Filtering phosphorus out of surface runoff with a phosphorus removal structure

Dustin Stoner, Chad Penn, and Jason Warren

Department of Plant and Soil Science

Oklahoma State University

chad.penn@okstate.edu

OKLAHOMA STATE UNIVERSITY RESEARCH

Why P management?

- Phosphorus (P) is essential to all forms of life on earth – no known toxic effects
- Adequate P levels in soils are essential for production of agronomic crops
- In most fresh surface water bodies growth of algae or aquatic plants is limited by P availability

Introduction

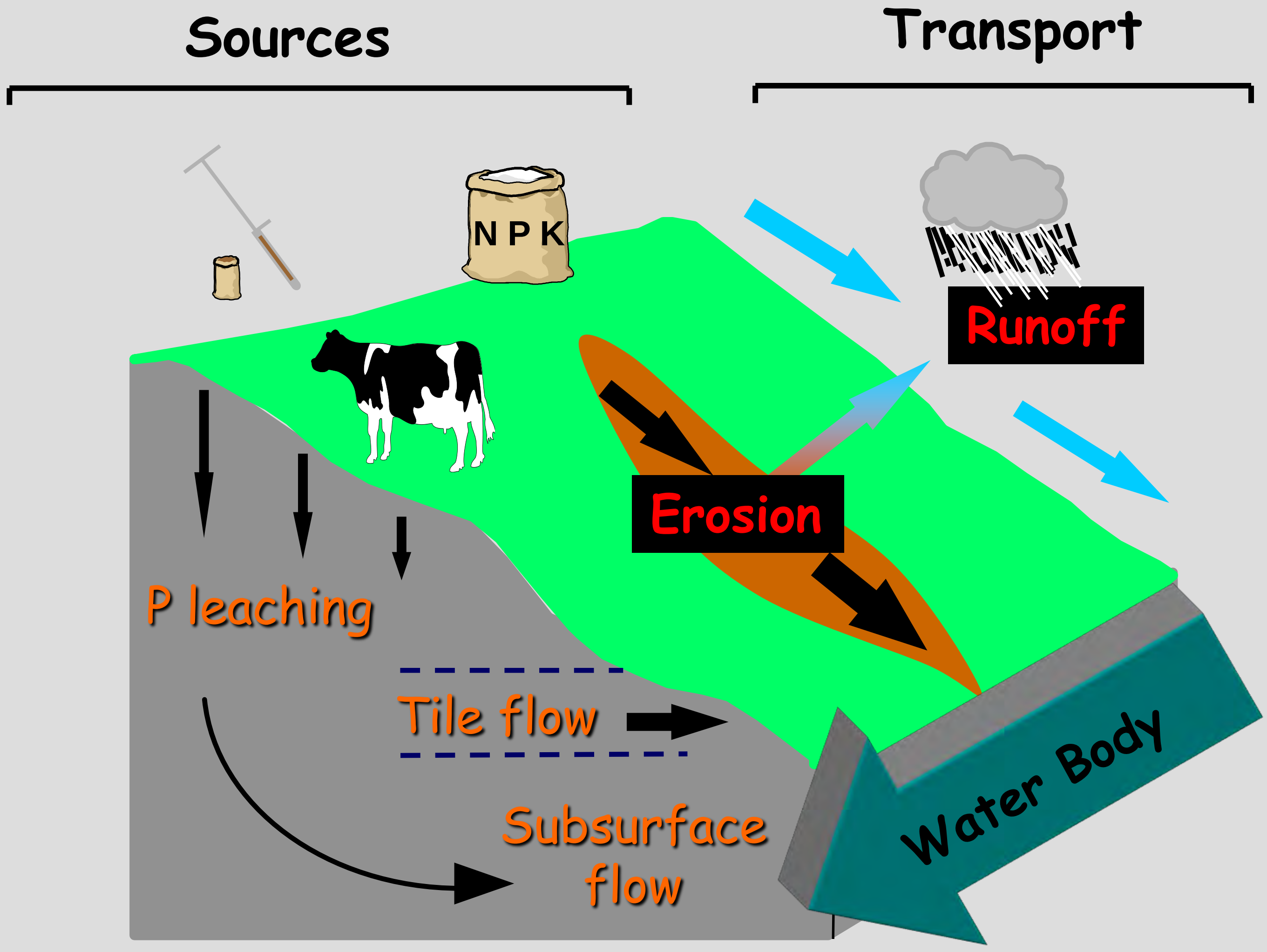
- Problem: phosphorus (P) in surface waters
  - P is a limiting nutrient among surface waters
    - Excessive P concentrations leads to eutrophication
      - Fish kills, odors, problems with water treatment processes (drinking water) and recreation

P transport to surface waters

- Occurs primarily via surface flow
  - Dissolved P – 100% biologically available
  - Particulate P – carried on eroded particles, not immediately bio-available
- If the soil becomes saturated with P the potential for P loss increases significantly

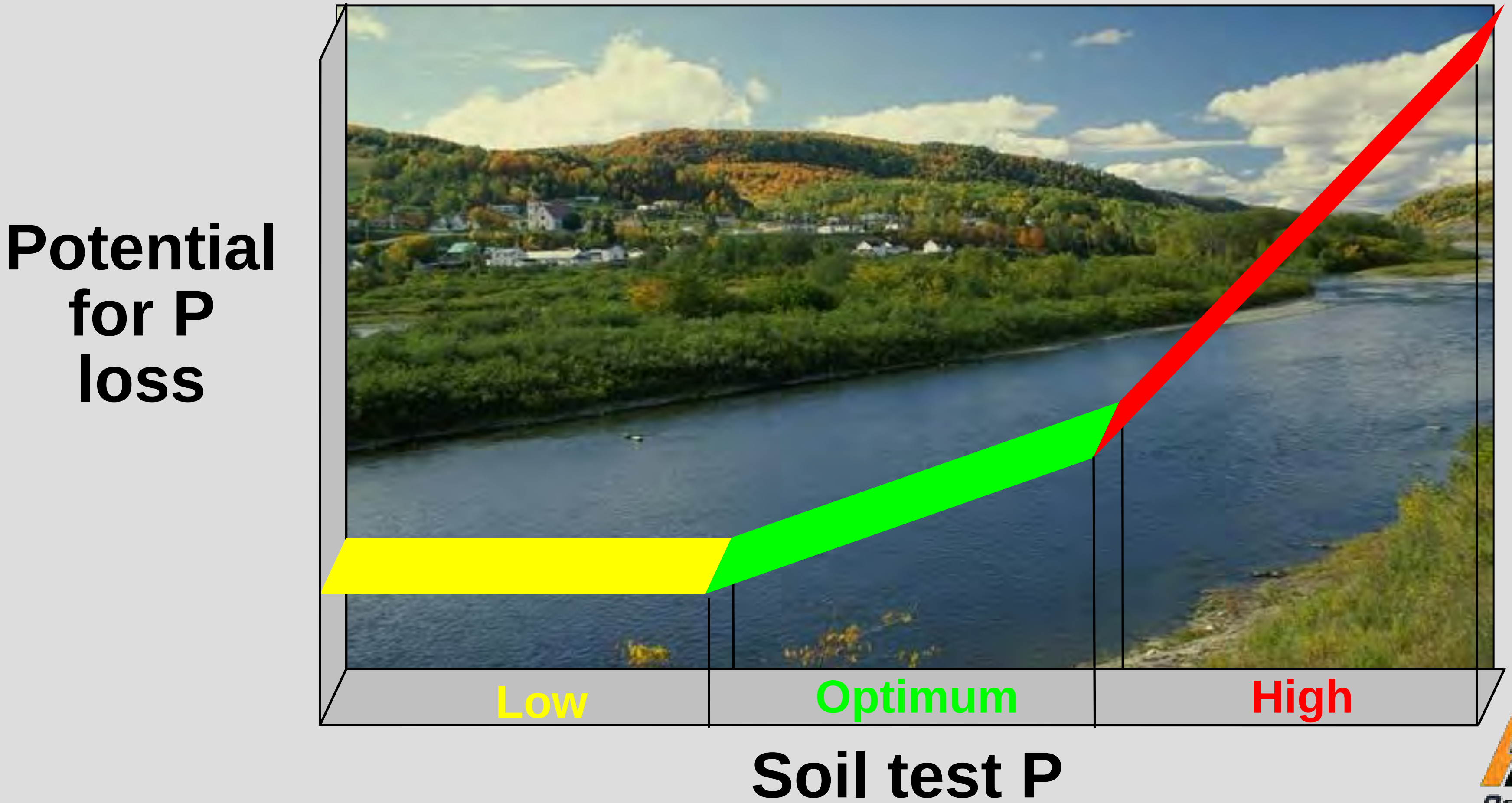
OKLAHOMA STATE UNIVERSITY RESEARCH

Phosphorus Losses: Source and Transport



P Losses to Surface Water

Risk Increases As Soil P Increases



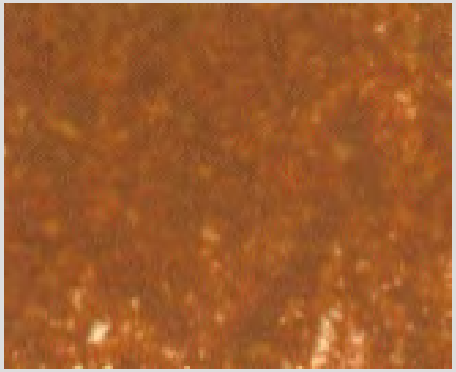
P losses to surface waters

- Particulate P loss is easy to prevent
  - Erosion control
- Dissolved P loss is difficult to prevent from soils with high P levels or systems with little P retention capacity
  - Even if we stop applying P to high P soils, they will continue to produce dissolved P in runoff for many years

Potential Solution for Dissolved P: P Sorbing Materials (PSM)

- Treatment of runoff and drainage water prior to reaching surface waters
  - Al, Fe, and Ca containing materials that chemically bind with P, reducing soluble P concentrations.
    - Al and Fe oxides/hydroxides: precipitation, ligand exchange, and electrostatic attraction
    - Ca: precipitation and electrostatic attraction
  - Many by-products contain potential P sorbing minerals

Example waste product PSM's



Acid mine drainage treatment residuals

Drinking water treatment residuals

Bauxite mining and production waste (red mud)

Fly ash

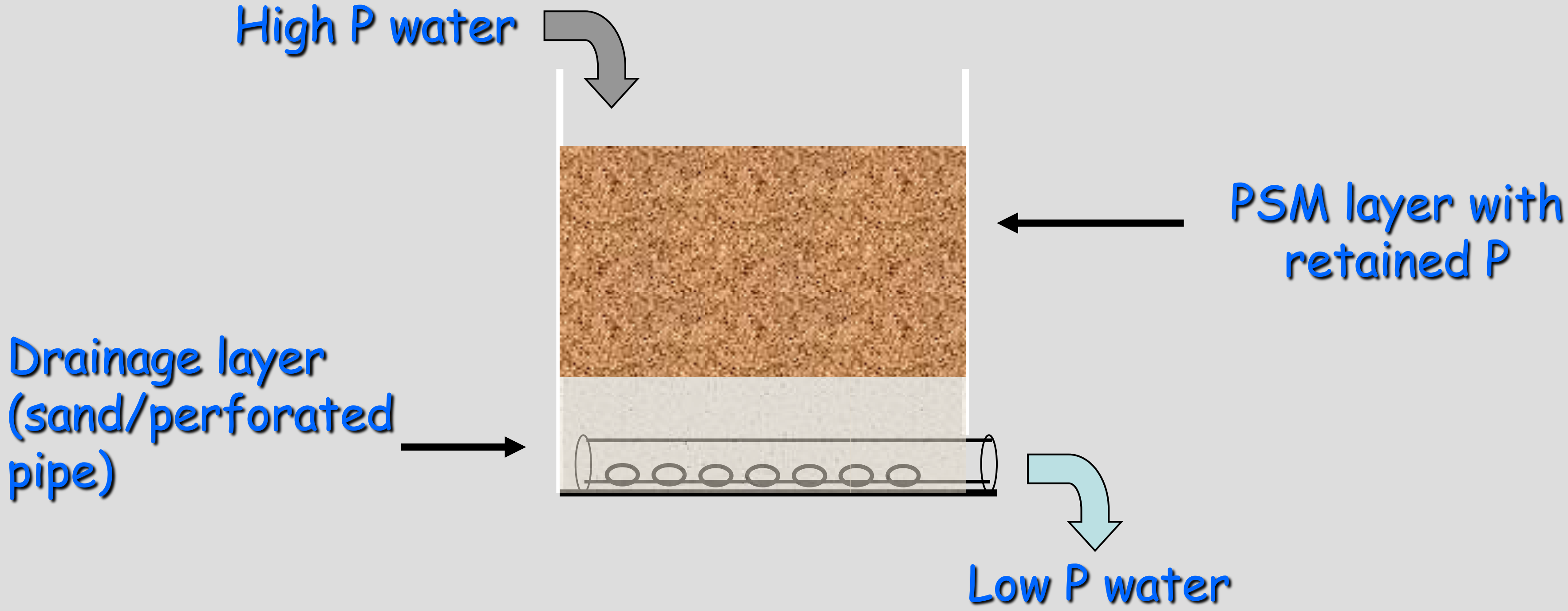
Paper mill waste

Steel slag waste

Waste recycled gypsum

OKLAHOMA STATE UNIVERSITY RESEARCH

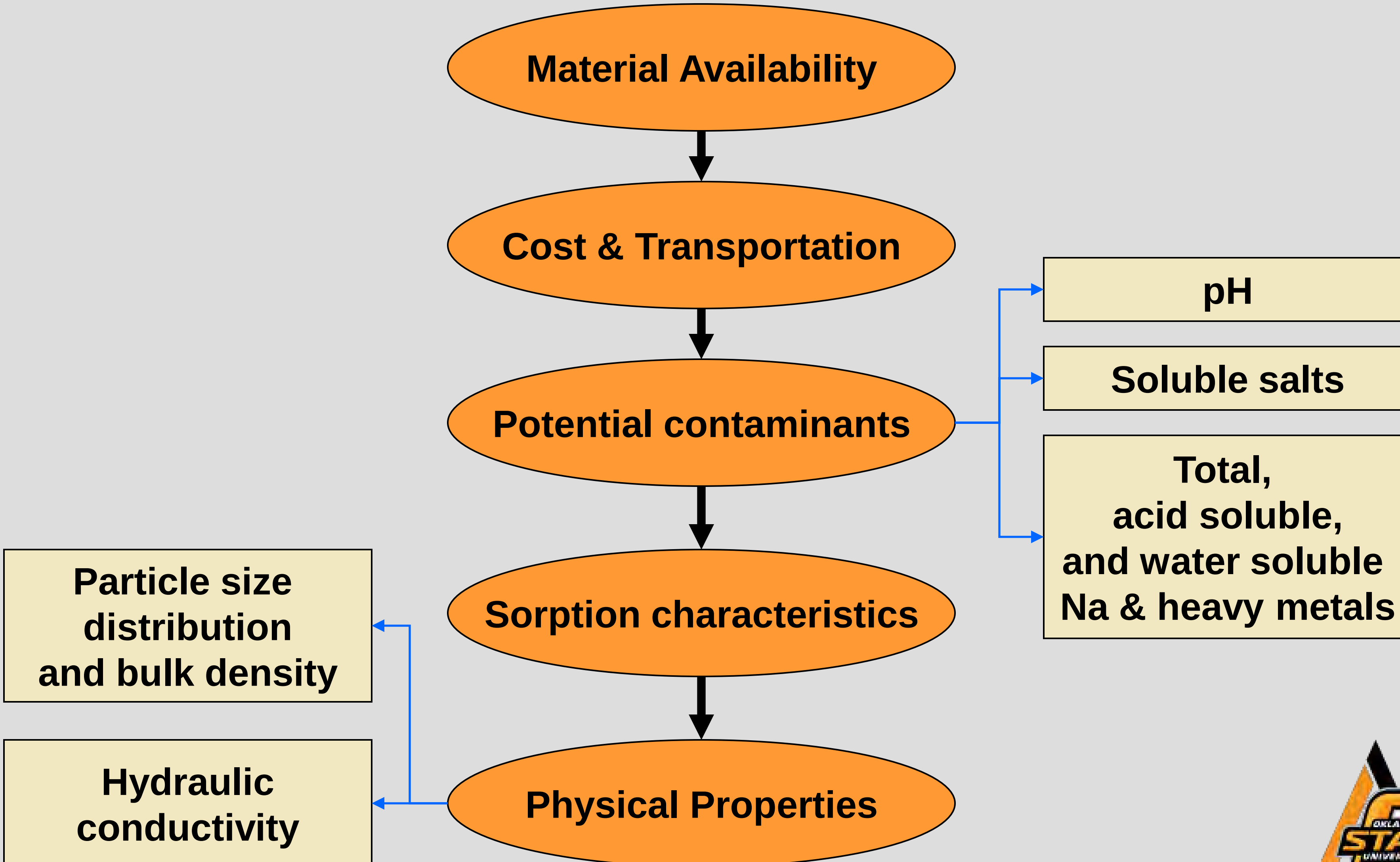
Solution: P removal structure theory



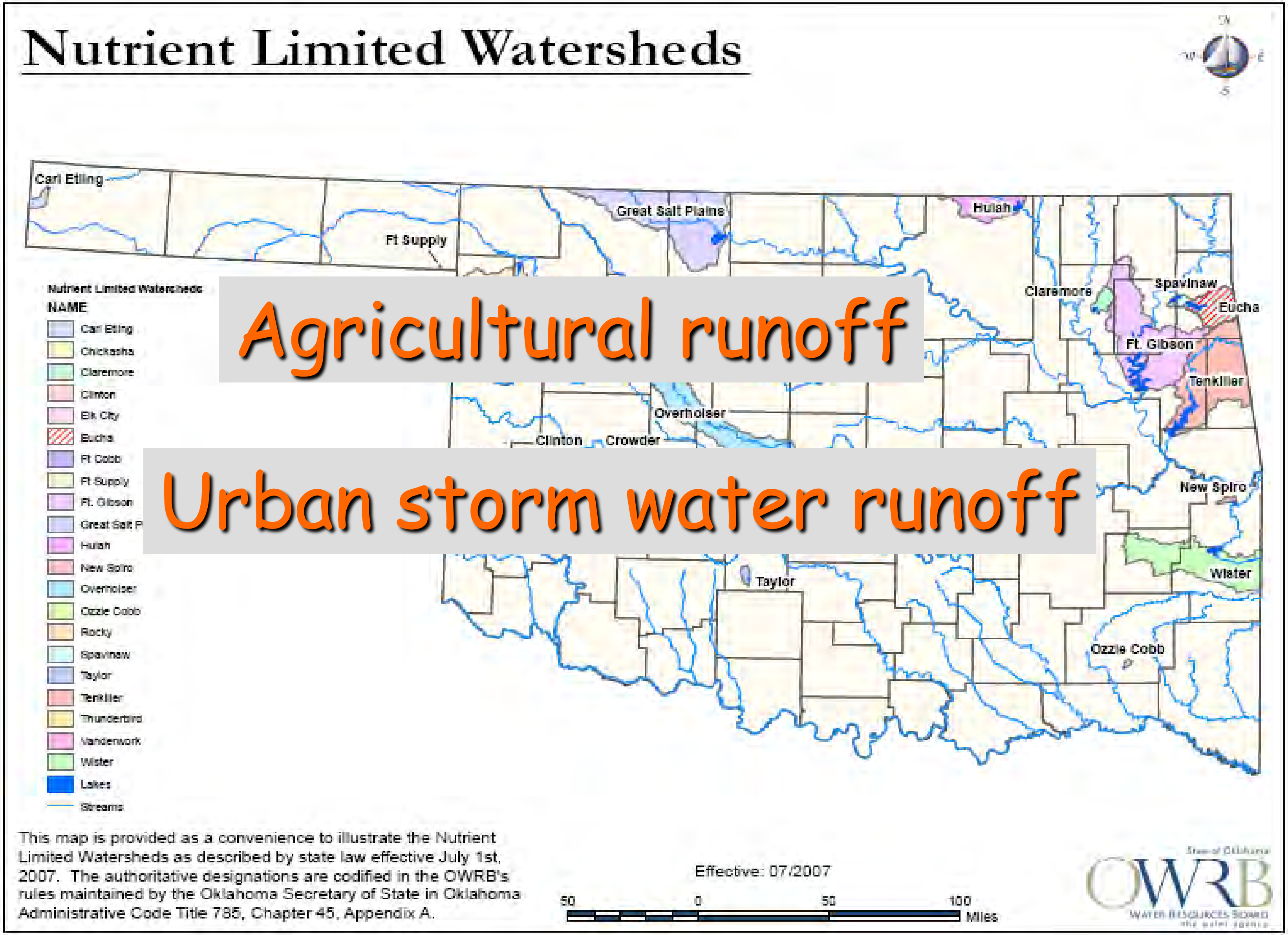
Advantages of P removal structures

- Ability to remove PSM after becoming saturated
  - P, various metals, and pesticides are removed from the system, preventing long term exposure.
  - spent P saturated material could have fertilizer value
- Remove particulate P (PP) in addition to dissolved P (DP)

Selection Process for PSMs



Potential Application



Agricultural runoff

Urban storm water runoff

Potential Application: Barnyard Runoff

- Treat runoff P originating from around poultry barns or manure storage areas

Research

Success Stories: AMDR box filter

- Stainless steel box (1 x 2 m) installed in field drainage ditch (500 lbs AMDR).
- Results: removed 99% of P, Zn, Cu, and As entering the box.

Success Stories: Stillwater Country Club Slag Filter

Distribution Manifold and Drain

P removal structure at SCC

- Cost: $2,000 for steel and welder time
- Slag was free (3 tons sieved)
- $200 to sieve and transport slag from Ft. Smith to Stillwater
- $2,200 total

Model development

- Developed a user friendly empirical model based on laboratory material characterization and flow-through P sorption experiments:

- Testing 14 different materials
  - Add P at constant rate
  - Vary retention time and P concentration
  - Measure P in outflow

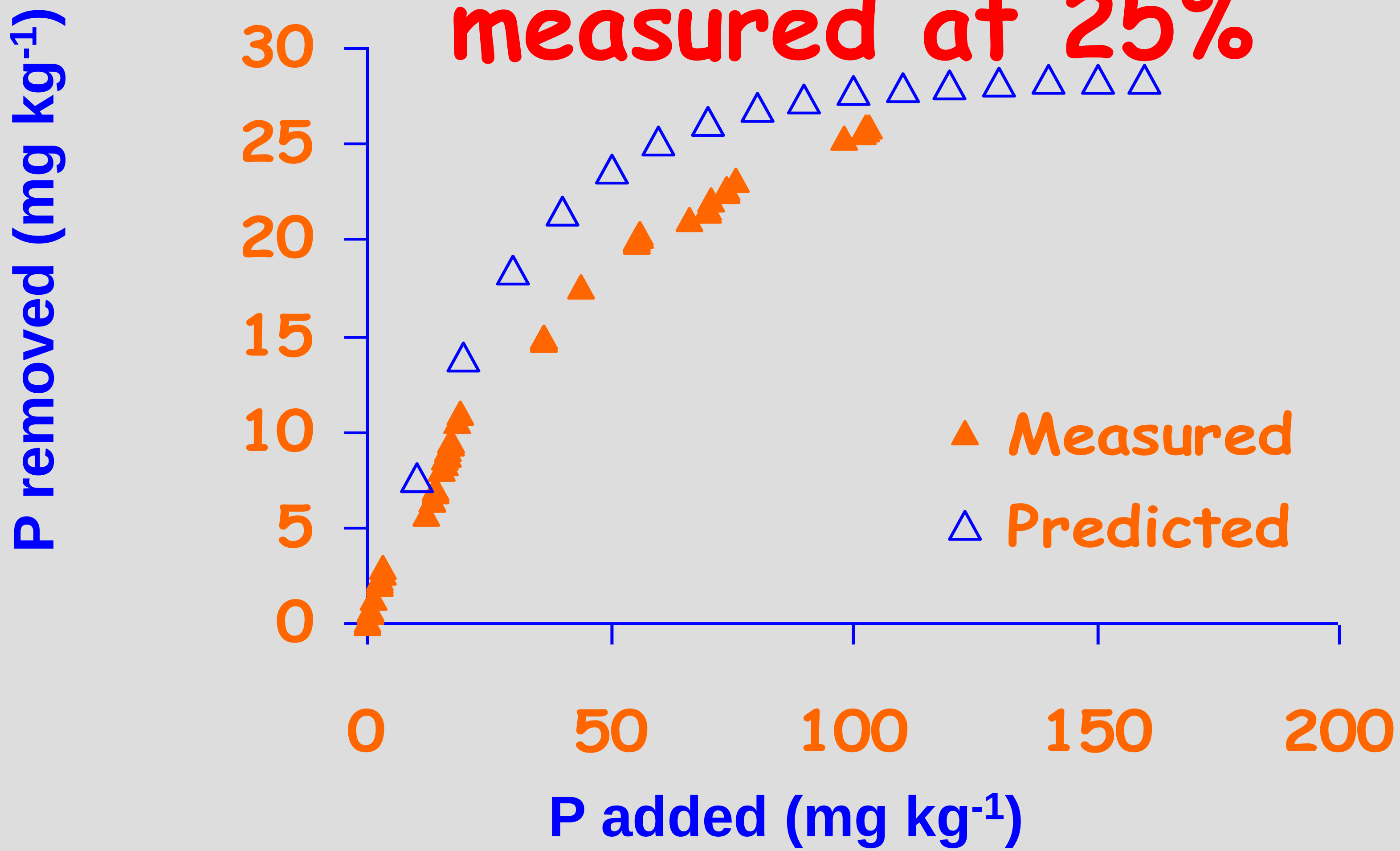
Model Development

- Ultimately, the model can be used for:
  - Sizing structures for removing targeted P loads at "hot spots"
  - Use to predict the life of a constructed structure
    - Users only need
      - basic watershed/runoff characteristics
      - typical P concentrations
      - routine characterization of material
        - » i.e. pH buffer capacity, pH, total Ca, Al, Fe, water soluble Ca

Model Prediction

Prediction of 28% at unlimited time: removal at point of saturation: measured at 25%

Prediction of 6 ... measured at 7-8 months



Comparison to other BMPs

- In the short term there is no BMP that can appreciably reduce soluble P losses
  - P "mining" with hay crops to reduce soil P levels
    - Bermuda grass and Rhyegrass-bermuda grass
      - 3 years to reduce soil P (Mehlich-3) from 300 to 240 ppm in Mississippi
  - Poultry litter transport programs
    - Only prevents soil P from increasing, does not decrease soil P

Cost of technology?

- Depends on available material and watershed characteristics
- Example of dairy farm watershed in NY
  - 400 acres delivered 94.5 lb DP/yr
  - Using WTR similar to Tulsa, need 4 tons/yr for 30% reduction
    - Assume DP in runoff is 0.5 ppm
  - 3 inch deep, 476 ft^2, \$10/ft^2, transport costs, annual cleanout, profit by private company
    - = \$41 per lb DP removed over 7 yr period.

OKLAHOMA STATE UNIVERSITY RESEARCH

Questions?