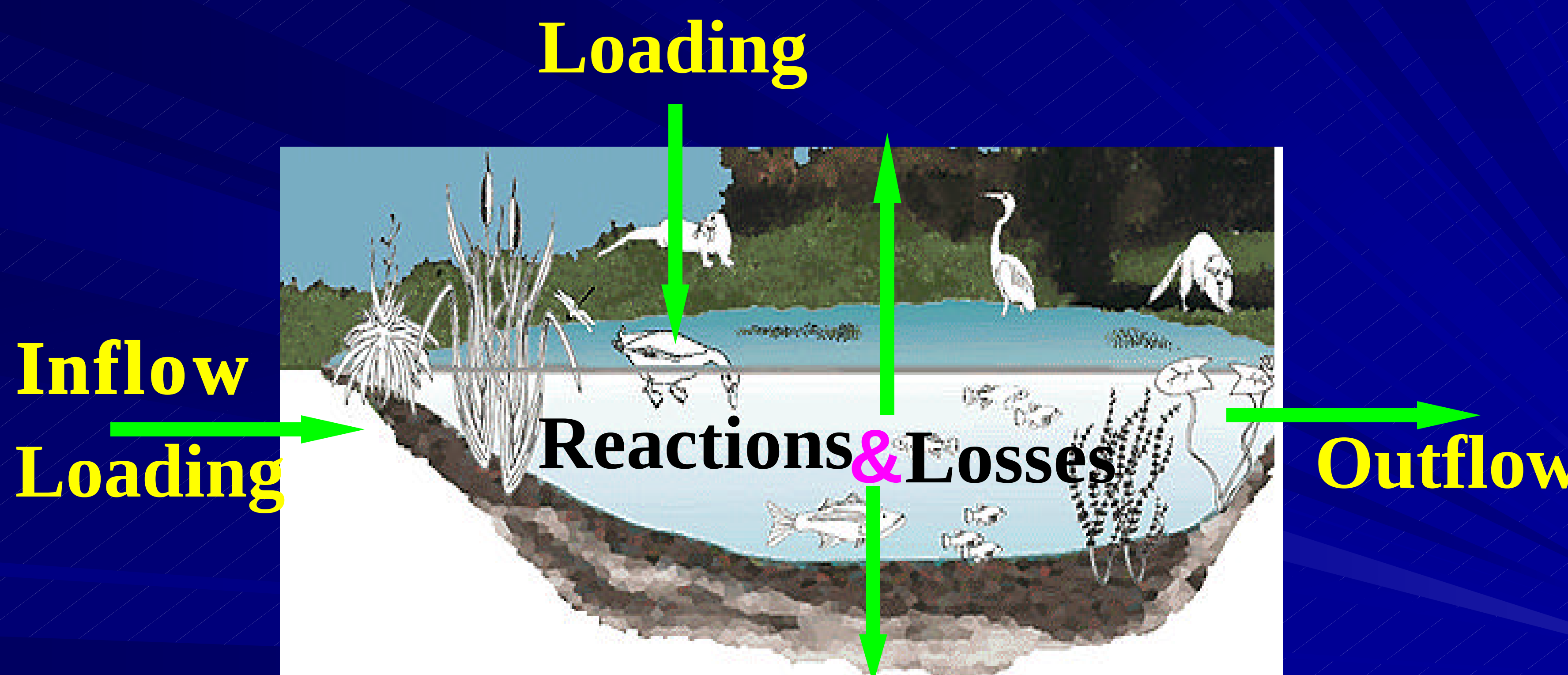
Nutrient Loading Models

U. Sunday Tim
William Crumpton

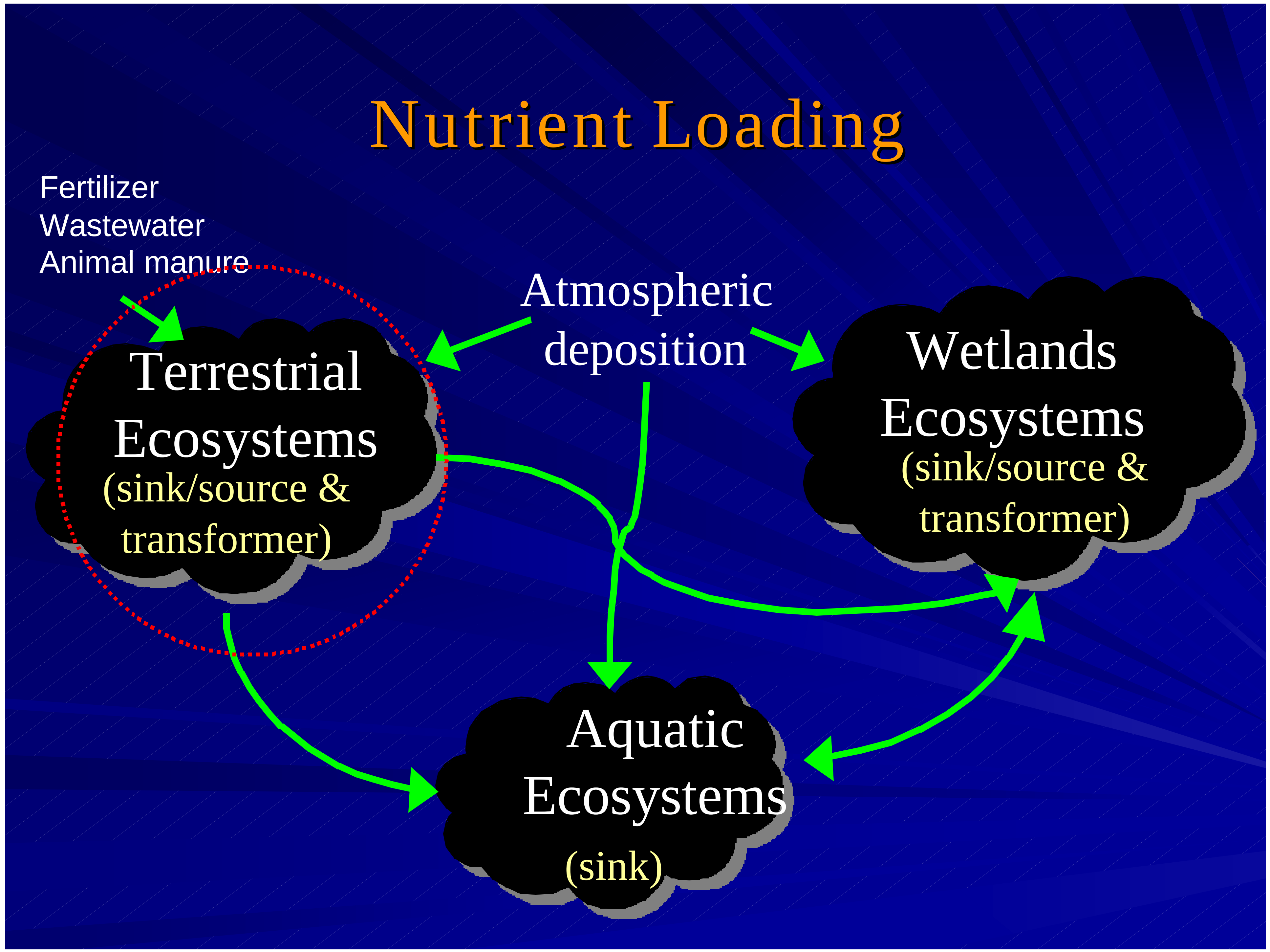
Iowa State University, Ames, Iowa

Evaluating Wetland Condition
for Nutrient Criteria: An Outreach Workshop

Mechanistic Water Quality Models: Components

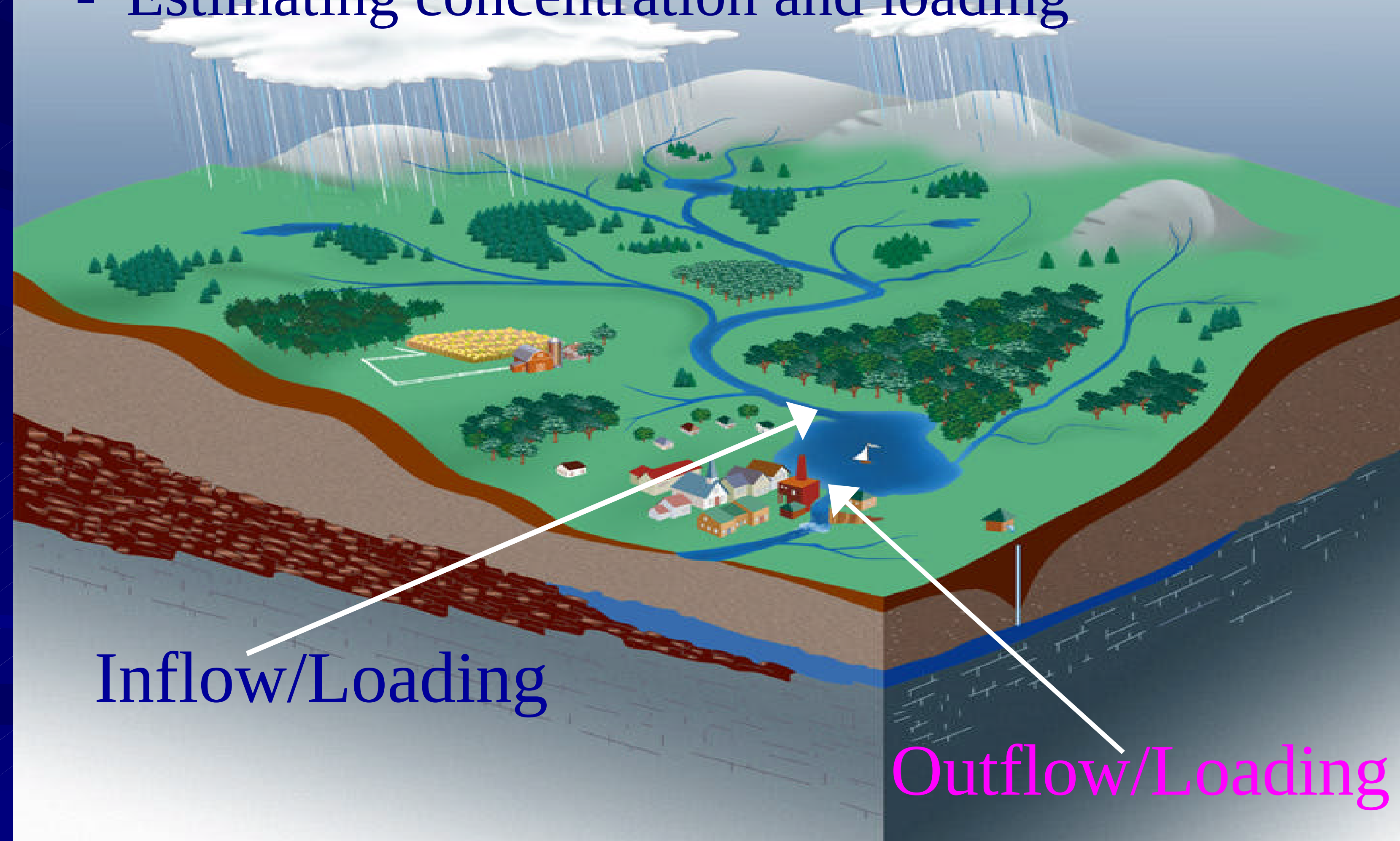


Concentration = Inflows – Outflows ± Reactions


Nutrient Loading
Fertilizer
Wastewater
Animal manure
Atmospheric deposition
Terrestrial Ecosystems
(sink/source & transformer)
Wetlands Ecosystems
(sink/source & transformer)
Aquatic Ecosystems
(sink)

What does it involve?

- Accurate prediction of flow volume and flow rate
- Estimating concentration and loading



Approaches for Estimating Nutrient Loading

- Direct measurements (flow, concentration)
- Unit area loading estimates
- Measured or estimated concentrations times simulated flows
- Simulation Modeling
  - Simulated flows and concentrations

Direct Measurement of Nutrient Loading

- Challenges
  - Documenting all diffuse sources
  - Transient/dynamic
  - Highly variable
  - What is representative?
  - What is projected?
  - Cost!

Nutrient Loading Models

What is a model?

Model can be defined as..

“ an assembly of concepts in the form of a mathematical equation that portrays understanding of a natural phenomenon.”

“a simplified version of a real investigated system that approximately simulates the latter’s excitation-response relations that are relevant to the problem considered.”

“ a metaphor for reality/a deliberately simplified construct of nature erected for purposes of understanding a system or phenomenon.”

Basic Modeling Approach

Hydrology → Loading

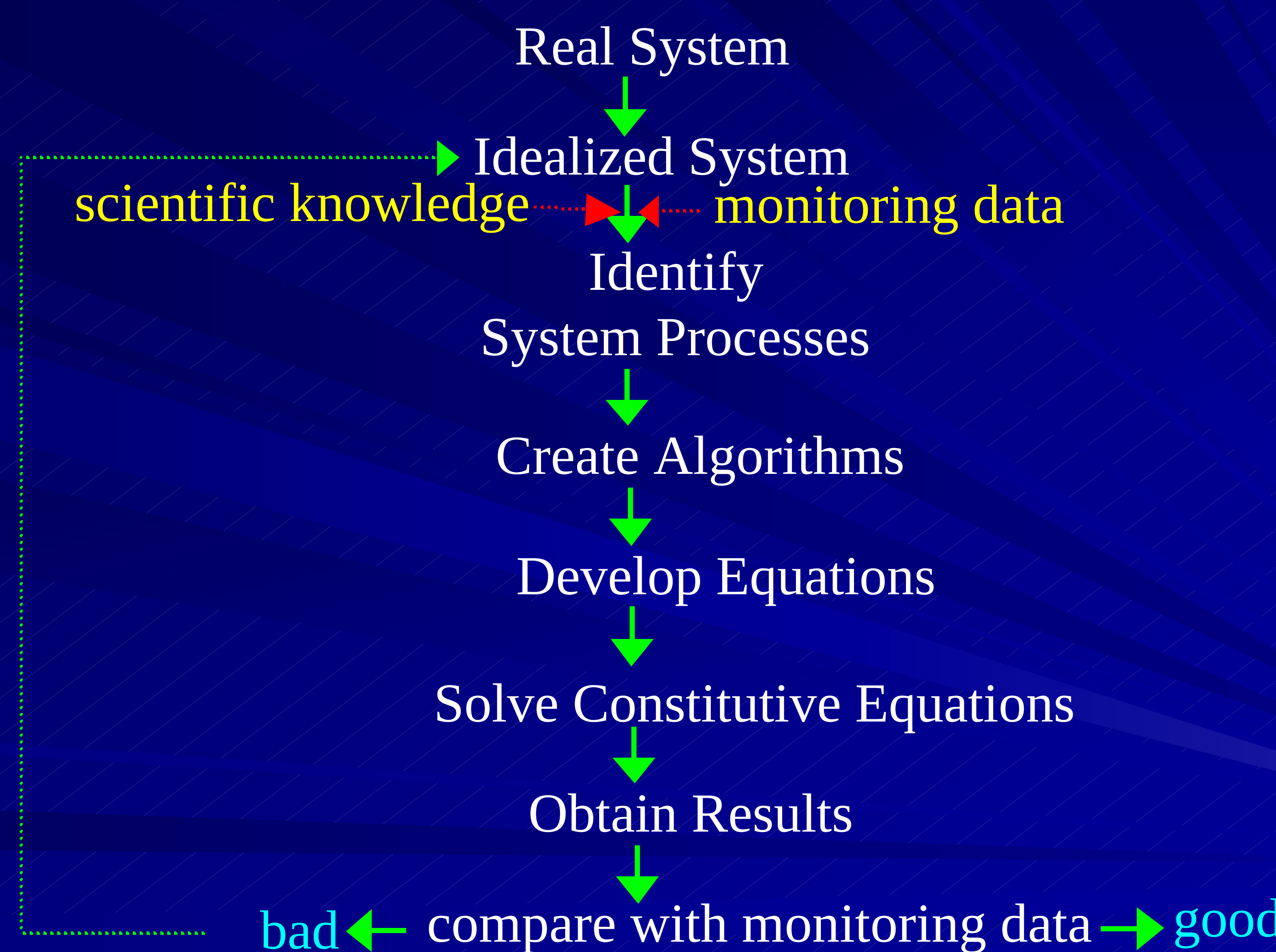
Quantity → Loading

Loading → Fate & Transport

Flow * Concentration = Load

Q * C = L

The Modeling Process



What can models do?

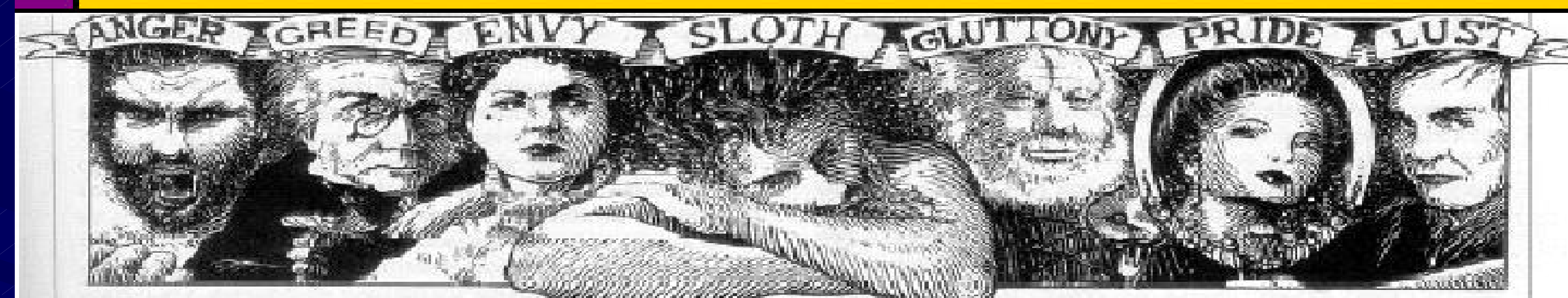
Benefits of Nutrient Loading Models

- Develop a relationship between external nutrient loads and resulting concentrations, which are useful in determining allowable loads.
- Define the relationship between nutrient concentrations and endpoints of concern, e.g., dissolved oxygen.
- Provide an increased understanding of the factors affecting nutrient concentrations, e.g., effects of land use changes.

Problems with modeling

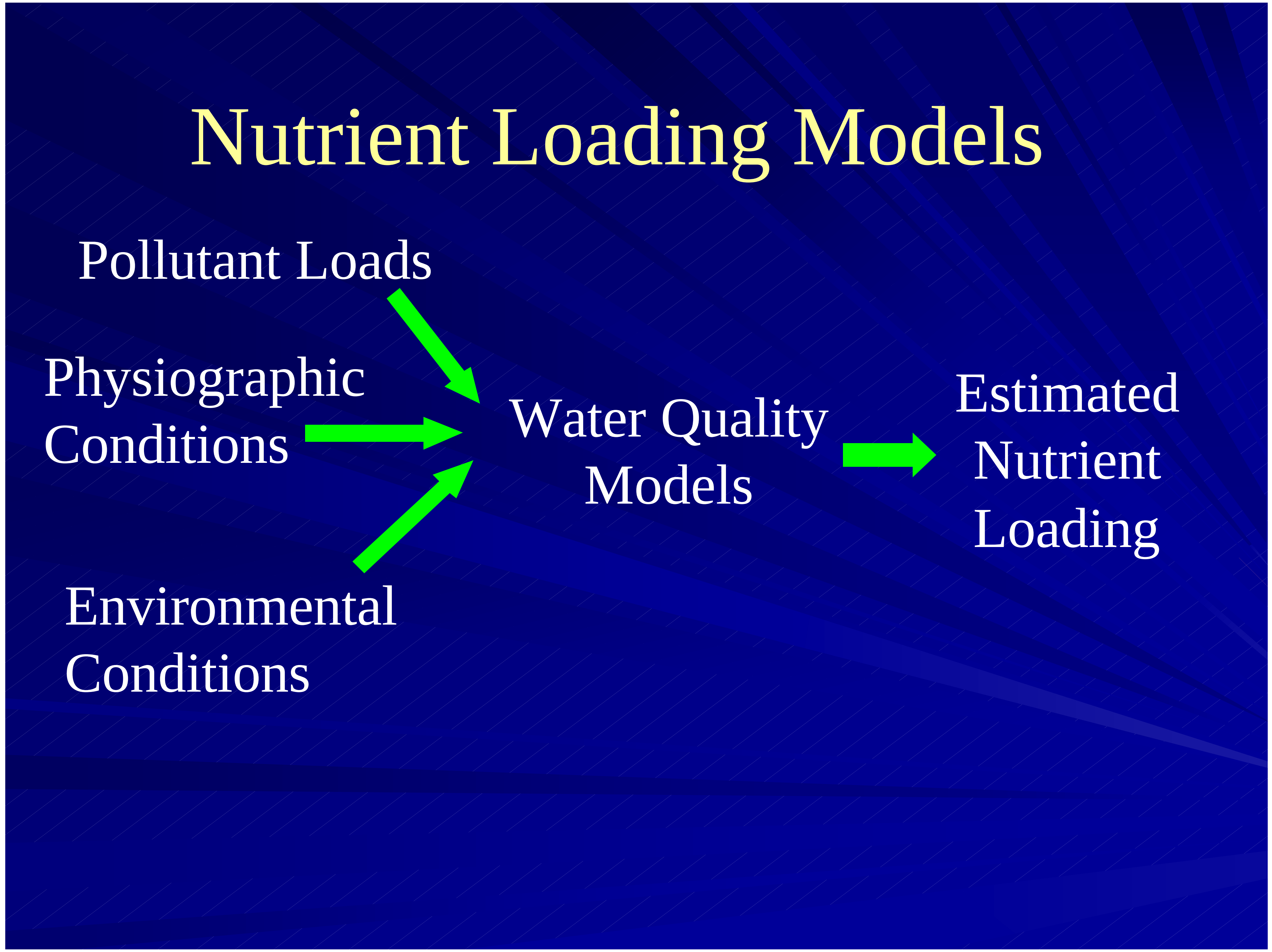
Limitations of models

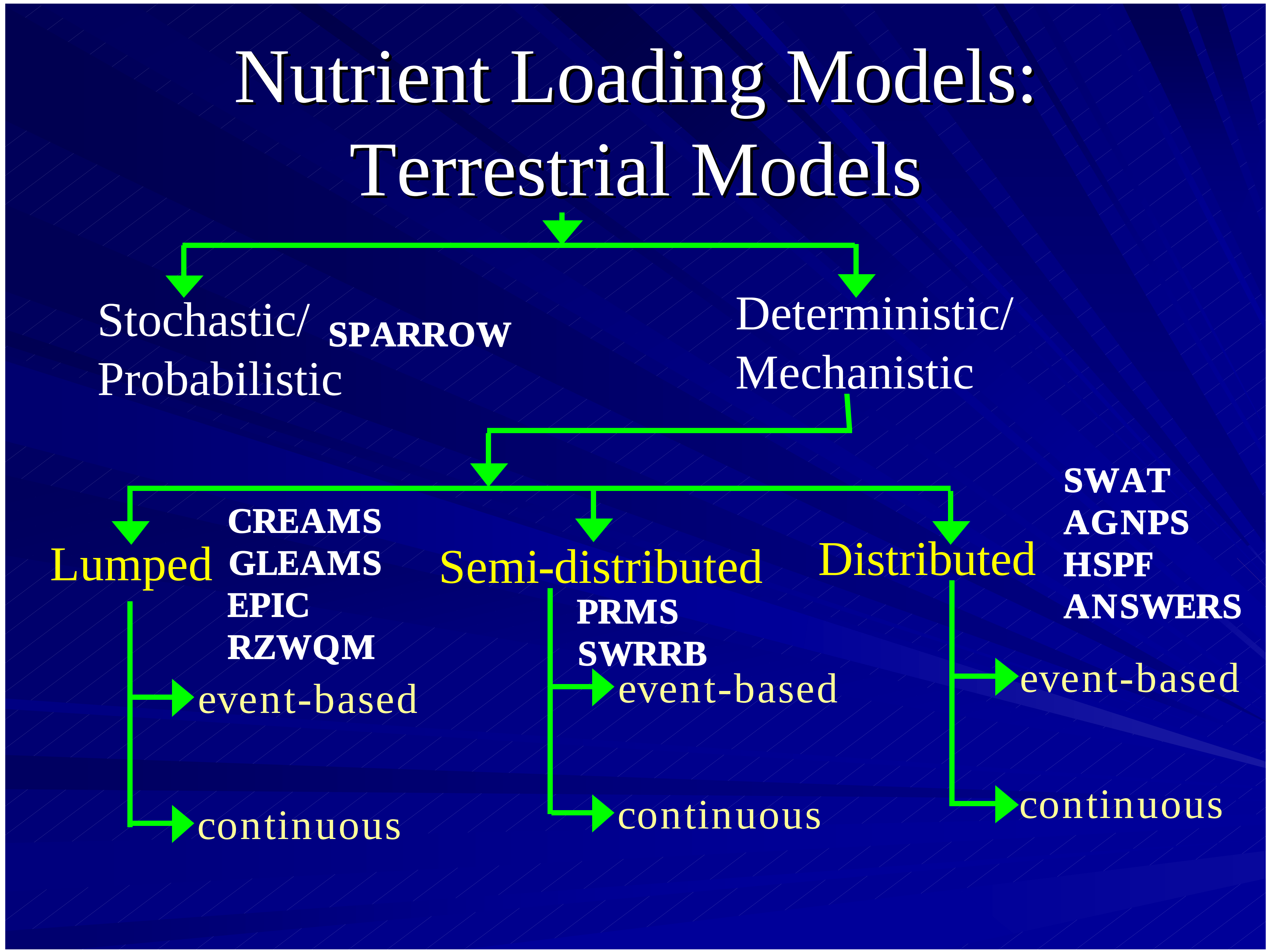
The 7 Deadly Sins of Process Modeling



- Hyper-comprehensiveness
- Grossness
- Data Hungriness
- Wrong-headedness
- Complicatedness
- Mechanicalness
- Expensiveness

Classes and types of nutrient loading models


Nutrient Loading Models
Pollutant Loads
Physiographic Conditions
Environmental Conditions
Water Quality Models
Estimated Nutrient Loading


Nutrient Loading Models:
Terrestrial Models
Stochastic/
Probabilistic
SPARROW
Deterministic/
Mechanistic
Lumped
CREAMS
GLEAMS
EPIC
RZWQM
event-based
continuous
Semi-distributed
PRMS
SWRRB
event-based
continuous
Distributed
SWAT
AGNPS
HSPF
ANSWERS
event-based
continuous

Complexity of Nutrient Loading Models

- Modeling complexity considers the
  - Technical detail and expertise
  - Level of modeling effort
  - Data collection and calibration needs
- Level I Models – Simplified/Desktop Models
- Level II Models – Mid-range Models
- Level III Models – Detailed Process-based/ Highly Complex Models

Terrestrial Models: Level I Modeling
(Desktop Analysis)

- Simplified modeling approach
- Less complex conditions and landscapes
- Based on existing measured data (concerns for data quality)
- Fast and cheap
- Useful for obtaining initial estimates of nutrient loads
- Examples: SIMPLE, SLOSS/PHOSPH, SPARROW, P-LOAD, etc,

Desktop Models: Loading Function Model (Level I)

- Loading $L = C_N * Q_R * CF$ (CF = Conversion Factor)

$$L = \sum_{i=1}^{365} (Q_i * C_i)$$

$$L = \sum_{n=1}^{12} \sum_{j=1}^{n_m} Q_{jm} \left[\sum_{j=1}^{n_m} \frac{C_{ijm}}{n_m} \right]$$

Terrestrial Models: Level II Modeling
(Mid-range Analysis)

- Require more complex mechanistic models to predict nutrient cycling
- Usually necessitates collection of additional data
- Resource demands additional consideration
- Examples: AGNPS, GWLF, CREAMS, EUTROMOD, etc.

Mid-Range Model: Generalized Watershed Loading Function (GWLF) Model

- Generalized Watershed Loading Function (GWLF) was developed in 1987 by Haith and Shoemaker at Cornell University
- Uses daily Temperature and Precipitation data to compute water fluxes in and out of watershed.
- Computes monthly dissolved and total Nitrogen and Phosphorous loads in stream-flow

Mid-Range Models: Generalized Watershed Loading Function (GWLF) Model

- Uses USLE/MUSLE and SCS Curve Number technique to estimate soil erosion (A_s) and surface runoff (Q_R)
- Nutrient Load $L = A_s * DR_k * N_c * ER_N$
  - $DR_k = \Phi$(land use, topography, land cover, soils, etc.)
  - N_c = conc. of nutrient in surface soil
  - ER_N = Enrichment ratio for particular nutrient

Terrestrial Models: Level III Modeling
(Detailed Process-based Analysis)

- Utilizes complex dynamic modeling approach
- Large amounts of input data are required
- Necessitates collection of additional data
- High level of technical expertise
- Examples: SWAT, HSPF, SWMM, STORM, WMS, HEC-HMS, SWRRB, AGNPS/AnnAGNPS, MIKE 11, etc.

Complex, Dynamic Models

- Soil Water Balance Component (hydrologic cycle)

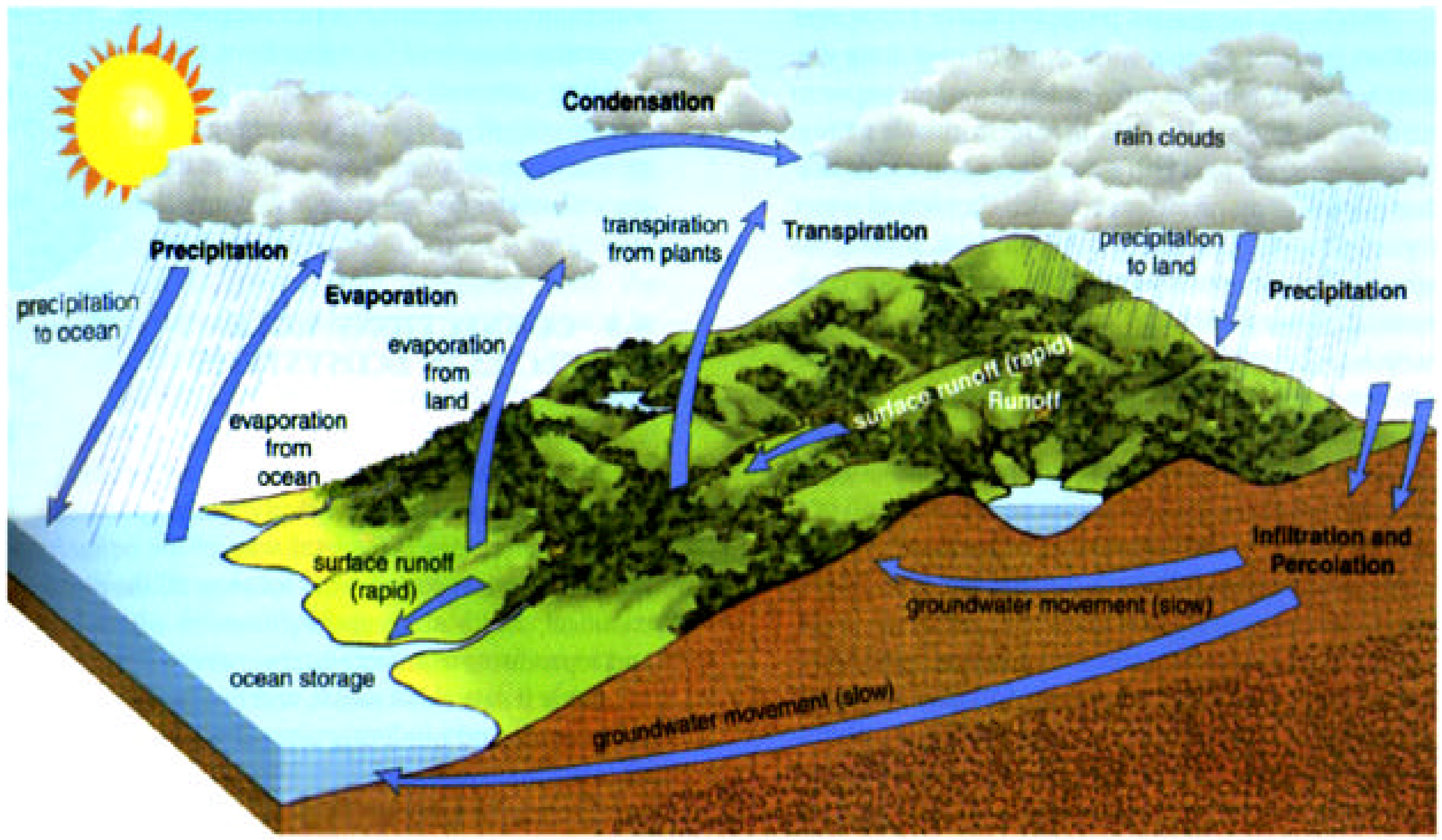
$$SW_t - SW = R_i - Q_i - ET_i - P_i - Q_R$$

- Soil Erosion ⇒ Sediment Yield
- Nutrient Loading

$$L = 0.001 * A_S * DR * N_c * ER$$

- Nutrient transformations (cycling)
- Numerical, process-based

Terrestrial Hydrologic Processes



Complex, Dynamic Models (Level III)

- Documents the biophysical conditions of watersheds and contributing areas:
  - Conservation of mass
  - Conservation of momentum
  - Conservation of energy
  - Laws governing chemical, biological, and physical reaction of nutrients in the terrestrial environment

How do users select a suitable model?

Avoiding Garbage In Garbage Out Problems

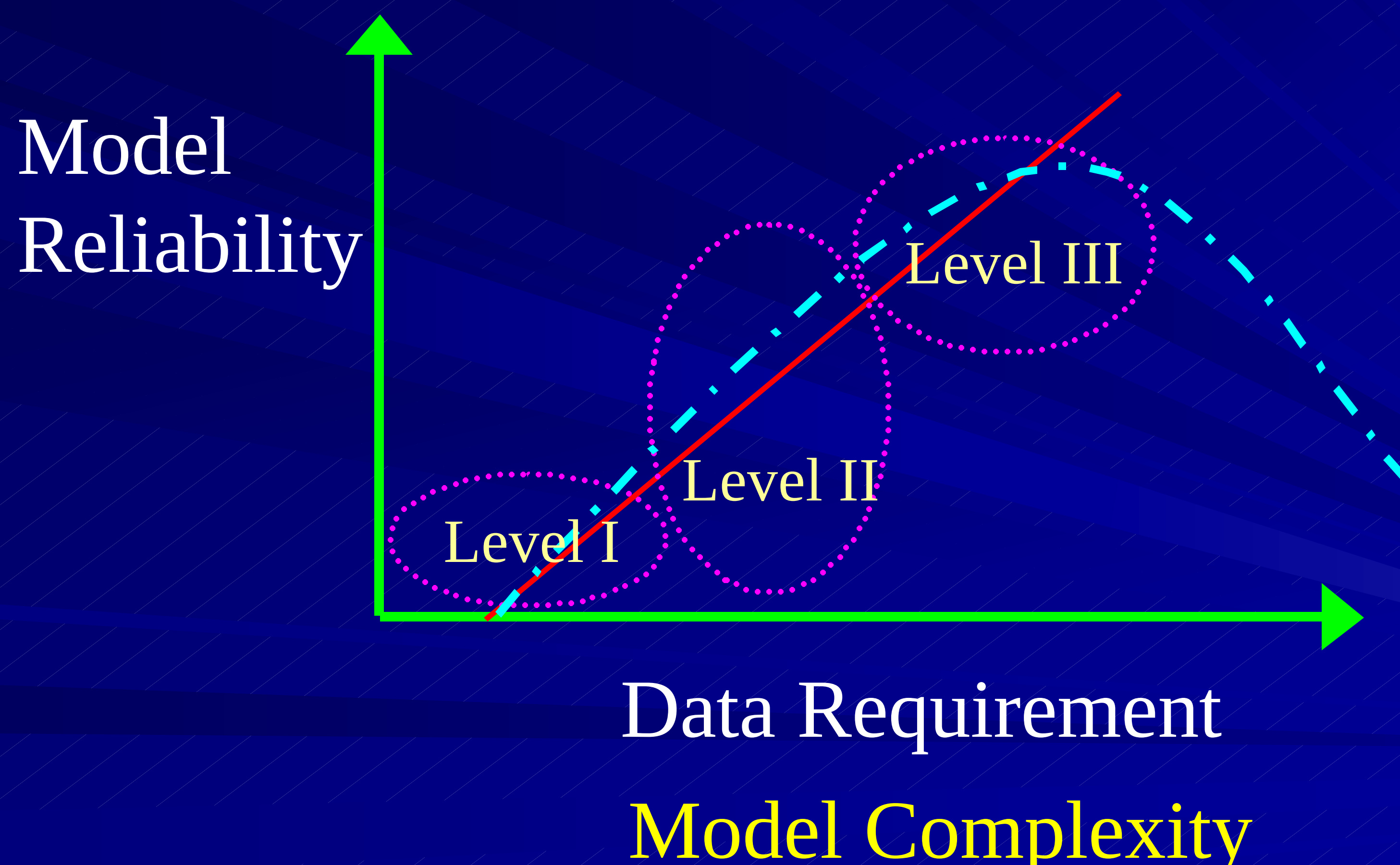
Nutrient Loading Models: Model Selection Criteria

- Is the model easy-to-use/user-friendly?
- What is the level of existing data?
- What level of resources/technical expertise exist?
- Does model provide adequate level for decision making?
- What are the nutrients/environmental endpoints of concern?
- Are spatial and temporal scales commensurate with management objectives?
- Does model handle uncertainty?

Evaluation of Model Options

- Increased model complexity results in:
  - Increased difficulty of obtaining reliable estimates of loading
  - Need for more input data
  - Increased level of technical expertise
  - Use of default values
  - Risk to policy decisions

Model Reliability and Data Requirements



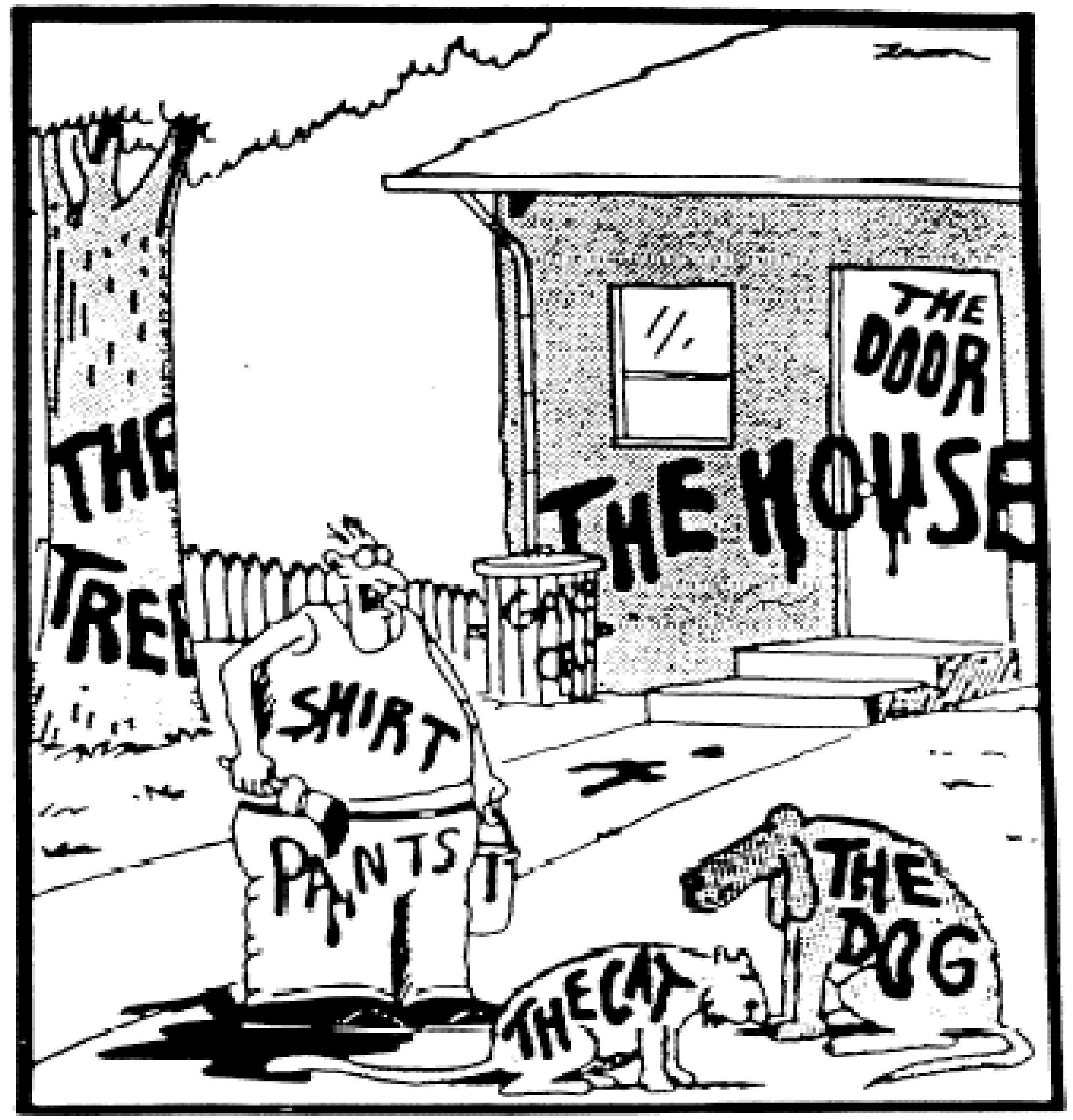
Good Modeling Etiquette

- Clearly define the modeling objective
- Match modeling approaches to specific needs, collecting no more data than necessary, and using no more modeling complexity than is really needed
- Strive to use models that combine strong theoretical foundations, objective information, and wisdom or good judgment
- Try to KISS, since complex models are data hungry, and certainly are unlikely to be understood by those who are asked to act on the basis of the model outputs

Issues to consider

Nutrient Loading Models:
Issues to Consider

- What policy goals are model predictions intended to achieve?
- How does the process of developing predictions influence the policy process?
- What are the direct economic and social impacts of the predictions?
- What factors influence how a prediction is used by society?
- How should model predictions be communicated to society?



"Now! *That* should clear up
a few things around here!"

That's it, folks!

Your turn…

Thanks for listening!