Development and Application of a Piedmont Stream Conceptual Model

Bruce Pruitt & Kyle McKay

2011 National Conference on Ecosystem Restoration (NCER)
Baltimore, Maryland
August 2, 2011

US Army Corps of Engineers
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GOALS AND OBJECTIVES

Goal: **Formulation of Conceptual Models for Piedmont Streams**

Objectives:

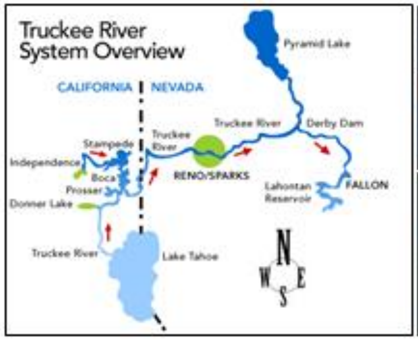
1) Discuss importance of restoration benefits and development of Piedmont conceptual models including regional application

2) Identify historic conditions & subsequent predominant modifiers / stressors

3) Present examples of Piedmont conceptual models

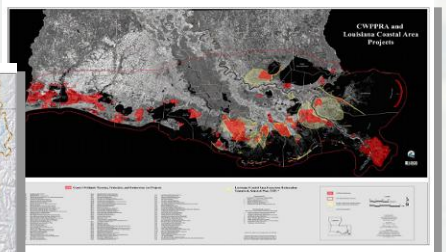
4) Discuss Process >> Function >> Benefits throughout presentation

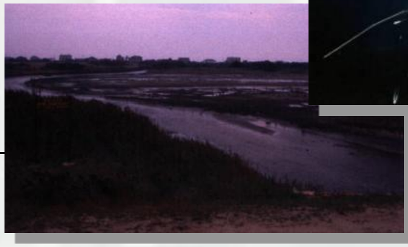
U.S. Army Corps of Engineers Ecosystem Restoration Mission

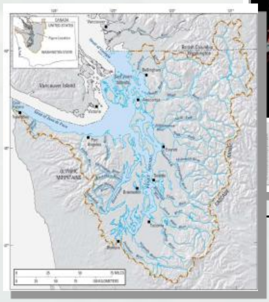


Restore significant ecosystem structure, function, and dynamic processes that have been degraded

- Nationally and regionally significant
- Wetlands, riparian zones, floodplains, and ***aquatic systems***







Assessing Restoration Benefits

- Which alternative is **preferred**?
- Are the benefits **worth** the investment?

- What is the **priority** among projects?
- What are the **cumulative benefits**?

Regional Benefits Analysis

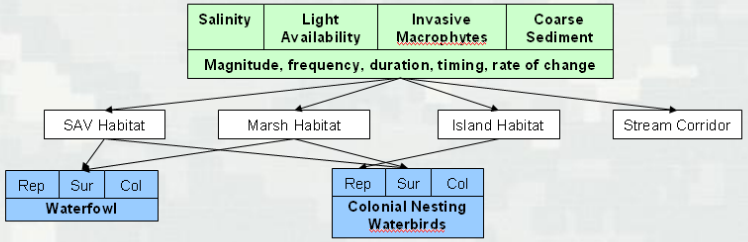
- Planning efficiency
  - ▸ Consistent scientific basis
  - ▸ Metric and model development
  - ▸ Simpler “roll-up” of benefits across a region

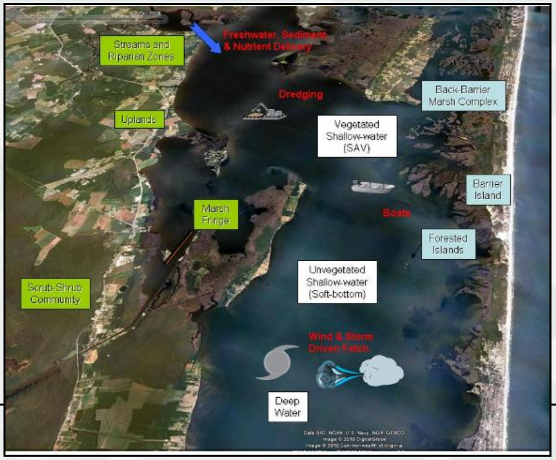
- Piedmont Stream Case Study
  - ▸ Conceptual model linking drivers and stressors to ecosystem services

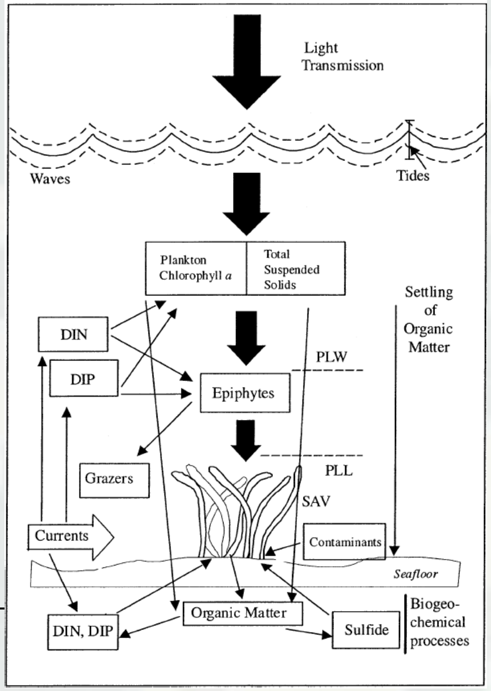
Figure: EPA Level III Ecoregion, William Graf, and Carla Atkinson

Why develop a conceptual model?

- Synthesize current understanding system function
- Understand and diagnose underlying stressors
- Develop a common “mental picture” from which to develop alternative restoration actions
- Identify metrics for project planning, monitoring, and adaptive management
- Guide numerical model development
- Guide and plan restoration alternatives
- Identify R&D needs

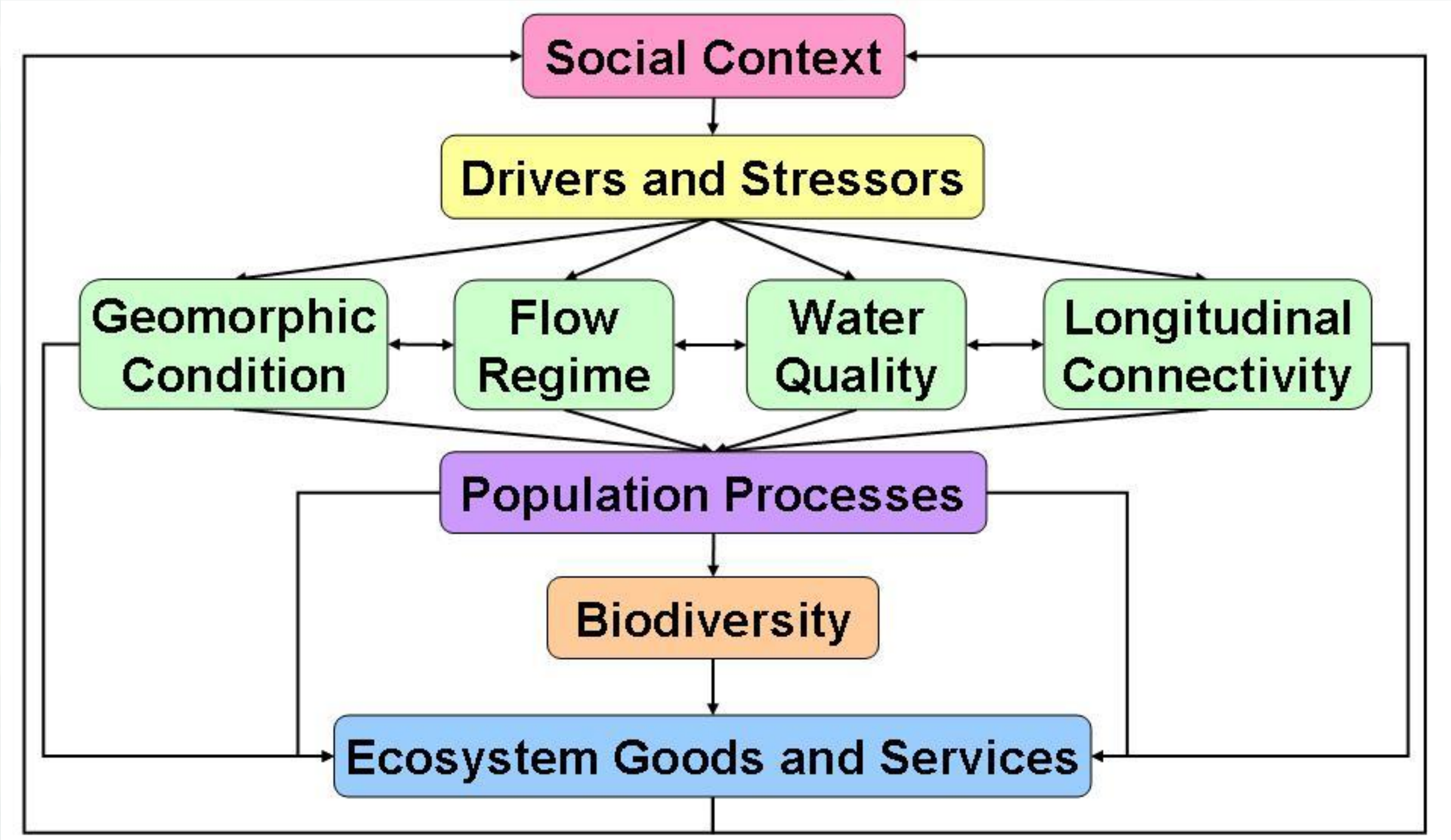






Figures: USACE Currituck Sound Restoration

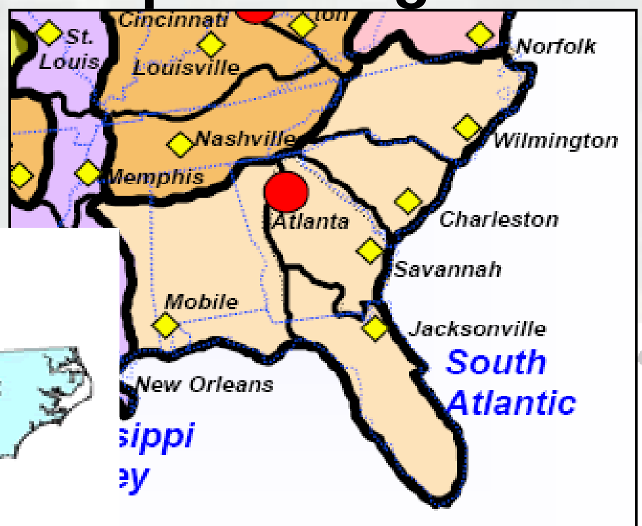
A Generalized Conceptual Model



Hyper-Drivers / Social Context

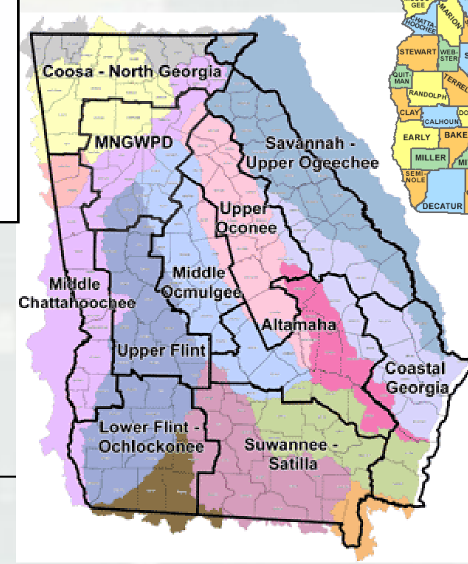
Public opinion	Funding	Population growth
Regulations	Legal constraint	Political jurisdiction
Quality of Life	Demand / Supply	Technology development

Corps of Engineers

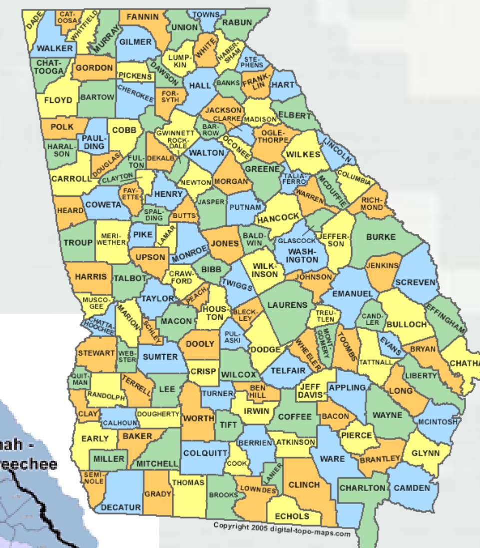


EPA

GA DNR

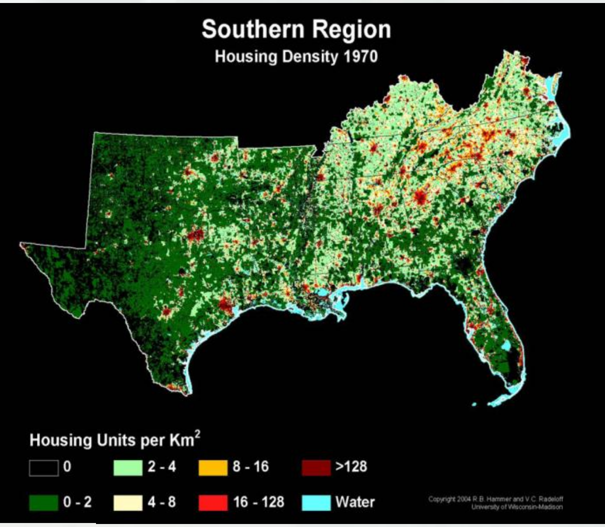


GA Counties



Drivers of Piedmont Streams

Resource Extraction	Sand and Gravel	Timber	Mines
Ecosystem engineers	Beavers	Invasive species	
Climate Change	Temperature	Precipitation	
Infrastructure	Transportation	Dams	Withdrawals
Urban Land Use	Channel alteration	Impoundments	Land Use
	Point sources	Non-point sources	
Agriculture Land Use	Silviculture	Crop	Animals



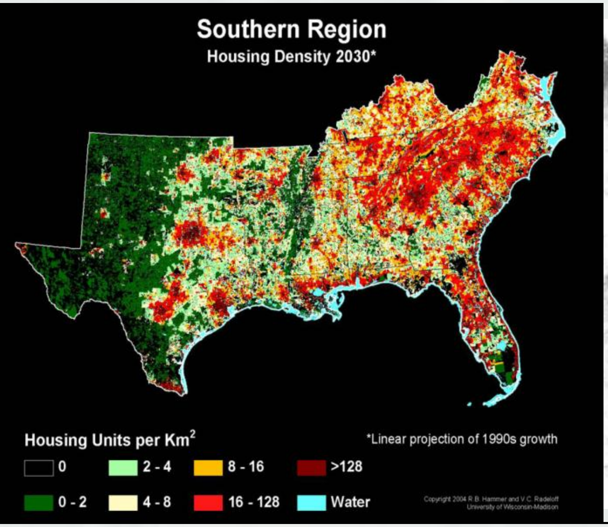


Figure: Hammer and Radeloff (2004), Rhett Jackson

State Conditions

- Geomorphic Condition
  - Channel evolution model + 1
- Flow Regime
  - Minimally altered, flashy, damped, damped with peaking; De-coupled stream from floodplain on frequent events
- Water Quality
  - Minimally altered, physio-chemical stress, nutrient enrichment, chemically contaminated
- Longitudinal connectivity
  - Bi-directional, upstream only, downstream only, disconnected

Figure: Schumm (1977) in Watson et al. (2002), NRCS (2007)

State Historic Conditions

32 times. Rows that run up and down the slope when cultivated form small ditches that concentrate the water and increase the amount of erosion. (See fig. 6.)

Where the upper soil is washed quite evenly from the surface of the land over wide areas, due to the moving water being quite uniformly distributed over the surface, erosion in the form of sheet washing occurs. (See fig. 1.) Where gullies are washed down the slopes, due to large volumes of water flowing over narrow strips of ground, generally in depressions or draws of a field, erosion known as gullying occurs. (See fig. 2.) Sheet washing is not so noticeable as gullying, and for this reason many farmers do not consider it very harmful. However, it is very destructive, since it robs the land of the surface soil which is known to contain a higher percentage of humus and other essential elements of fertility than the subsoil. Also it is practically impossible to secure the full benefit of expensive fertilizers and manure where sheet washing occurs, since they are

Fig. 6.—View showing erosion between cotton rows where rows are run directly up and down the slope, a practice which is responsible for a large percentage of badly eroded lands.

rapidly washed away along with the surface soil. If methods were employed to prevent sheet washing, few gullies would ever be formed in a field, since sheet washing finally develops into gullying.

METHODS OF PREVENTING EROSION.

Since erosion is due largely to the rapid movement of the rain water over the surface of the ground, methods of preventing erosion must cause the water either to sink into the soil or flow away slowly over the surface to a drainage channel. If the rain water were absorbed by the soil as fast as it falls, there would be very little erosion.

In order to drink up surface water rapidly a soil must be very permeable, which means that it must contain fairly large open spaces through which the rain water can pass easily, or where it can be stored temporarily. Some soils are naturally very permeable. A number of ways of increasing the permeability of a soil are deep

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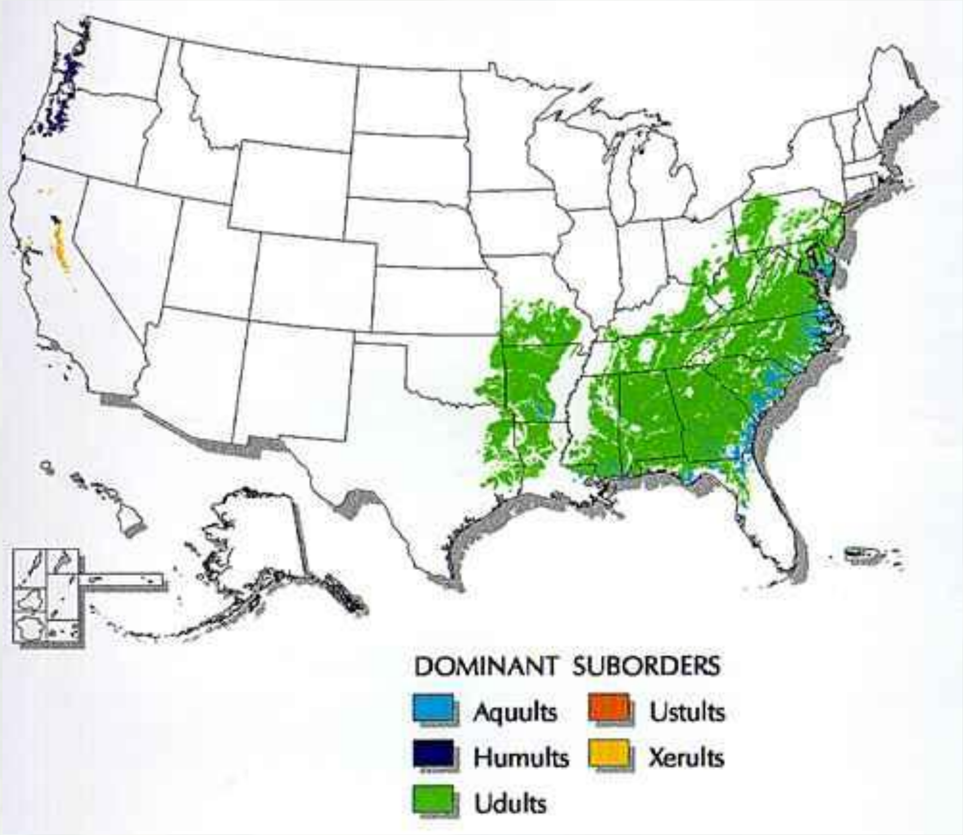
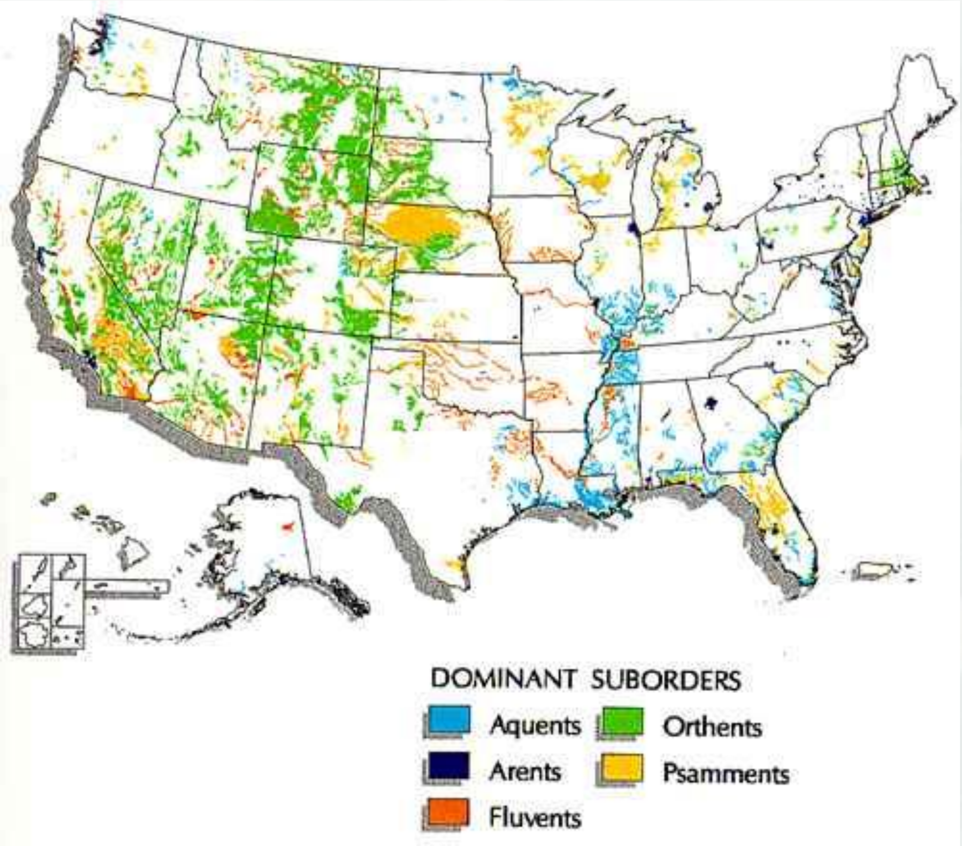
http://soils.usda.gov/technical/classification/orders/



Ultrisols


DOMINANT SUBORDERS
Aquents
Orthents
Arents
Psamments
Fluvents

Entisols

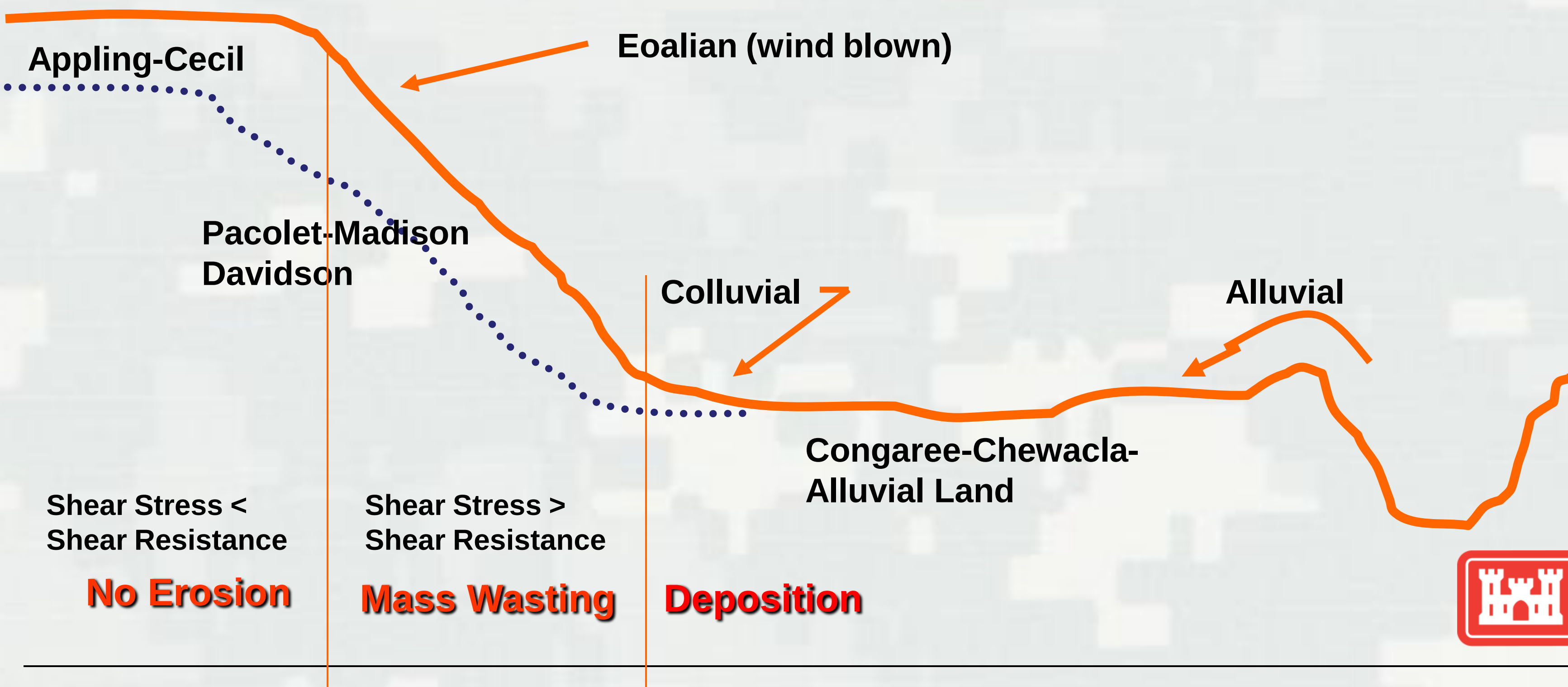
CORRESPONDENCE BETWEEN A TYPICAL PIEDMONT CATENA AND SOIL ASSOCIATIONS

1) Shear Stress

$$\tau = \gamma \, d \cos\theta \sin\theta$$

τ = shear stress
γ = specific weight of water
d = mean depth of flow
θ = local slope angle

2) R = Shear resistance of soil surface horizon



State: Geomorphic Condition

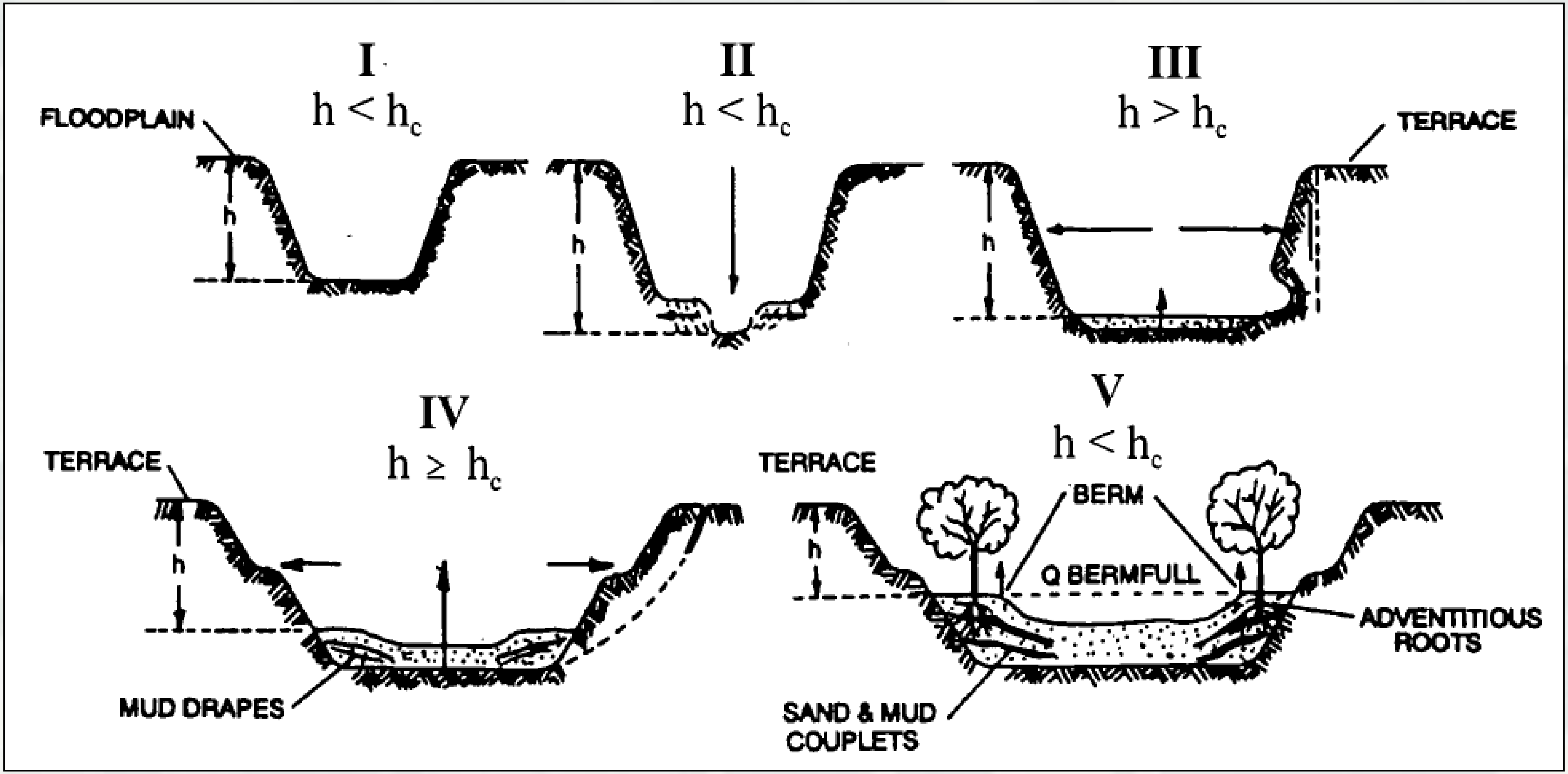
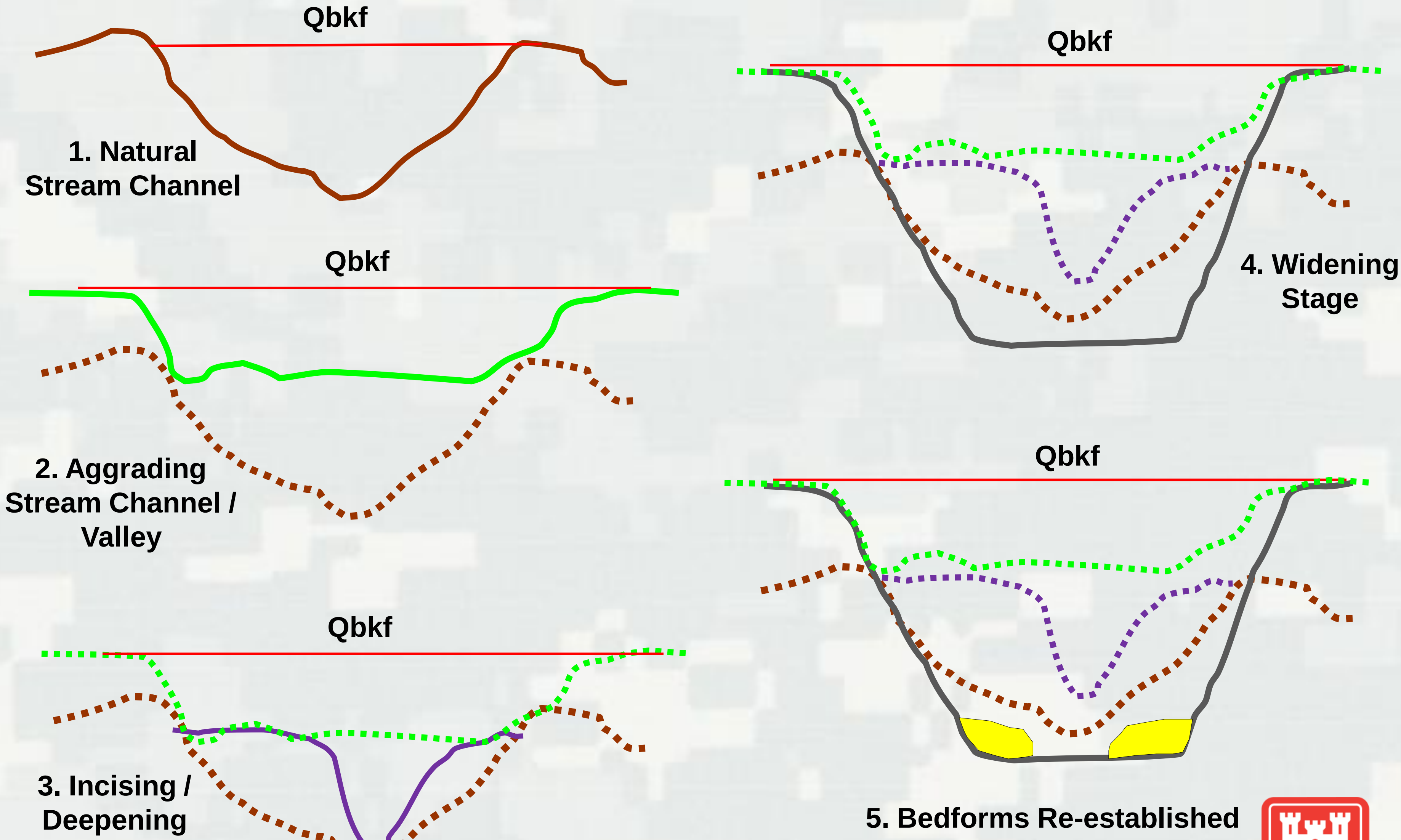


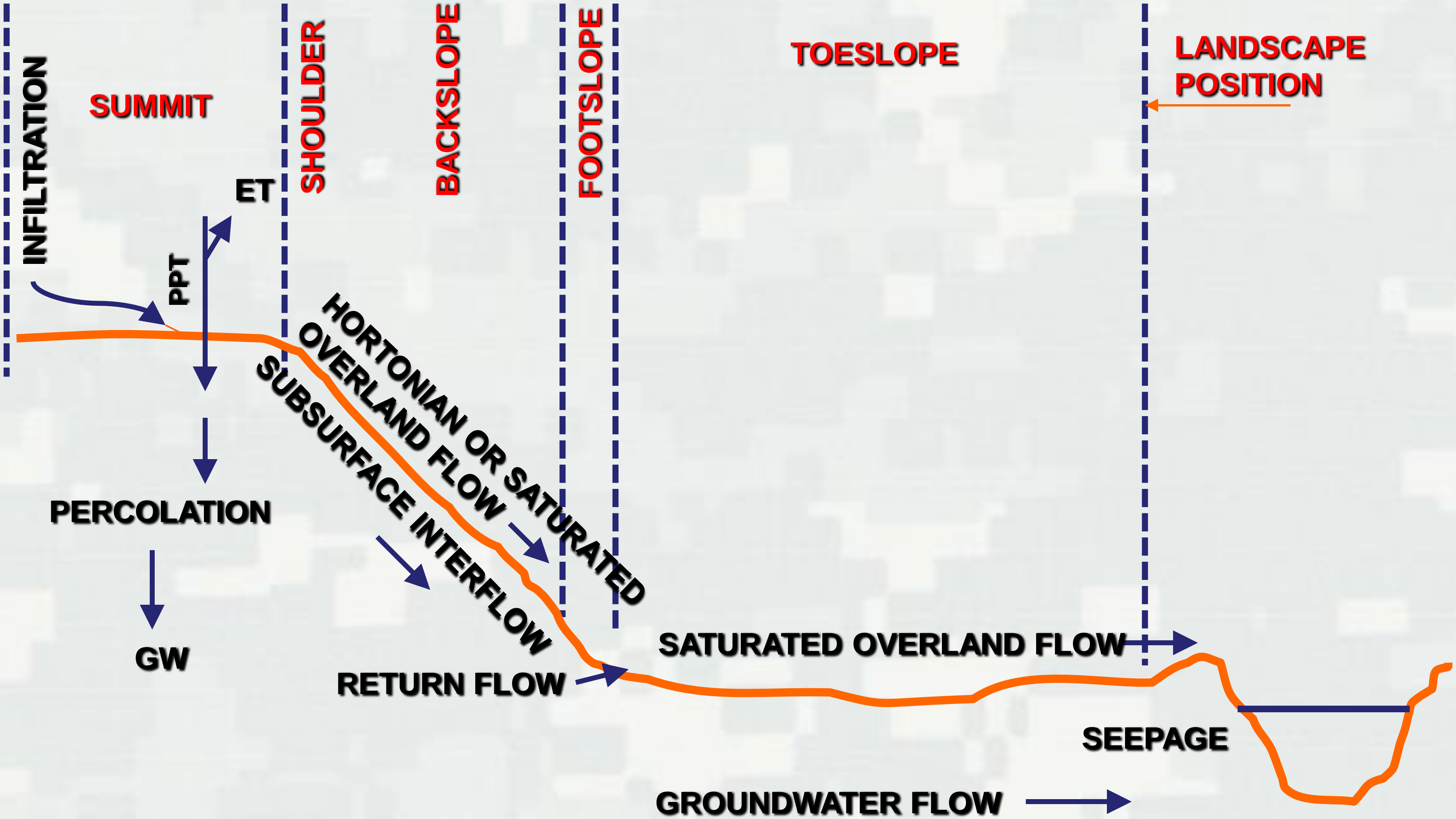
Figure: Schumm (1977) in Watson et al. (2002)

Piedmont Channel Evolution Following Cotton Era

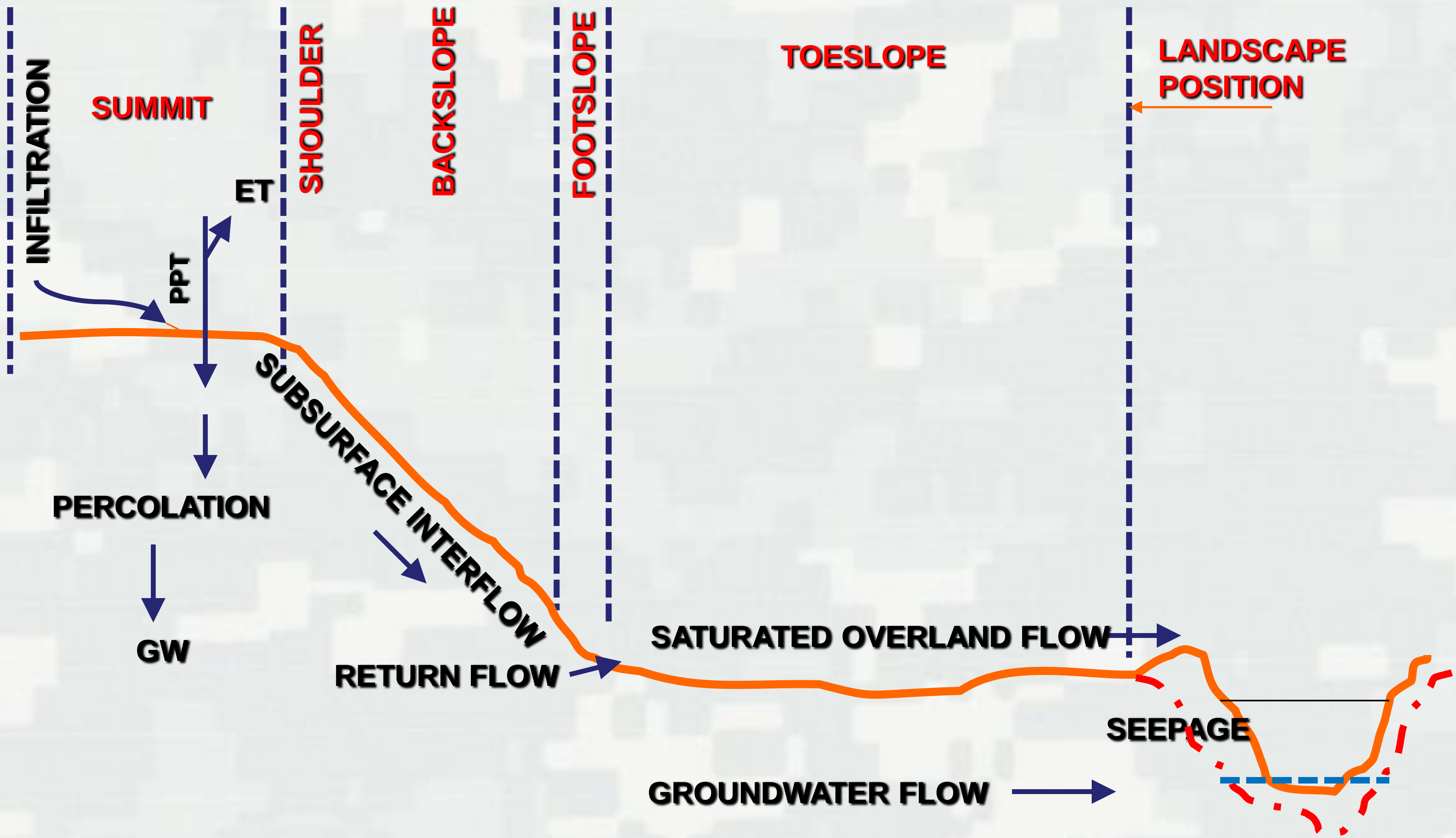
(Introduced at NCER 2011, Pruitt)



State: Hydrologic Condition

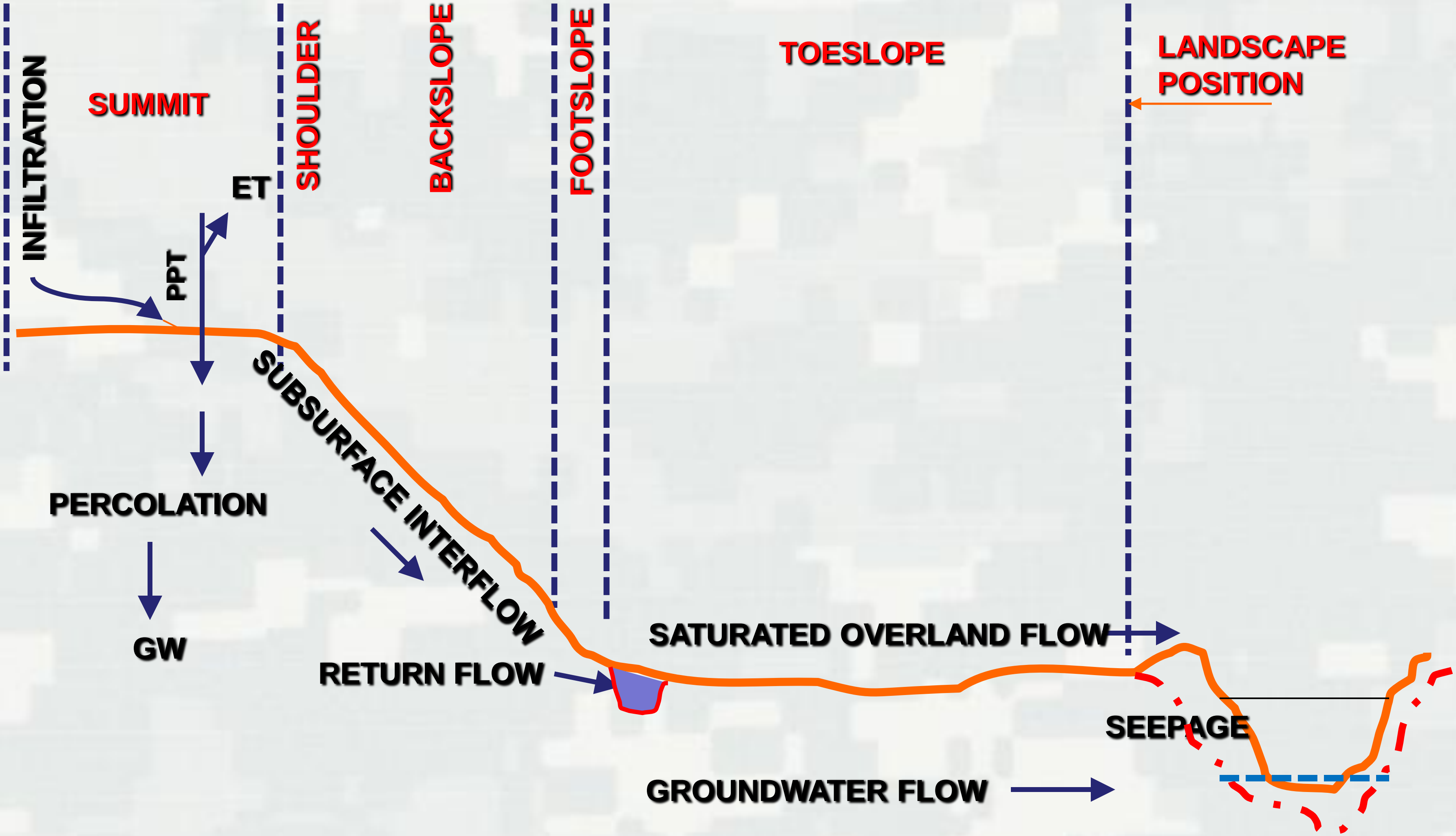


HILLSLOPE HYDROLOGY CONCEPTUAL MODEL

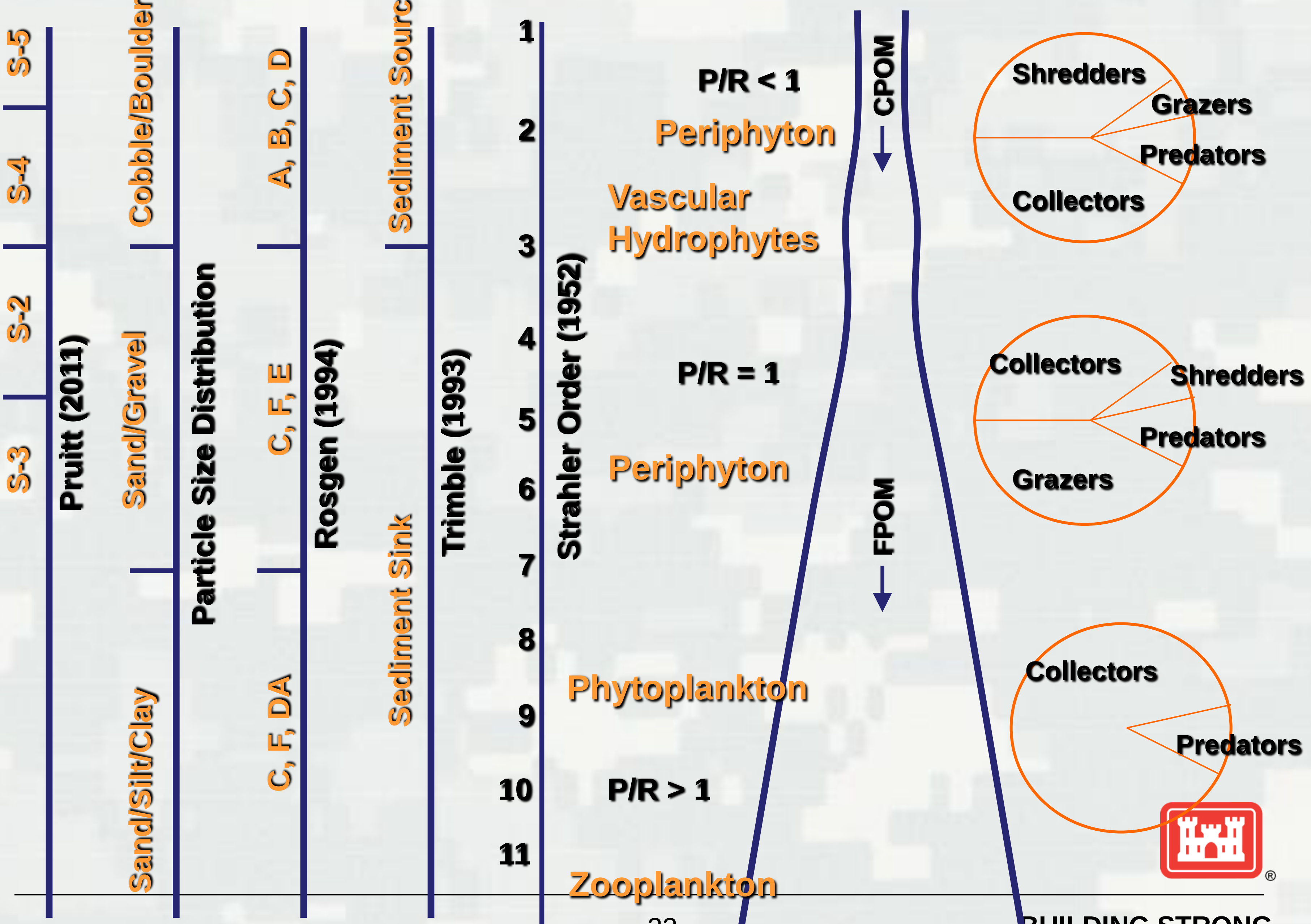


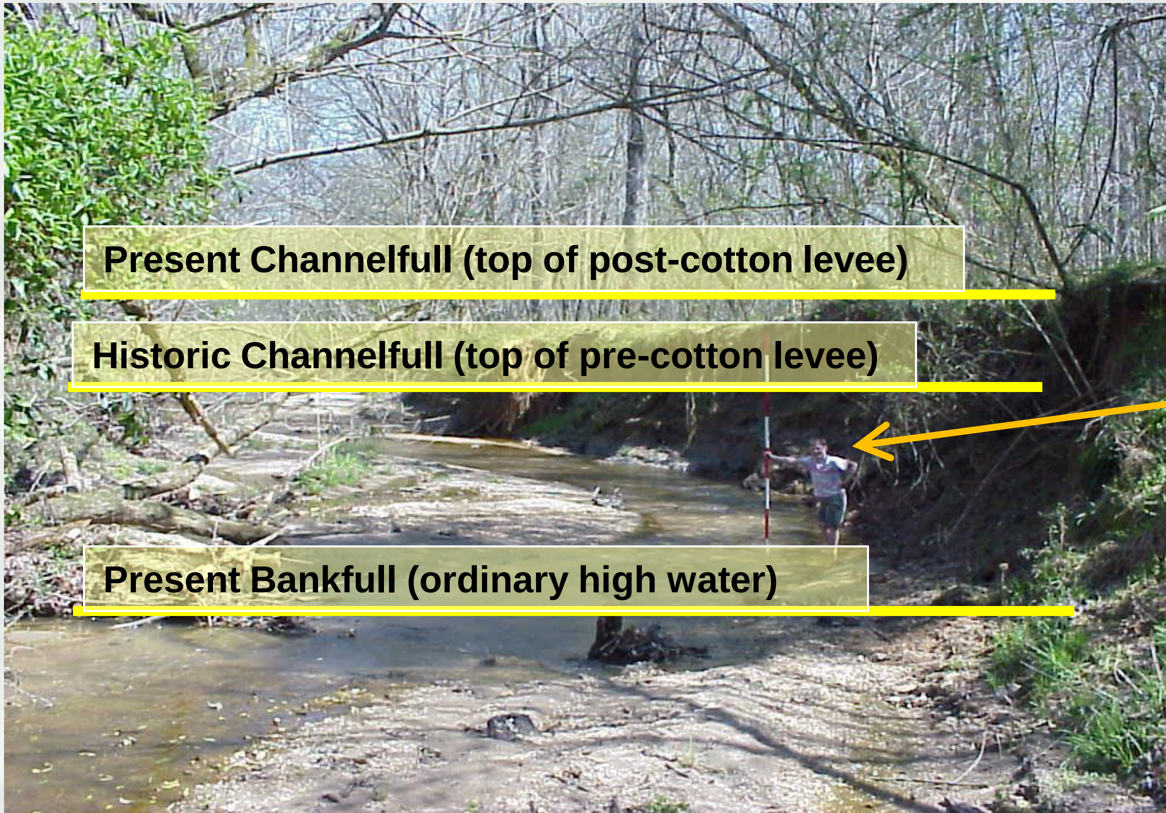
Farm Those Rich Bottoms!

Piedmont HGM Subclass - Seepage (Pruitt 2001)


INFILTRATION
SUMMIT
SHOULDER
BACKSLOPE
FOOTSLOPE
TOESLOPE
LANDSCAPE
POSITION
ET
PPT
SUBSURFACE INTERFLOW
PERCOLATION
GW
RETURN FLOW
SATURATED OVERLAND FLOW
SEEPAGE
GROUNDWATER FLOW

River Continuum Concept (Vannote 1980)





Future Fluvial Gemorphologist

Loss of Functions and Benefits ?

Restoration?

State: Water Quality

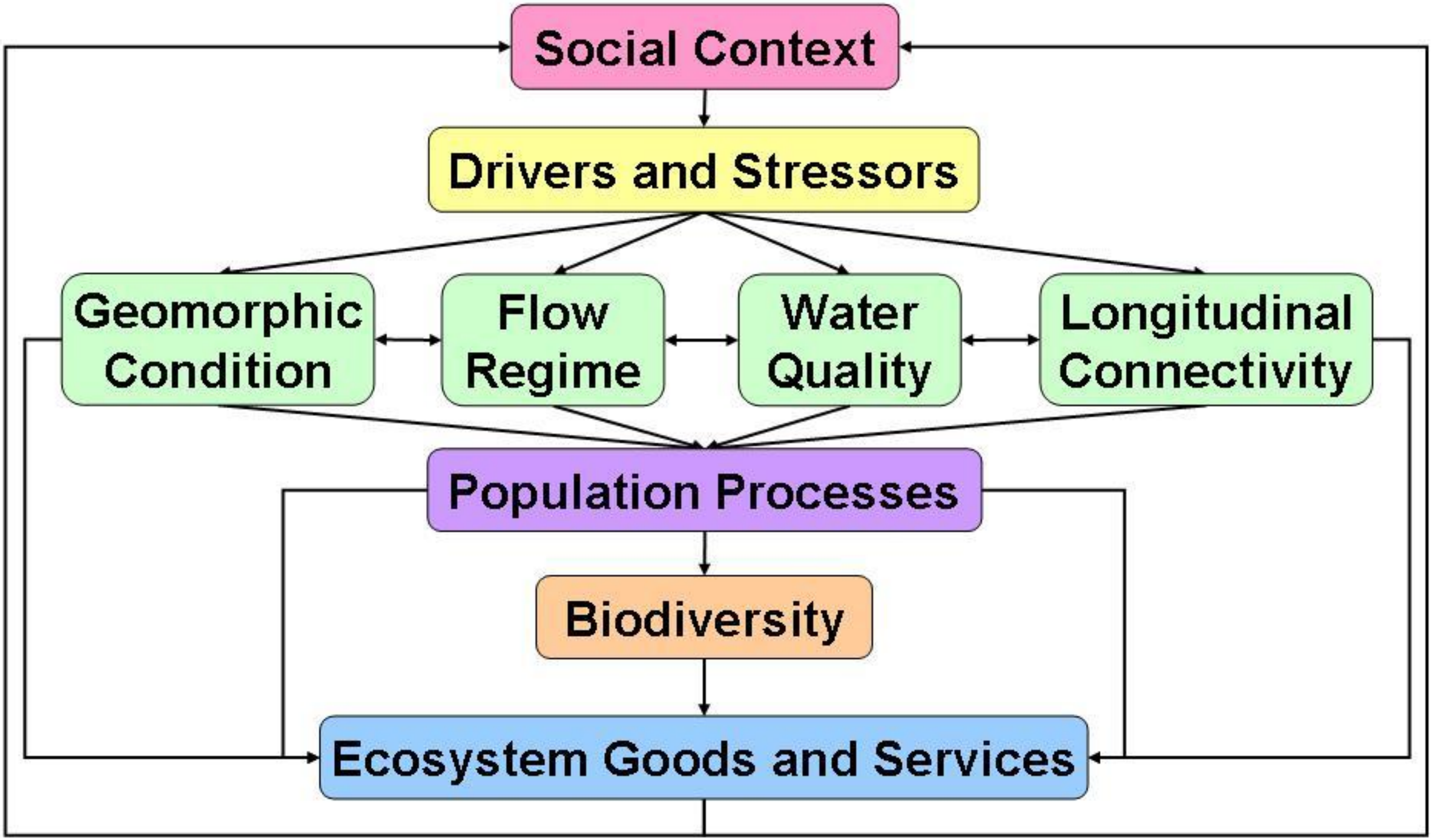
State	Typical Constituents	Typical Stressors
1. Unaltered	n/a	n/a
2. Physio-Chemical Alteration	Temperature, dissolved oxygen	Reservoirs, WWTPs
3. Nutrient Enrichment	Nitrogen, phosphorus, fecal coliform	Agricultural runoff, urban runoff
4. Chemical Contamination	Metals, synthetic organics, emerging contaminants	Mine drainage, industrial runoff, point sources

What ecosystem services are provided by Piedmont Streams?

Existence Value			
Heritage Value			
Cultural Value	Aesthetics	Spiritual	Historical
	Educational	Social cohesion	
Recreation	Boating	Fishing	Hunting
	Water contact	Wildlife Observation	
Flow Regime	Flood attenuation	Flood Conveyance	
	Hydropower		
Resource extraction	Sand and gravel	Timber	Ore
Water Quantity	Municipal	Industrial	Agricultural
Water Quality	Treatment cost	Waste assimilation	
Air quality	Microclimate regulation	Carbon sequestration	
Public Health	Vector control		

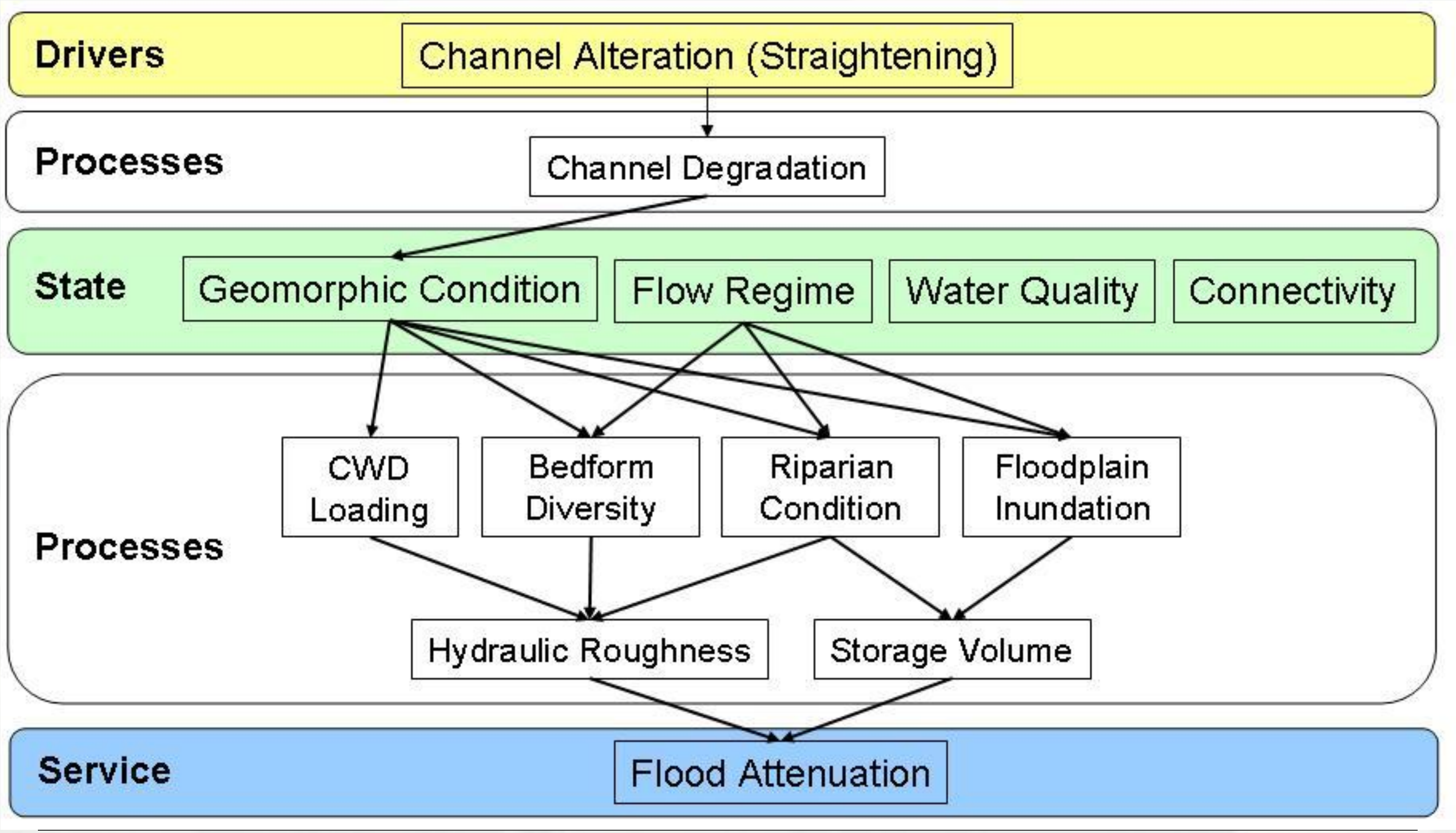
Applying a Piedmont stream conceptual model

A reminder…

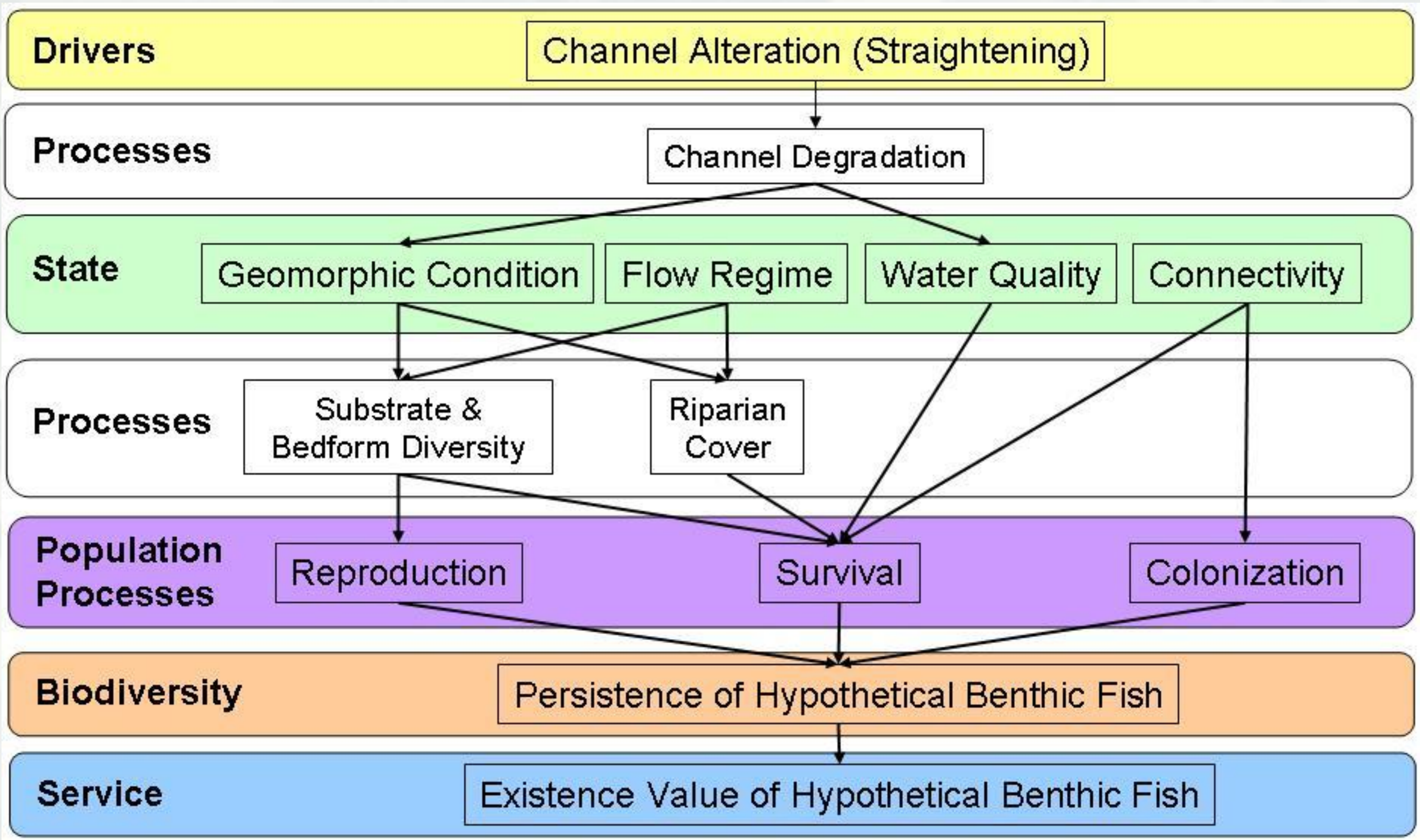


Social Context
Drivers and Stressors
Geomorphic Condition
Flow Regime
Water Quality
Longitudinal Connectivity
Population Processes
Biodiversity
Ecosystem Goods and Services

Example 1: Flood Attenuation



Example 2: Existence Value



Take-away Points

- Measuring the “benefit” of restoration is challenging
- In the Piedmont, restoration requires understanding present **<u>and past</u>** drivers
- Conceptual modeling can inform restoration design and decision making by creating a process-based view of the world
- Next steps:
  - Mapping the mechanisms
  - Developing a web-based platform
  - Beta testing on real projects!



The Team

Environmental Benefits Analysis Research Program Website
http://cw-environment.usace.army.mil/eba/

Piedmont Team Members

Kyle McKay (USACE Env Lab)
Brenda Rashleigh (EPA-ORD)
Chris Anderson (Auburn)
Ana Del Arco Ochoa (Coimbra)
Mary Freeman (USGS)
Dean Trawick (USACE Mobile)
Joanna Curran (Virginia)

Contact Information

Bruce Pruitt
706-201-8678
Bruce.Pruitt@usace.army.mil

Questions?