Predicting soil texture with geomorphic process models in the eastern Mojave Desert

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What is Soil Texture

- Percentages of gravel, sand, silt and clay (and sub-fractions)
- Vertical horizonation due to soil development

Why Do We Want it

- Soil Texture directly affects the following landscape components:
- Hydrological
- Biological
- Physical

Soil Texture and Hydrology

Soil Texture and Bulk Density are primary drivers in calculations of hydraulic behavior

- How much water can infiltrate into soil
- How long moisture stays in the soil

Soil Texture and Biology

- Plants and animals respond to water budget
- Some components need a stable surface free of physical disturbance
- Nutrient and habitat availability

What should a soil texture map have?

Horizontal coverage

- Describes observed data and predict unsampled areas
- Describe natural variability (there's a LOT!)
- Appropriate scale
- Some understanding of uncertainty of predictions

Vertical component

- All of the above
- Soil horizonation from soil development

Approach

Collect field data

- Sample representative environments
- Focus on important and variable soils

Extrapolate observed data using:

- Surficial Geology
- Geomorphic Process Models

Field Sampling

- Focus on wide-spread and biologically important soils
- Sample to capture variability
- Vertical samples to capture soil horizons

1. Top 10cm is where most soil development changes occur
2. Sample at 0-1cm, 1-5cm, 5-10cm intervals to capture relative soil development

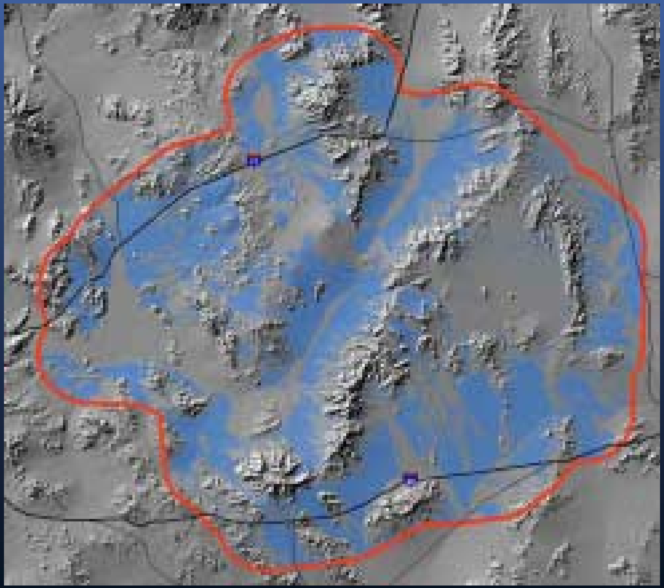
Focus: Holocene alluvial fan deposits

Widespread

Biologically important

Most variable

1. Geologically variable
2. Biologically variable



Particle Size Data

Samples sieved at USGS Sacramento Lab

- Lab returns weight percent of 11 size fractions

So now we know how much gravel, sand, silt, clay (etc) are at a point (actually, at nearly 400 points)…

What’s next?

Surficial Geologic Maps: depositional process and age

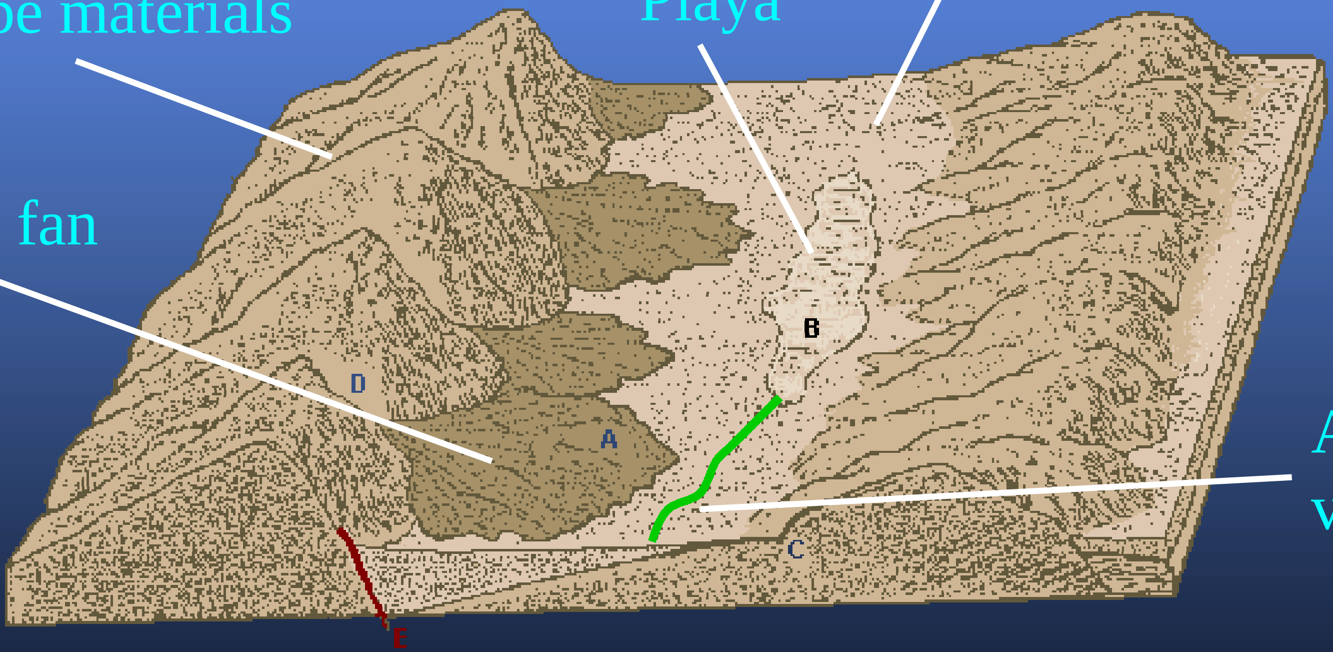
Mountains with hillslope materials

Alluvial fan

Playa

Piedmont (coalesced fans, bajadas)

Axial valley wash



Others: Eolian sand dunes and sheets
Groundwater discharge deposits

Surficial Geologic Maps: Depositional process and age

- Mapped units have a class of soil development that can be used to determine what has happened to a deposit after it was put there
- Fine sand, silt and clay additions with age

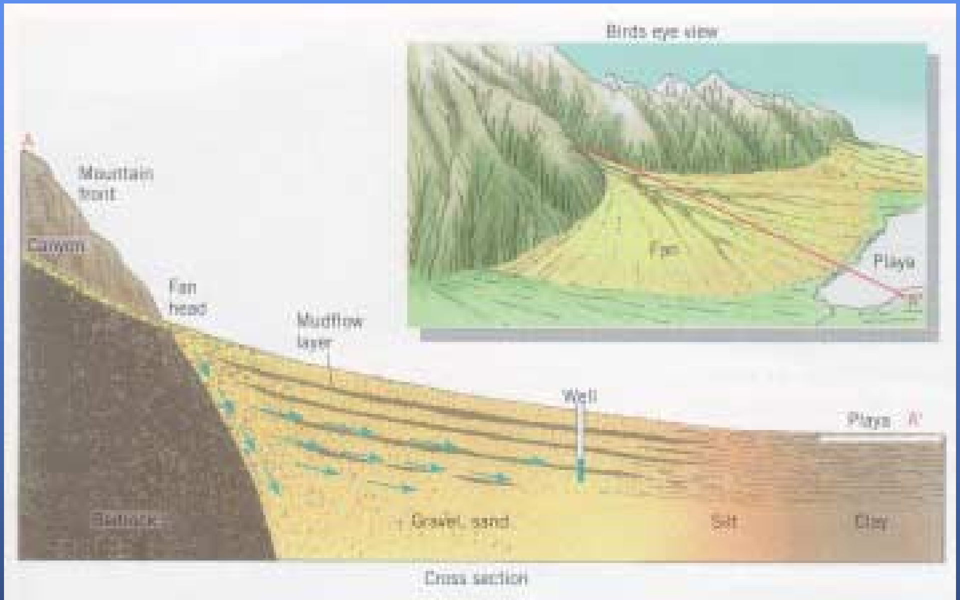
Geomorphic Process Models

- Physics-based models of processes that sculpt the landscape
- Appropriate only for specific types of landscapes
- Specify affect of landscape form on the processes acting on that form

So, if you can model a process governing deposition of alluvial material based on landscape form, then you can use the landscape (via a DEM) to predict depositional characteristics

Geomorphic Processes on Alluvial Fans

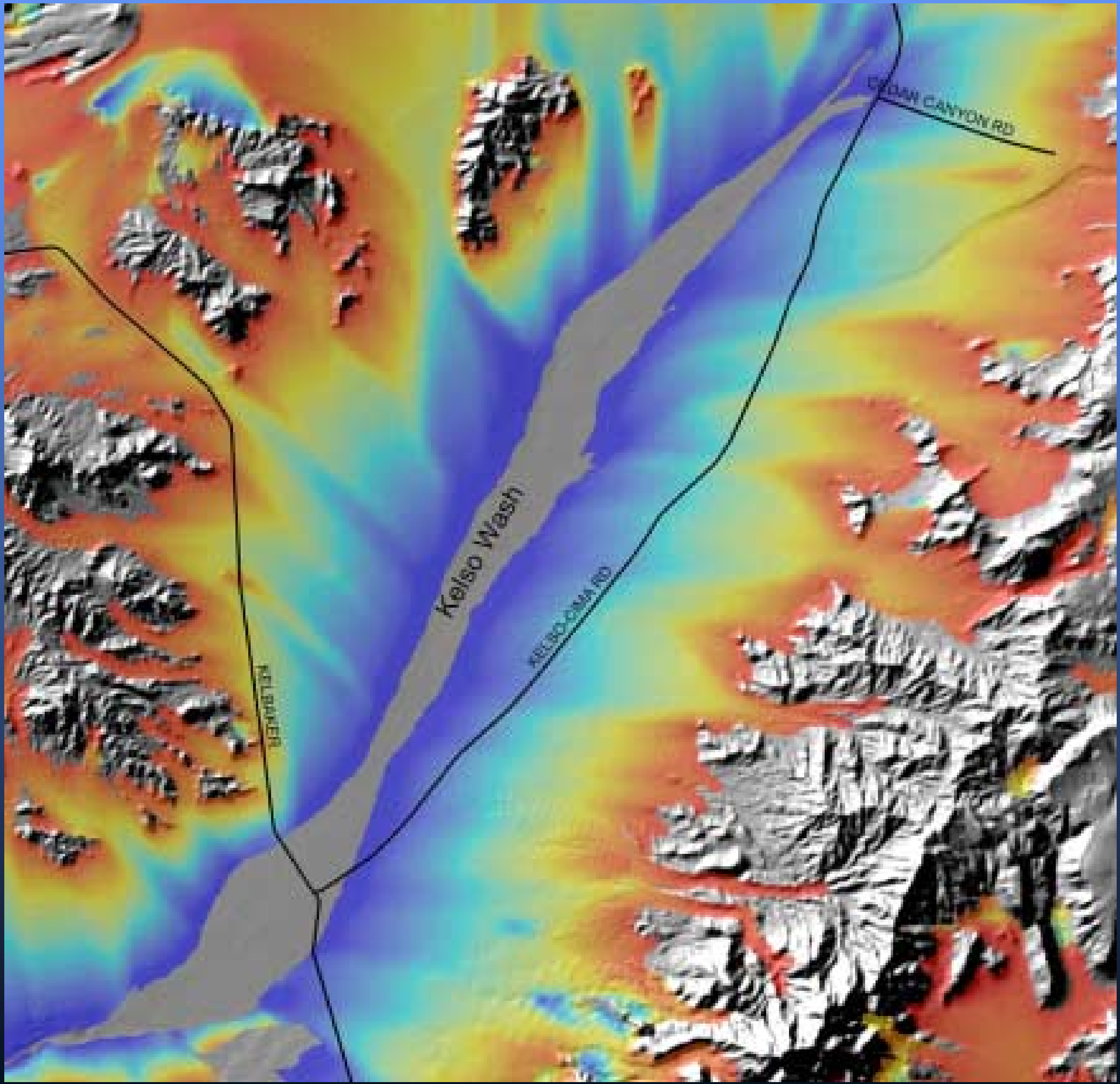
- Sediments on most alluvial fans are deposited by water, which is driven by gravity (moderated by slope) and is resisted by friction on the streambed
- Sediments in rivers, and fans, tend to be finer-grained as they progress from their sources



1. Model location on a fan
2. Normalize location to account for large variations between fans (lengths and slopes) and within
3. Use the fan location to model ‘fining’ process on a fan

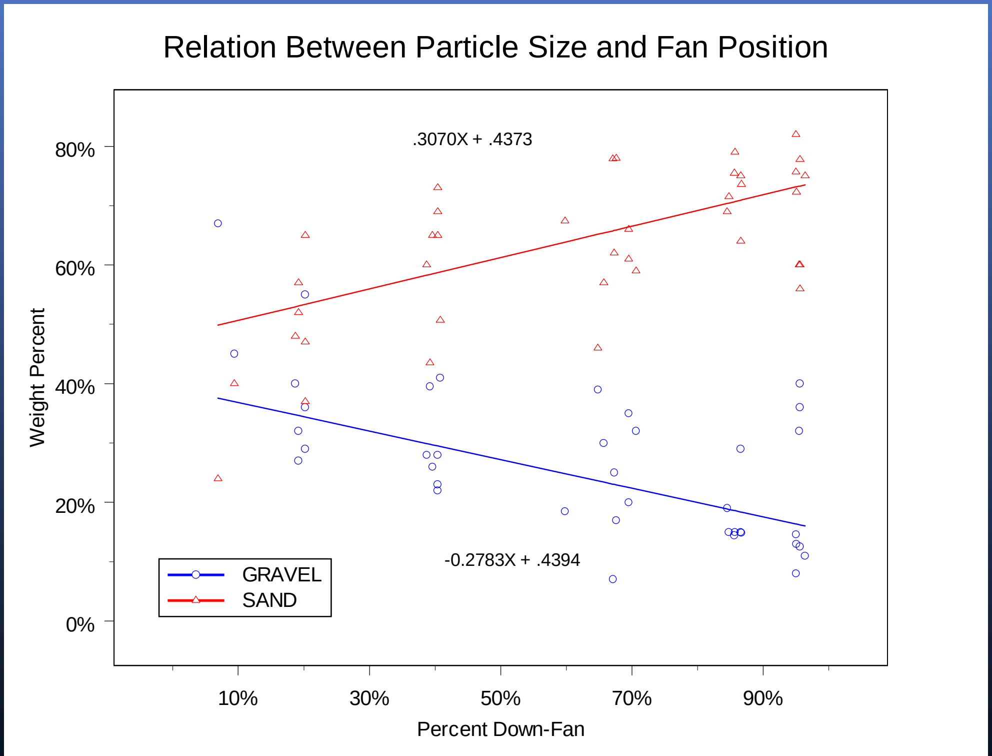
Alluvial Fan Position Model

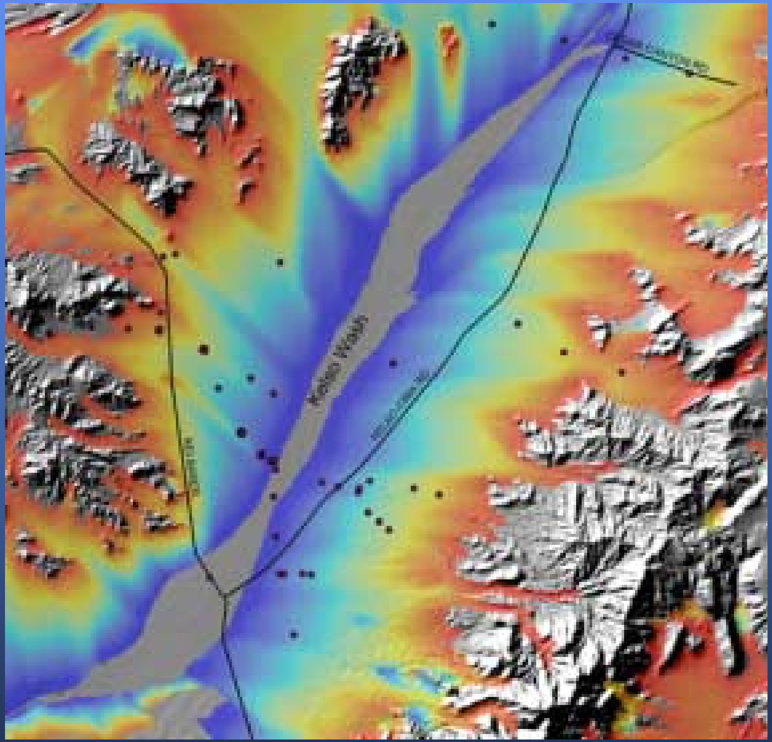
1. Use geology database to define alluvial environment
2. Use geology to clip source (mountain fronts) and sinks (playas and large washes) from DEM
3. Model water flowpath across a fan from source to sink
4. From predicted flow paths, we can calculate the distances along the path from source to sink, then normalize the location



Determine Soil Texture and Landscape Relationships

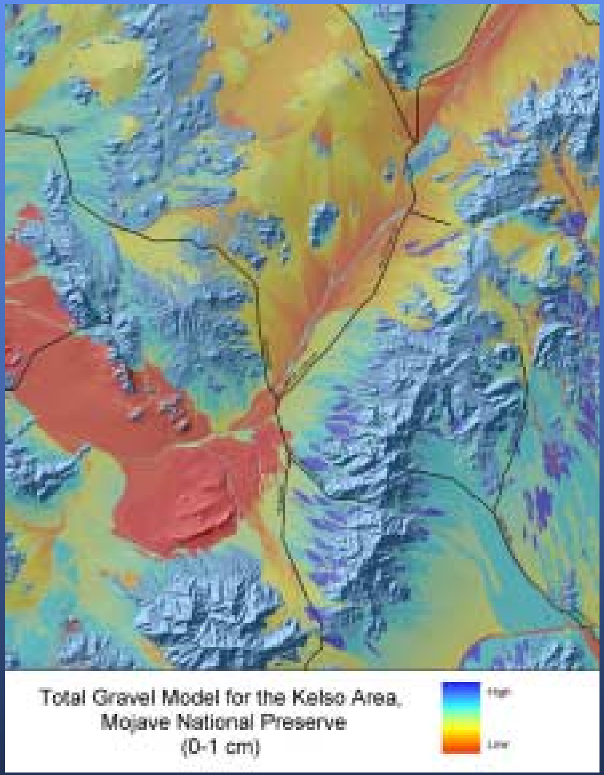
- Spatially interact sample locations with the fan position model in GIS
- Look for statistical relationships between texture and fan position

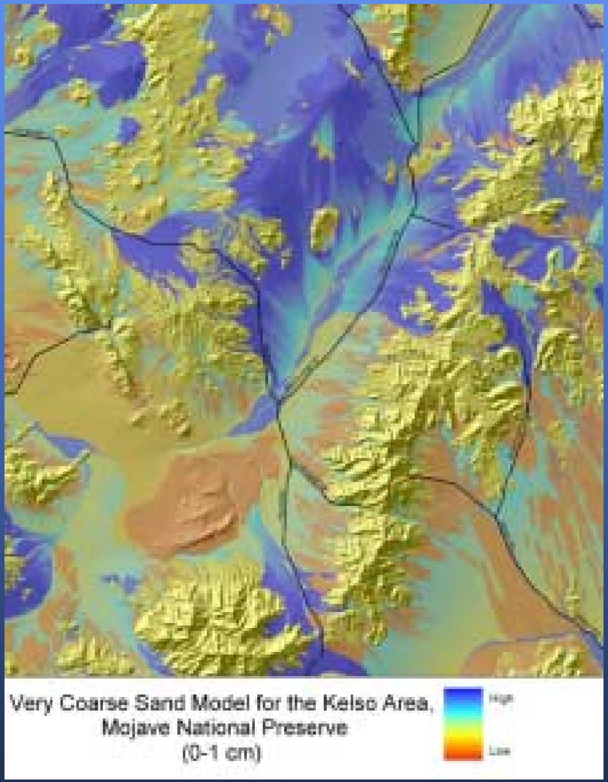


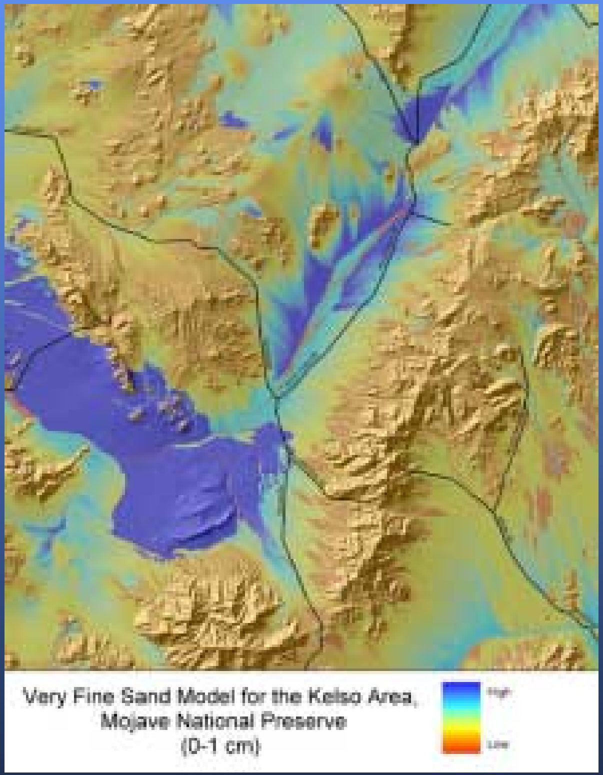


- Develop regression equations for each particle size fraction, AND for each sample horizon

Apply Soil Texture to Fan Position Model

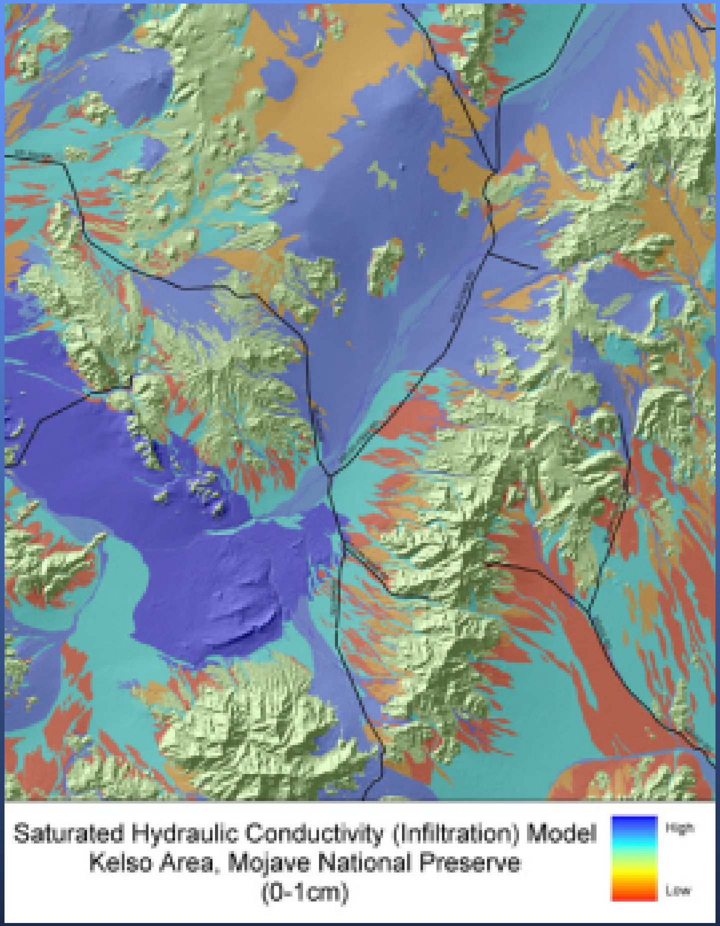


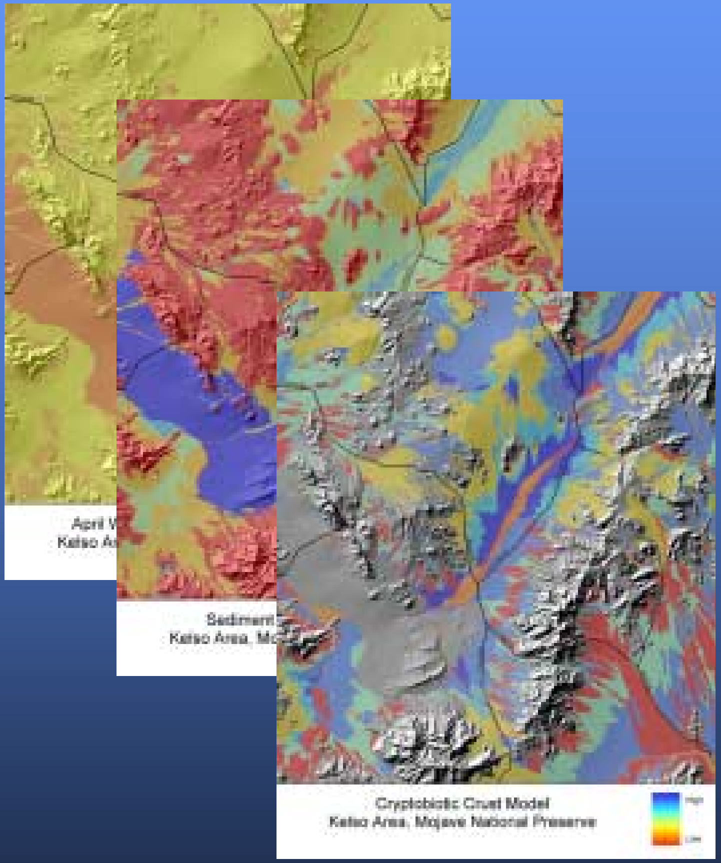




- Apply the model equations to alluvial environments that have little soil development
- For other areas use summary statistics from samples

Derivative Maps from Soil Texture Models





- Infiltration, soil crusts, wind erosion….

Refinements

- Lithology: different rock types weather to different sizes of material, so they may have different starting materials

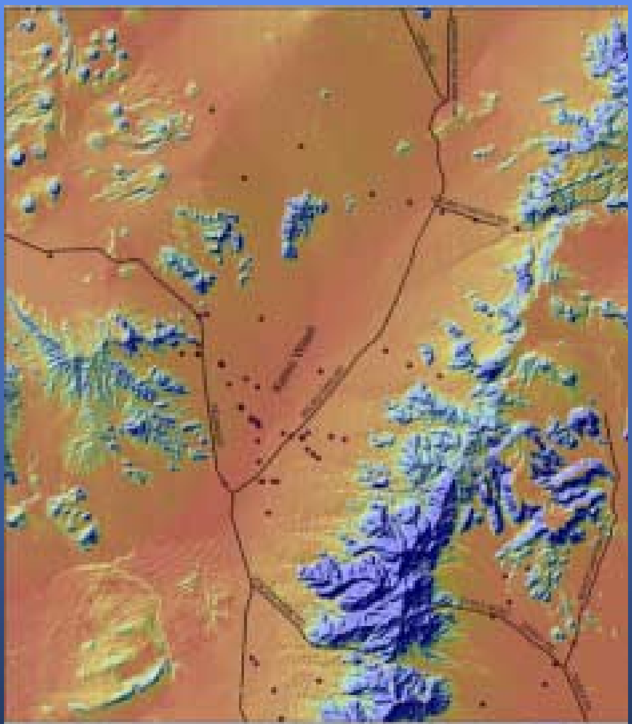
  ↳ ‘grus-weathering’ fans are already included

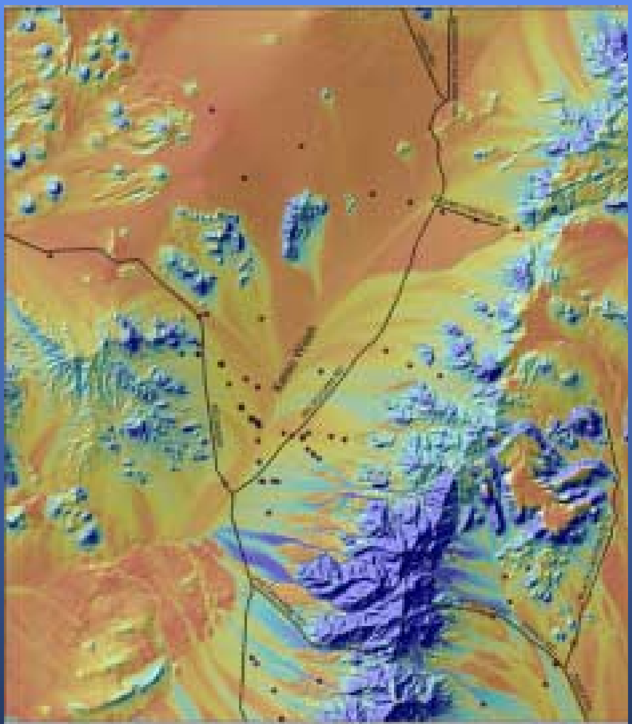
- Other landscape variables may be useful

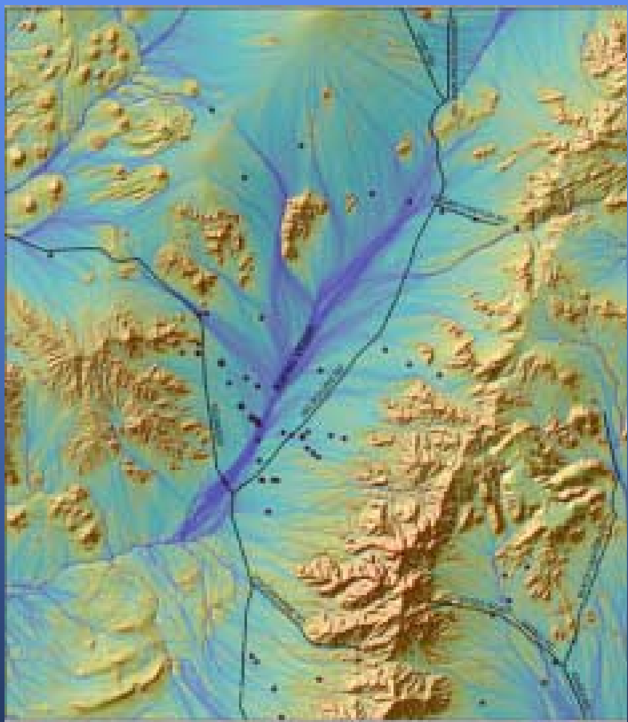
  Local variables: Slope, probability of flooding, etc

  Regional: catchment area, geometry, etc

Refinements (ongoing)

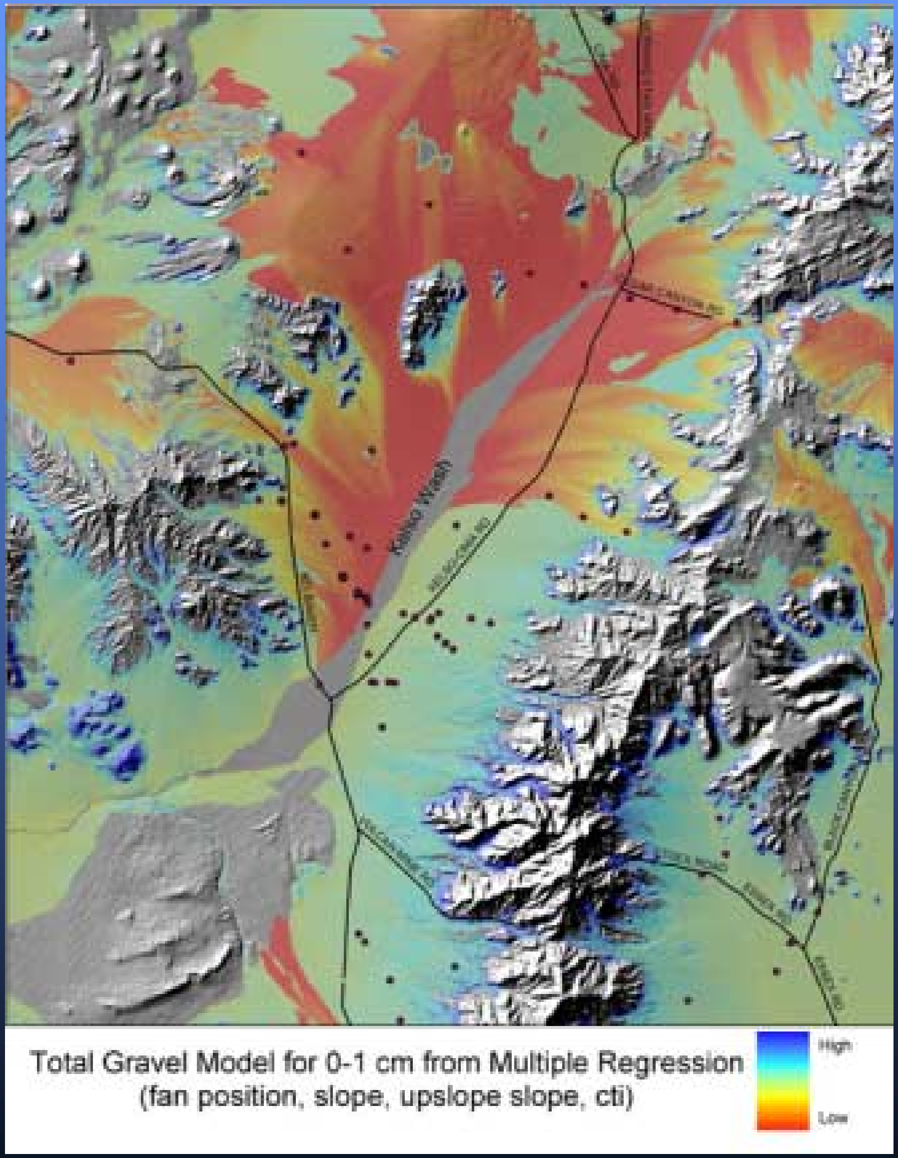

Local Slope


Upslope Slope
(catchment slope dominated)


Compound Topographic Index
(catchment area and slope)

- Multiple regression of particle size and several landscape parameters

Multiple Linear Regression Example



Preliminary Total Gravel map of 0-1 cm layer incorporating:

<u>Fan position</u>

<u>Slope</u>

<u>Uplsope Slope</u>

<u>CTI</u>

<u>Lithology (grussy vs. non)</u>

(geologic age not considered)

Further Work (beginnings)

Error Analysis

- Find areas where model is wrong based on sample data, and figure out why, or quantify uncertainty

Natural Variability

- Is the model wrong or is the system just complex

More Process Types for Alluvial Fans

- This is a fluvial (stream based) model, but debris flows are common, if we understand where and how they occur, we can look for new process models

Under-represented Environments

- Hillslopes, wash, eolian, and mixed environments also need data and some smart way of extrapolation

Conclusions

- Understanding of landscape processes is needed to determine how materials have been deposited and changed since deposition
- Geomorphic process models try to numerically describe the process in relation to landscape form
- Process models can be calibrated with robust field sampling to distribute the field data
- Things are complex, and we need to understand that, and try to qualify uncertainty