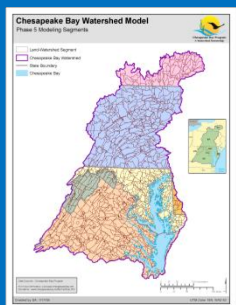
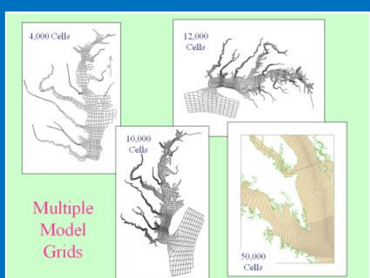
Regional Atmospheric Deposition Model

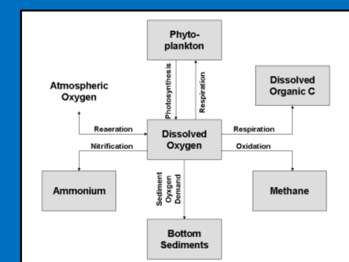


Watershed Model

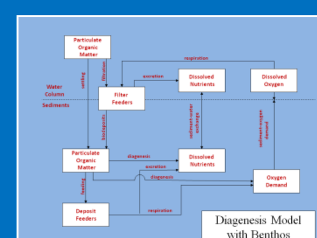


Hydrodynamic Model

Eutrophication Model



Sediment Diagenesis

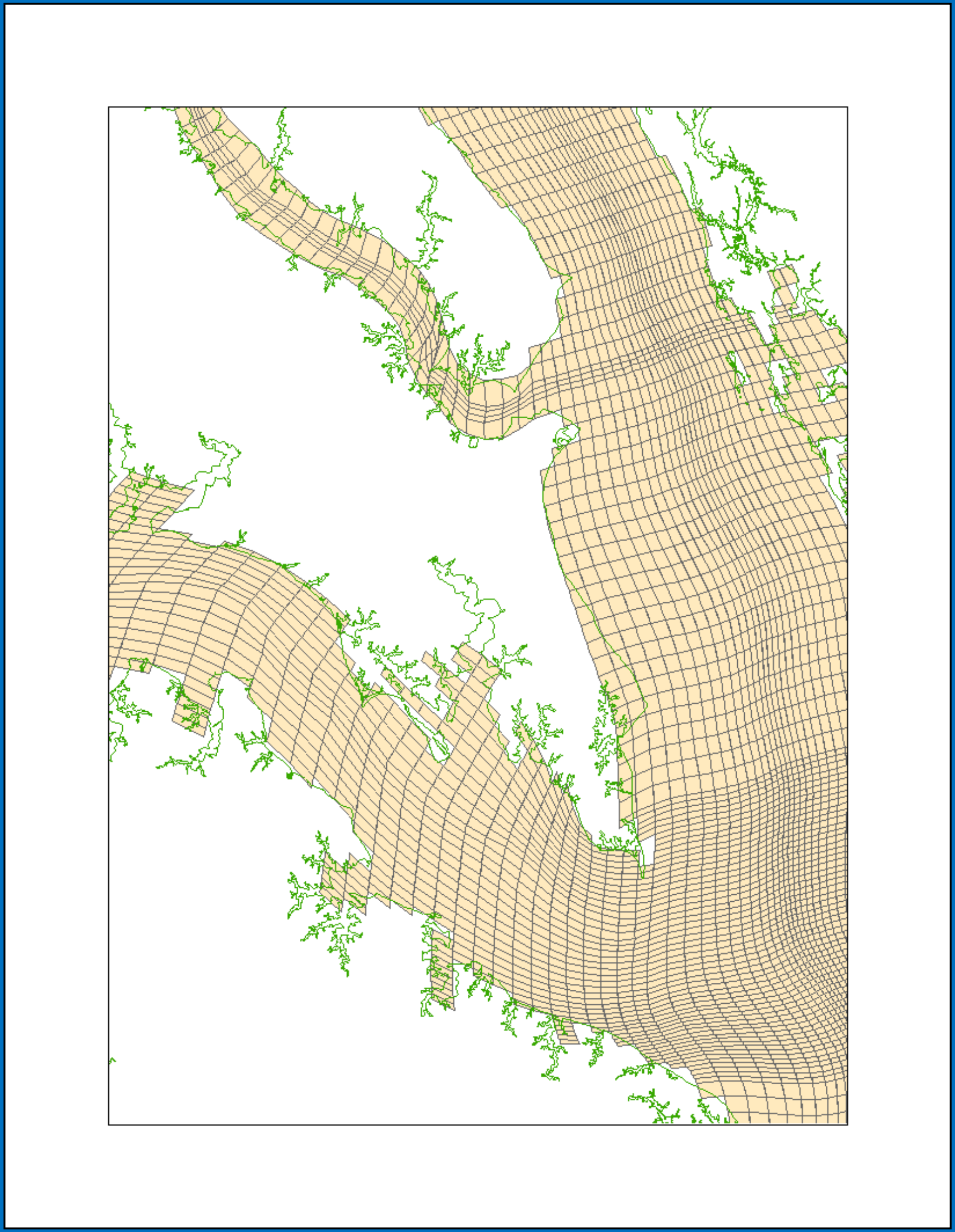


The CBEMP

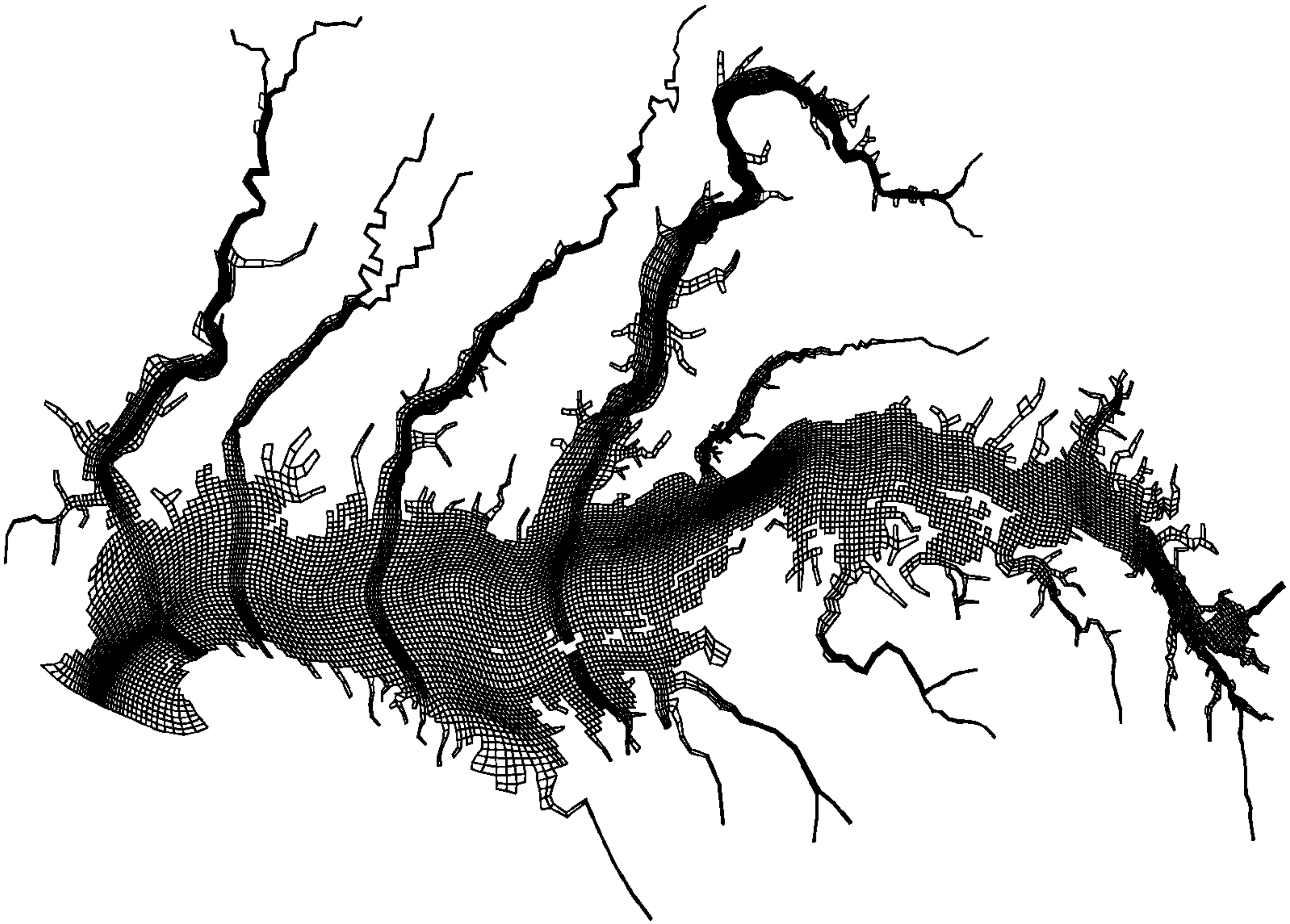
The CH3D Hydrodynamic Model

- Originally developed by Peter Sheng circa 1986.
- Extensively modified since by USACE WES. This version referred to as CH3D-WES.
- Coded in FORTRAN. Although the code has been extensively modified, the code is consistent with 1986 standards.
- Provides computations of surface elevation, 3-D velocities, vertical diffusivity, salinity, temperature.

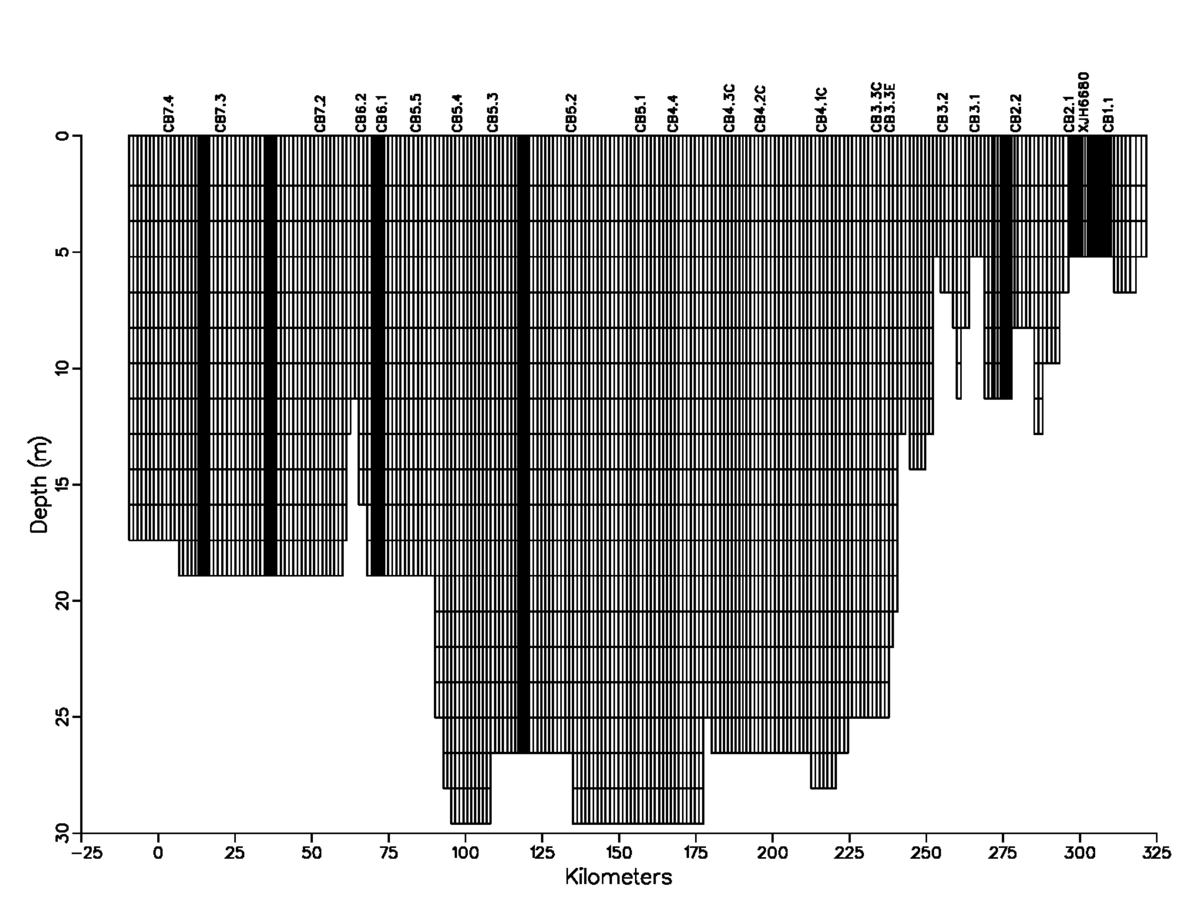
Non-Orthogonal Curvilinear Coordinates



Chesapeake Bay Grid



Z-grid Along Bay Axis



Elevation view of grid along a transect from the mouth of the bay (km 0) to the head of tide (≈ km 320). Note that variations in depth are represented by variations in the number of cells in the vertical dimension.

Present Chesapeake Bay Configuration

- 11,064 surface cells
- 56,920 total cells
- 1 to 19 layers in vertical
- average grid cell is 1,025 x 1,025 m in extent
- surface layer = 2.14 m thick at mean tide
- sub-surface layers = 1.53 m thick
- 90 sec time step
- Forced by daily runoff from WSM, daily observed winds, intra-tidal surface-level at mouth, monthly observed salinity at mouth.
- Provides realistic intra-tidal computations. Simulations available for 1985 – 2005

Independent Hydrodynamic and Water Quality Models

Hydrodynamic model run one time.

Stored on computer disk.

Hydrodynamics used repeatedly (100's of times) by eutrophication model.

The CE-QUAL-ICM Water Quality Model

- Developed for Chesapeake Bay circa 1988.
- Finite-volume model which incorporates transport processes from an external source.
- Has been coupled to the CH3D, EFDC, ROMS, and FVCOM hydrodynamic models.
- Formulations have been widely disseminated and duplicated.
- Kinetics are built around cycles including carbon, nitrogen, phosphorus, and oxygen.

CE-QUAL-ICM

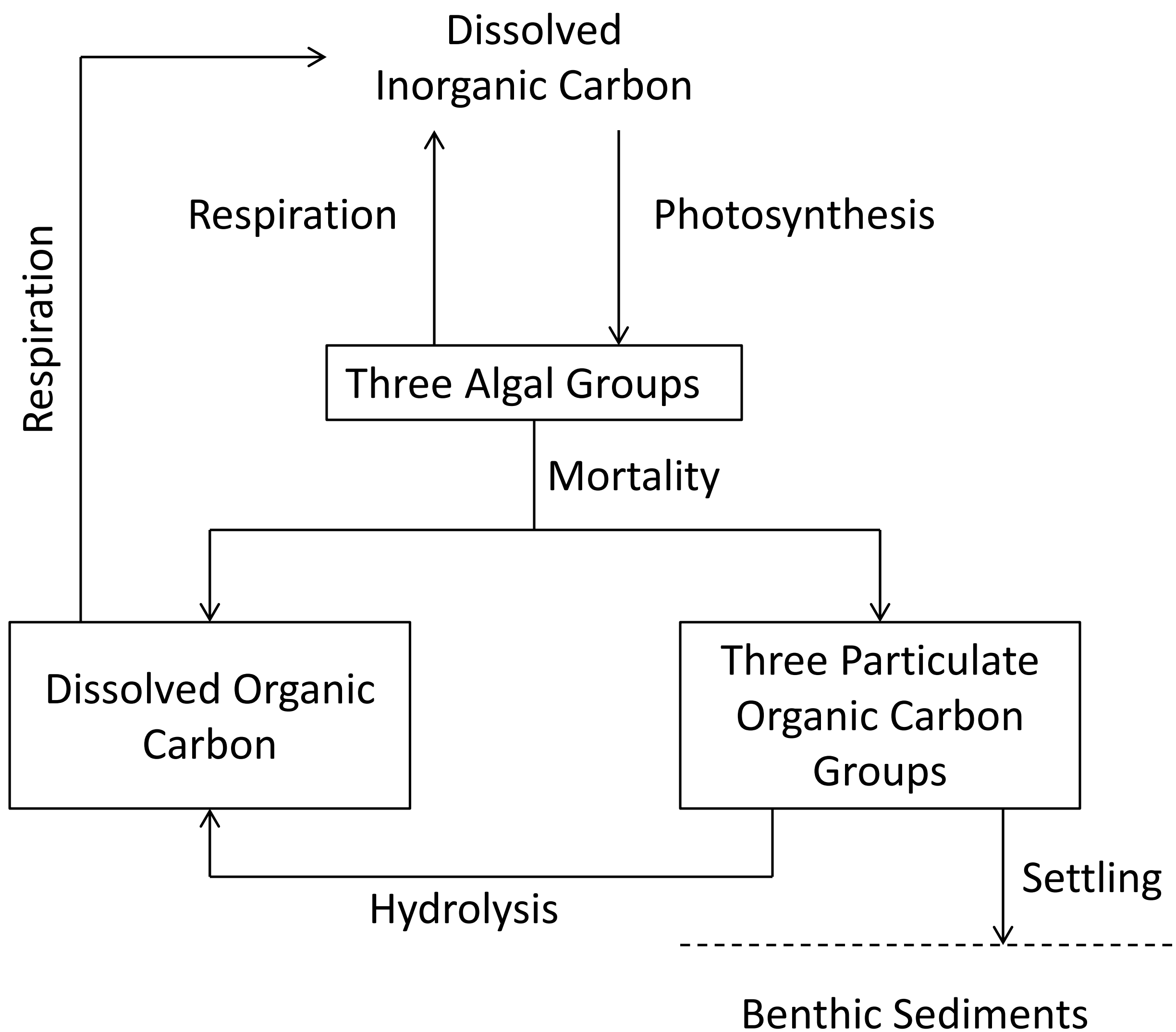
The foundation of CE-QUAL-ICM is the solution to the three-dimensional mass-conservation equation for a control volume. Control volumes correspond to cells on the model grid. CE-QUAL-ICM solves, for each volume and for each state variable, the equation:

$$\frac{\delta V_j \cdot C_j}{\delta t} = \sum_{k=1}^{n} Q_k \cdot C_k + \sum_{k=1}^{n} A_k \cdot D_k \cdot \frac{\delta C}{\delta x_k} + \Sigma S_j \qquad (1)$$

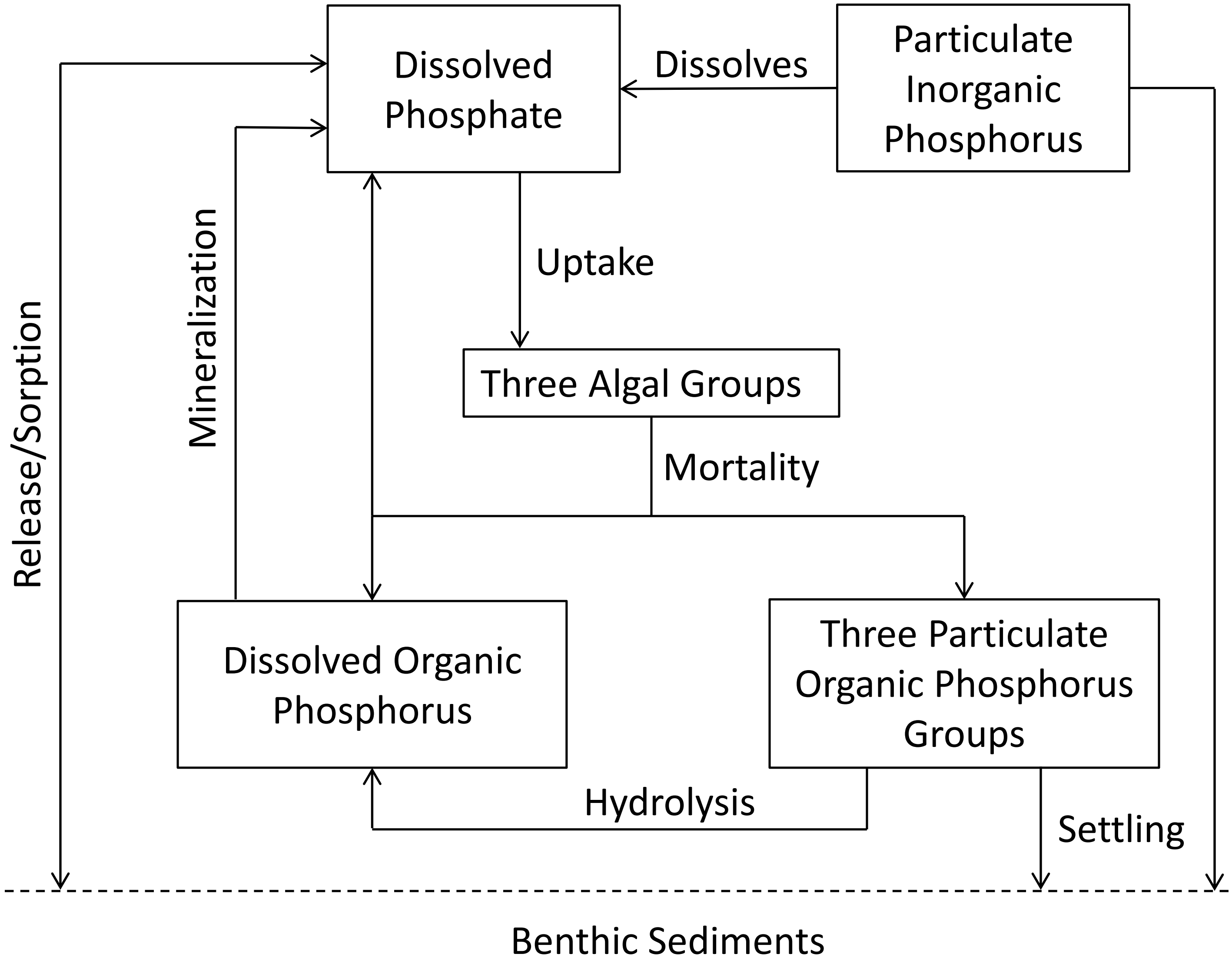
in which:

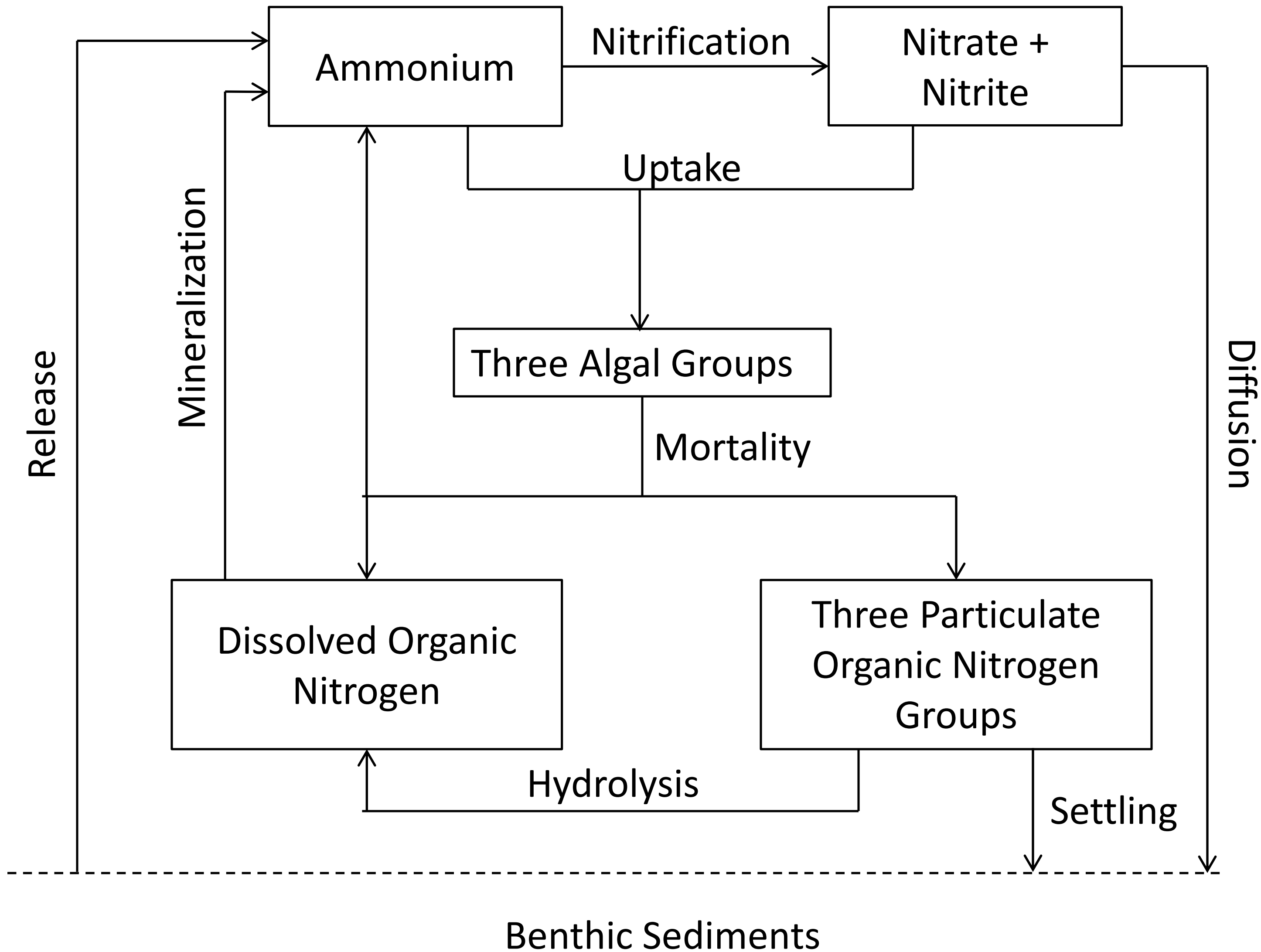
V_j = volume of j^{th} control volume (m^3)
C_j = concentration in j^{th} control volume ($g\ m^{-3}$)
t, x = temporal and spatial coordinates
n = number of flow faces attached to j^{th} control volume
Q_k = volumetric flow across flow face k of j^{th} control volume ($m^3\ s^{-1}$)
C_k = concentration in flow across face k ($g\ m^{-3}$)
A_k = area of flow face k (m^2)
D_k = diffusion coefficient at flow face k ($m^2\ s^{-1}$)
S_j = external loads and kinetic sources and sinks in j^{th} control volume ($g\ s^{-1}$)

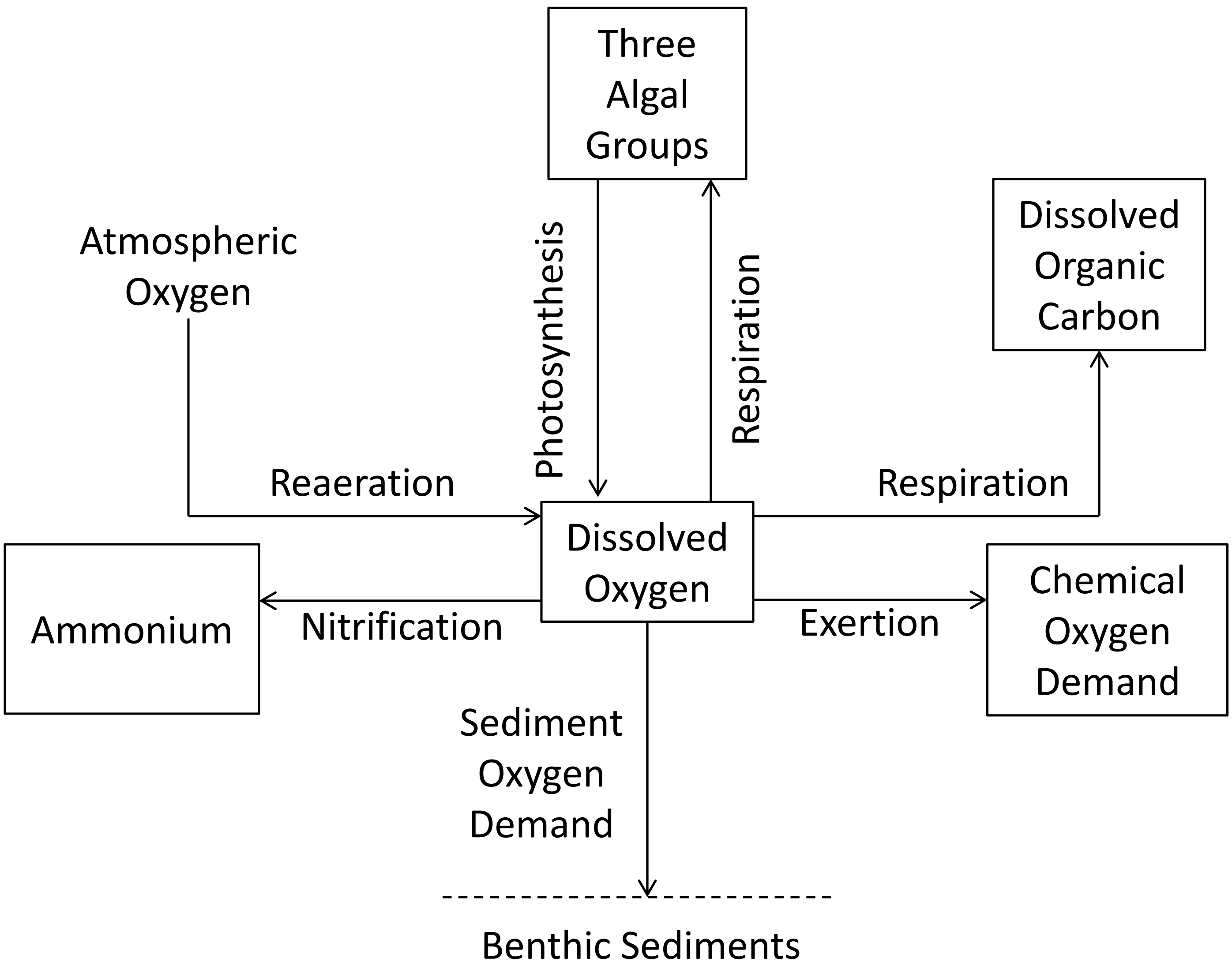
- ICM uses the same grid as CH3D. Spatial scale is the same.
- ICM is provided with hourly transport from CH3D, daily loads from Watershed Model, monthly boundary conditions at mouth of Bay.
- Computational time scale is minutes. Realistic time scale for predictions is daily to several days.



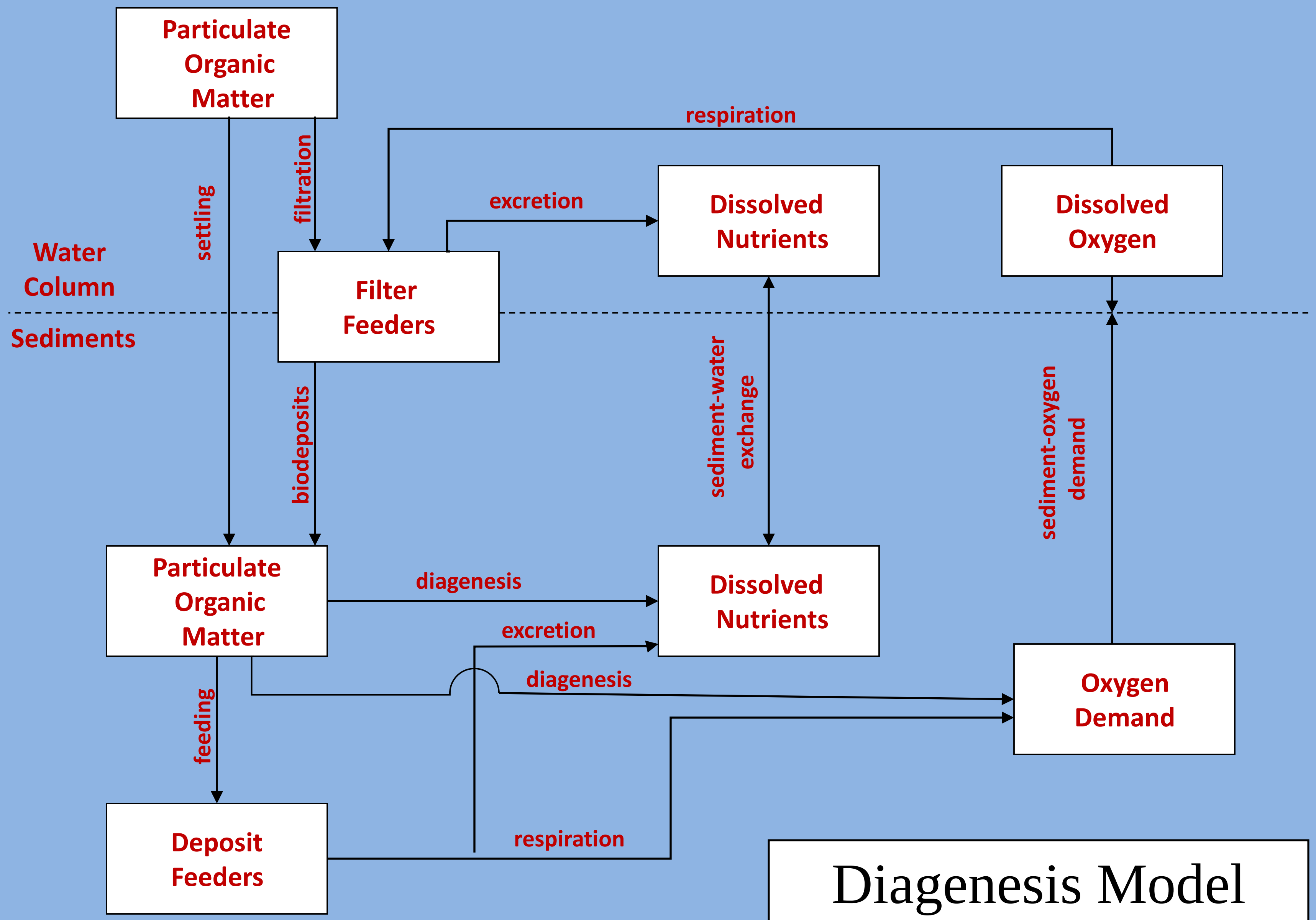
Dissolved
Inorganic Carbon
Respiration
Photosynthesis
Respiration
Three Algal Groups
Mortality
Dissolved Organic
Carbon
Three Particulate
Organic Carbon
Groups
Settling
Hydrolysis
Benthic Sediments


Dissolved Phosphate
Particulate Inorganic Phosphorus
Dissolves
Uptake
Three Algal Groups
Mortality
Mineralization
Release/Sorption
Dissolved Organic Phosphorus
Three Particulate Organic Phosphorus Groups
Hydrolysis
Settling
Benthic Sediments


Ammonium
Nitrification
Nitrate +
Nitrite
Uptake
Mineralization
Release
Three Algal Groups
Mortality
Diffusion
Dissolved Organic
Nitrogen
Three Particulate
Organic Nitrogen
Groups
Hydrolysis
Settling
Benthic Sediments



Three Algal Groups
Dissolved Organic Carbon
Atmospheric Oxygen
Photosynthesis
Respiration
Reaeration
Respiration
Dissolved Oxygen
Ammonium
Nitrification
Exertion
Chemical Oxygen Demand
Sediment Oxygen Demand
Benthic Sediments



Diagenesis Model with Benthos

The Sediment Diagenesis Model

- Driven by need to predict response of sediment-water nutrient and oxygen exchanges to management actions in watershed.
- Developed for Chesapeake Bay circa 1988 by Dominic DiToro.
- There have been some refinements but the original framework is intact.
- The model has been widely disseminated and duplicated but not substantially improved.
- The spatial scale is the same as the hydrodynamic and water quality models. The diagenesis model considers a 10 cm thick active sediment layer.
- The computational time scale is the same as the water quality model. The model responds to conditions in the water column instantaneously. Years of integration are required, however, to equilibrate with burial and refractory diagenetic processes.

Where are We Going?

- The major issues with the current model framework involve the configuration and resolution of the hydrodynamic model.
- It seems to be a “given” that we will move to an unstructured grid with triangular elements.
- We ought to consider whether the transport will be exported to the water quality model or whether the water quality will be run simultaneously with hydrodynamics.

Where are We Going?

- We may improve the water quality kinetics (add iron?) but it doesn't appear anything crucial is missing. In fact lately we have been eliminating rather than adding.
- The above holds for the sediment diagenesis model also.
- Need to get carbon into the Watershed Model.