Phosphorus dynamic simulation in APEX

Legacy Phosphorus Modeling Workshop

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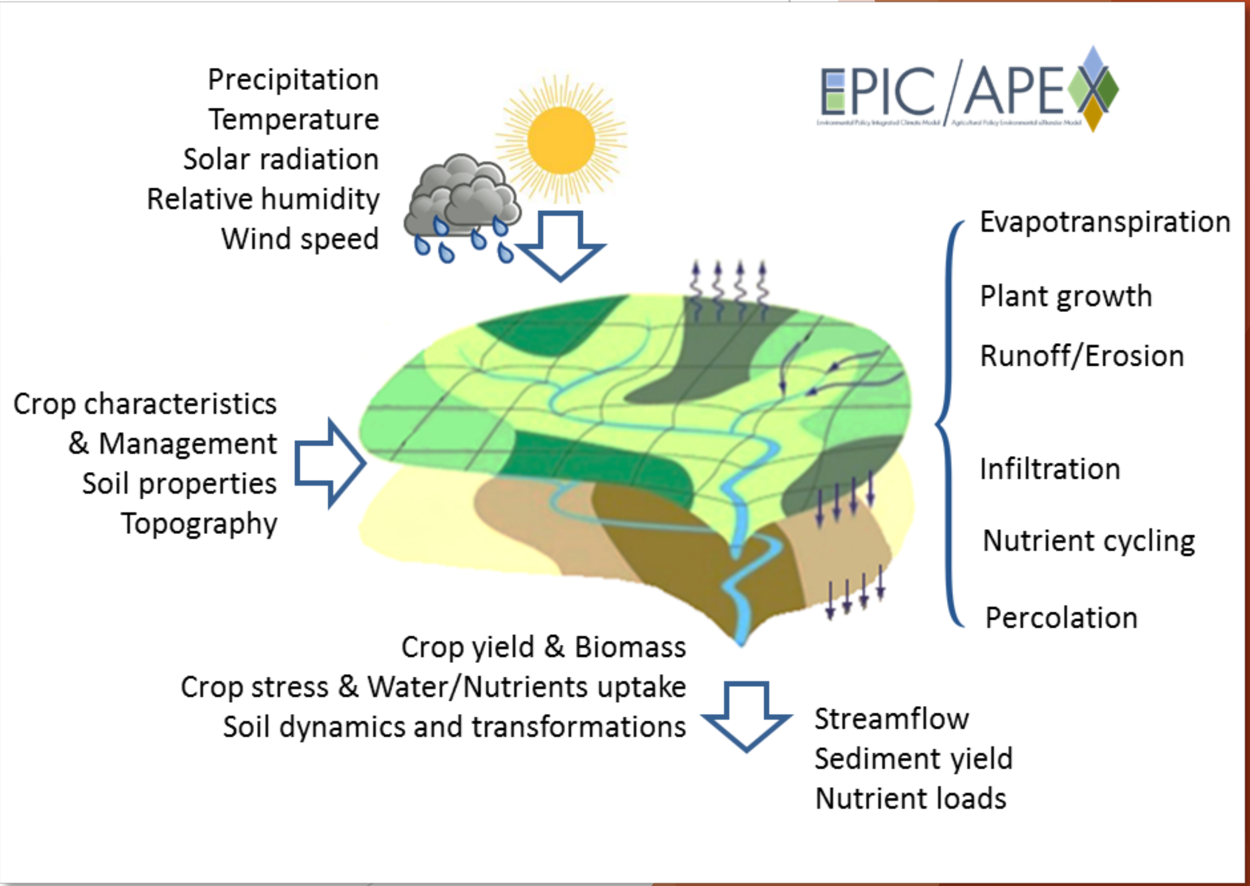
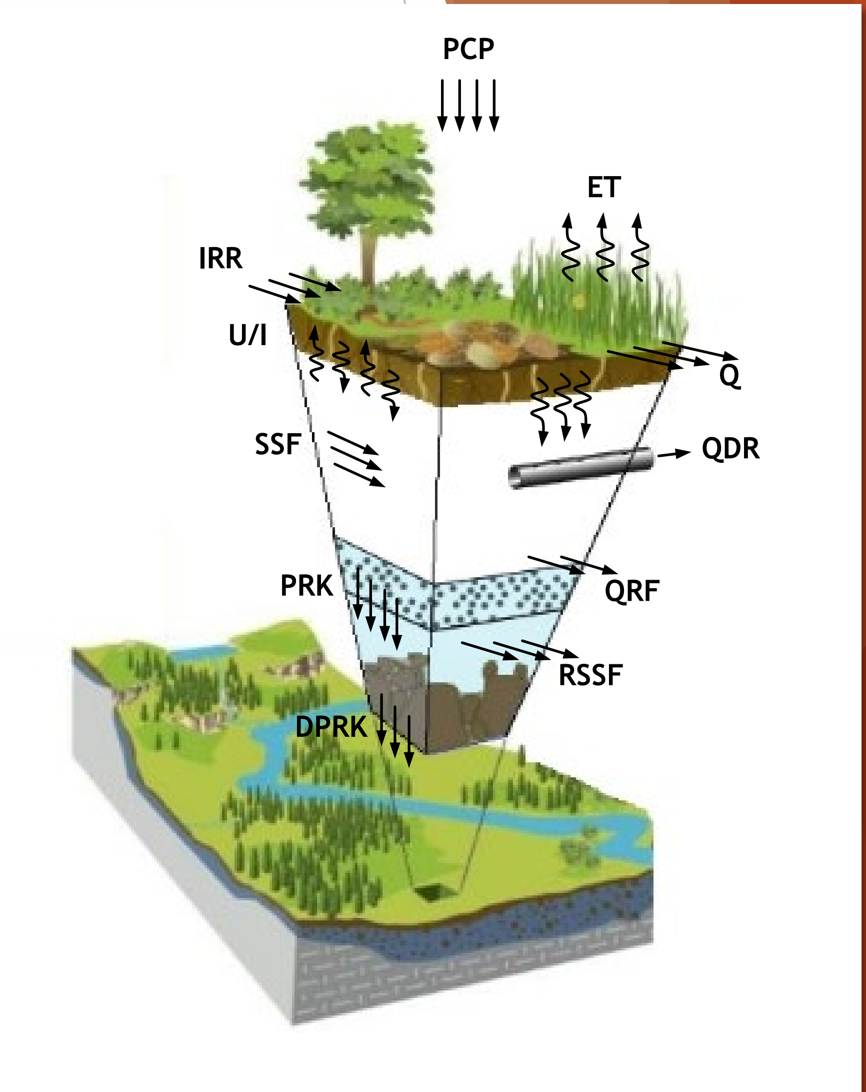
Agricultural **P**olicy **E**nvironmental e**X**tender

- Physically based and continuous daily time-step mode
- Developed to predict the impact of various land management strategies on:
  - Soil, water, air quality
  - Erosion and sediment yield
  - Plant productivity
- Subdivide farms or fields by:
  - Soil type
  - Landscape position
  - Management configuration



General processes simulated in APEX

- **Hydrology**
  - Evapotranspiration
    - Five different options available
      - Penman-Monteith
      - Penman
      - Priestley-Taylor
      - Hargreaves
      - Baier-Robertson
  - Surface runoff
    - USDA-NRCS curve number
    - Green and Ampt infiltration equation
  - Subsurface flow (vertical and horizontal flow)
    - Storage routing approach ("tipping bucket")
  - Routing (water, sediment, nutrients, pesticides)



General processes simulated in APEX

- Hydrology
- **Plant growth**
  - Single plant growth model (each plant has unique parameters)
  - Radiation use efficiency approach (growth) and heat units accumulation (phenology)
  - Growth constraints
  - Nutrient uptake: difference between plant nutrient content and optimal nutrient content
  - P supply limited by mass flow of labile P to the roots

Source: http://uwf.edu

General processes simulated in APEX

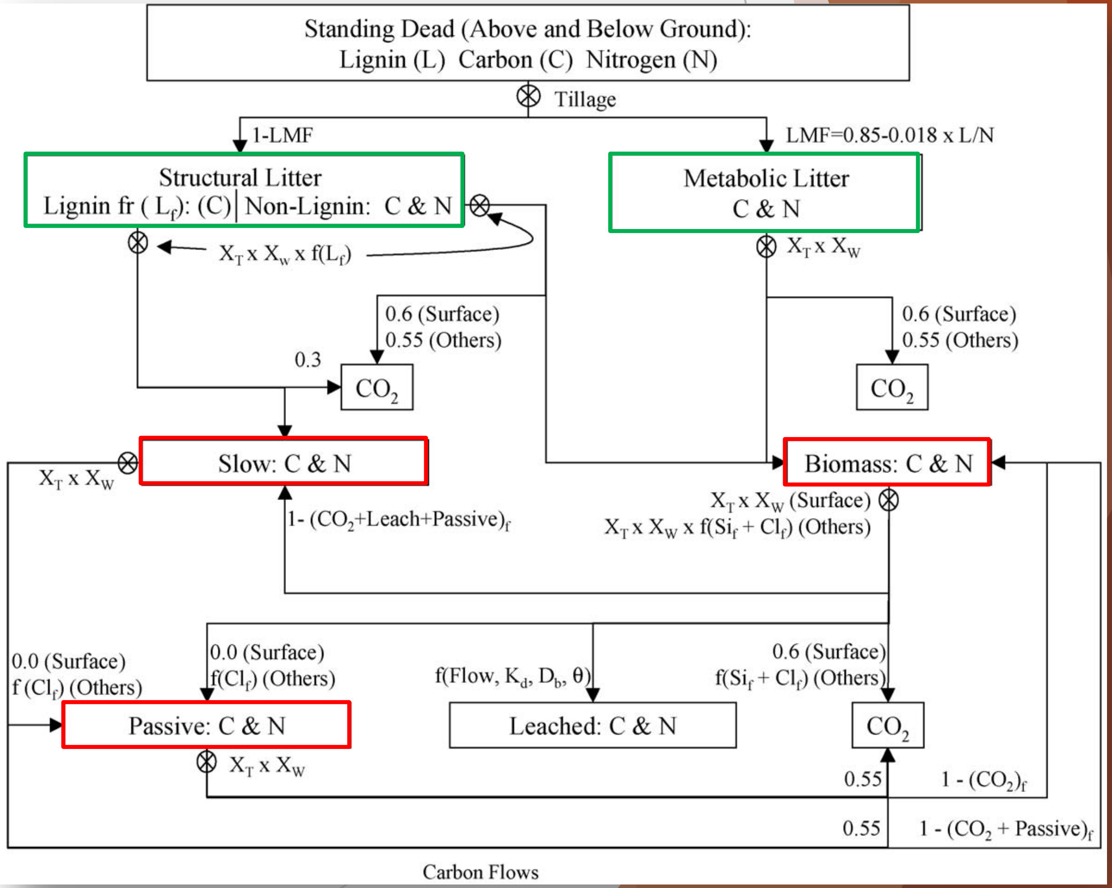
- Hydrology
- Crop growth
- **Soil and nutrient dynamics**
  - Erosion (water and wind induced)
    - Eight options available for water induced soil erosion
      - USLE: Universal Soil loss Equation
      - MUSLE: Modified USLE
      - MUST: Modified MUSLE theoretical based equation
      - MUSS: Small Watershed MUSLE
      - MUSI: Modified MUSLE with input parameters
      - RUSLE: Revised Universal Soil Loss Equation
      - RUSLE2: Modified RUSLE
      - AOF: Onstad-Foster
  - Nutrient cycling (soil C, N, and P)

Source: https://www.nrcs.usda.gov

Photo credit: USDA

Soil carbon and nitrogen cycling

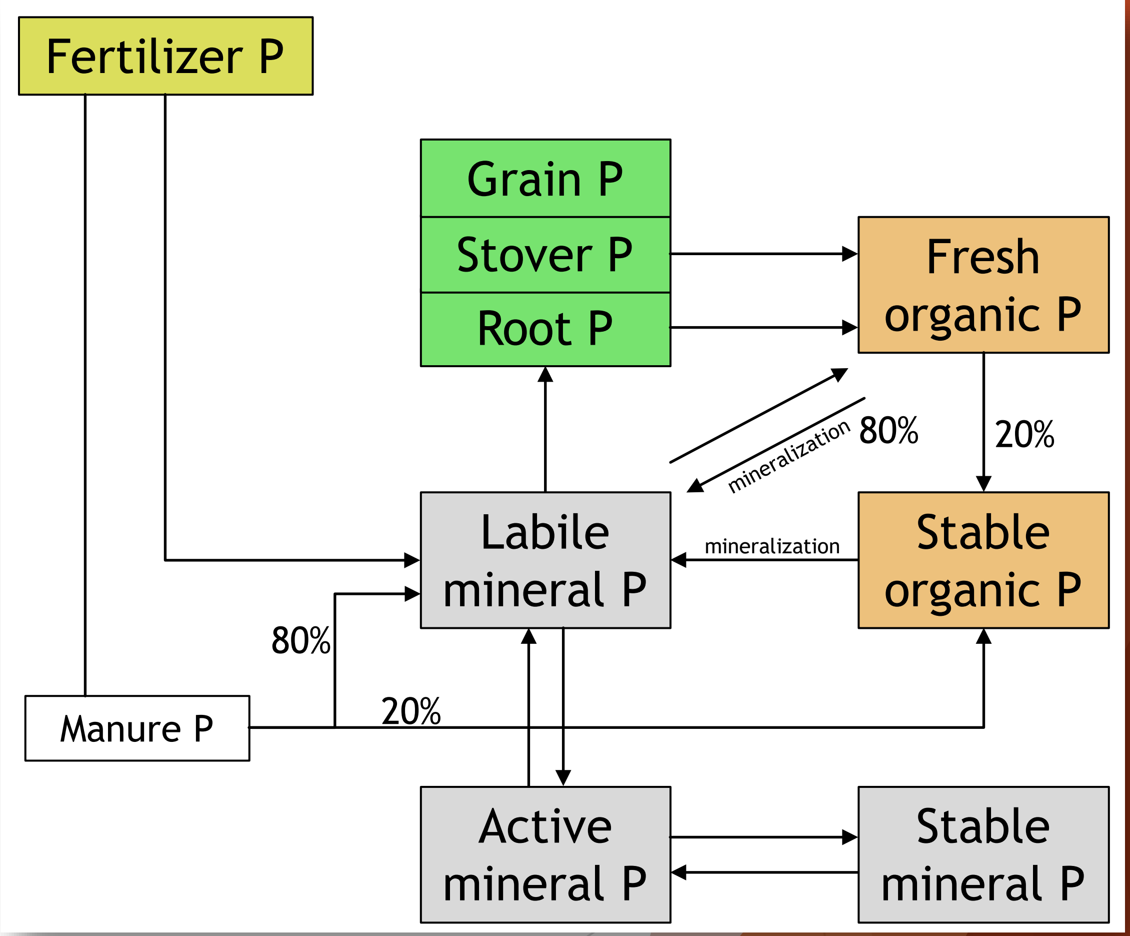
- Approach based on the Century Model (Parton et al., 1994)
- Distributes C and N across soil layers into several pools (organic and inorganic).
  - Metabolic litter (<1 year)
  - Structural litter (1 year)
  - Biomass (<1 year)
  - Active-slow humus (5 years)
  - Stable-passive humus (200+ years)
- Main processes
  - Fertilizer and manure N applications
  - Plant N uptake
  - Mineralization, immobilization
  - Nitrification, denitrification
  - Ammonia volatilization



Credit: Izaurralde et al., Ecological Modelling 192 (2006) 362-384

Phosphorus cycling

- Mineral P model developed by Jones et al., 1984
- Mineral P transferred among 3 pools:
  - Labile (plant available)
  - Active mineral
  - Stable mineral
- Soil organic P
  - Fresh organic pool (crop residues and microbial biomass)
  - Stable organic pool (soil humus)
- Main processes
  - Fertilizer and manure P applications
  - Plant P uptake
  - Mineralization
  - Organic P transport on sediment
  - Soluble P losses in percolation, surface runoff, lateral subsurface flow, and tile flow



Modified from: Jones et al., (1984) Soil Sci. Soc. Am. J. 48:800-805

Phosphorus losses

- **Surface**
  - Runoff (soluble P)
  - Sediment (organic P)
- **Subsurface**
  - Percolation
  - Quick return flow / tile drainage

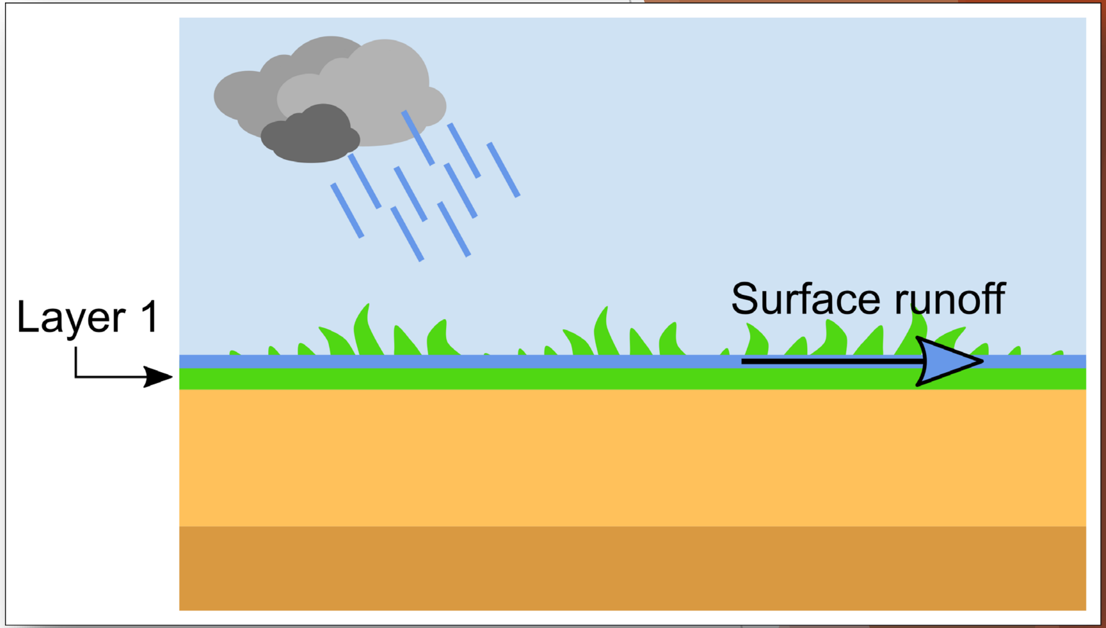
GLEAMS linear equation

Langmuir adsorption model

Source: USDA-NRCS New Mexico

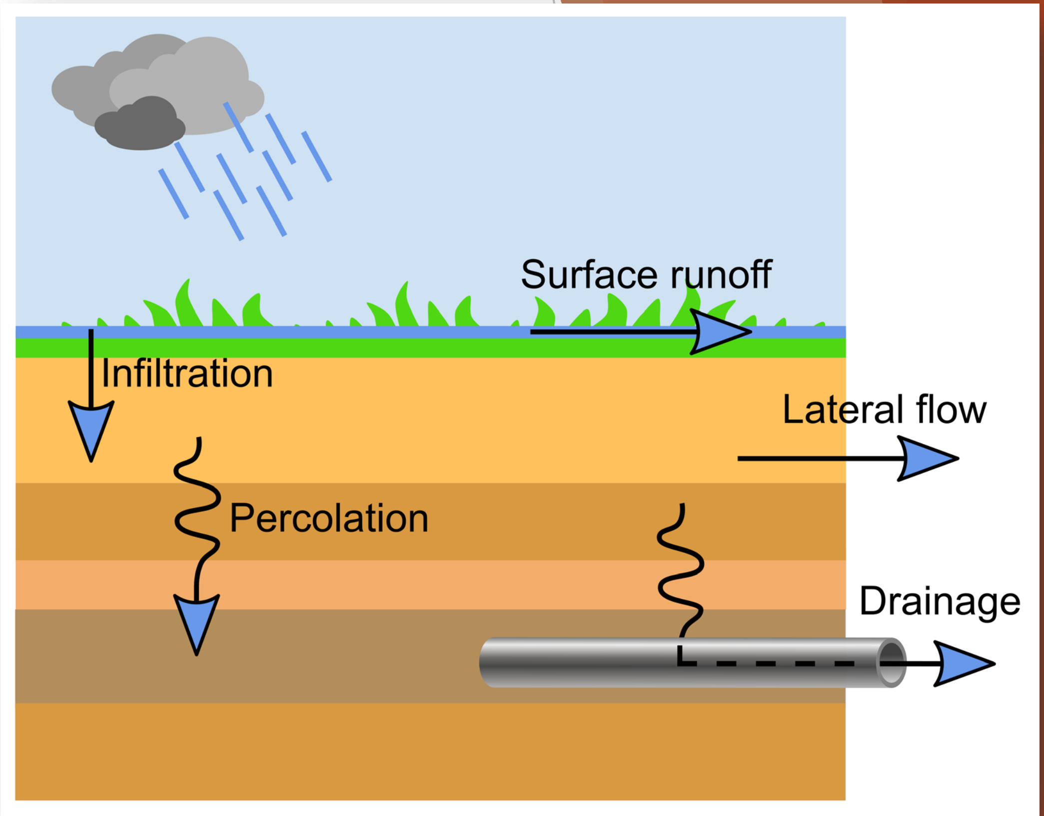
Source: USDA-NRCS Tim McCabe

Phosphorus losses



- Surface
  - Runoff (soluble P)
    - GLEAMS linear sorption equation
      - Amount of water in surface runoff
      - Amount of labile P available
    - Langmuir adsorption model
      - Amount of water in surface runoff
      - Amount of labile P available
      - Soil clay content
      - Soluble P adsorption coefficient (P conc. in sediment / P conc. in water)
  - Runoff P from manure
    - Calculated with GLEAMS
      - Mineral P available from manure in first soil layer
      - Amount of water in surface runoff
  - Sediment (organic P)
    - Sediment transport of P simulated with a loading function
      - Amount of sediment
      - Amount of organic P available in top soil layer

Phosphorus losses



- Subsurface (estimation for each soil layer)
  - Percolation (linear equation for top soil layer)
    - Bottom layers: GLEAMS or Langmuire approach
      - Amount of percolating water
      - Amount of labile P available
      - Soil clay content
      - **Variable** soluble P adsorption coefficient (P conc. in sediment / P conc. in water)
  - Quick return flow / Tile drainage (GLEAMS or Langmuir)
    - Amount of labile P available for losses
    - Ratio between quick return flow and total subsurface flow
    - Losses assigned to tile drainage if drainage system present in soil layer

Phosphorus in reservoirs and ponds

Flow in

Generated from all the upstream subareas

- Sediment (Y_{in})
- Organic P attached to sediment (YOP_{in})
- Soluble P in surface runoff (QP_{in})

Reservoir

- Variable sediment and P content
  - Sediment and organic P in and out
  - Deposition

$$RSY = RSY_0 + Y_{in} - Y_{out} - DEP$$

$$RSOP = RSOP_0 + YOP_{in} - YOP_{out} - DEP_{OP}$$

- Deposition based on change in concentration
  - Normal, beginning, and final concentration
  - Sediment settle
  - Time to return to normal concentration after runoff

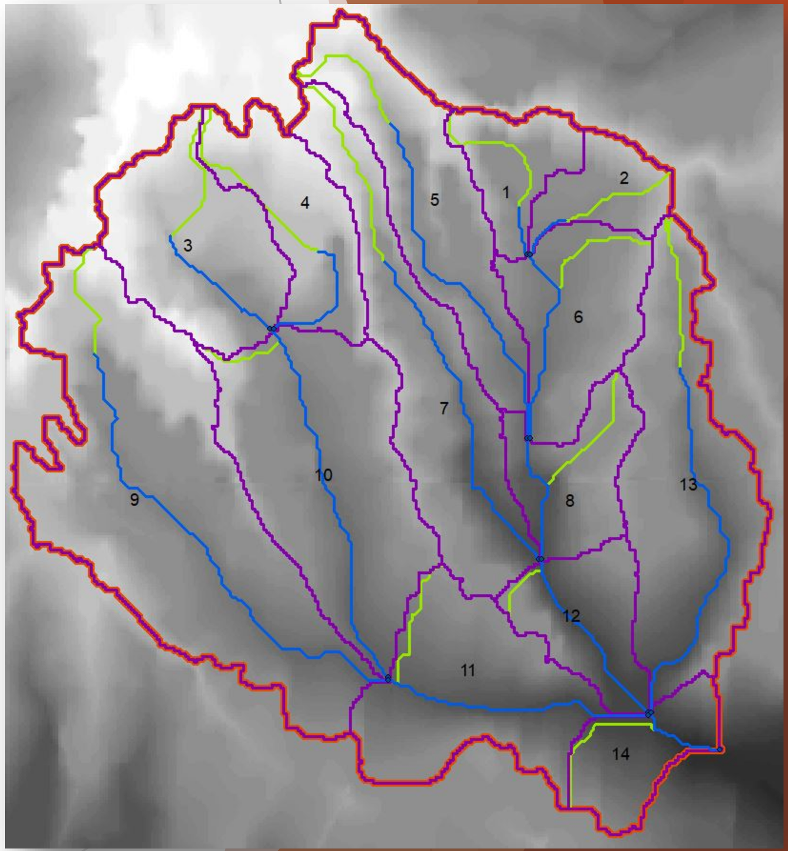
$$DEP = RSV \times (CY - CY_0)$$

Flow out

- Organic P attached to sediment
  - Concentration × sediment out $YOP_{out} = COP \times Y_{out}$
- Soluble P in water outflow
  - Concentration × flow out $QOP_{out} = CSP \times Q_{out}$

APEX routing component and phosphorus

- Routing of water, sediment, nutrients, and pesticides between subareas and through channel systems.
- Interactions between subareas:
  - Surface runoff
  - Return flow
  - Sediment deposition and degradation
  - Nutrient transport
  - Groundwater flow
- Sediment routed through channel and floodplain separately.
- Transport concentration capacity is a function of flow velocity.
- Change in sediment yield in routing reach calculated with inflow sediment concentration and potential concentration.
  - IF flow sediment conc. > potential sediment conc. ➡ deposition occurs



APEX routing component and phosphorus

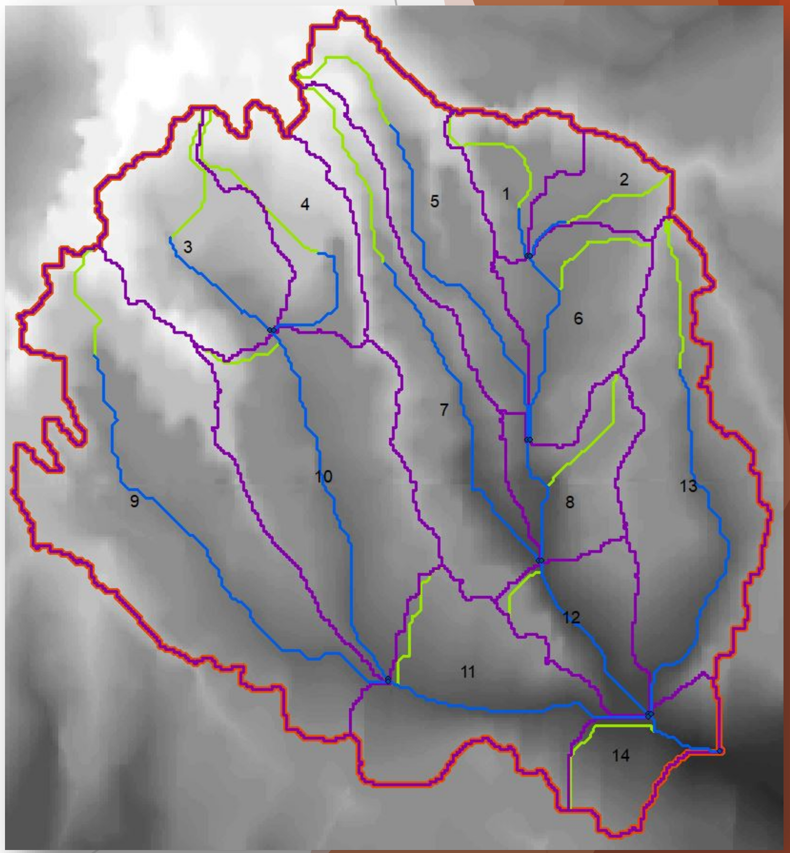
- Organic form of P is transported by sediment and is routed using an enrichment ratio approach.

$$YP_{out} = 0.001 \times CP_{in} \times ER \times Y_{out}$$

- Where:
  - YP_{out}: Organic P outflow (kg ha^{-1})
  - CP_{in}: Inflow organic P concentration (g Mg^{-1})
  - ER: Enrichment ratio $ER = {}^{PO_{in}}/_{PO_{out}}$

    Org. P content of inflow / Org. P content outflow
  - Y_{out}: Outflow sediment yield (Mg ha^{-1})

- Mineral form of P: constant concentration in flow through channel.



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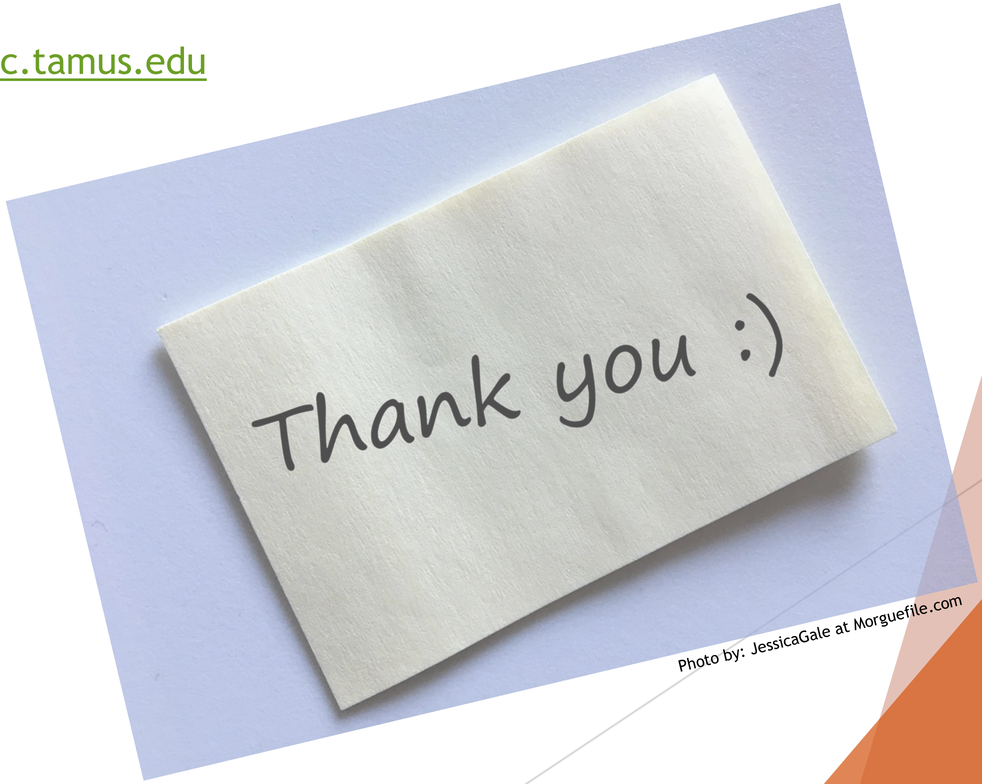

Photo by: JessicaGale at Morguefile.com