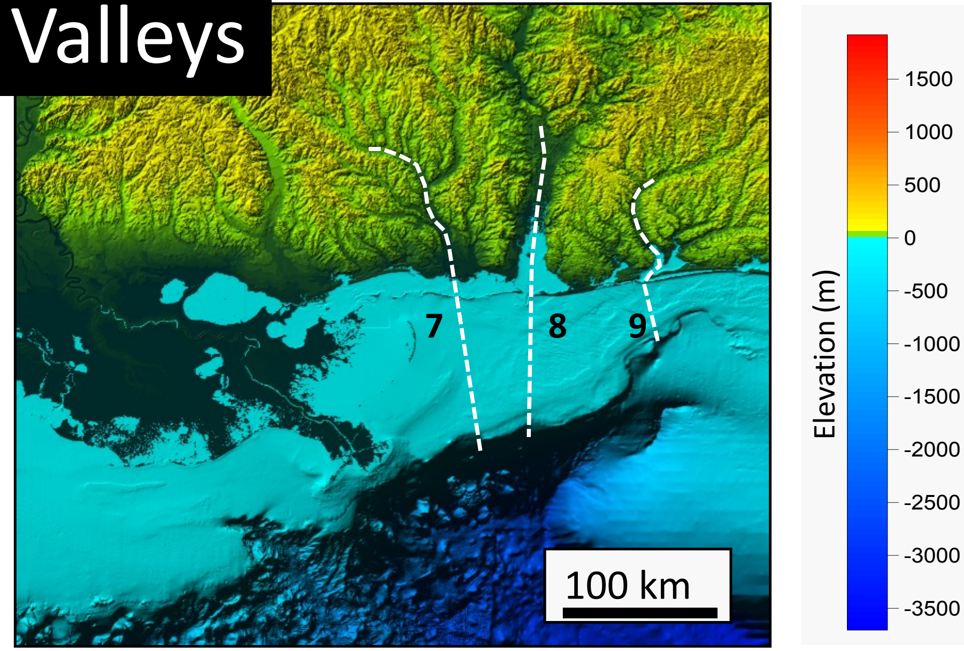
NASA

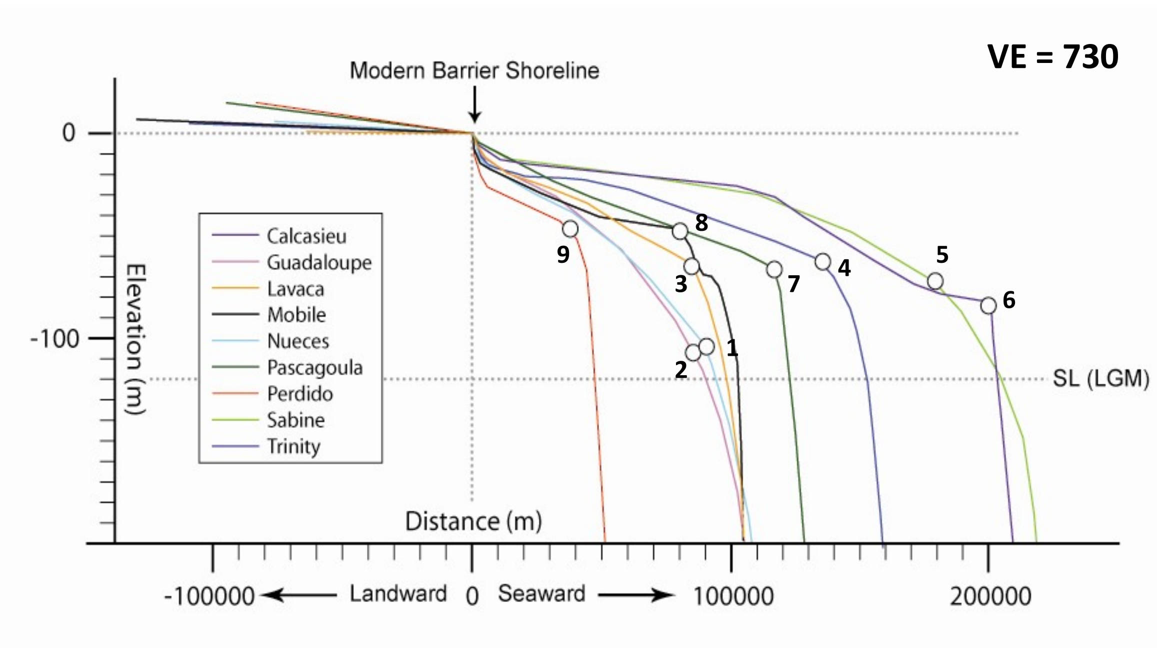


Mars Crater Landscape - NASA

Incised Valleys







System	Shelf Width (km)	Depth of Shelf Break (m)
Nueces (1)	90	105
Guadeloupe (2)	85	105
Lavaca (3)	85	65
Trinity (4)	135	60
Sabine (5)	180	70
Calcasieu (6)	200	80
Pascagoula (7)	115	65
Mobile (8)	80	50
Perdido (9)	40	50

Incision begins once critical shear stress is reached.

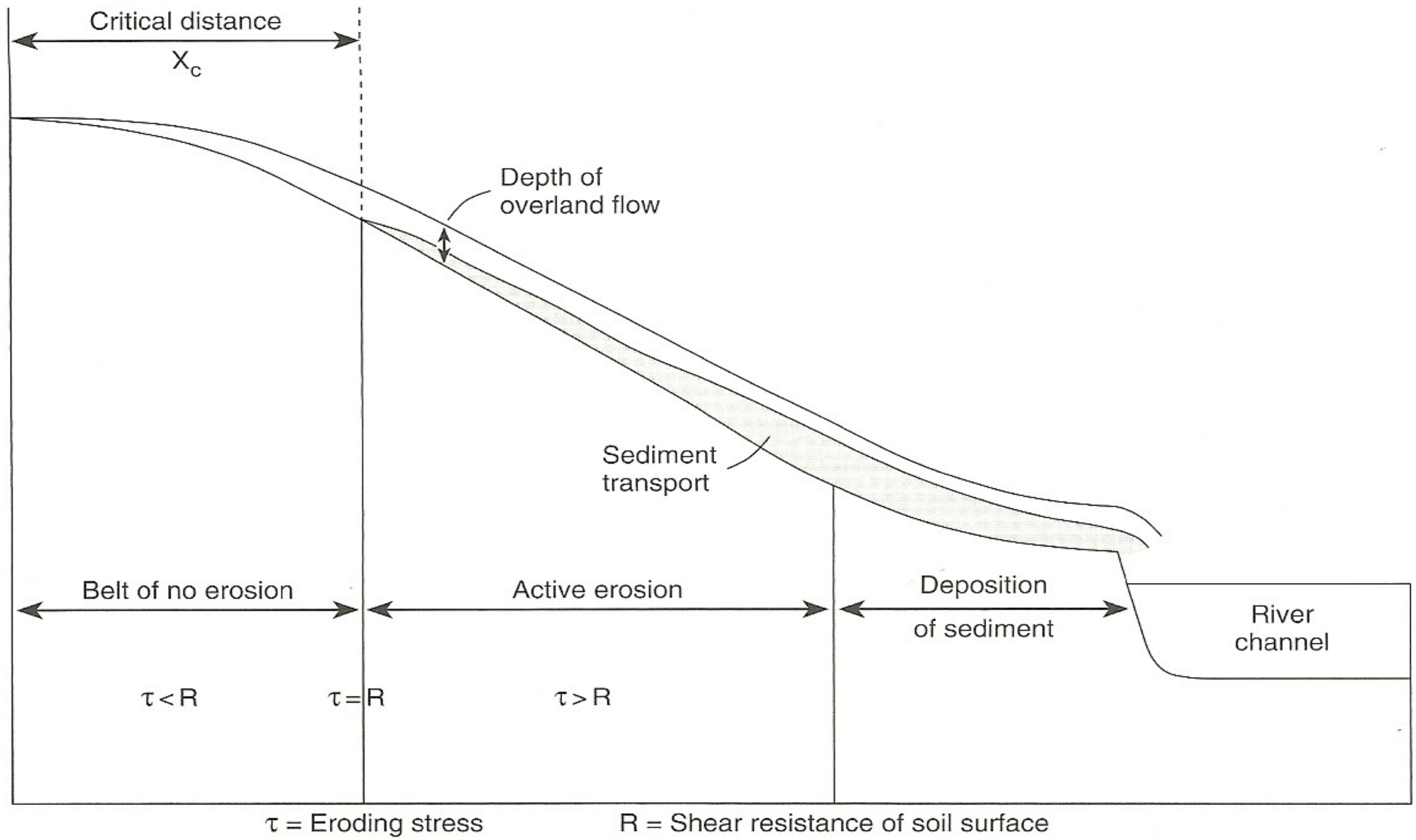
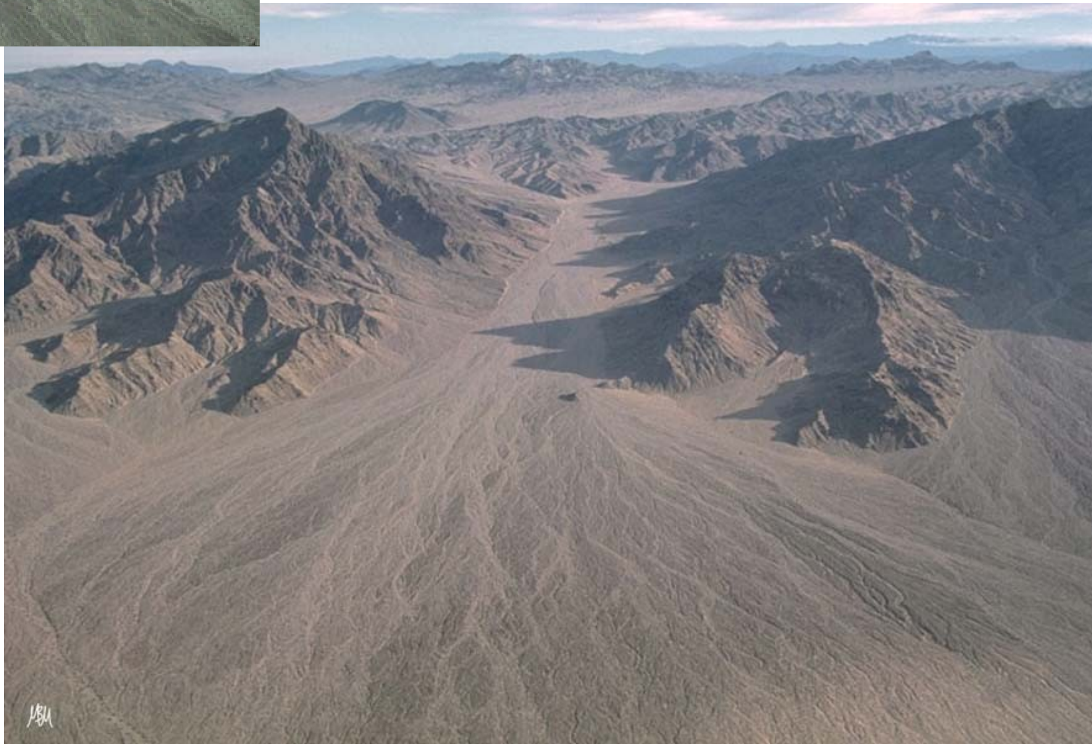


Figure 4.5 Horton's model of overland flow and rill formation. Adapted from Horton (1945).

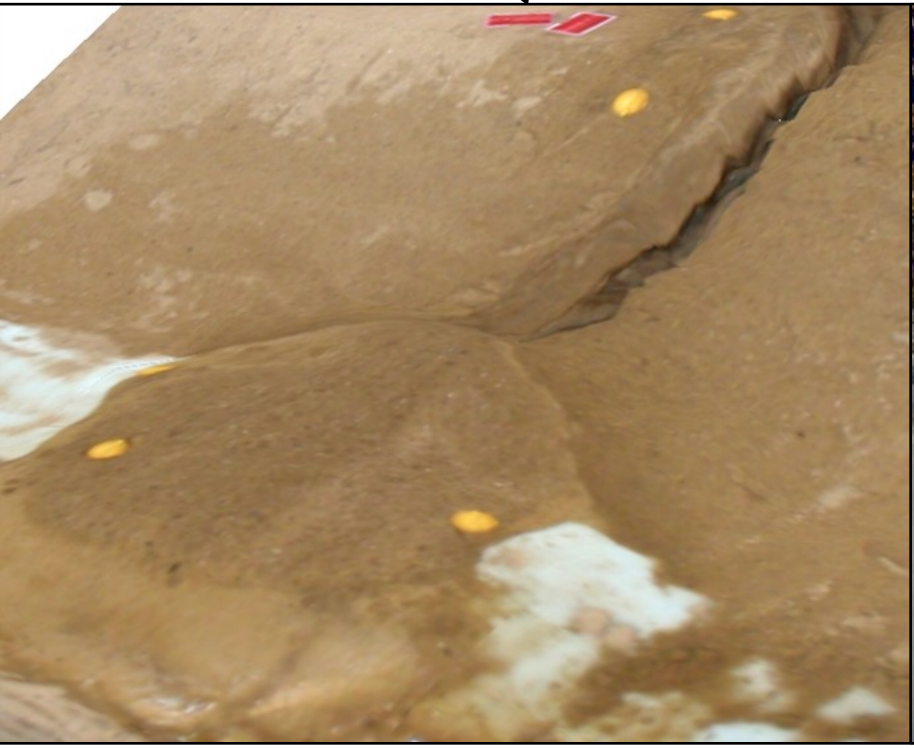
Deposition: Decrease in Stream Competence

- Reduction in flow discharge
- Decrease in slope
- Increase in boundary resistance
- Flow separation
- Obstructions

Death Valley



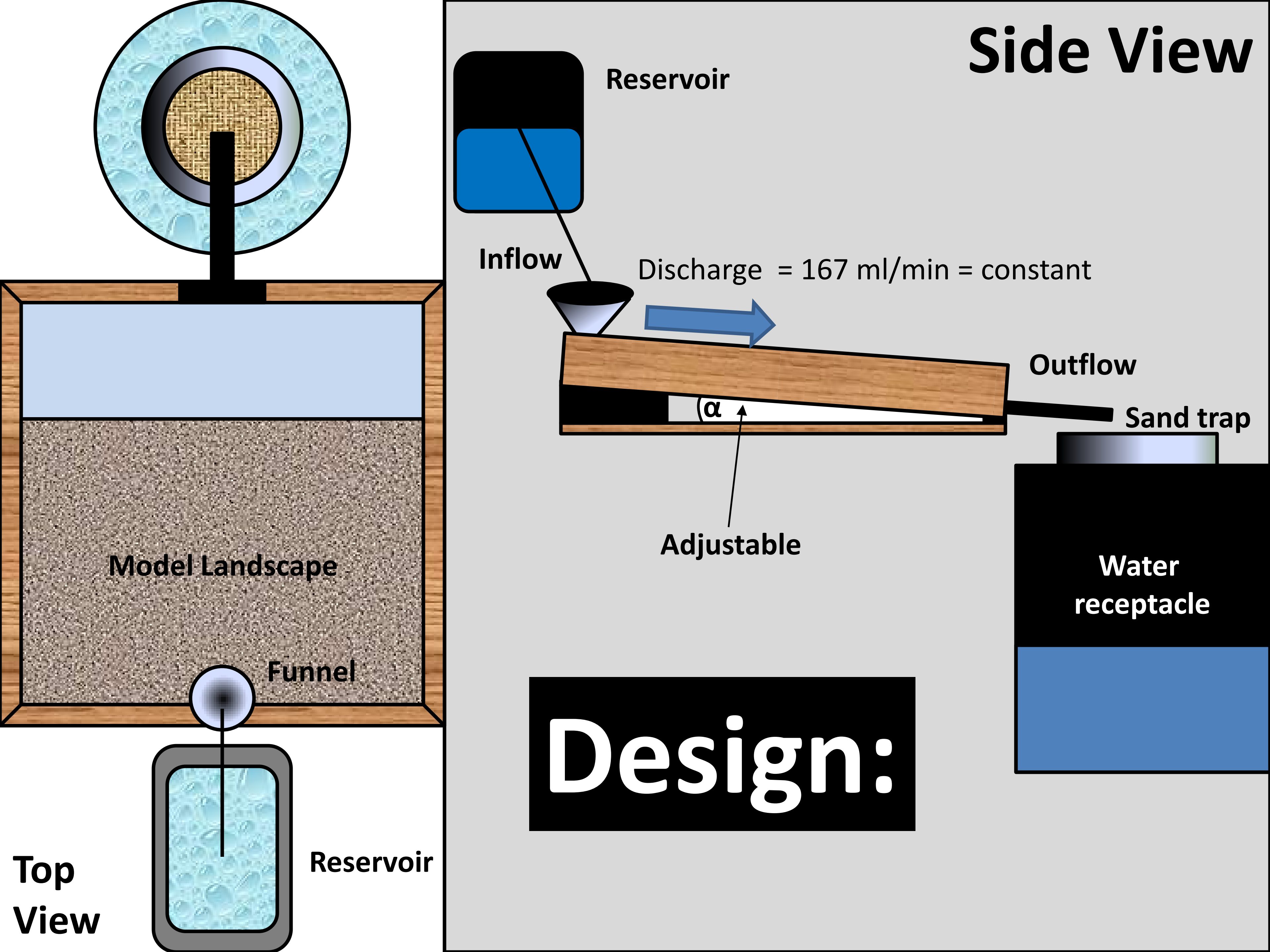
2D Monopoly houses (…no elevation values for those…)



…in the sandbox…
…cm-scale
…in 6 minutes…

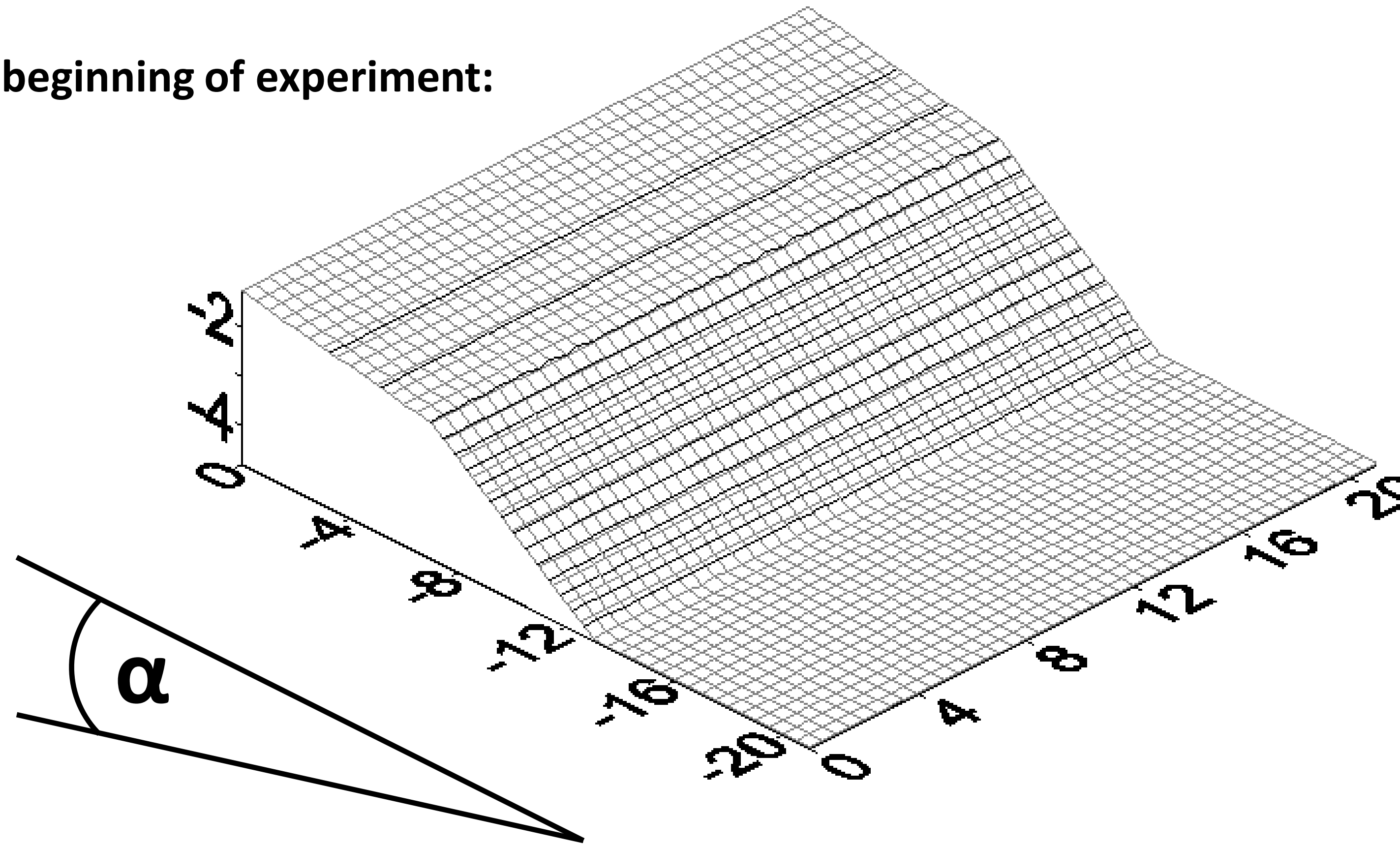
…in Death Valley…
…km-scale
…over 1,000s of yrs…

…our Sandbox:


Side View
Reservoir
Inflow
Discharge = 167 ml/min = constant
Outflow
Sand trap
α
Adjustable
Water
receptacle
Design:
Model Landscape
Funnel
Reservoir
Top
View

Experimental Setup

Landform at beginning of experiment:



Run 1: α = 3°, dry initial conditions

Run 2: α = 5°, wet initial conditions

Run 3: α = 3°, wet initial conditions

Our Constants and Variables

- Constants
  - Initial topographic relationships
    - Convexity and concavity
  - Discharge
  - Sediment composition

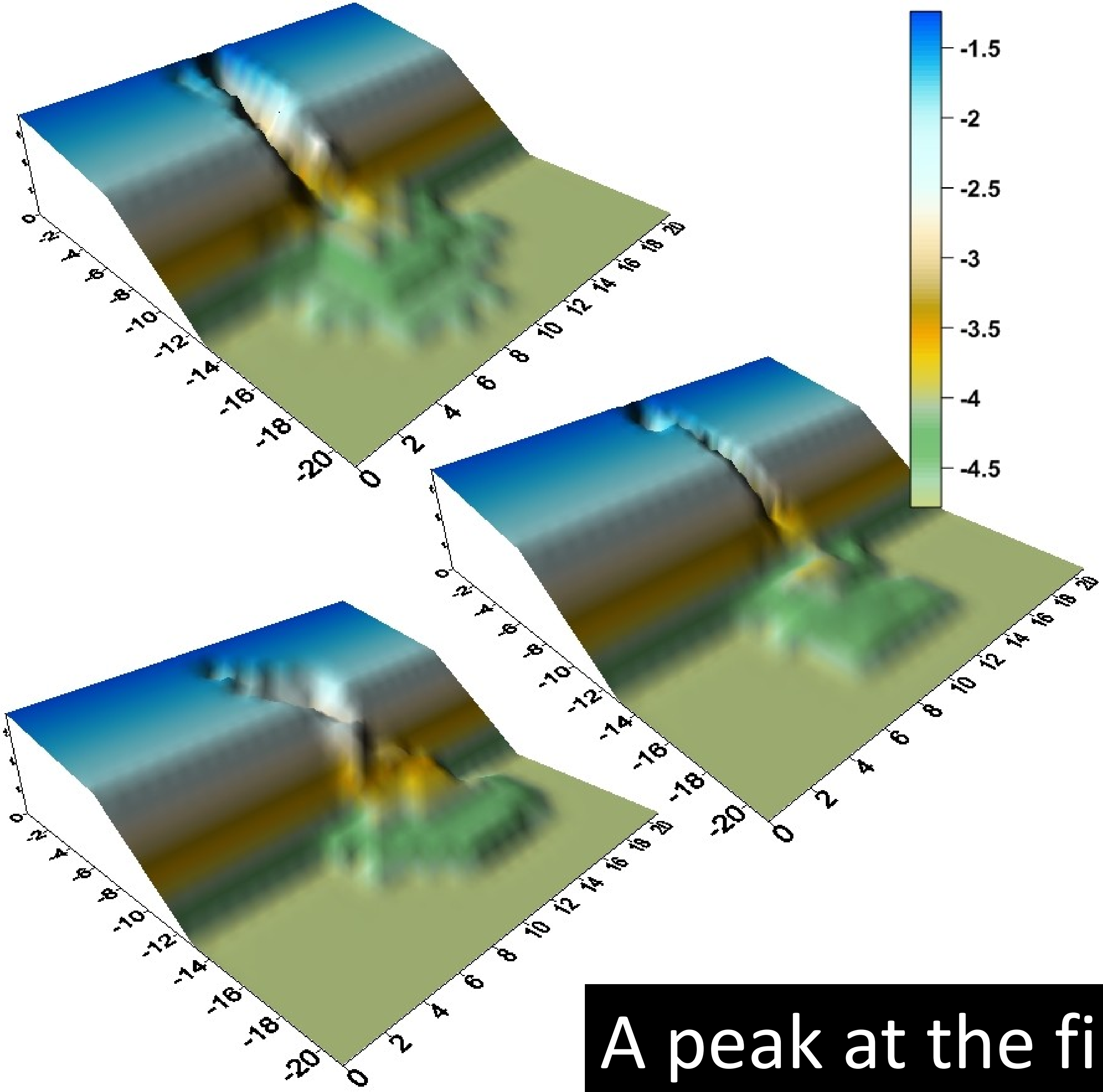
- Variable
  - Inclination of the model landscape
  - Antecedent moisture conditions

3 Runs:

- Run 1:
  - Box angle = 3 degrees
  - Antecedent conditions: bone dry

- Run 2:
  - Box angle = 5 degrees
  - Antecedent conditions: moist

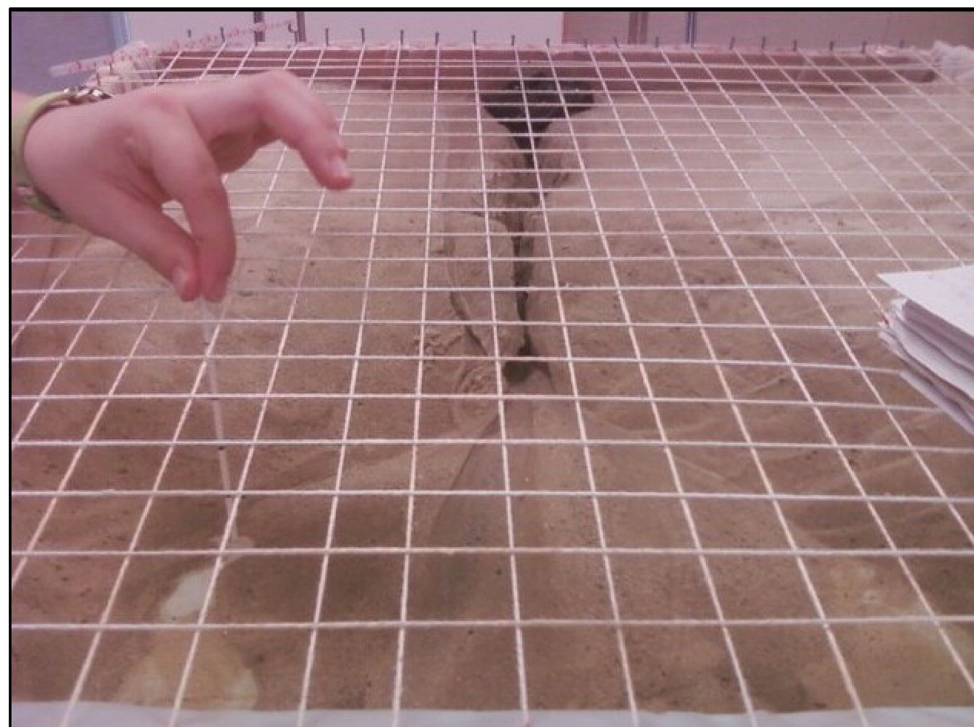
- Run 3:
  - Box angle = 3 degrees
  - Antecedent conditions: drenched



A peak at the final results

Measuring Methods

- Q = constant = 167 ml/min
- Surface elevations measured (to the nearest 0.25”) every 90 sec. relative to top of box (using a 1”X1” grid)

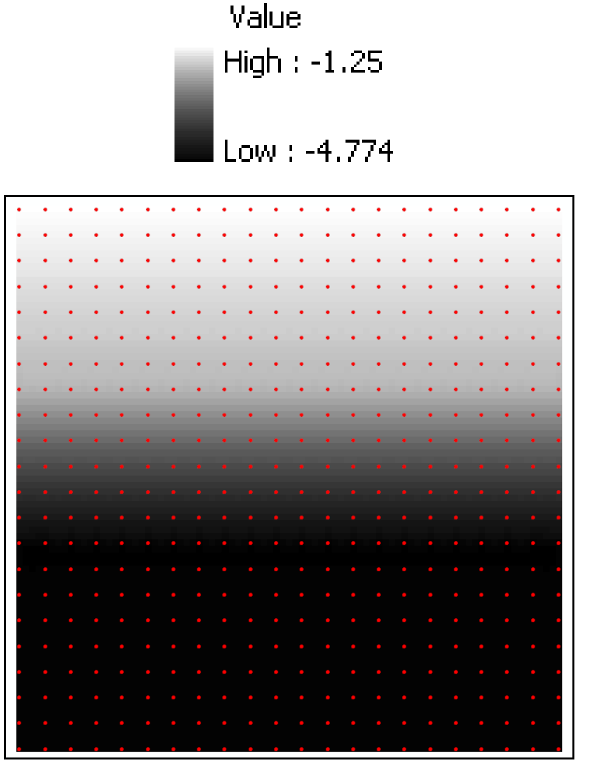


Measuring Elevation

Regulating Discharge

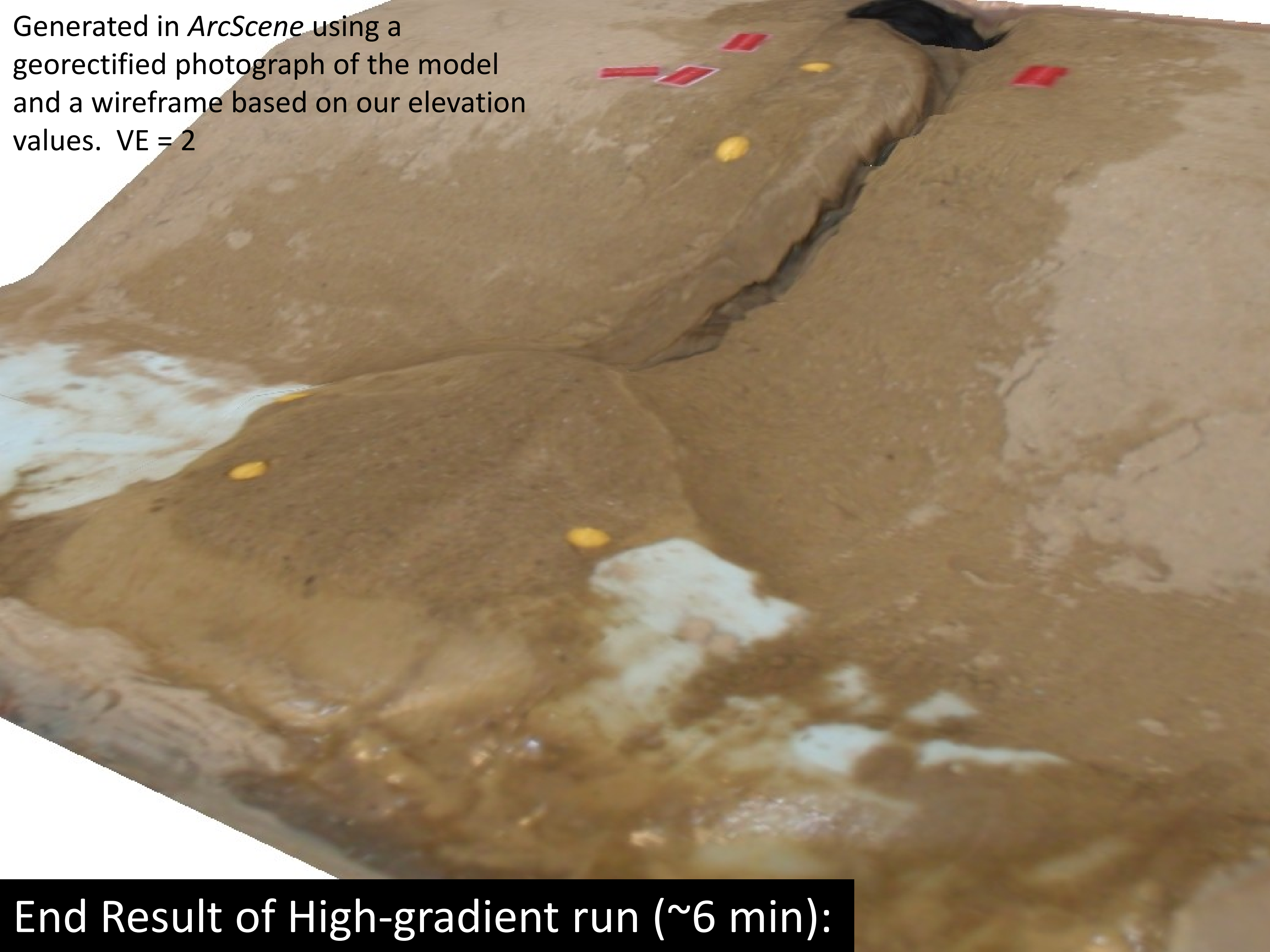
Digital Modeling

- ArcGIS Version 9.3
  - Elevation values imported as .txt-file
  - Grid created from points using interpolation tool
    - Kriging method
      - Linear semivariogram model
    - Output grid spacing = 0.25



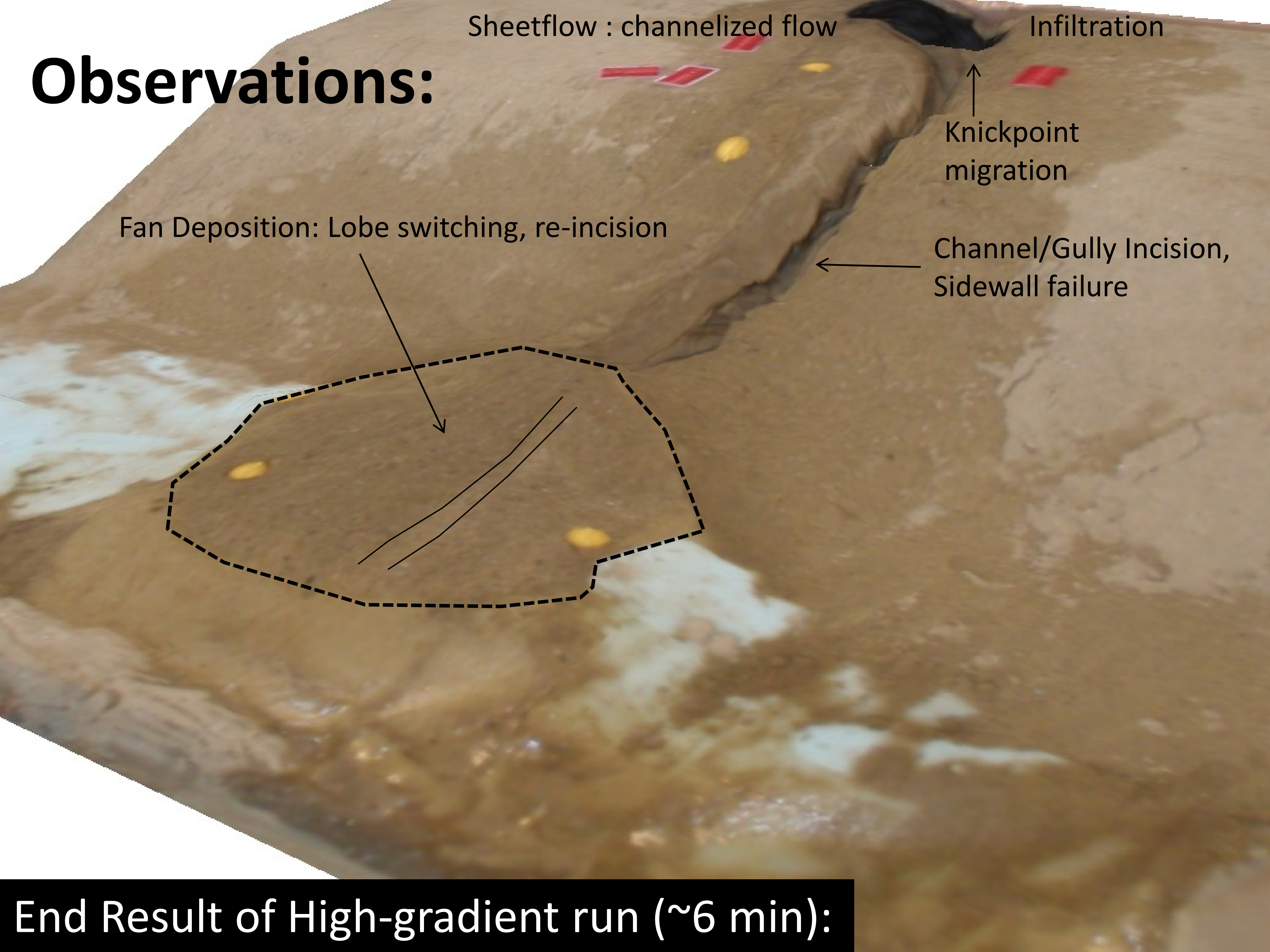
Digital representation of initial topography with points of elevation measurement as red dots. Vertical datum = top of sandbox.

Generated in *ArcScene* using a georectified photograph of the model and a wireframe based on our elevation values. VE = 2



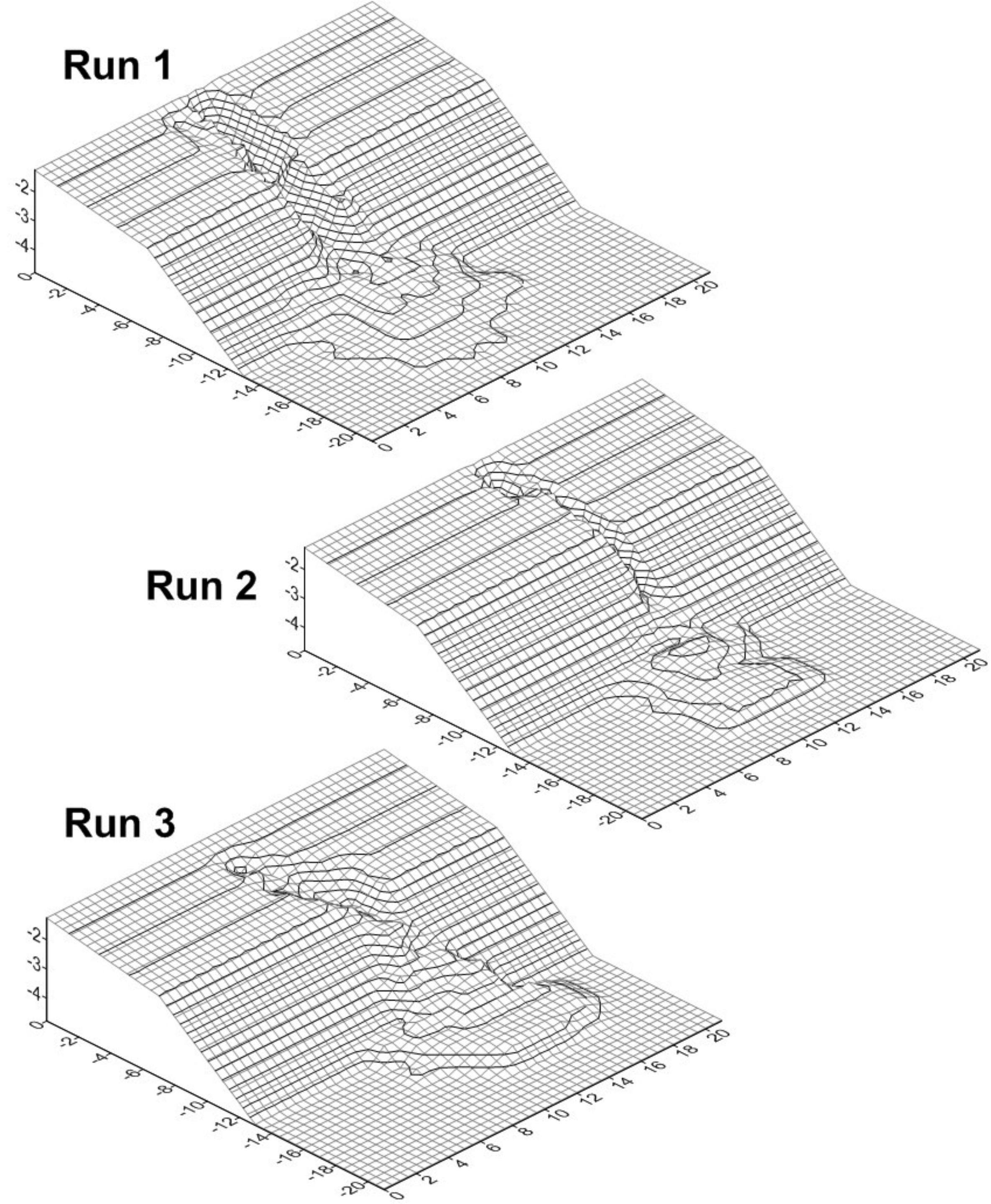
End Result of High-gradient run (~6 min):

Observations:



End Result of High-gradient run (~6 min):

Sediment Volumes?



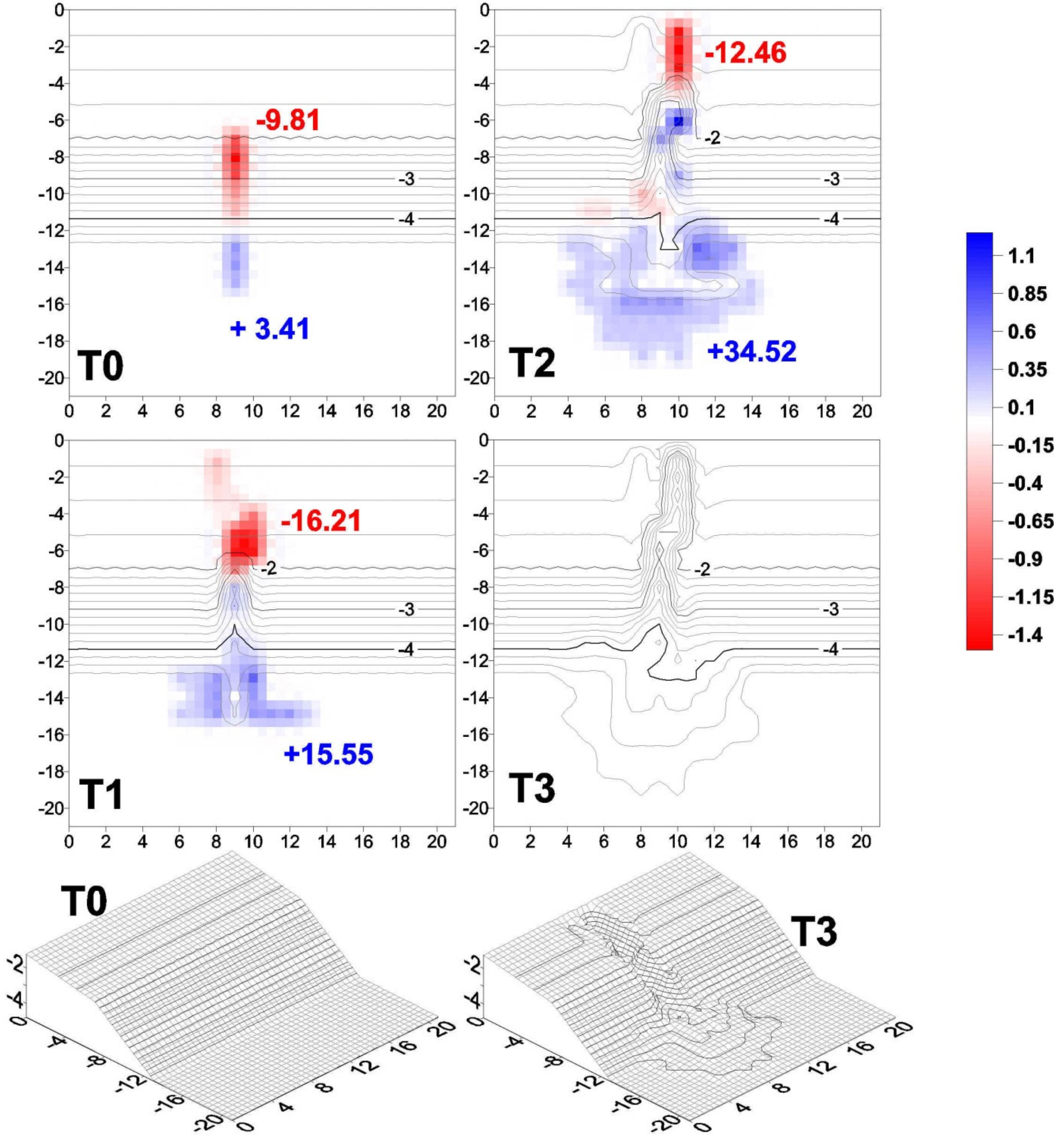
Net Change Maps and Volumetric Calculations

- Using the *Raster Calculator* function in ArcGIS, we subtract older DEMs from newer ones to obtain maps of net change.
- Net change maps are used to determine volume of sediment above (+) and below (-) the ‘zero plane’, which is marks areas lacking net change, separating regions of deposition and erosion, respectively.

Results: Evolutionary Model – Run 1

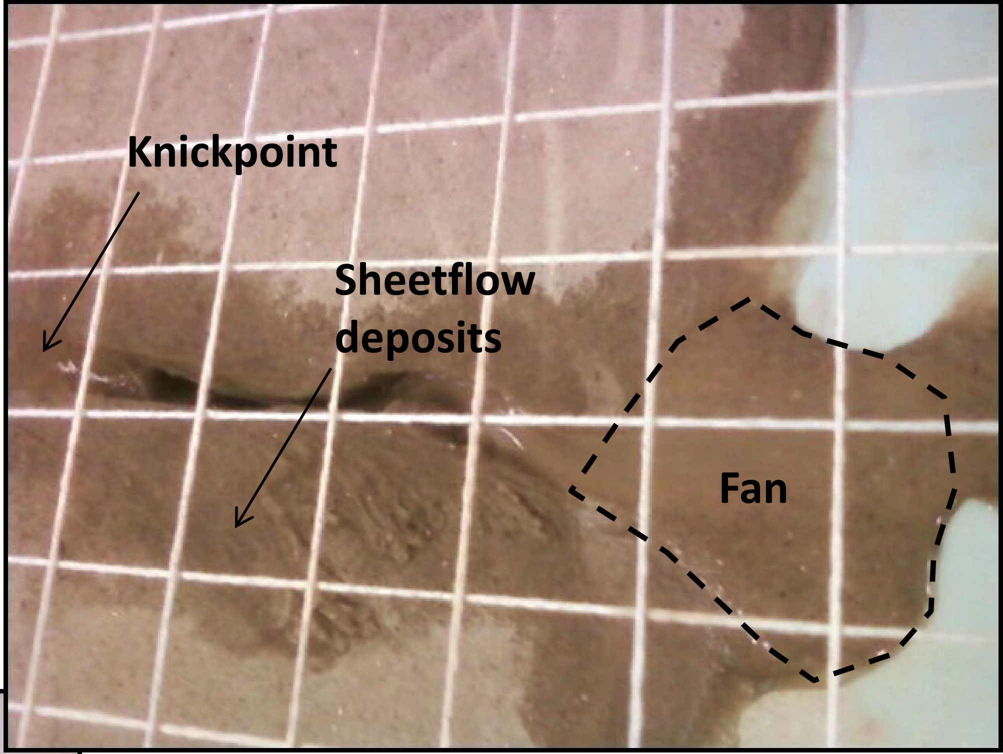
- T0-T1 (0-90 sec)
  - Sheet flow dominates until incision occurs at the break-in-slope
  - Knickpoint migration initiates and sediment is transferred to the base of the slope (i.e. starts building a fan)
- T1-T2 (90-180 sec)
  - Fan builds as knickpoint continues to erode more material, delta lobes switch to fill accommodation space
  - Vertical profile nears equilibration
- T2-T3 (180-270 sec)
  - Vertical profile equilibrates
  - Not much sediment is transferred from the upland to the fan
  - High sediment yields are attributed to sidewall failure, which happens in pulses. When no sediment is transferred downstream, incision into the fan is prevalent.

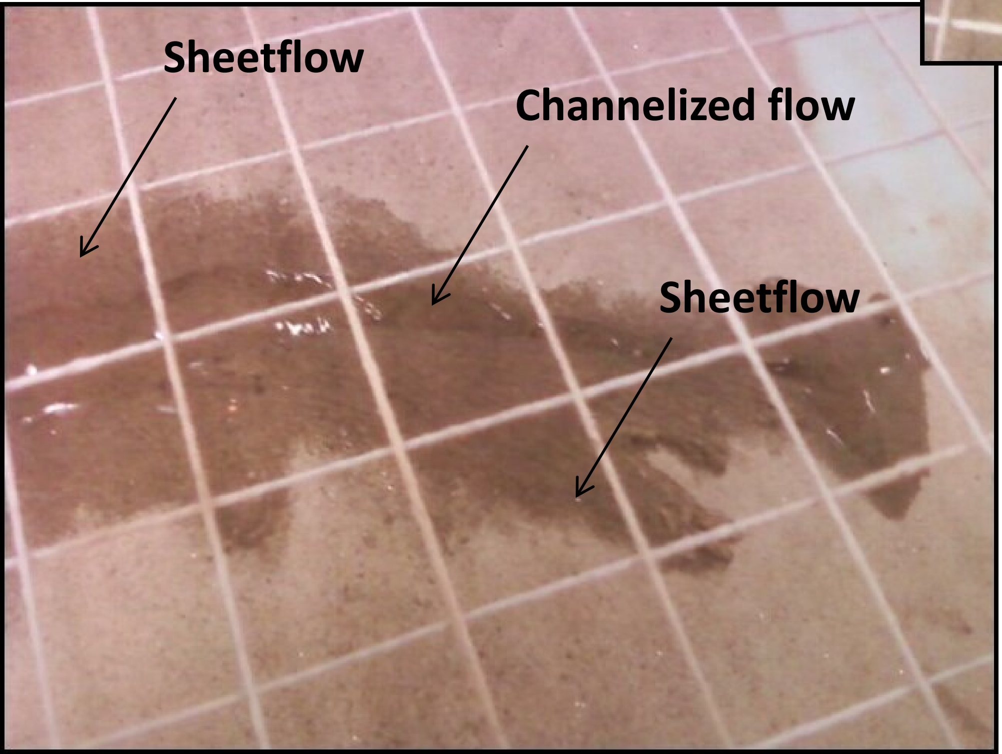
Run 1:

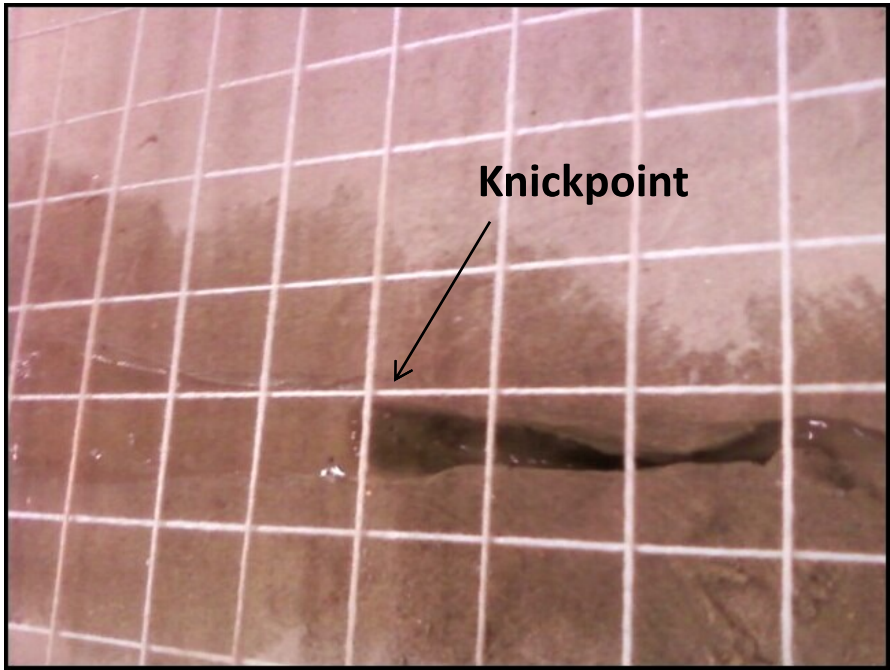


T0
-9.81
+ 3.41
T2
-12.46
+34.52
T1
-16.21
+15.55
T3
-2
-3
-4
1.1
0.85
0.6
0.35
0.1
-0.15
-0.4
-0.65
-0.9
-1.15
-1.4

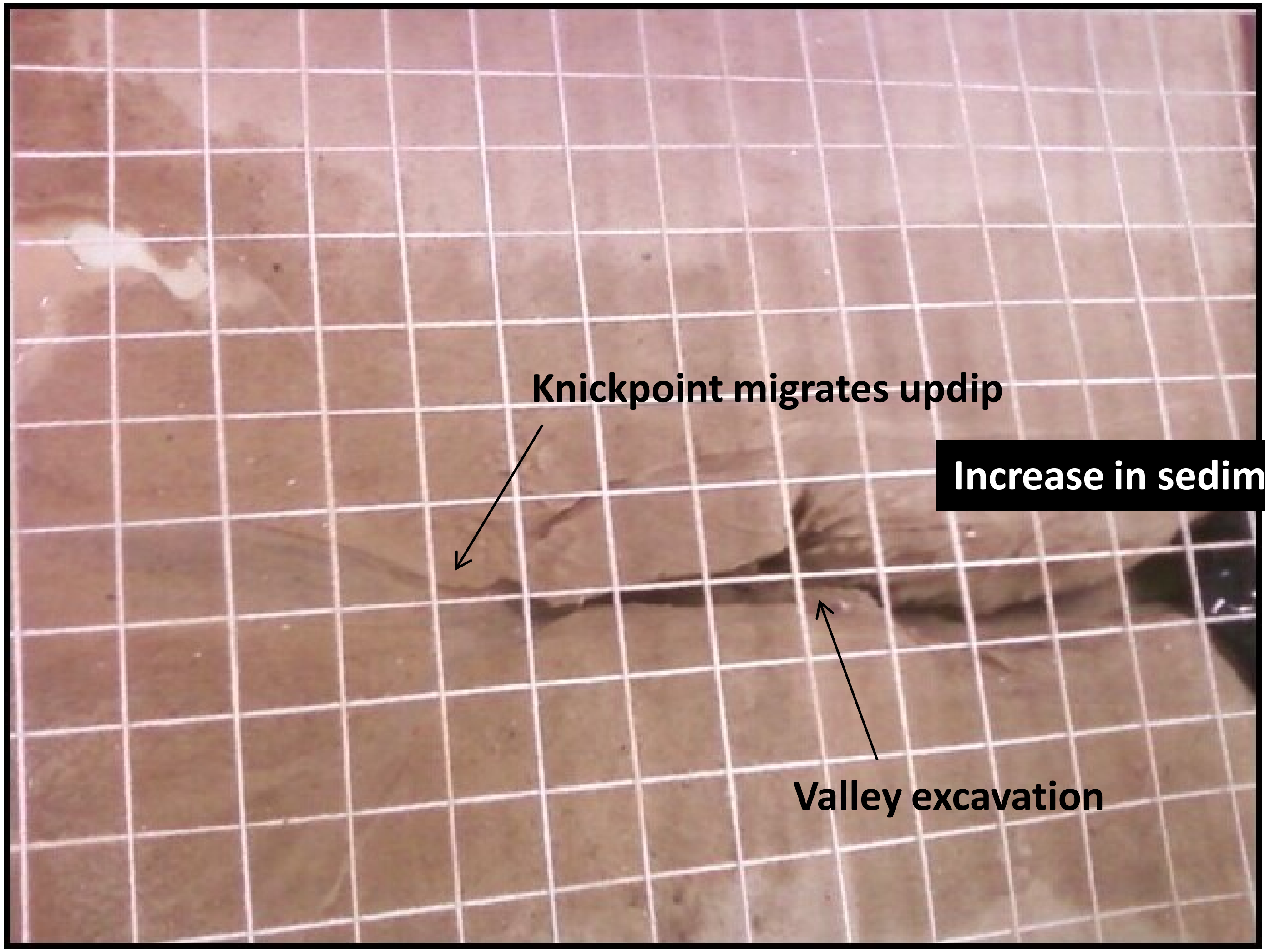
Run 1 (0-90 sec):


Knickpoint
Sheetflow deposits
Fan

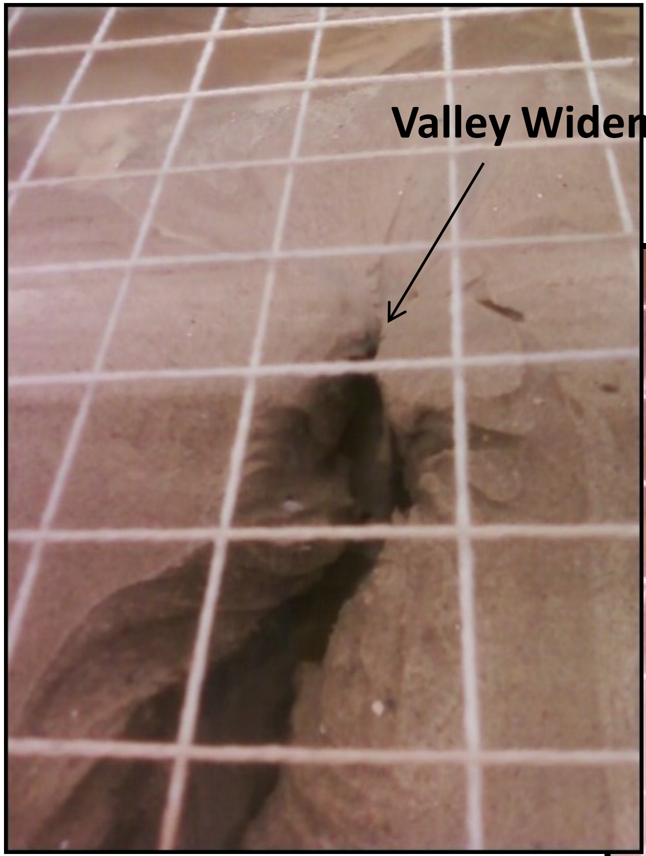

Sheetflow
Channelized flow
Sheetflow


Knickpoint

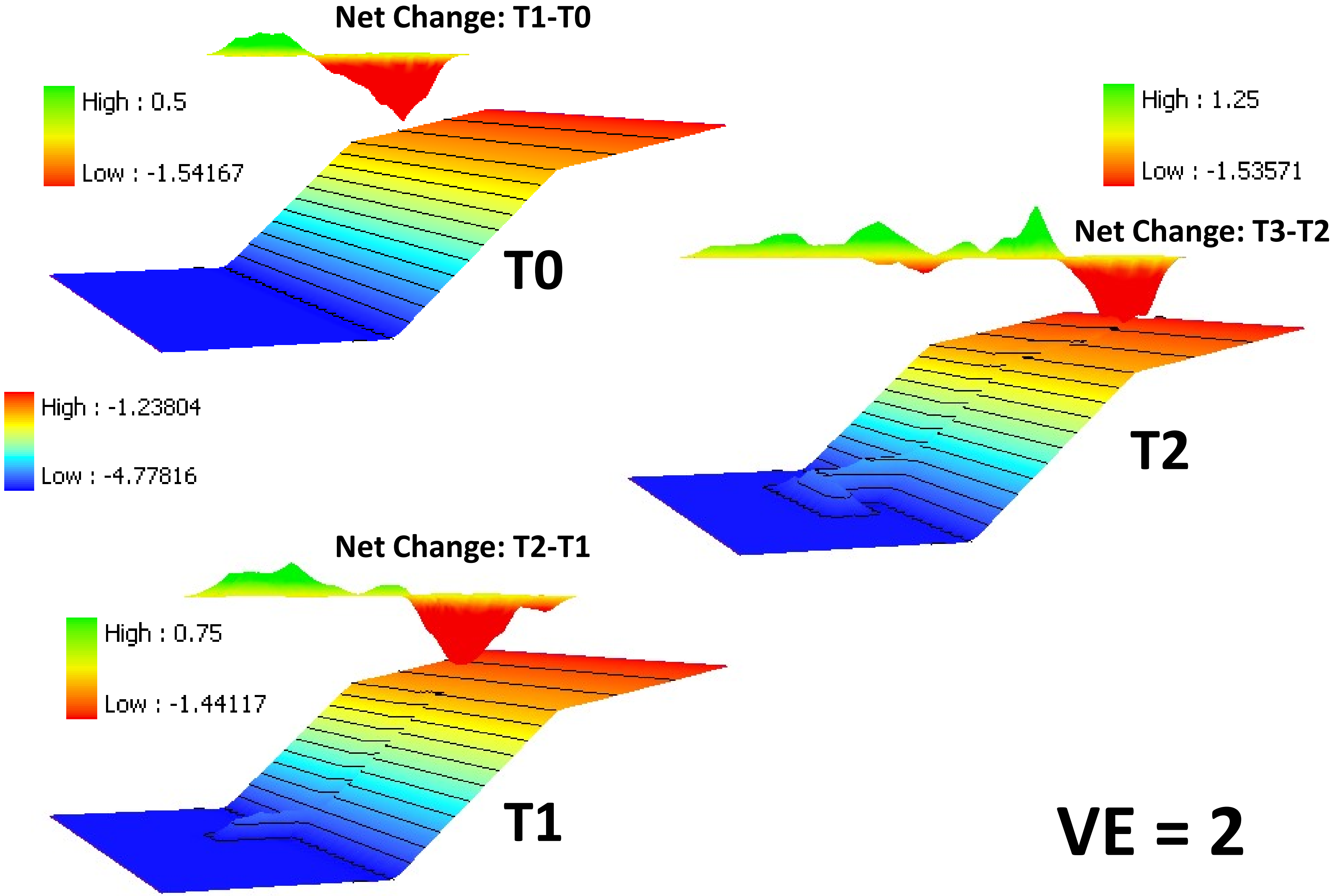
Run 1 (90-180 sec):



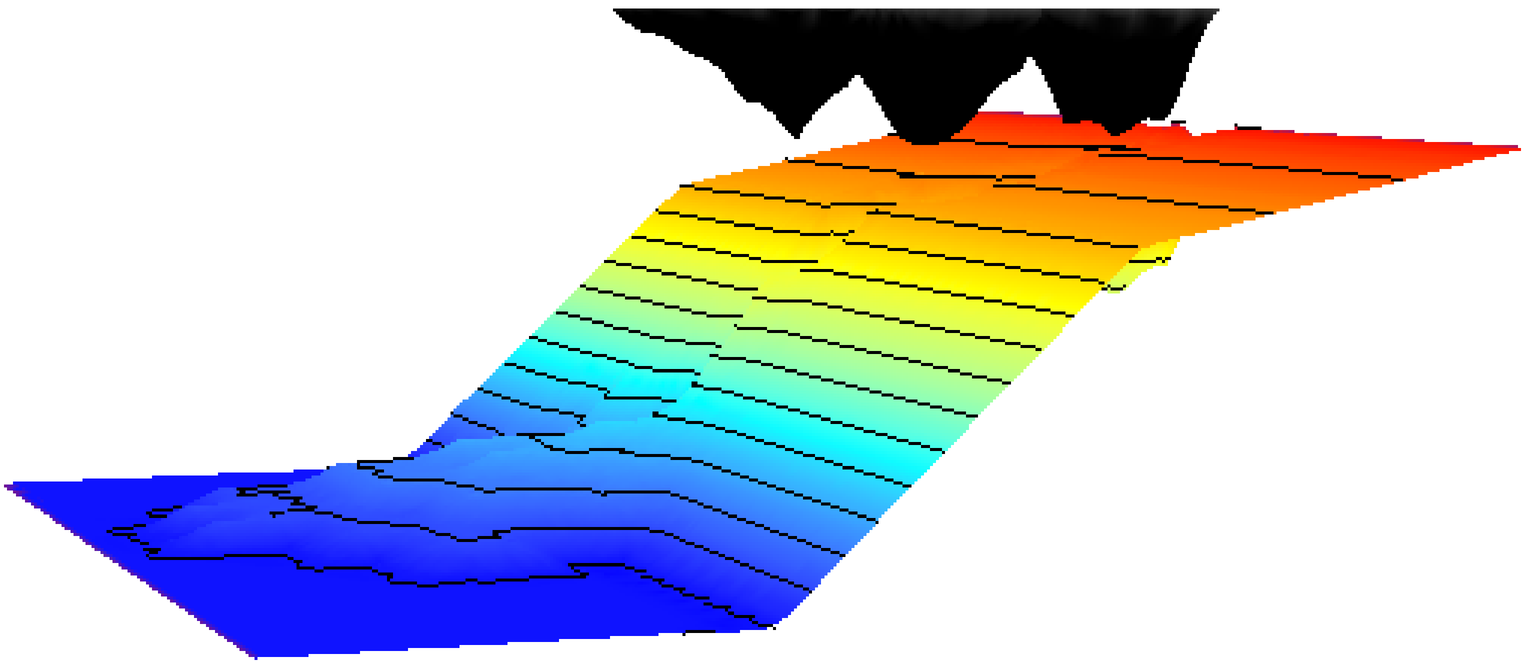
Run 1 (180-240 sec):



Run 1:


Net Change: T1-T0
High : 0.5
Low : -1.54167
T0
High : 1.25
Low : -1.53571
Net Change: T3-T2
High : -1.23804
Low : -4.77816
T2
Net Change: T2-T1
High : 0.75
Low : -1.44117
T1
VE = 2

Knickpoint at: **T1 T2 T3**

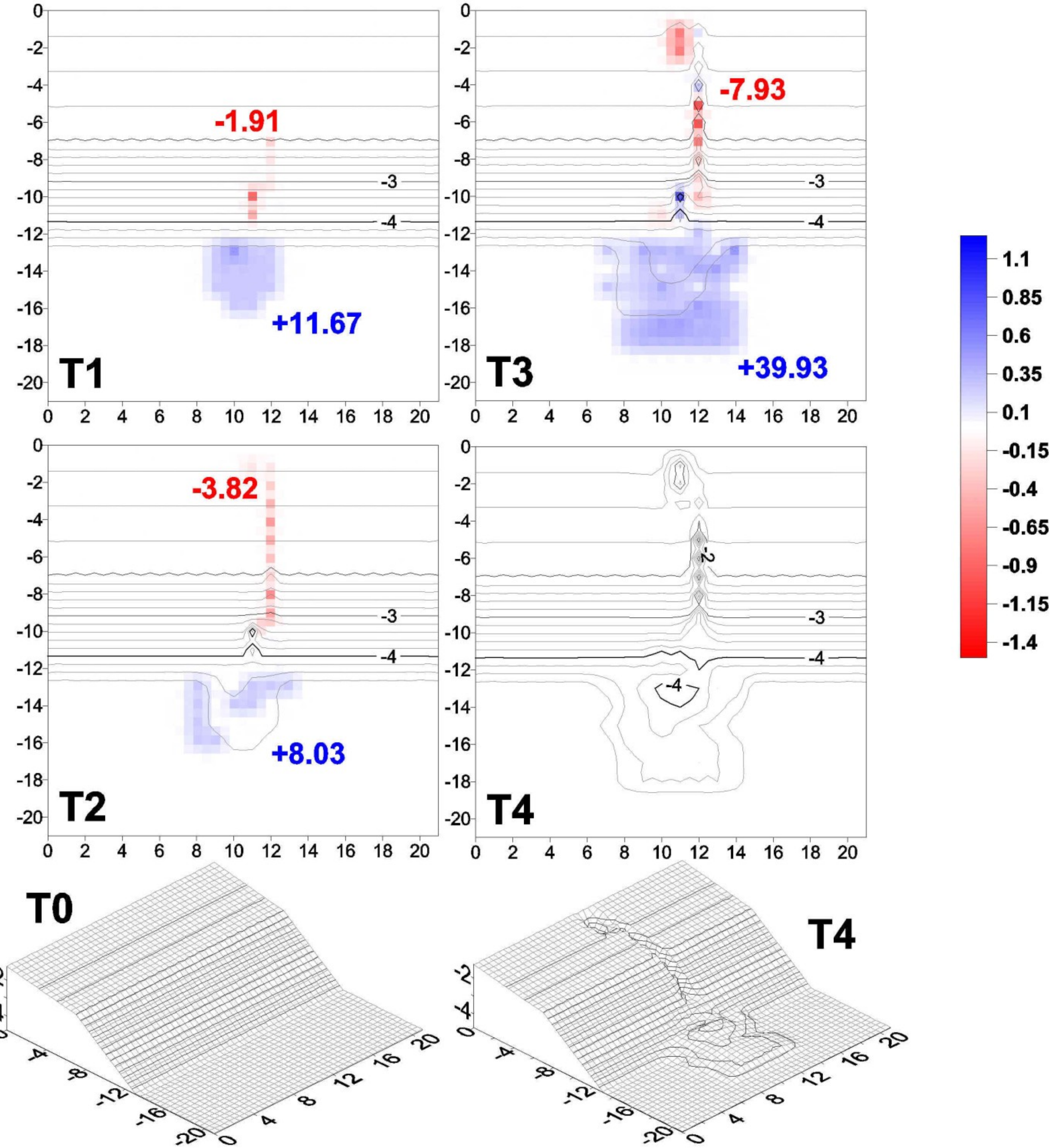


Constant rate of knickpoint migration!

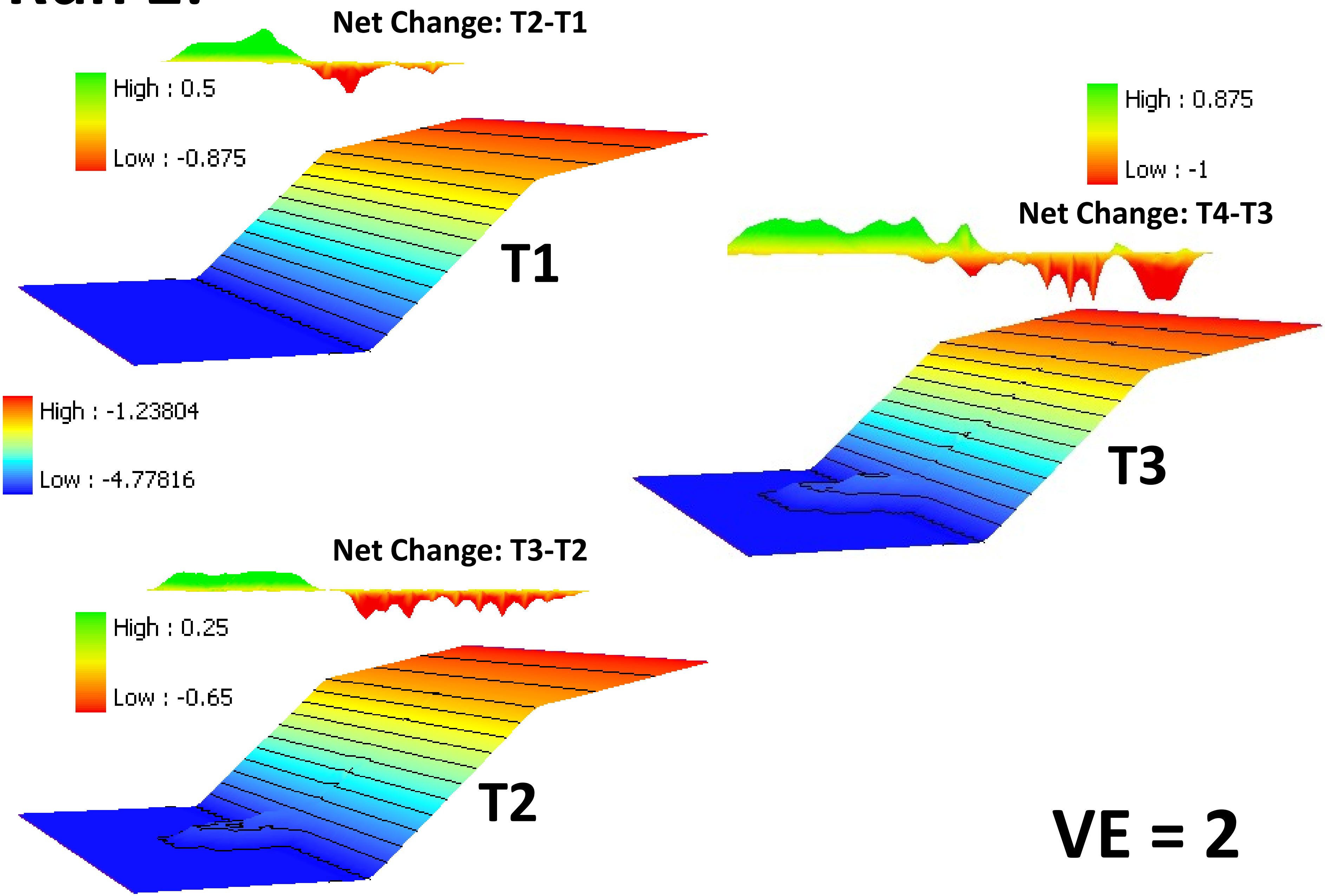
Results: Evolutionary Model – Run 2

- T0-T2 (0-180 sec)
  - Sheet flow dominates until incision occurs at the break-in-slope, which takes longer than during Run 1
- T2-T3 (180-270 sec)
  - Incision is more spatially confined than during Run 1
  - No distinct knickpoint, but rather a long zone of vertical adjustment
  - Fan builds rapidly, but is much less dynamic that the fan which formed during Run 1 (fewer lobe-switching events)
- T3-T4 (270-360 sec)
  - Vertical profile nears equilibration
  - Sediment is redistributed along the valley (isolated pockets of erosion and deposition
  - Sidewall failure
  - No incision into the fan is noticed

Run 2:


T1
-1.91
+11.67
T3
-7.93
+39.93
T2
-3.82
+8.03
T4
T0
T4
1.1
0.85
0.6
0.35
0.1
-0.15
-0.4
-0.65
-0.9
-1.15
-1.4

Run 2:

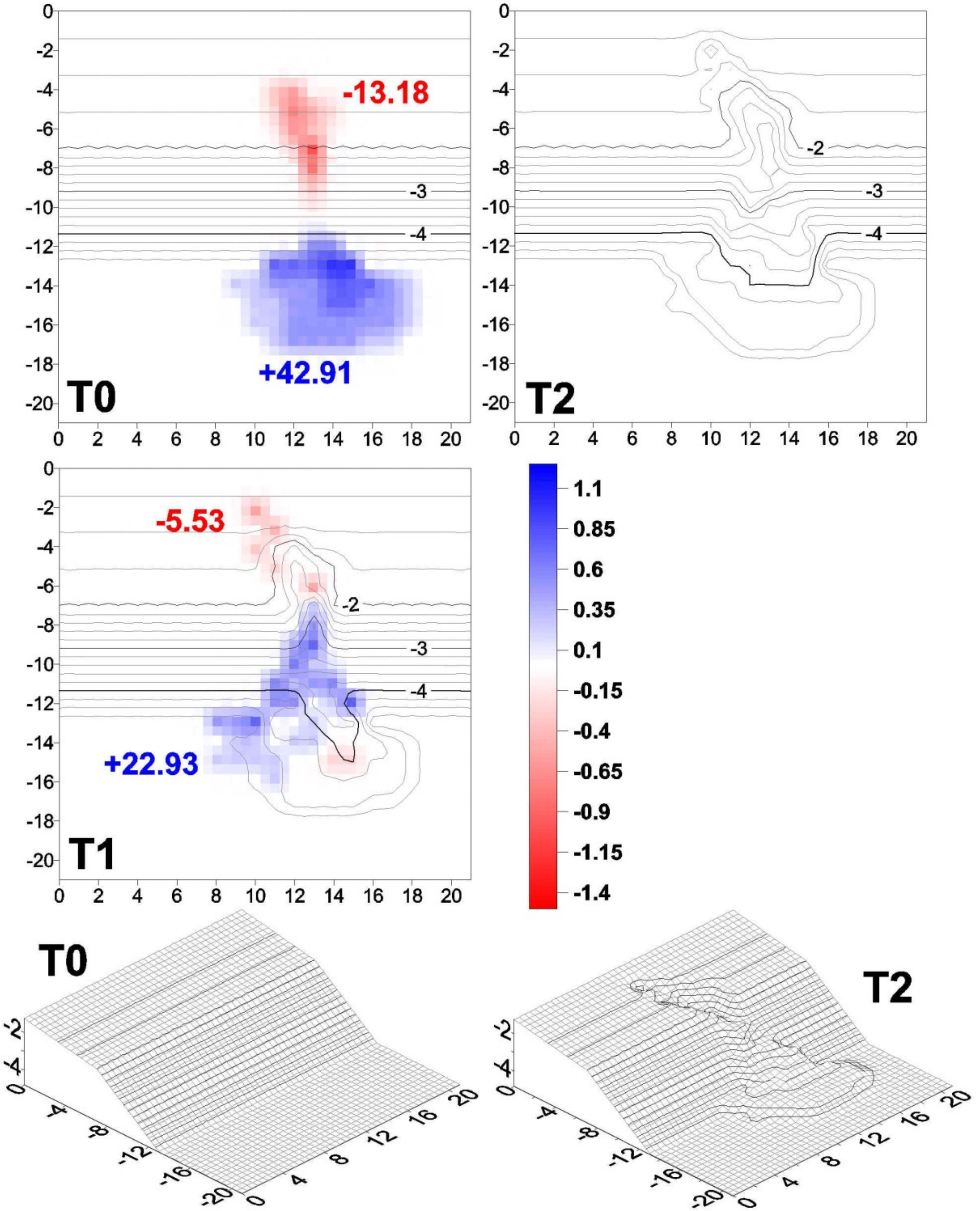


Net Change: T2-T1
High : 0.5
Low : -0.875
T1
High : 0.875
Low : -1
Net Change: T4-T3
High : -1.23804
Low : -4.77816
T3
Net Change: T3-T2
High : 0.25
Low : -0.65
T2
VE = 2

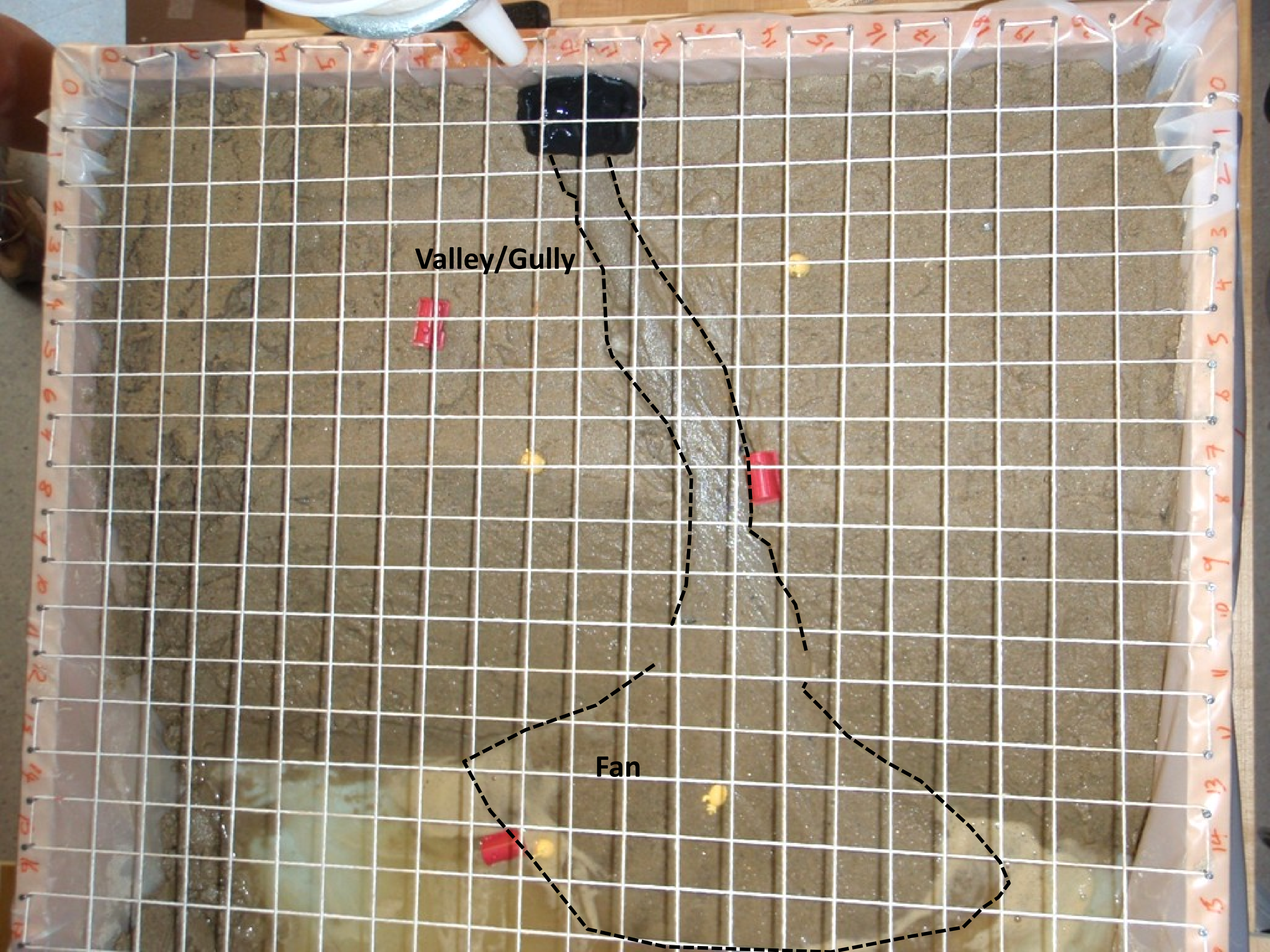
Results: Evolutionary Model – Run 3

- T0-T1 (0-90 sec)
  - Lack of channelized flow (little organization)
  - Slushy downhill movement of water and sediment (rapid)
  - Very fast rate of knickpoint migration
  - System is close to reaching vertical equilibrium
  - Rapid delta/fan growth
- T1-T2 (90-180 sec)
  - System equilibrates
  - Not much sediment transferred to delta
- T2-T3 (180-270 sec)
  - Incision into delta

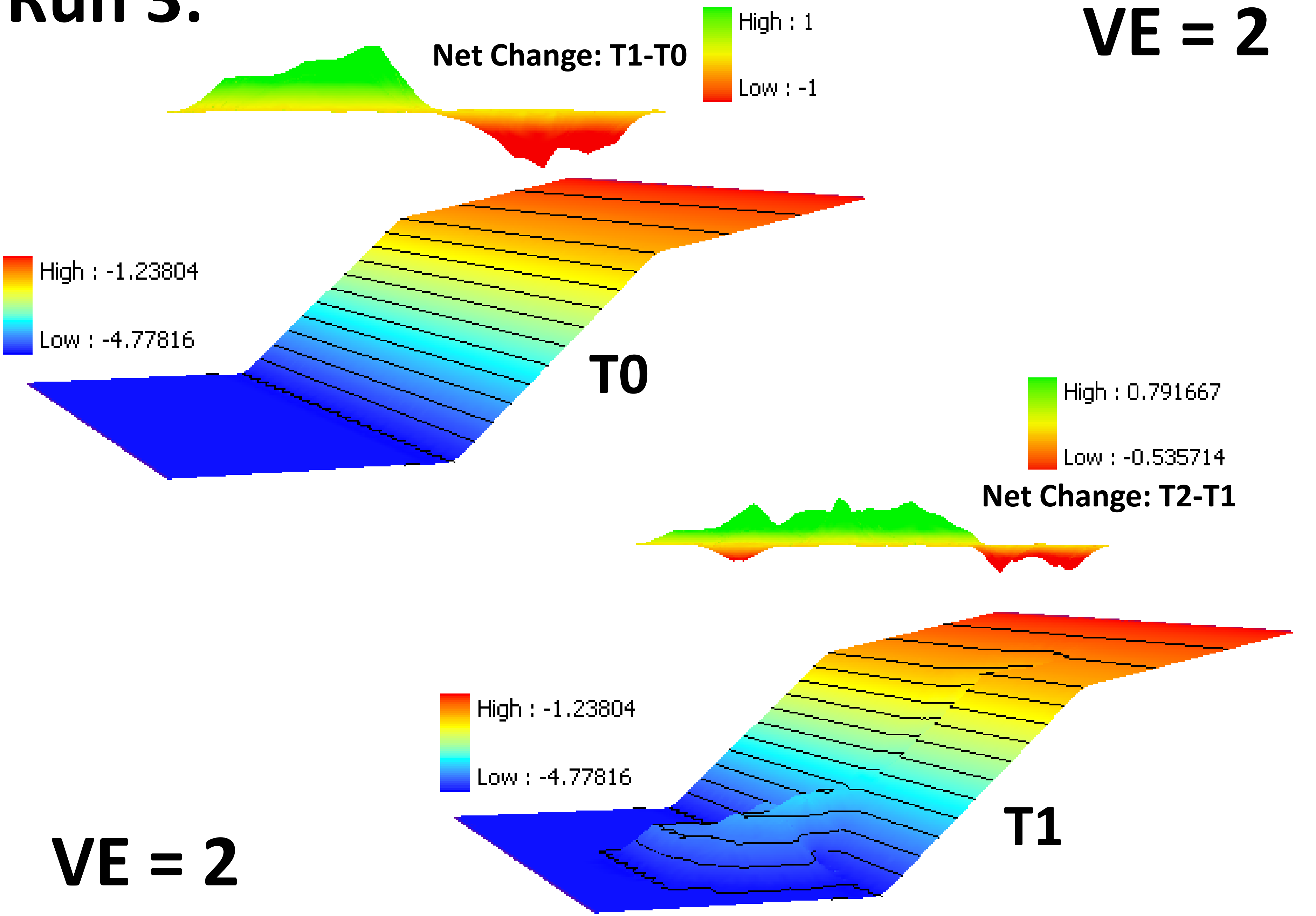
Run 3:



-13.18
+42.91
T0
T2
-5.53
+22.93
T1
-2
-3
-4
1.1
0.85
0.6
0.35
0.1
-0.15
-0.4
-0.65
-0.9
-1.15
-1.4


Valley/Gully
Fan

Run 3:

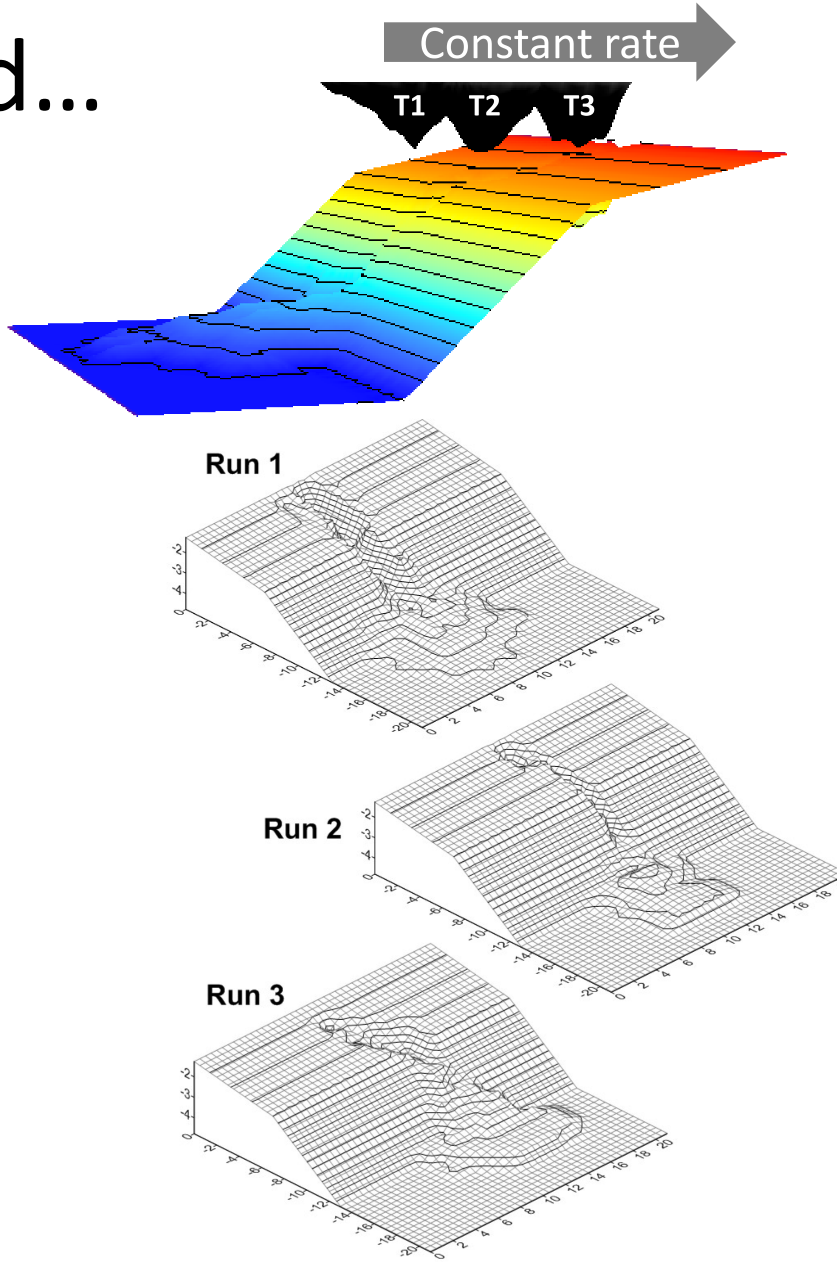


VE = 2
Net Change: T1-T0
High : 1
Low : -1
High : -1.23804
Low : -4.77816
T0
High : 0.791667
Low : -0.535714
Net Change: T2-T1
High : -1.23804
Low : -4.77816
T1
VE = 2

Sediment Budgets

- Discrepancies:
  - Erosion harder to measure accurately than deposition
    - Erosion is underestimated when delta/fan deposition follows valley excavation (which is hard to measure from above…)
  - Deposition can be underestimated due to:
    - Loss from system (down the drain…)
    - Deposition below vertical sampling interval

Things we have learned…



- Rates of knickpoint migration are primarily a function of discharge (Q)
- Antecedent conditions in the flume have a very strong influence on the nature of incision (valley widths) and, to a limited degree, response times (when knickpoint migration initiates)
- There is a degree of self-regulation
  - A decrease in sediment supply from the upland results in downstream incision