Academy

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Enabling Delta Life

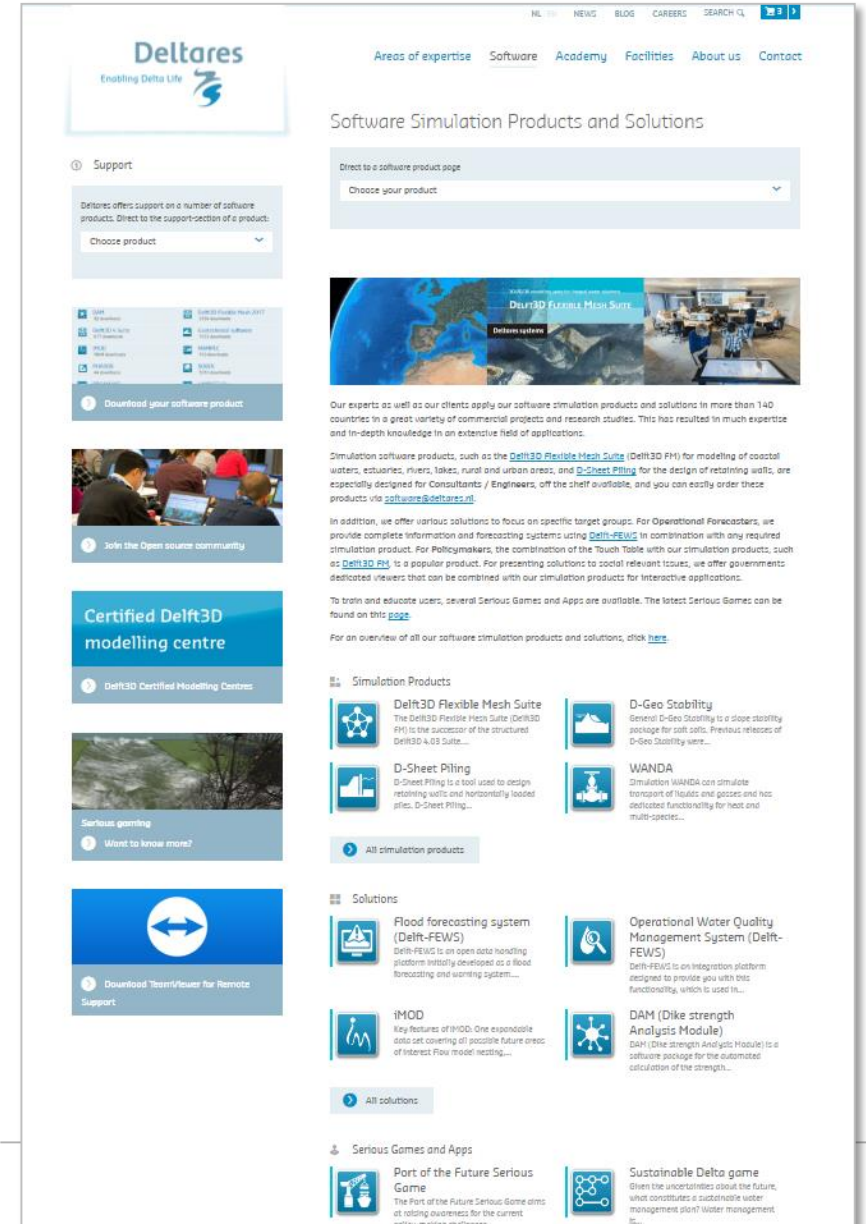
Introductory Course
Delft3D-WAQ

Water quality modelling,
introduction and concepts

WAQ_Topics_02

WAQ_Introduction_03

Deltares software



https://www.deltares.nl/en/software/:

- **Simulation products**
- **Solutions**
- **Serious Games and Apps**
- **Web and Touch Table applications**
- **Toolboxes**

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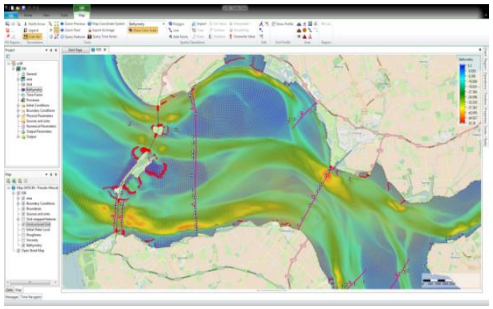
Why we develop software

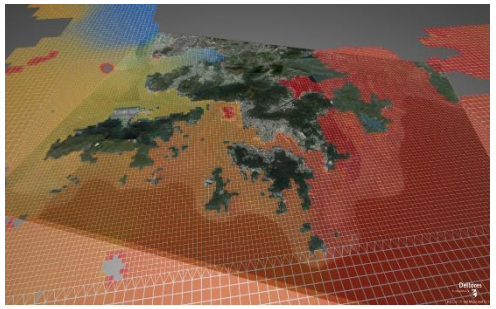
Open source community:
- **21.000+ persons**
- **214 countries**
- **400-500 sessions per day**

Specialist advise



Knowledge sharing

Research



Collaboration

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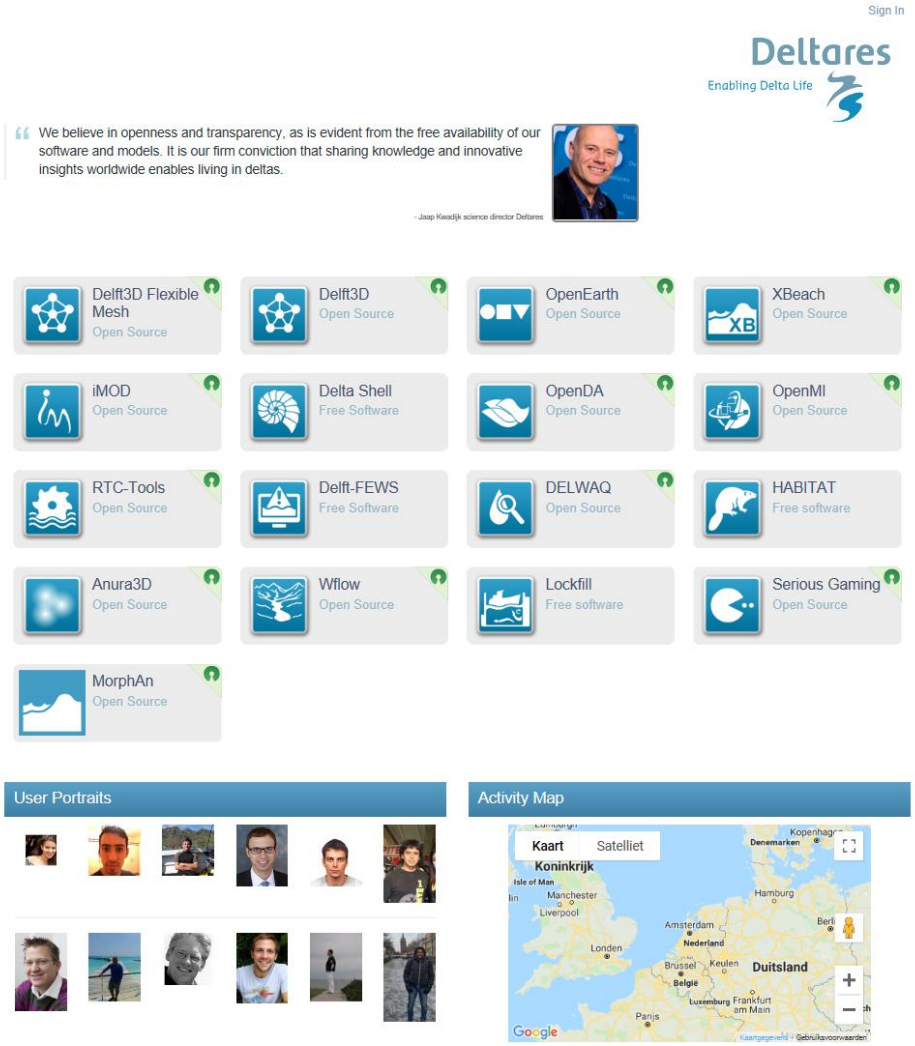
Open Source & Free Software



https://oss.deltares.nl/:

21.000+ members, 200+ countries:

- **Delft3D**
- **Delft-FEWS**
- **OpenEarth**
- **XBeach**
- **iMOD**
- **…**

Free software

Open source code

Good Modelling Practice

Forum

Announcements

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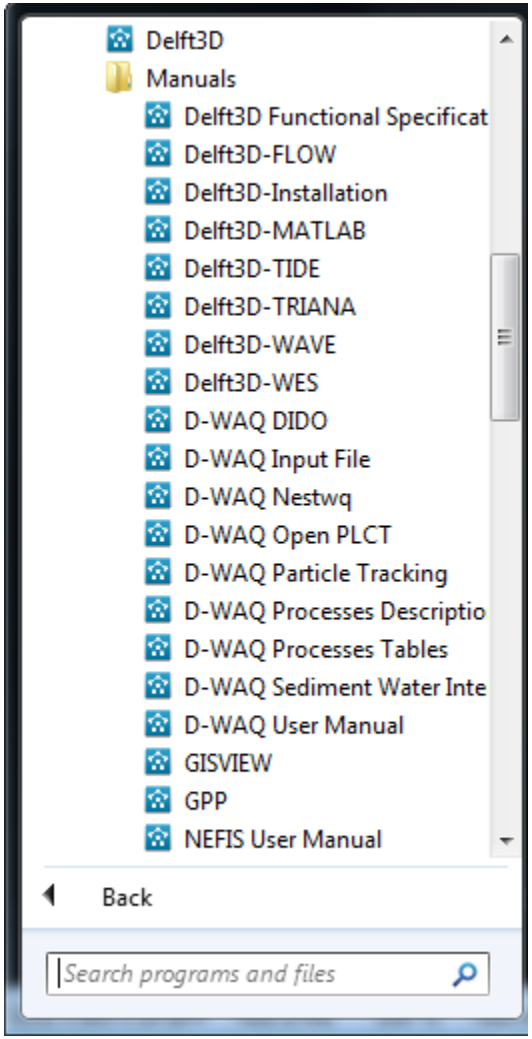
User manuals

D-Water Quality comes with a set of nine manuals

Where to look?

Getting started → D-WAQ User Manual
Process details → D-WAQ Process Description
Advanced input → D-WAQ Input File



Overview of topics (1)

- functional specifications Delft3D-WAQ
- water quality modelling, introduction and concepts
- steps in water quality modelling
- transport modelling and numerical aspects
- Process Library Configuration Tool

- water Quality Processes:
  - oxygen - BOD, processes and formulation
  - nutrients, cycles of nitrogen, phosphorus and silicon
  - general introduction on algae growth

- exercises

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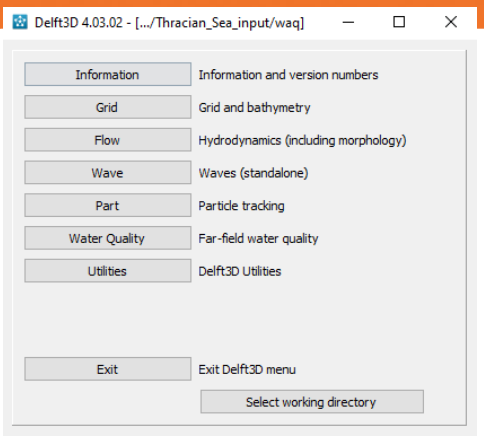
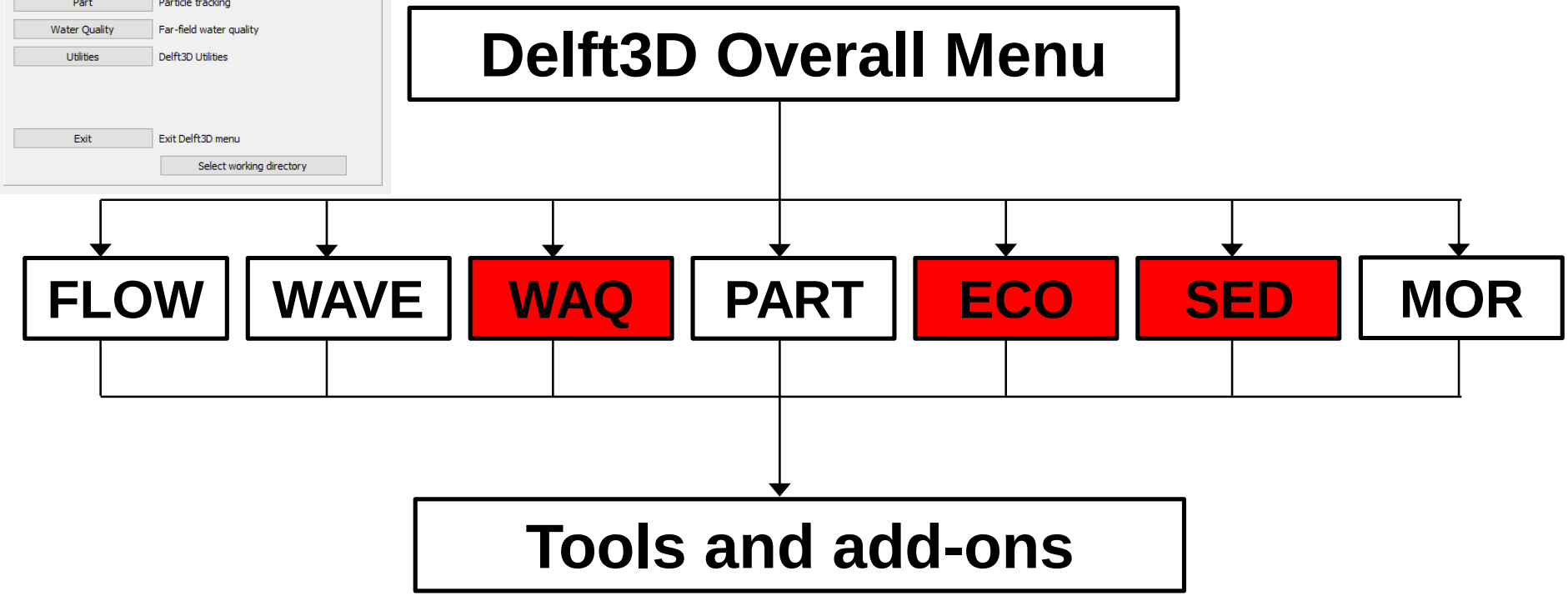
Delft3D system overview





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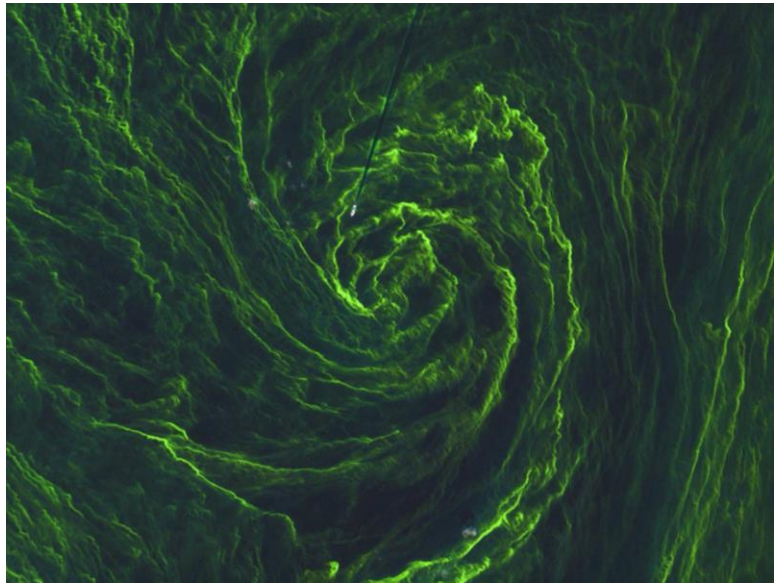
Issues in Water Quality Modelling (1)

- Quantitative aspects water management
  - drinking water, flooding (dikes, dams, etc.)
- Salinity (affects ecosystem)
- Bacterial pollution
- Organic material (BOD, COD)
- Nutrient enrichment (eutrophication)
- Algae blooms
- Oxygen depletion



Source: ESA Sentinel-2A

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Issues in Water Quality modelling (2)

- Aesthetic criteria (taste, colour, smell)
- Sediment plumes
- Toxic substances
- Thermal pollution
- Radioactive pollution

CREDIT: AP PHOTO/KIN CHEUNG

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Issues in Water Quality modelling (3)

- Concentration of substances (compared to water quality objectives)
- Distribution of pollutants (how does a discharge of pollutants influence water quality)
- Effect of changes (Environmental Impact Assessment)

Source: CMEMS

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Concept of Delft3D-WAQ

How do we model water quality?

WAQ_Introduction_03

Concept

Two main components:

1. **Transport of substances:** in the water column is computed using advection-dispersion equation.
2. **Ecological processes:** concentrations of the state variables are determined by ecological processes meaning numerous physical, chemical and biological reactions

$$\frac{\partial C}{\partial t} = \underbrace{-u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y} - w\frac{\partial C}{\partial z}}_{\textit{advective transport}} + \underbrace{\frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_z\frac{\partial C}{\partial z}\right)}_{\textit{diffusive and /or dispersive transport}} + S + P$$

C	concentration of the state variables [g m^{-3}]
u, v, w	velocity vector components [m s^{-1}]
D_x, D_y, D_z	dispersion tensor components [m^2 s^{-1}]
x, y, z	coordinates [m]
S	source and sink term of mass due to loads and boundaries
P	source and sink term of mass due to processes
t	time [s]

Source/sink

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Conceptual background

Administrate the mass balance of a substance in a segment

Components of the mass balance

- changes by transport
- changes by processes (physical / chemical)
- changes by sources / discharges

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Conceptual background

To proceed one step in time, solve for each segment:

$$M_i^{t+\Delta t} = M_i^t + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{Tr} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{P} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{S}$$

- **Tr: change due to transport**
- **P: change due to processes**
- **S: change due to sources**

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Transport

$$M_i^{t+\Delta t} = M_i^t + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{Tr} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_P + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_S$$

Derived from hydrodynamic model (e.g. Delft3D-FLOW or SOBEK)

both advective and dispersive transport

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Processes

Physical: reaeration, settling, resuspension

Chemical: denitrification, decay of organic matter

Biological: algae growth

Processes can

- remove a substance from or add a substance to the system (denitrification)
- convert a substance (nitrification $NH_4^+ \rightarrow NO_3^-$, settling IM1 $\rightarrow$ IM1S1)

$$M_i^{t+\Delta t} = M_i^t + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{Tr} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{P} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{S}$$

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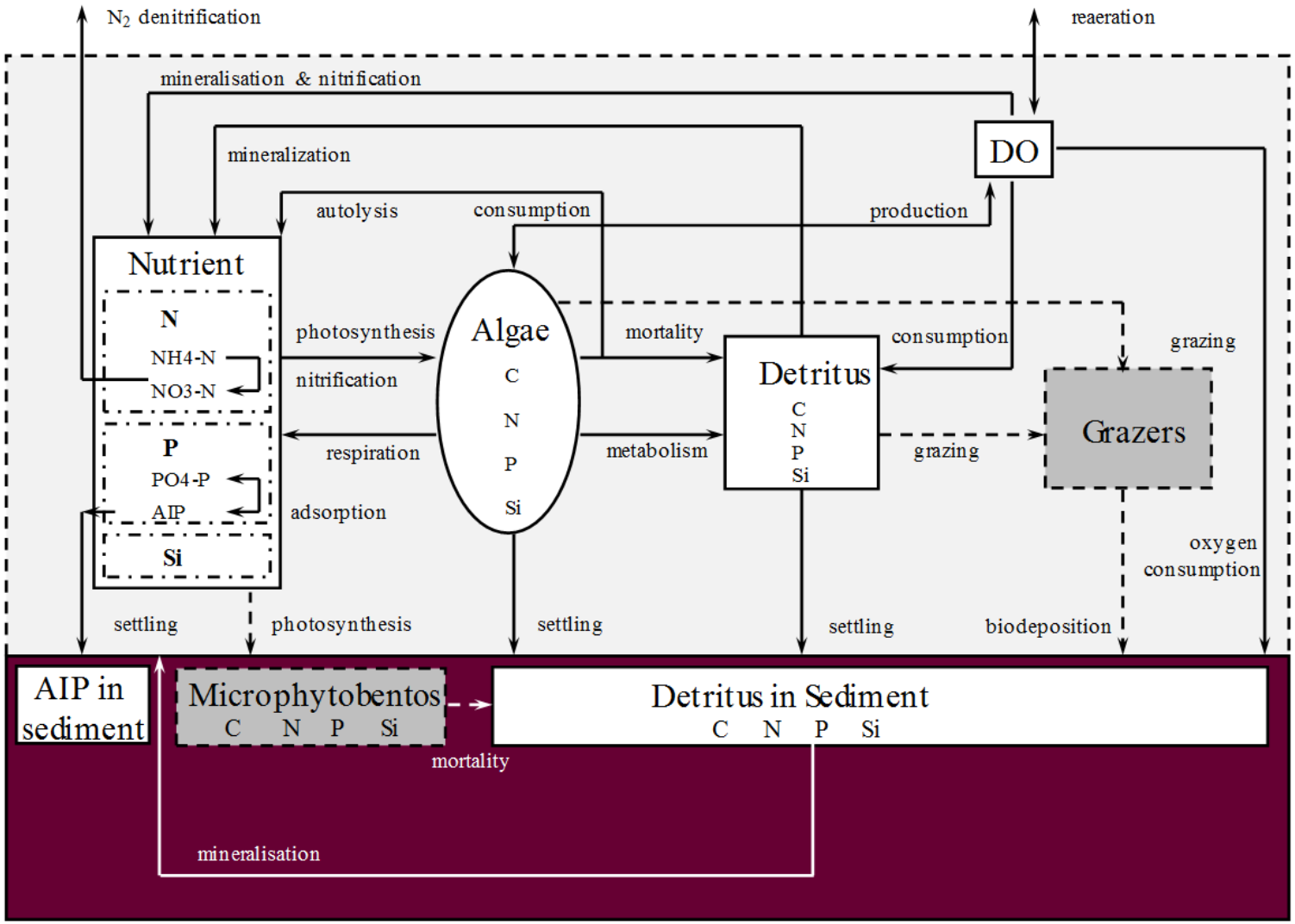
Important ecological processes

Process type	Process
Phytoplankton processes	Primary production
	Respiration
	Mortality
Nutrient cycle	Decomposition of particulate organic matter
	Nitrification
	Denitrification
	Burial
	Uptake of inorganic nutrients
	Autolysis
	Mineralization
	Sedimentation of adsorbed inorganic phosphorus (AIP)
	Adsorption/desorption of orthophosphate
Oxygen dynamics	Reaeration
	Respiration
	Oxygen production (primary production)
Energy availability	Extinction of light
Others	Settling
	Decomposition of particulate organic matter

Important ecological processes



Sources / discharges

Waste loads

River loads

Boundary loads

Diffusive loads (atmospheric deposition)

$$M_i^{t+\Delta t} = M_i^t + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{Tr} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{P} + \Delta t \left(\frac{\Delta M}{\Delta t} \right)_{S}$$

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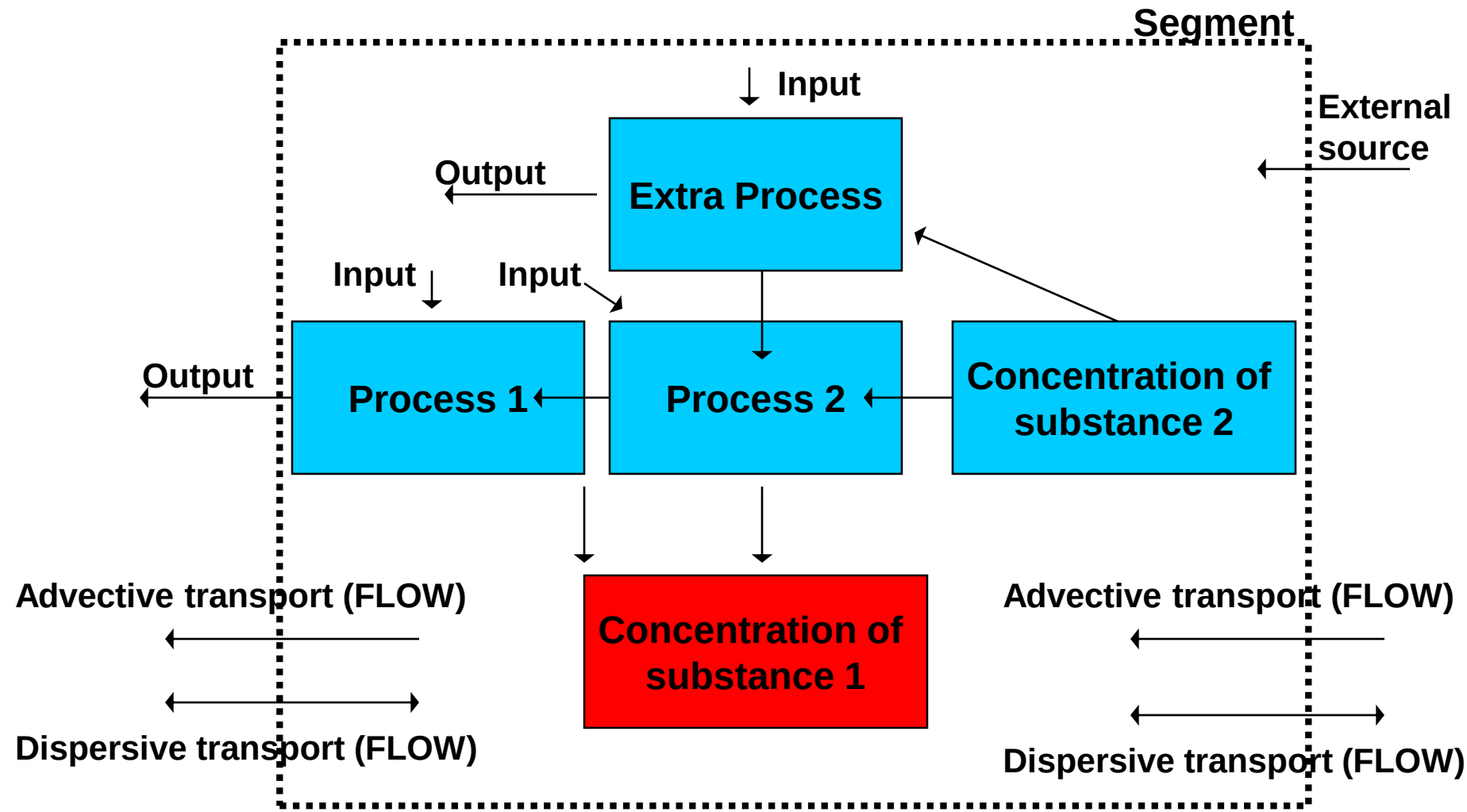
Mass and concentrations in a segment



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