Development of Nutrient Sub-Model (SWWRP-NSM)

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Background

As Environmental Problems have become more complex and system oriented, it has become necessary to describe nutrient fate and transport on a more physical basis.

In order to evaluate individual projects in sufficient detail and at the same time evaluate projects on a system wide basis, complex models have to be able to exchange information with each other.

Background

To have a full system-wide water quality and contaminant capability in SWWRP, the different hydrologic and hydraulic engines must utilize a common water quality and contaminant approach to prevent the arbitrary portioning of constituents.

The goal of this research effort is to upgrade existing hydrologic and hydraulic models (i.e., water engines) using a common water quality approach in order to facilitate their linkage and application on a system wide basis.

NSM Modules

- Plant Dynamics Module
- Soils Module
- Overland Fate and Transport Module
- Channel Fate and Transport Module

Plant Dynamics Module

The process descriptions utilize a single plant growth model to simulate all types of land cover (SWAT/EPIC).

The algorithms are able to differentiate between annual and perennial plants.

Annual plants grow from the planting date to the harvest date or until the accumulated heat units equal the potential heat units for the plant.

Perennial plants maintain their root systems throughout the year, becoming dormant in the winter months. They resume growth when the average daily air temperature exceeds the minimum, or base, temperature required.

Plant Dynamics Module

Plant growth is modeled by simulating leaf area development, light interception and conversion of intercepted light into biomass assuming a plant species specific radiation-use efficiency.

In the initial period of plant growth, canopy height and leaf area development are controlled by the optimal leaf area development curve.

This curve is a function of the fraction of potential heat units for the plant and two shape factors (l_1 and l_2).

Plant Dynamics Module

The amount of total plant biomass partitioned to the root system is 30-50% in seedlings and decreases to 5-20% in mature plants.

Plant maturity is assumed to be reached when the fraction of potential heat units accumulated is equal to 1.0.

Once maturity is reached, the plant ceases to transpire and take up water and nutrients.

Plant Dynamics Module

Plant nitrogen and phosphorus uptake is controlled by the plant nitrogen and phosphorus equations.

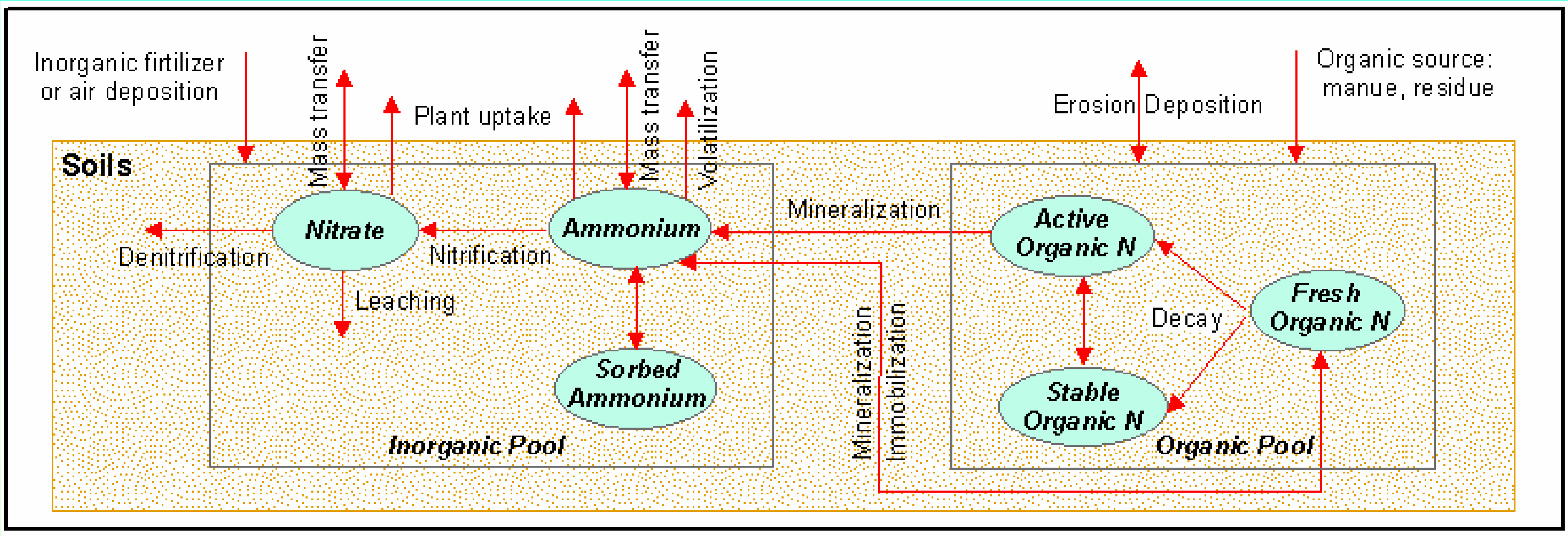
The plant nitrogen and phosphorus equations calculates the fraction of nitrogen and phosphorus in the plant biomass as a function of growth stage given optimal growing conditions.

Plant Growth Constraints:

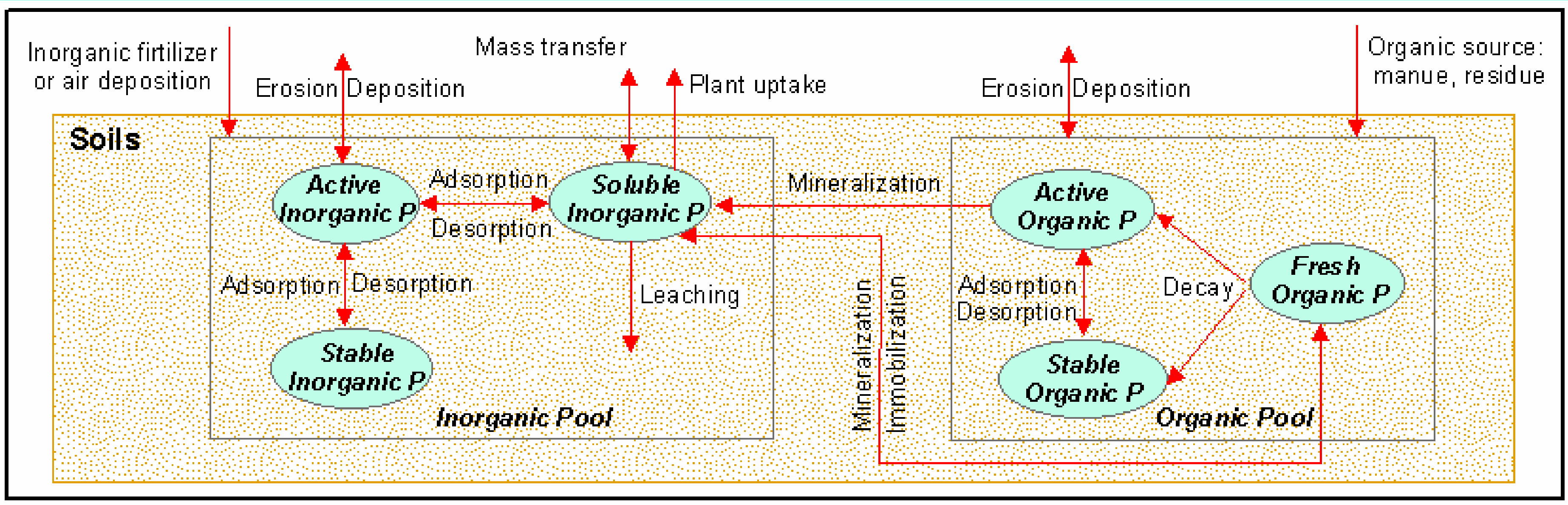
- Water Stress
- Temperature Stress
- Nitrogen Stress
- Phosphorus Stress

Actual Plant Growth is computed after applying all the stressors to the Optimal Plant Growth.

Soil Nitrogen
Processes Simulated by NSM



Soil Phosphorus Processes Simulated by NSM



Mass Transfer between Soils and Overland Flow

Mass Transfer Between Overland Flow and Upper Soil Layer

In order to provide a complete description of the dominant pools and fluxes in the water column, a single upper soil layer is included to maintain mass balance. The general mass balances for the dissolved state variables in the upper soil layer can be expressed as follows:

$$\frac{\partial (h_s C_{j,s})}{\partial t} = k_e \left(\frac{C_{j,s}}{\phi} - C_j \right) + \sum R_{j,k}$$

$C_{j,s}$ = concentration of dissolved species j in bulk volume of upper soil layer [M/L^3]
C_j = concentration of dissolved species j in the water column [M/L^3]
h_s = upper soil layer thickness [L]
k_e = mass transfer rate coefficient [L/T]
ϕ = porosity of the upper soil layer

Equilibrium Partitioning

Equilibrium Partitioning for Inorganic Species

- *Dissolved*

$$C_d = f_d C_T$$

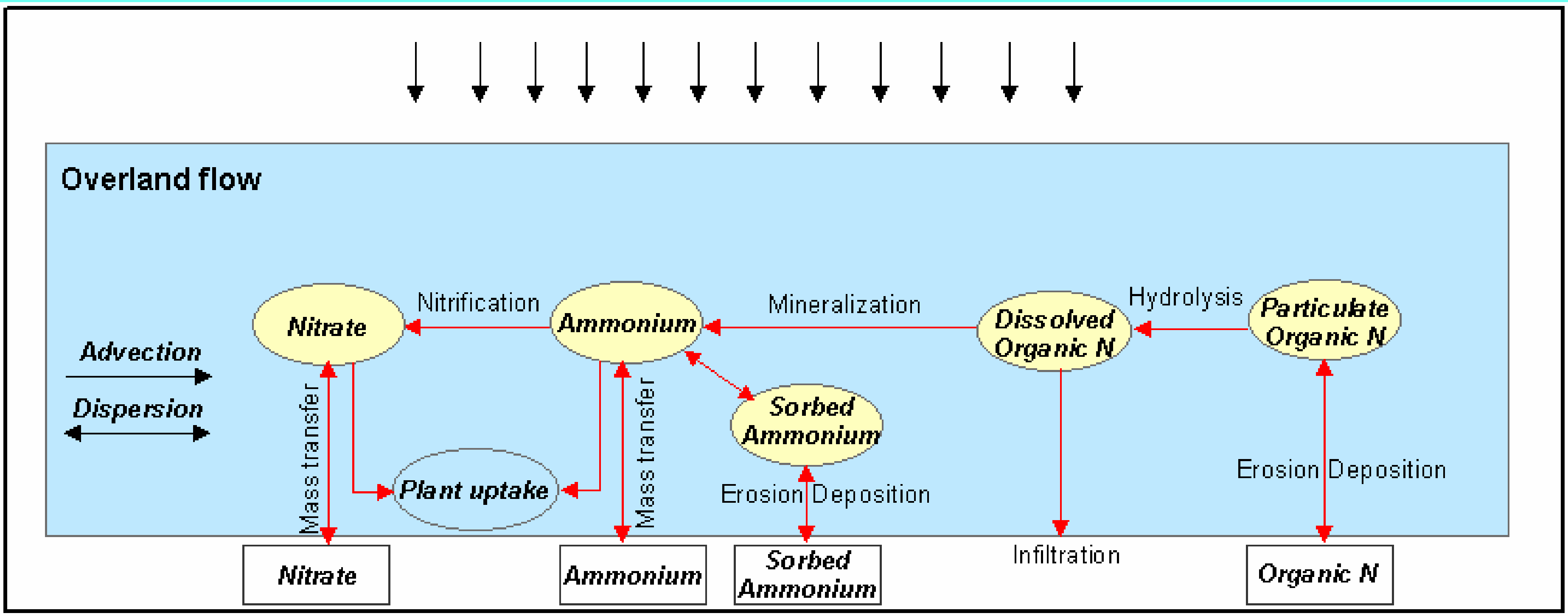
- *Sorbed to sediment (multiple) particles*

$$C_p = \sum_{n=1}^{N} f_{pn} C_T$$

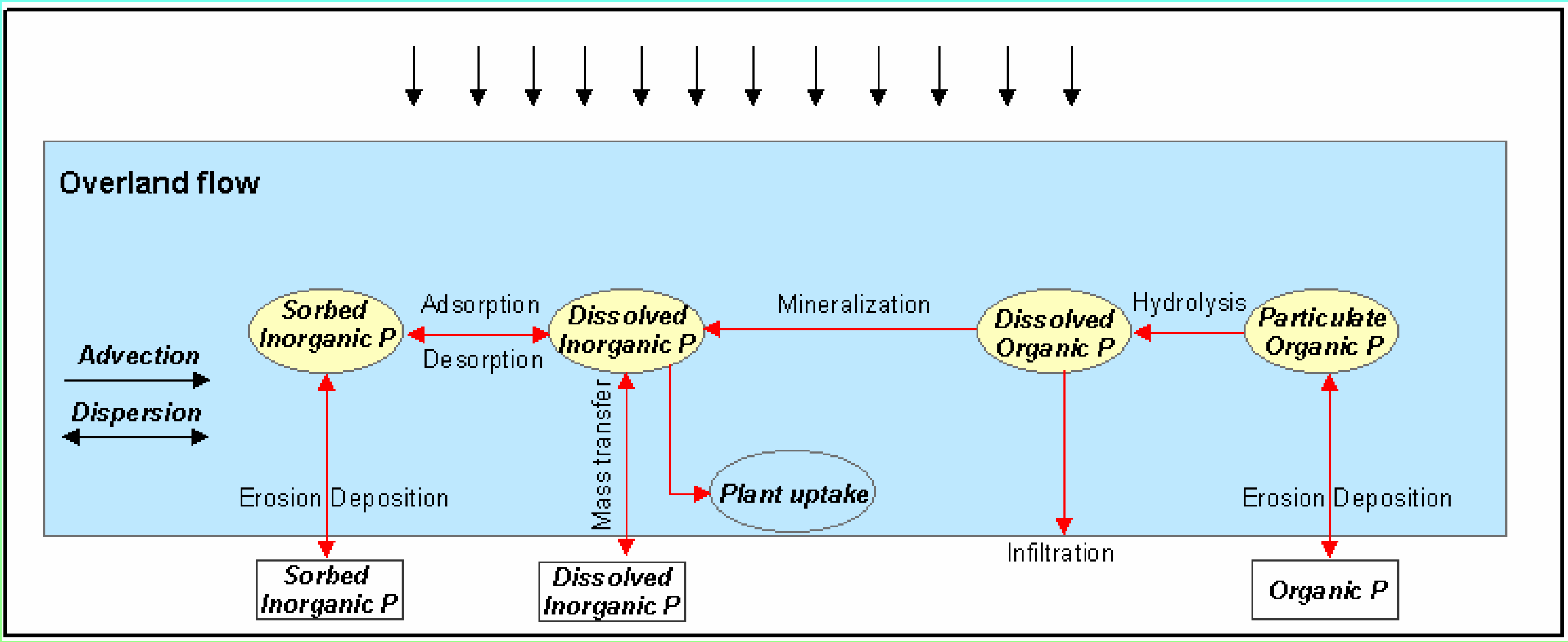
$$C_T = \left(1 + + \sum_{n=1}^{N} m_n \mathrm{k}_{px_n}\right) C_d$$

f_d = fraction of the total chemical in the dissolved phase
f_{pn} = fraction of the total chemical in the sorbed phase associated with particle "*n*"
k_{pxn} = particle-dependent partition coefficient [L^3/M]
n = particle index = 1, 2, 3, etc.
m_n = concentration of particle "*n*" [M/L^3]

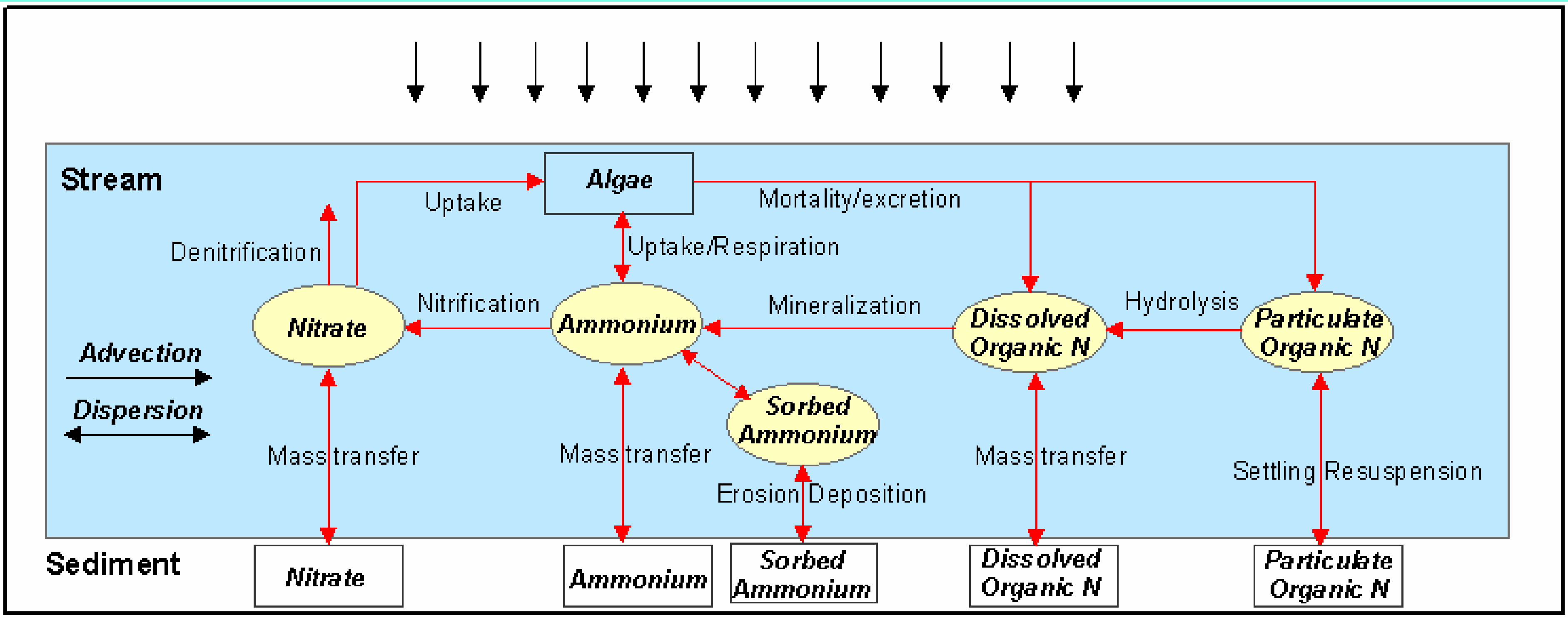
Overland Nitrogen Processes Simulated by NSM



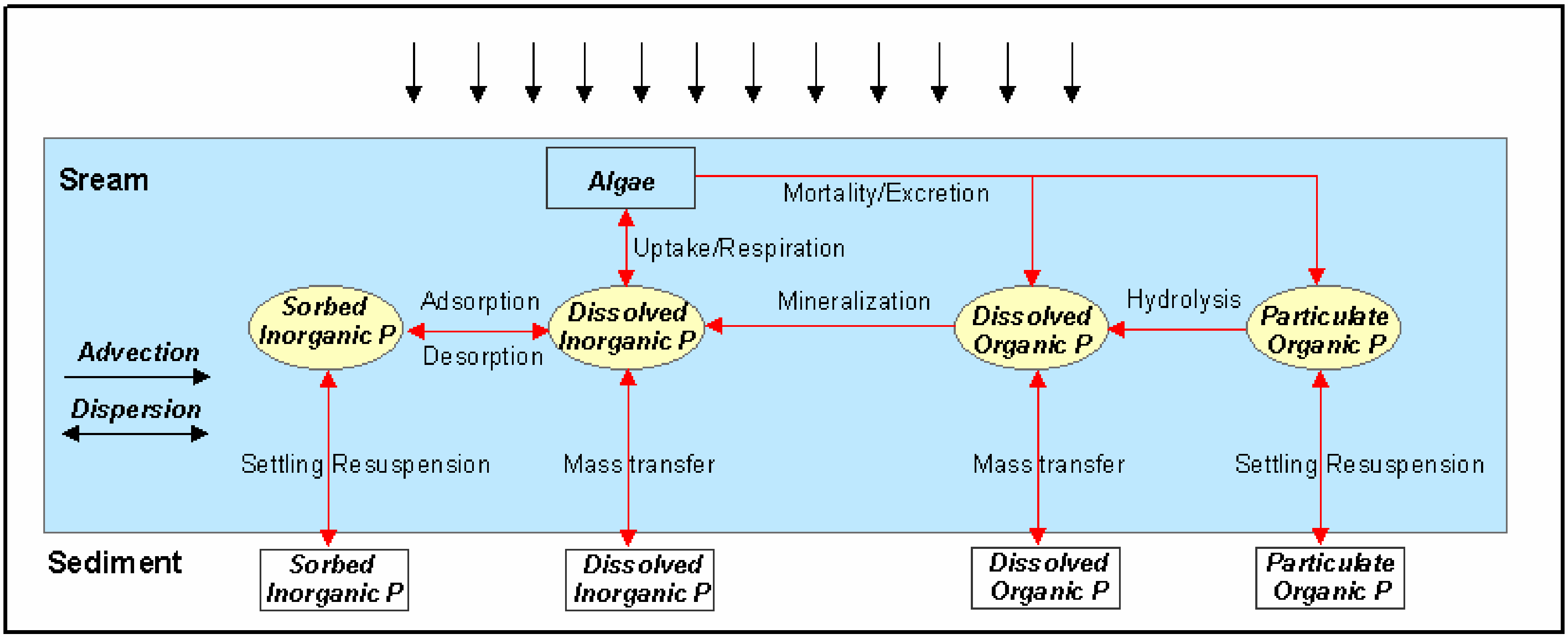
Overland Phosphorus Processes Simulated by NSM



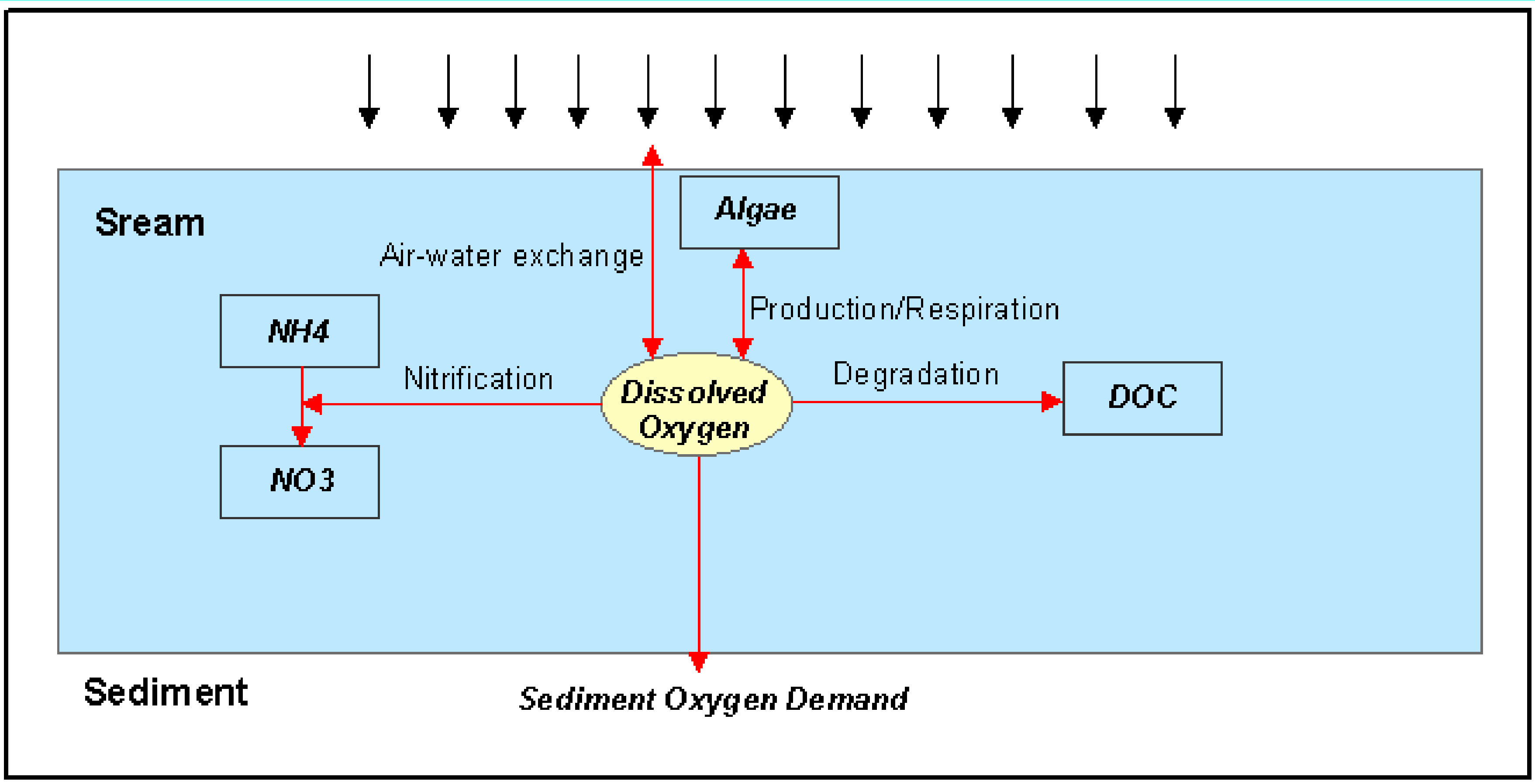
In-Stream Nitrogen Processes Simulated by NSM



In-Stream Phosphorus Processes Simulated by NSM



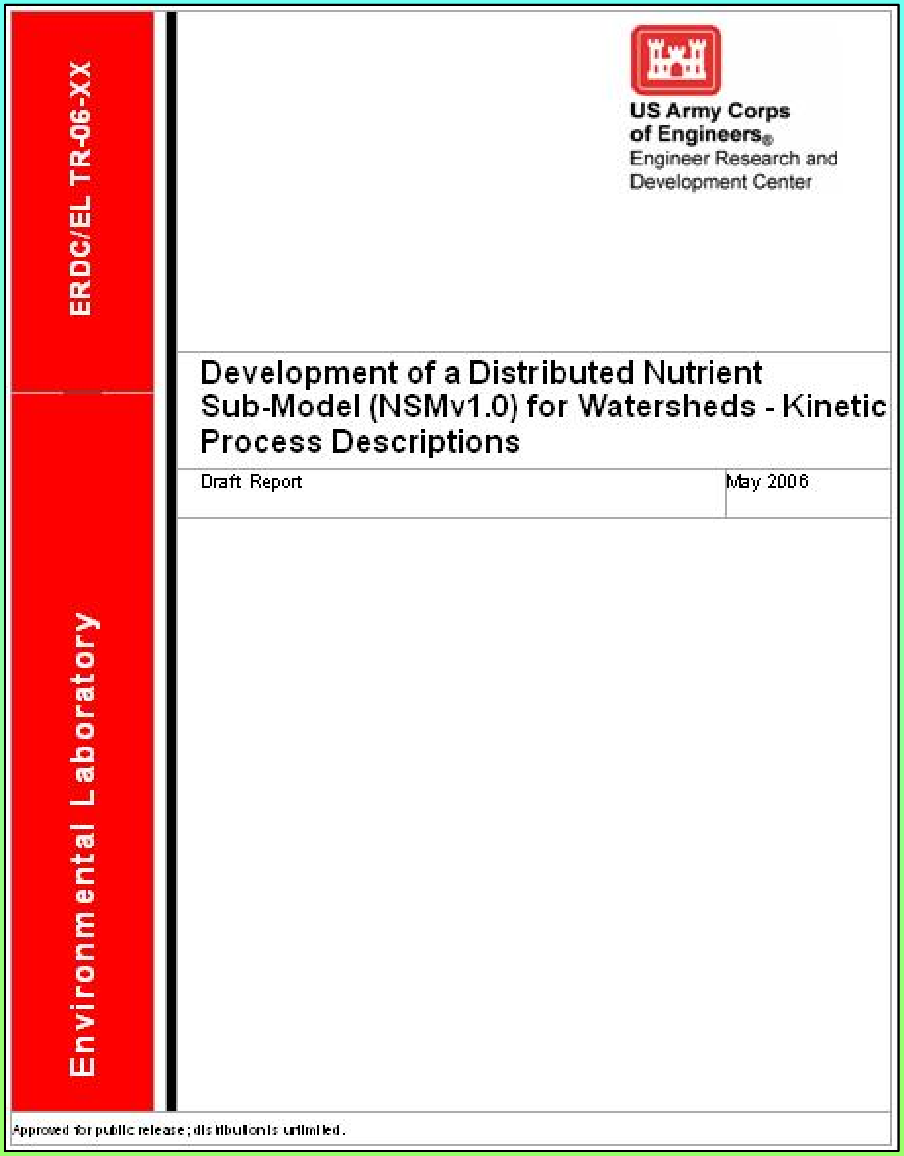
In-Stream Dissolved Oxygen



Future Development

- Update Channel Kinetics to include CE-QUAL-W2 and CE-QUAL-ICM kinetics.
- Update Plant Dynamics to include EDYS kinetics.
- Integrate NSM into existing USACE H&H modeling systems (e.g. HEC-RAS, HEC-HMS, and ADH).
- Work with CHL/BYU to incorporate NSM data requirements and visualization into WMS.

NSMv1.0 Technical Report



ERDC/EL TR-06-XX

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Development of a Distributed Nutrient Sub-Model (NSMv1.0) for Watersheds - Kinetic Process Descriptions

Draft Report

May 2006

Approved for public release; distribution is unlimited.

Contains detailed formulations for Soils, Overland, and Channel Processes.

Plant Dynamics formulations will be in upcoming NSMv1.1 Technical Report.