# Mechanistic Models in Nutrient TMDL Development

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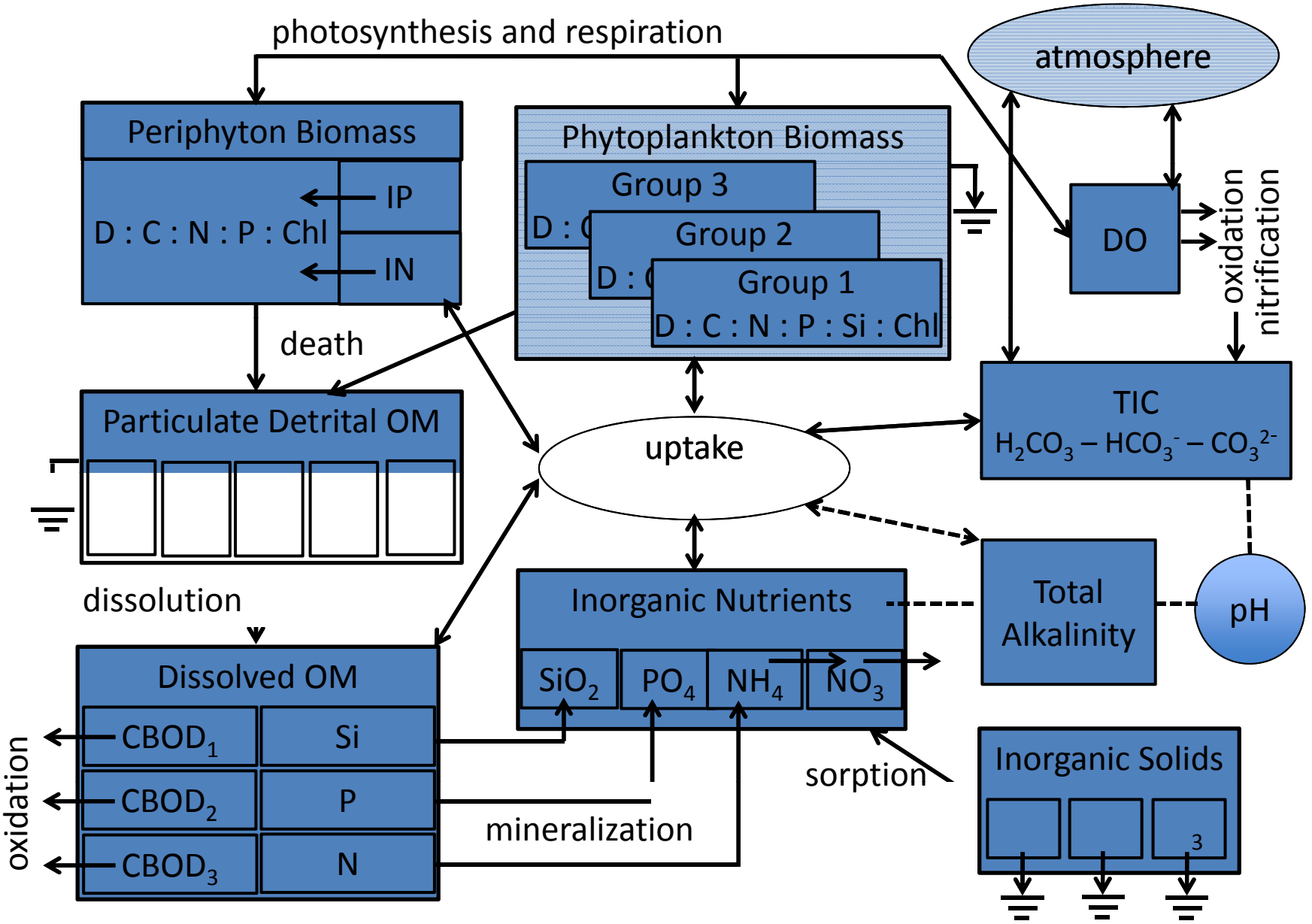
US EPA Region 4

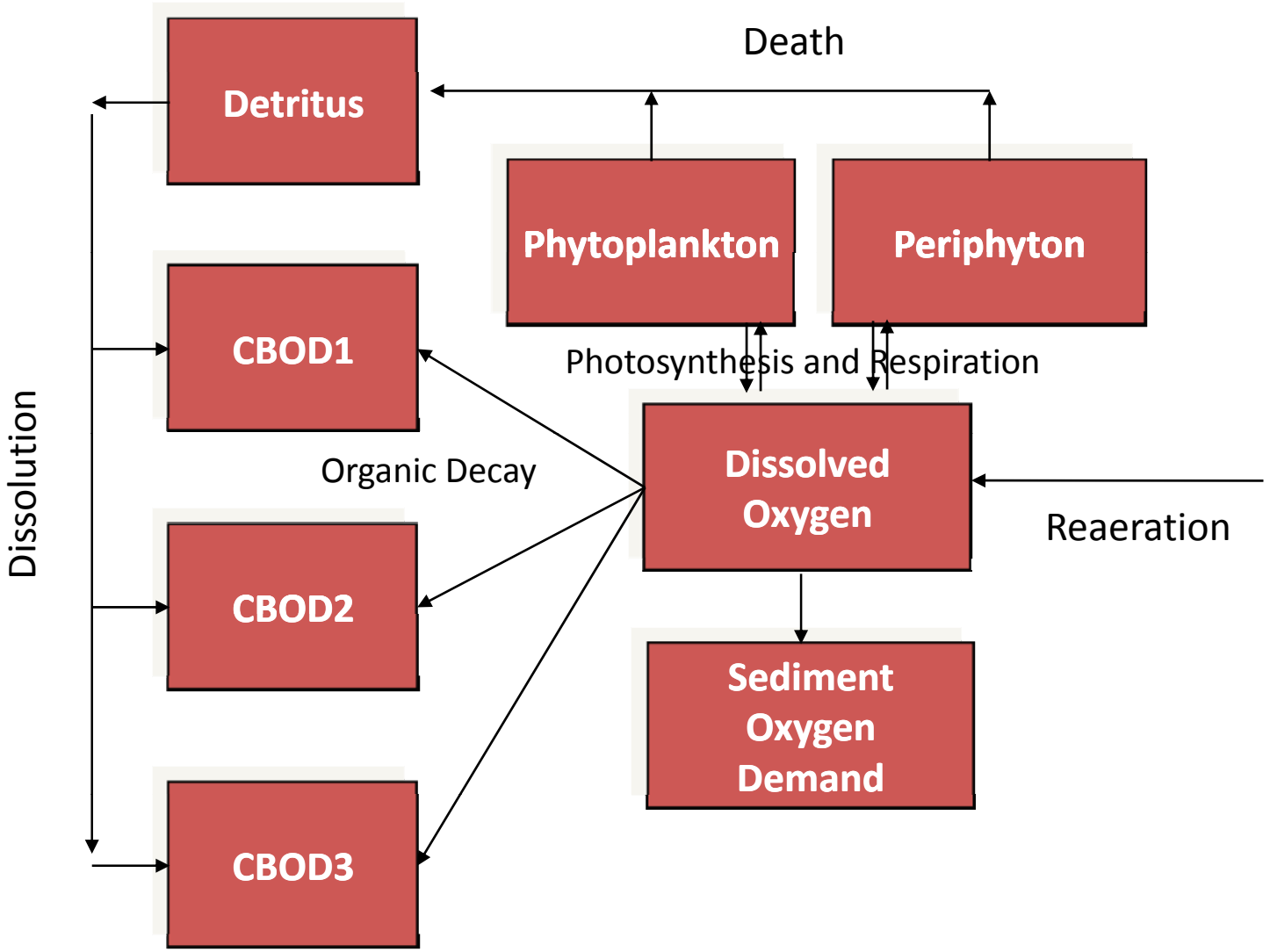
# Eutrophication – Water Quality Issues

- General Water Quality
  - salinity, pH, solids
- Nutrient Enrichment
- Dissolved Oxygen Depletion
- Algal Production
  - Phytoplankton (lakes, reservoirs, estuaries)
  - Periphyton (streams)

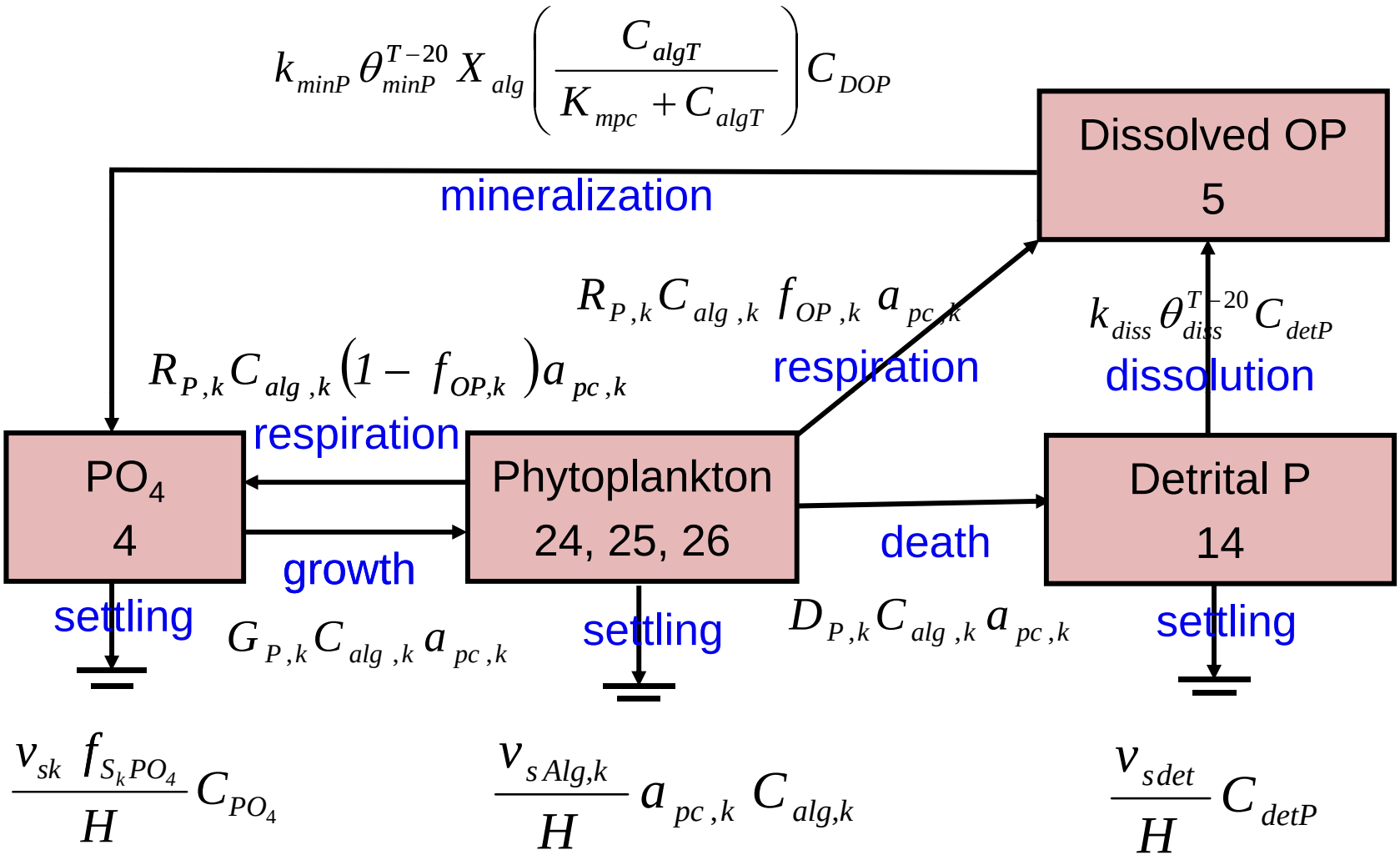
# Variables and Processes



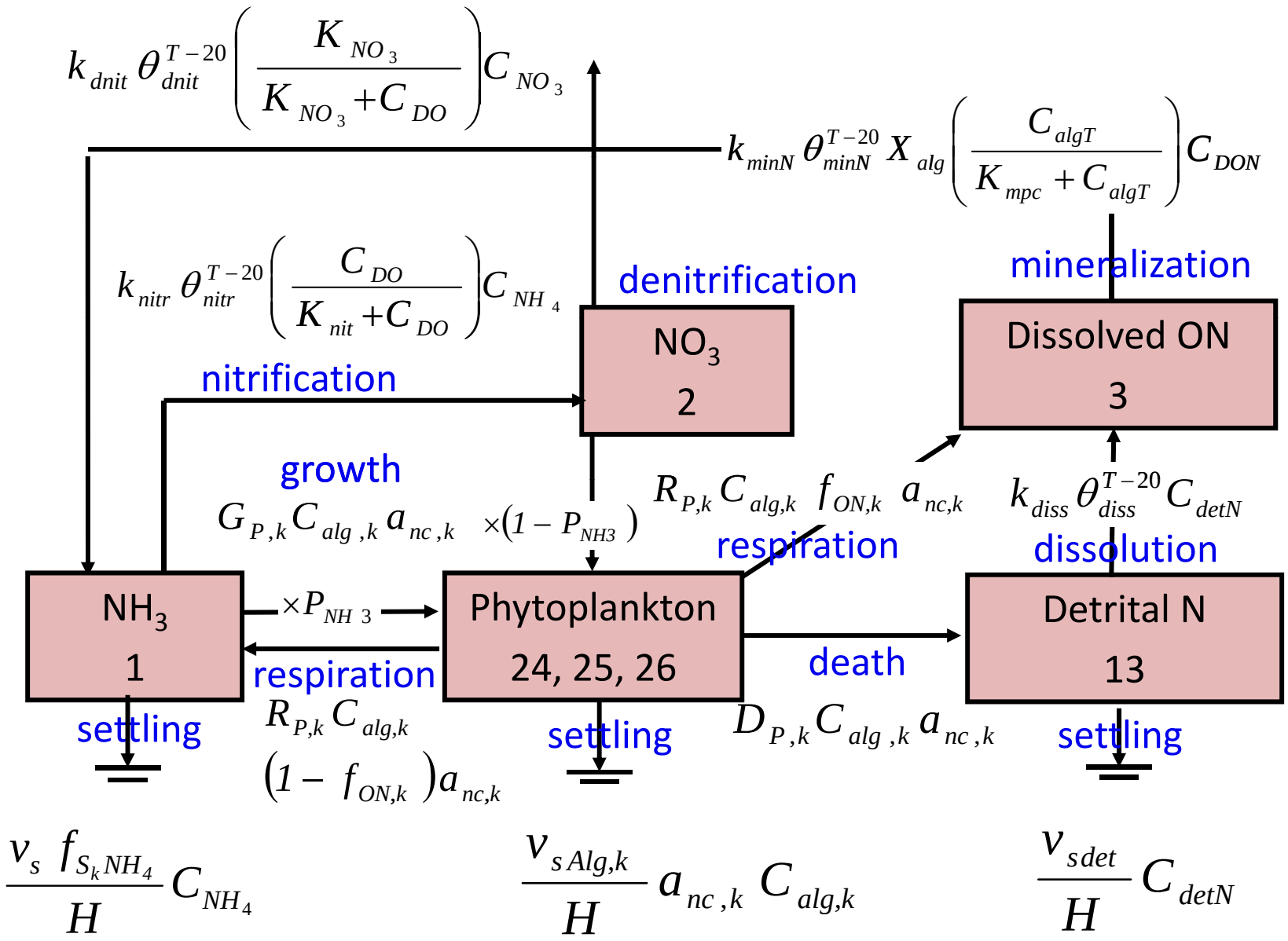
# DO Balance Processes



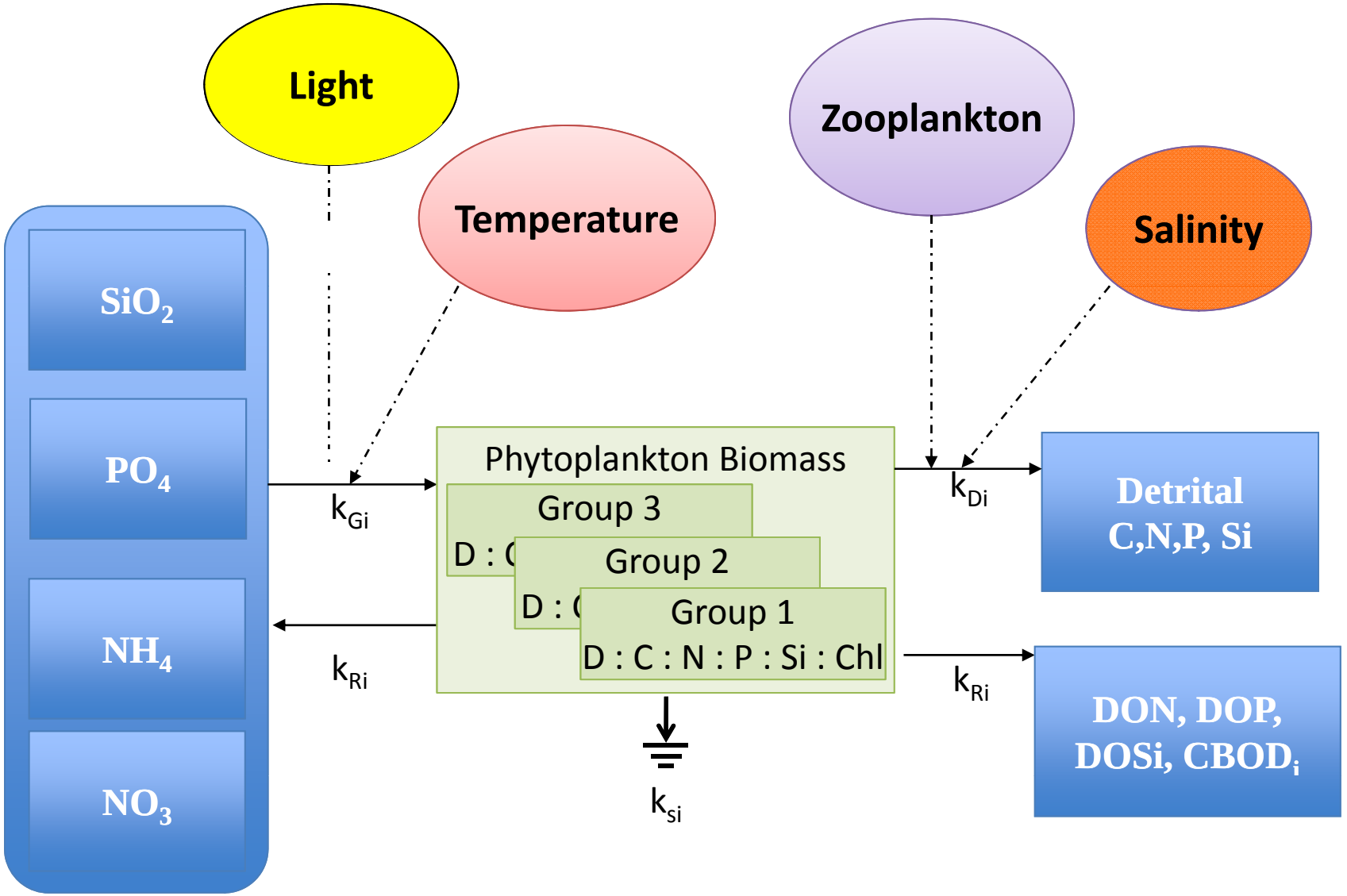
# Phosphorus Cycle

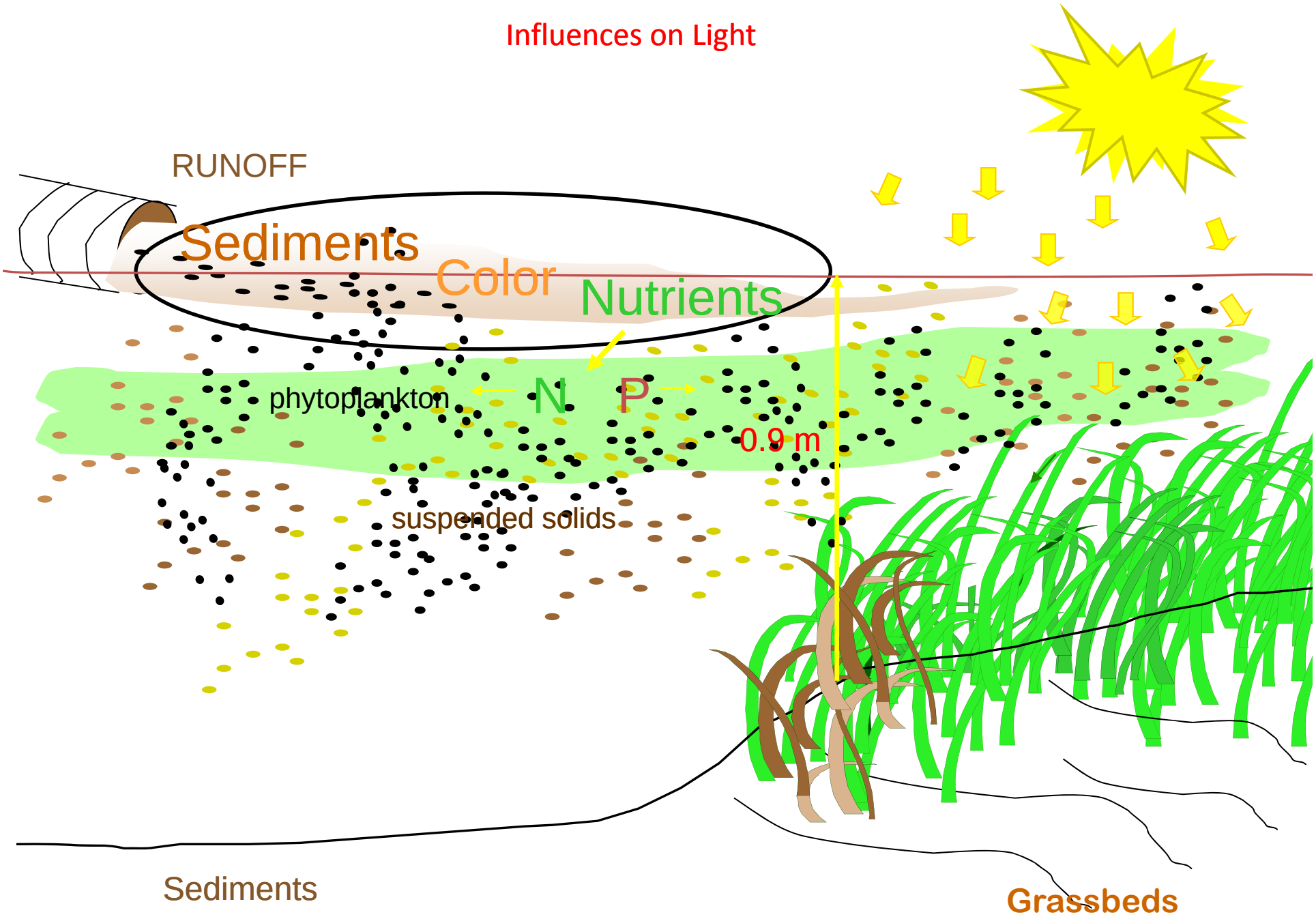


# Nitrogen Cycle



# Phytoplankton Kinetic Processes




Influences on Light
RUNOFF
Sediments
Color
Nutrients
phytoplankton
N
P
0.9 m
suspended solids
Sediments
Grassbeds

# Calculated Light Extinction

$$K_e = K_{eback} + K_{eshd} + K_{esolid} + K_{eDOC} + K_{eCDOM}$$

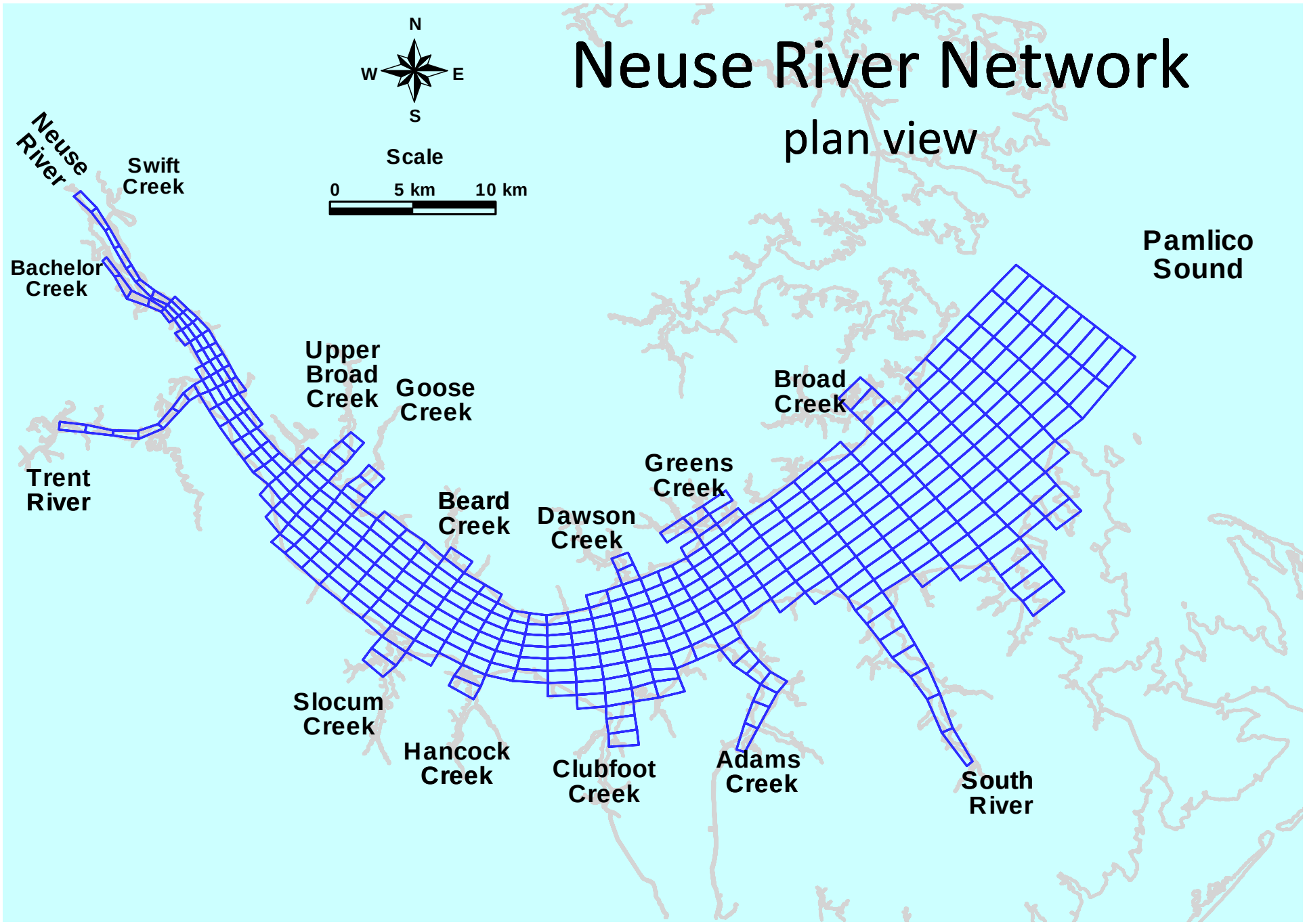
$K_{e\,back}$ = background light extinction due to ligands, color, etc.

$K_{e\,shd}$ = algal self shading,

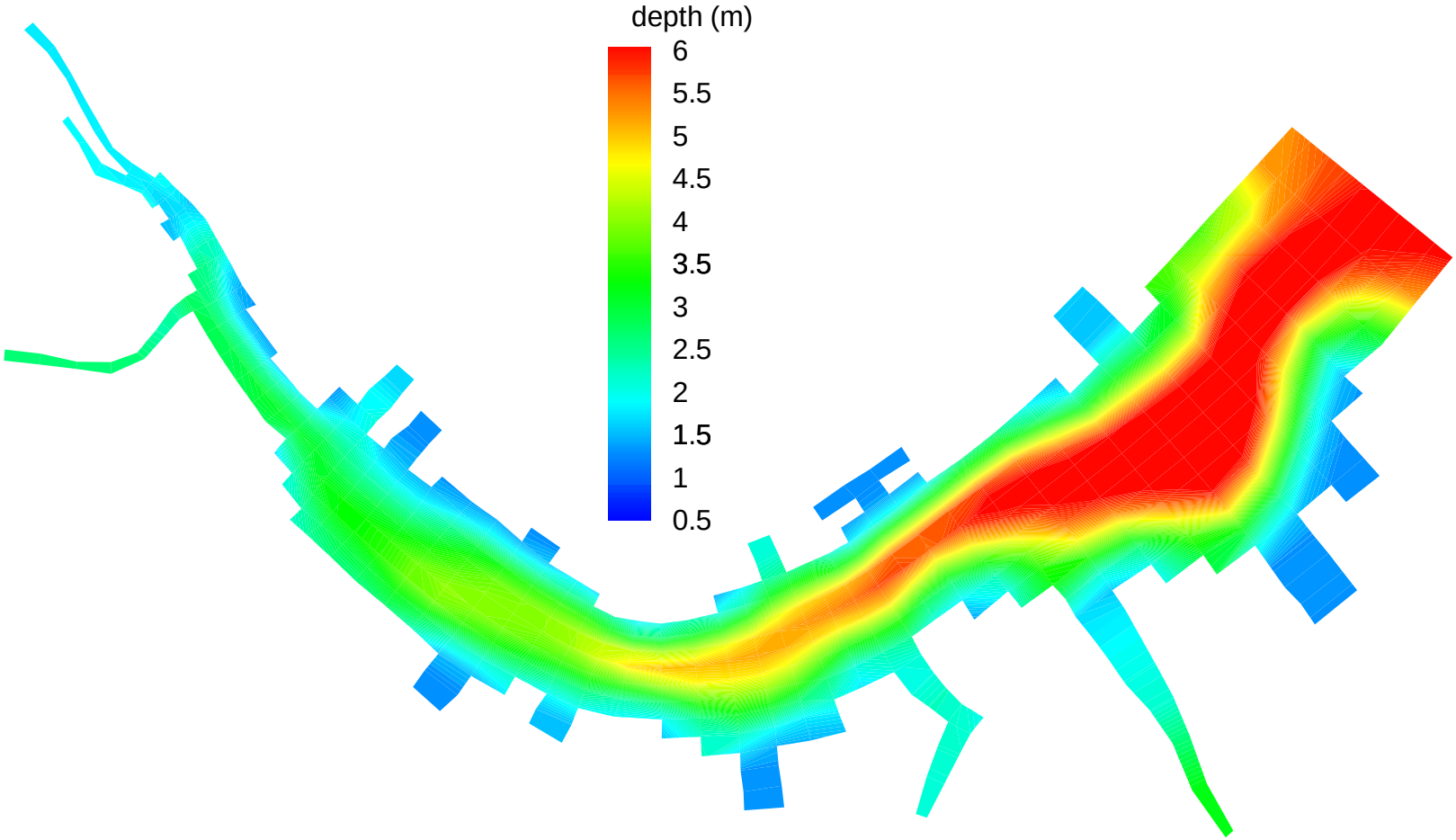
$K_{e\,solid}$ = solids light extinction

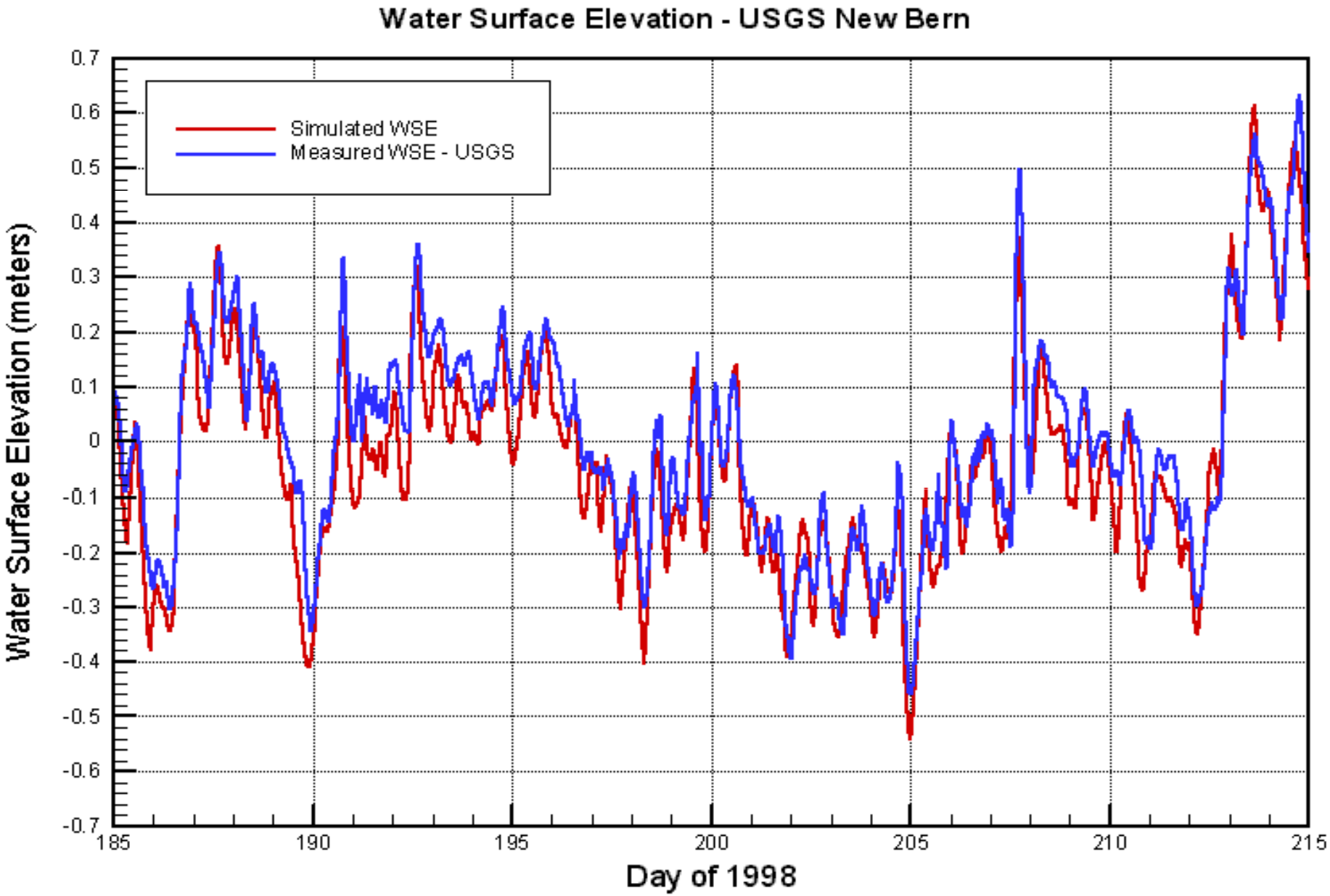
$K_{e\,DOC}$ = DOC light extinction

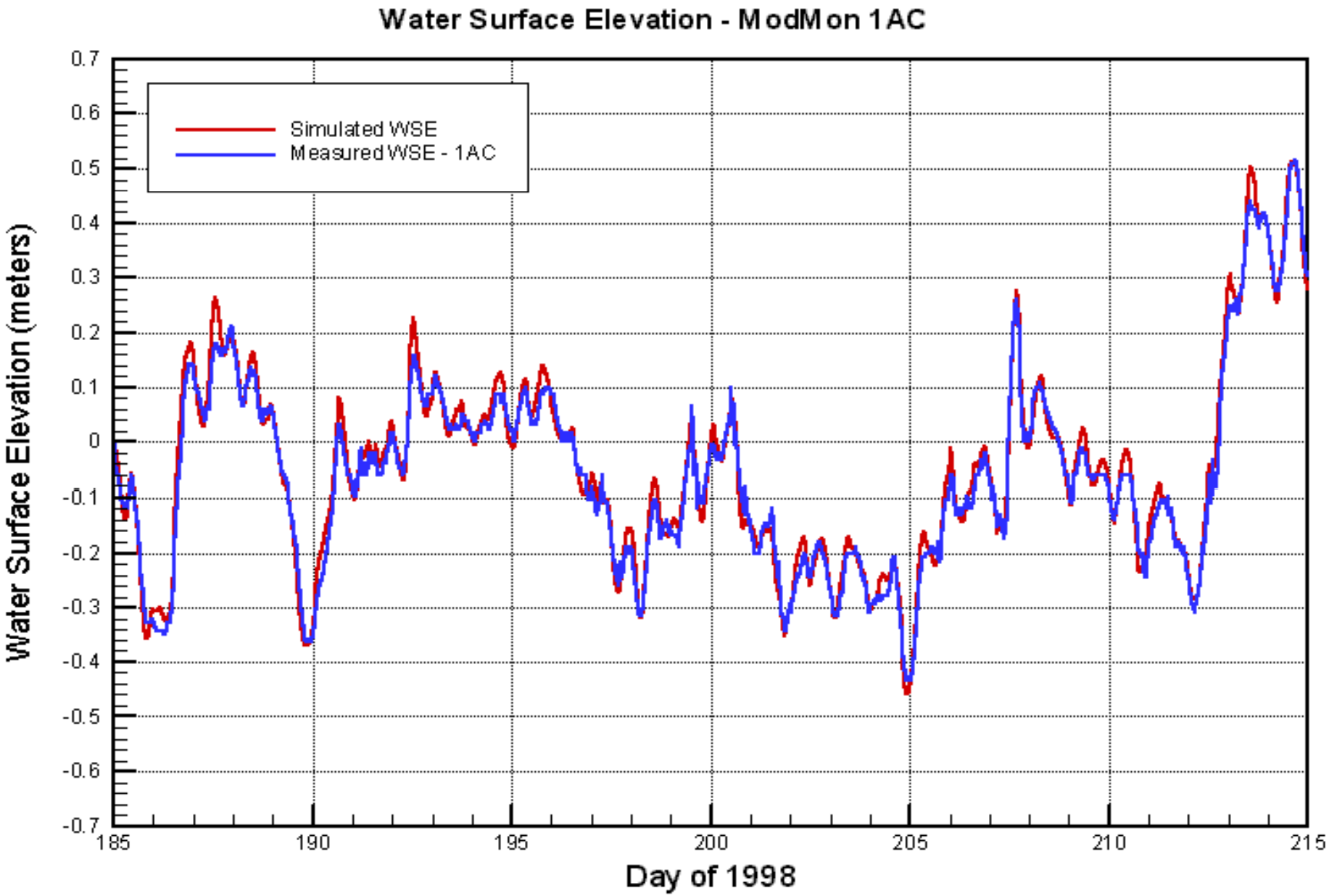
$K_{e\,CDOM}$ = CDOM light extinction marine waters

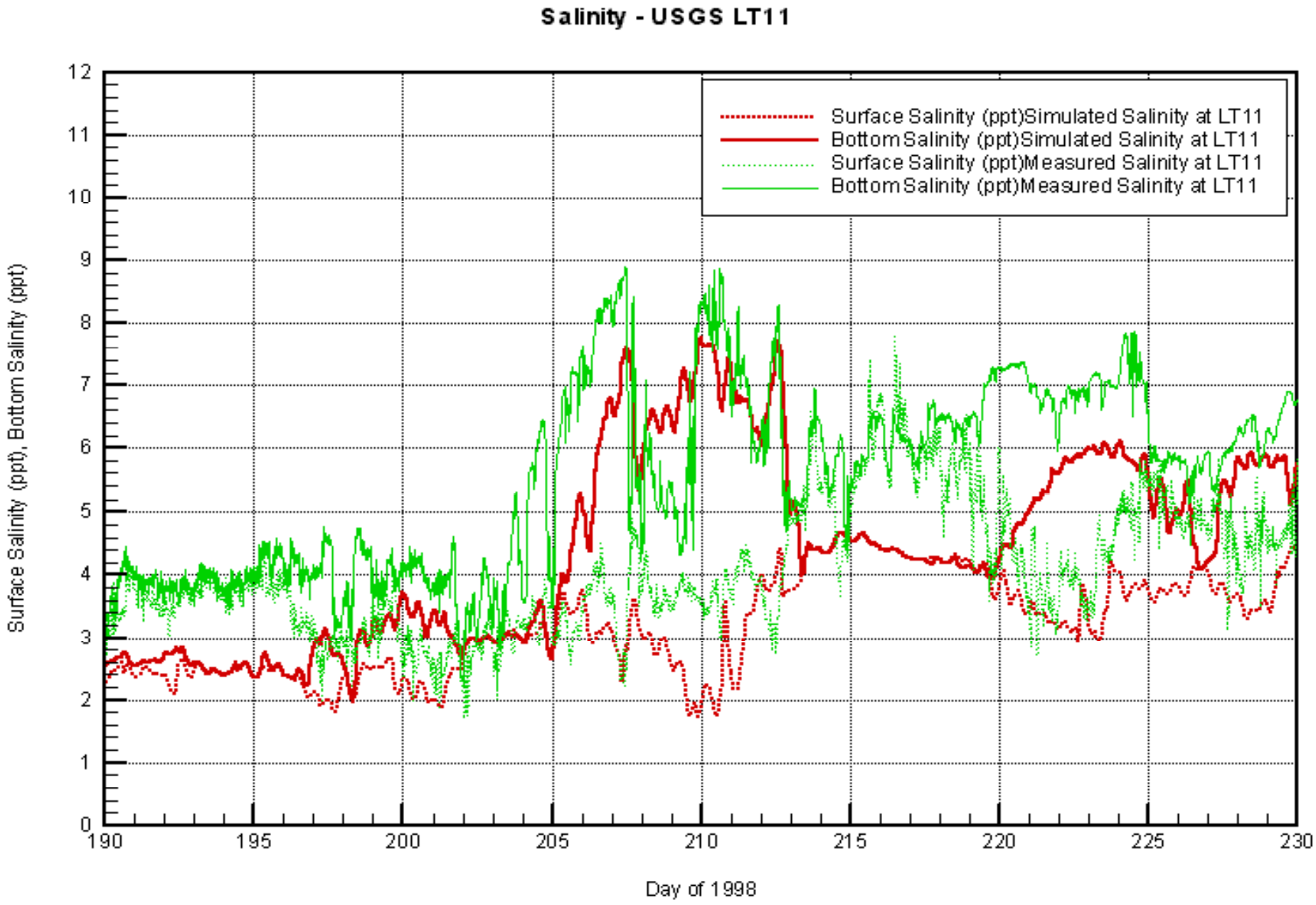

Neuse River Network
plan view
N
W
E
S
Scale
0
5 km
10 km
Neuse River
Swift Creek
Bachelor Creek
Trent River
Upper Broad Creek
Goose Creek
Beard Creek
Dawson Creek
Greens Creek
Broad Creek
Pamlico Sound
Slocum Creek
Hancock Creek
Clubfoot Creek
Adams Creek
South River

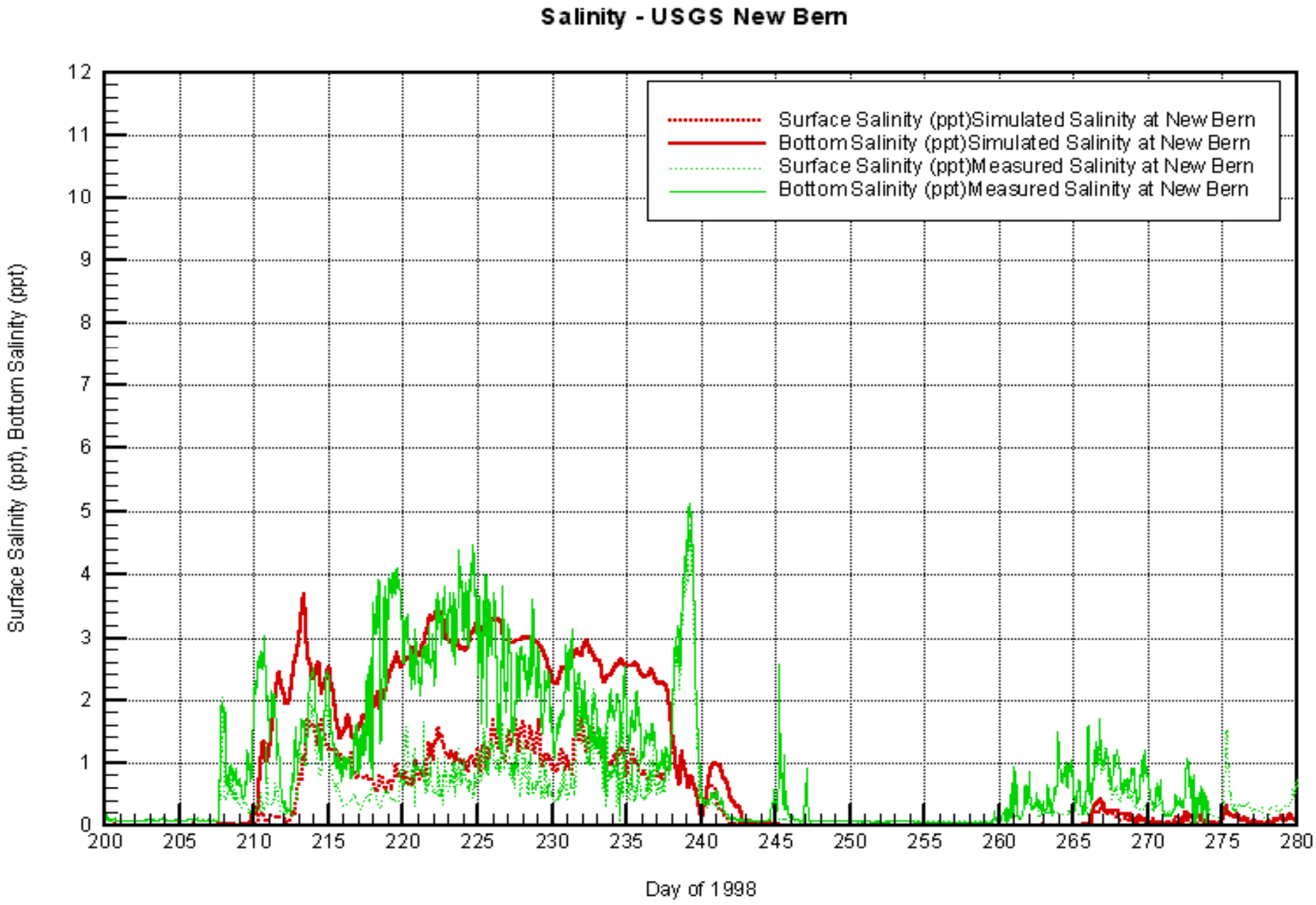
# Neuse Bathymetry

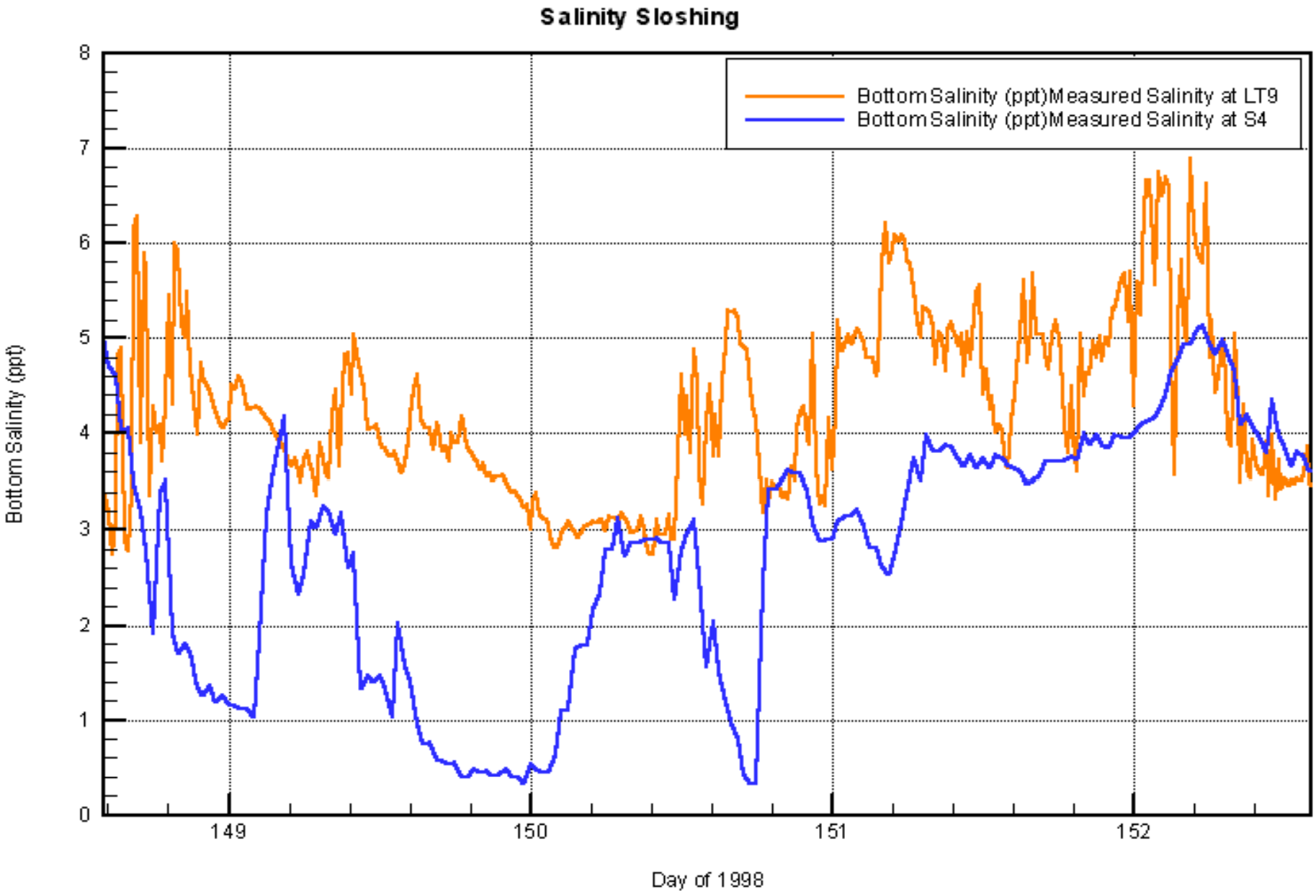


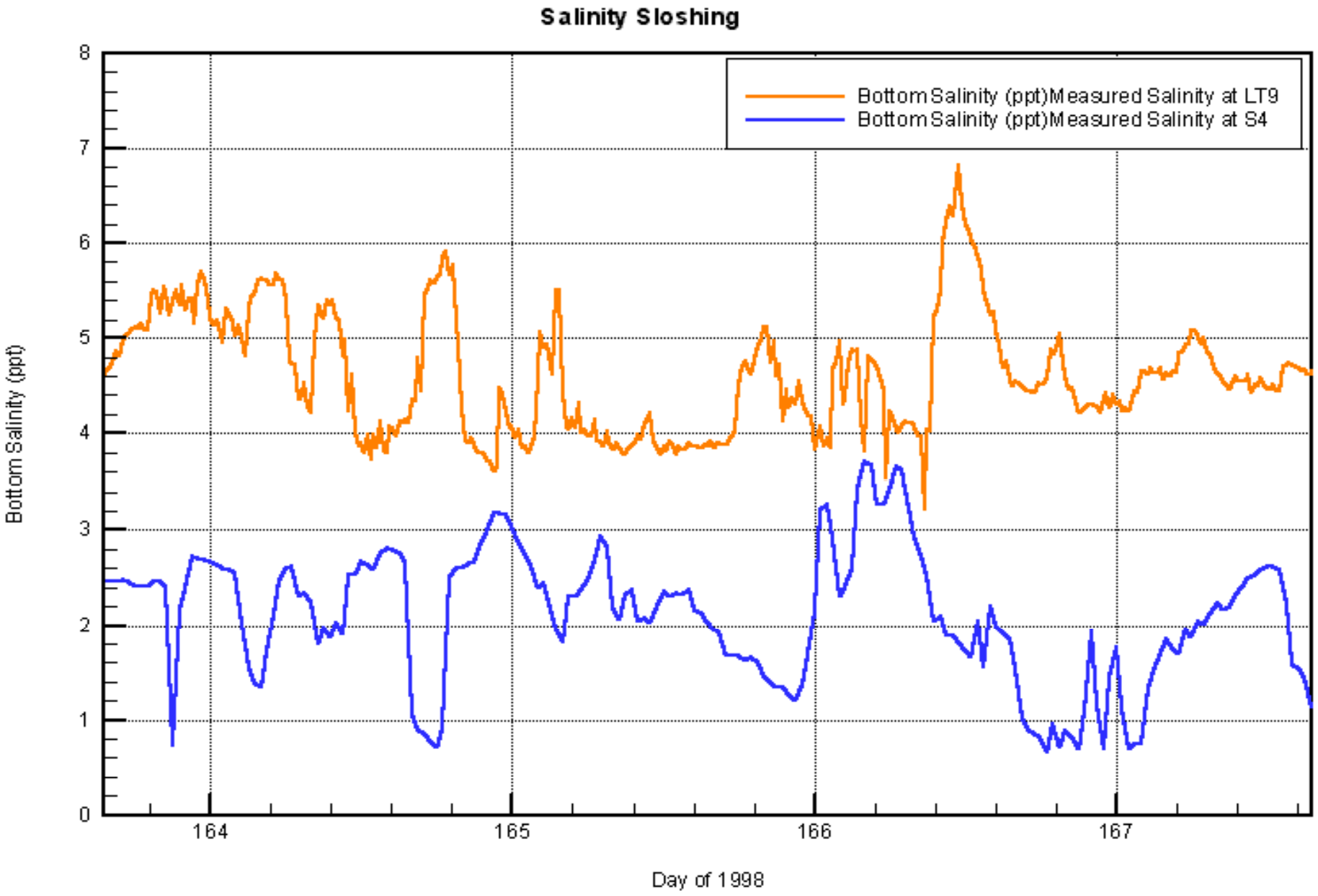

Water Surface Elevation - USGS New Bern
Simulated WSE
Measured WSE - USGS
Water Surface Elevation (meters)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
185
190
195
200
205
210
215
Day of 1998

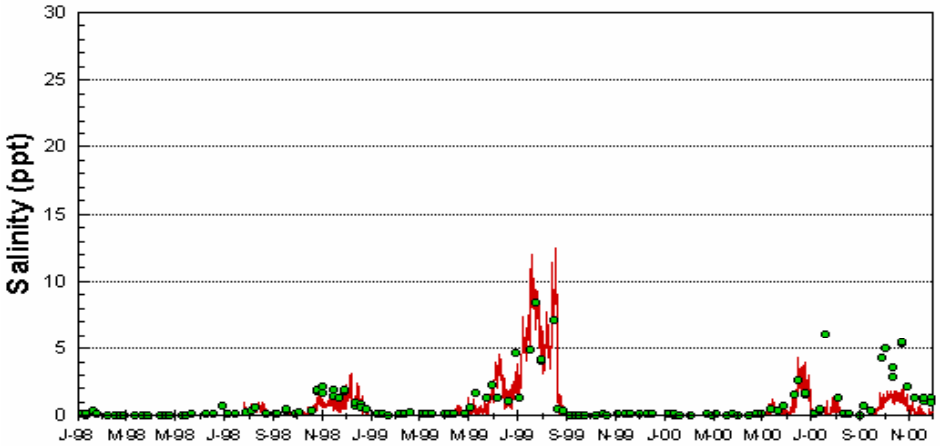

Water Surface Elevation - ModMon 1AC
Simulated WSE
Measured WSE - 1AC
Water Surface Elevation (meters)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
185
190
195
200
205
210
215
Day of 1998

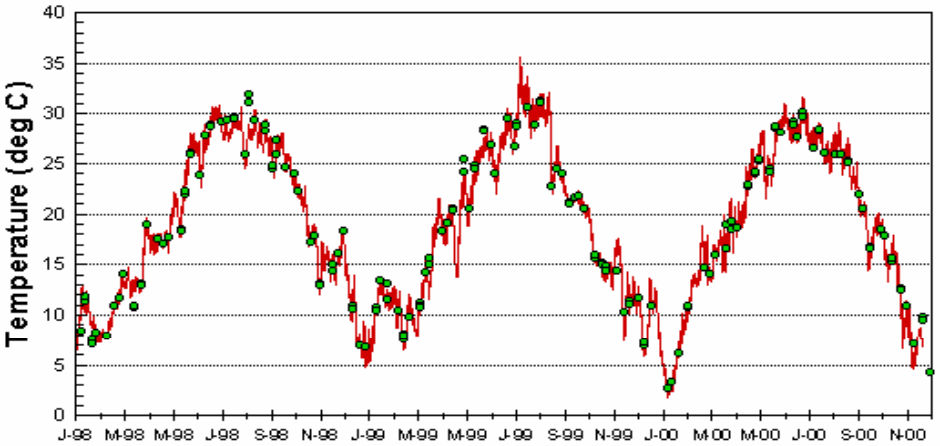

Salinity - USGS LT11
Surface Salinity (ppt)Simulated Salinity at LT11
Bottom Salinity (ppt)Simulated Salinity at LT11
Surface Salinity (ppt)Measured Salinity at LT11
Bottom Salinity (ppt)Measured Salinity at LT11
Surface Salinity (ppt), Bottom Salinity (ppt)
Day of 1998
0
1
2
3
4
5
6
7
8
9
10
11
12
190
195
200
205
210
215
220
225
230

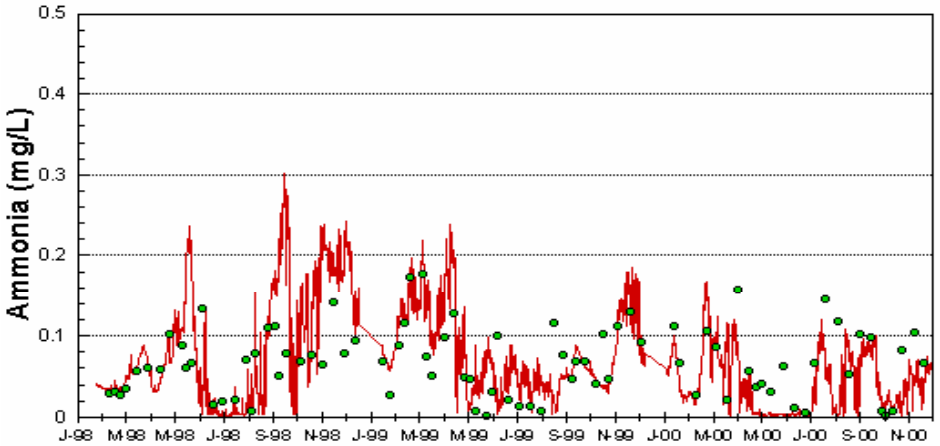

Salinity - USGS New Bern
Surface Salinity (ppt)Simulated Salinity at New Bern
Bottom Salinity (ppt)Simulated Salinity at New Bern
Surface Salinity (ppt)Measured Salinity at New Bern
Bottom Salinity (ppt)Measured Salinity at New Bern
Surface Salinity (ppt), Bottom Salinity (ppt)
Day of 1998
0
1
2
3
4
5
6
7
8
9
10
11
12
200
205
210
215
220
225
230
235
240
245
250
255
260
265
270
275
280

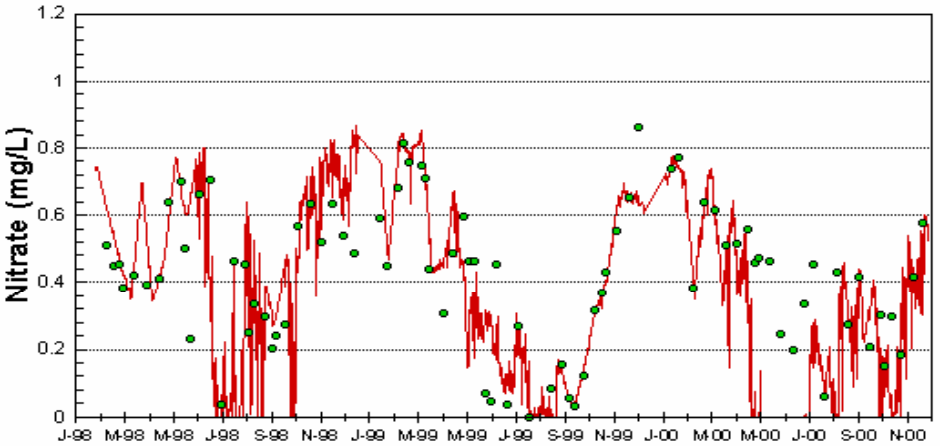

Salinity Sloshing
Bottom Salinity (ppt)Measured Salinity at LT9
Bottom Salinity (ppt)Measured Salinity at S4
Bottom Salinity (ppt)
Day of 1998
0
1
2
3
4
5
6
7
8
149
150
151
152

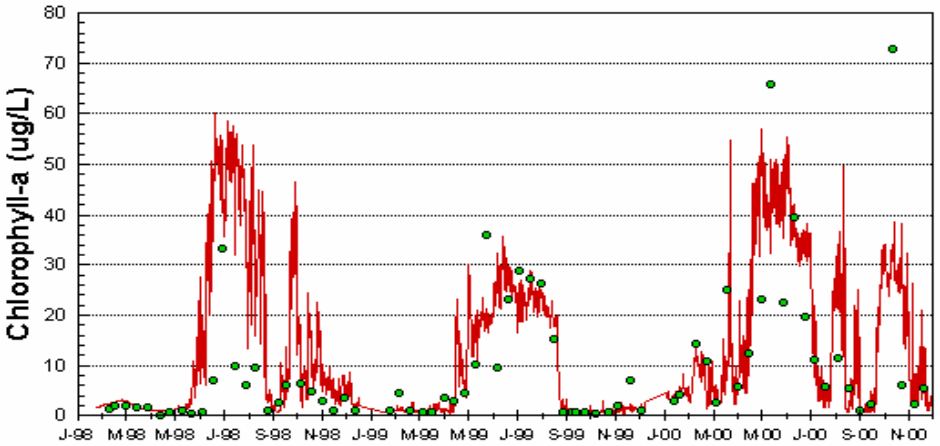

Salinity Sloshing
Bottom Salinity (ppt)Measured Salinity at LT9
Bottom Salinity (ppt)Measured Salinity at S4
Bottom Salinity (ppt)
Day of 1998
0
1
2
3
4
5
6
7
8
164
165
166
167

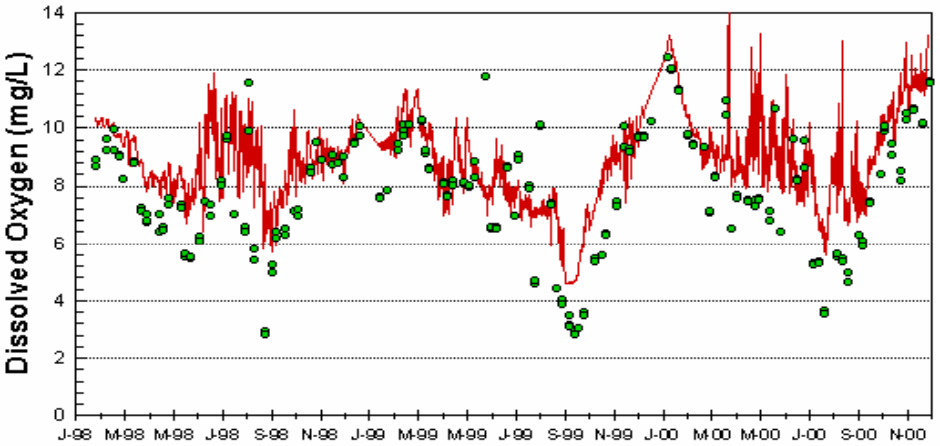

Salinity (ppt)
0
5
10
15
20
25
30
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

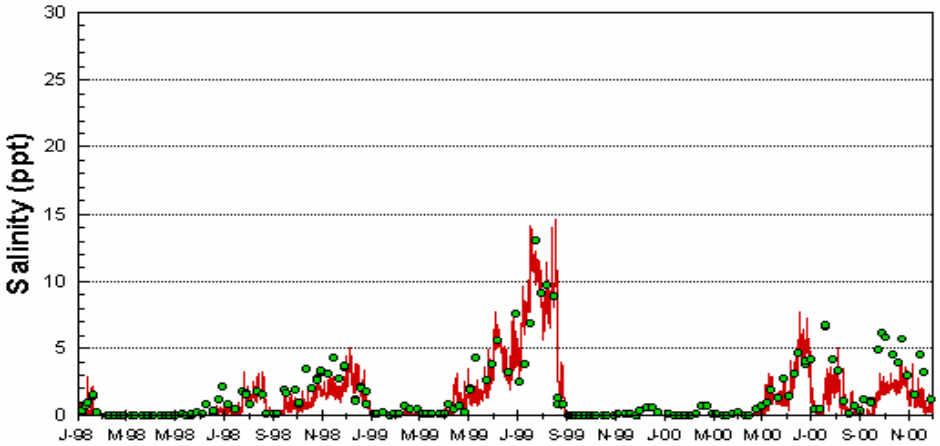

Temperature (deg C)
0
5
10
15
20
25
30
35
40
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

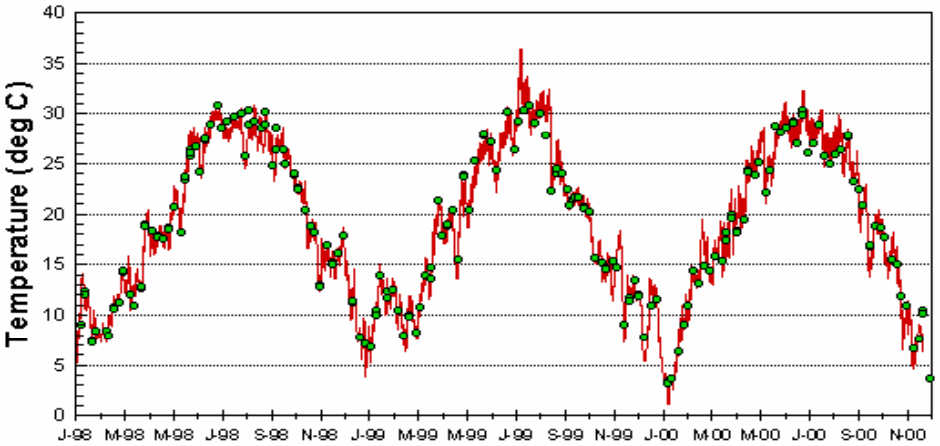

Ammonia (mg/L)
0
0.1
0.2
0.3
0.4
0.5
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

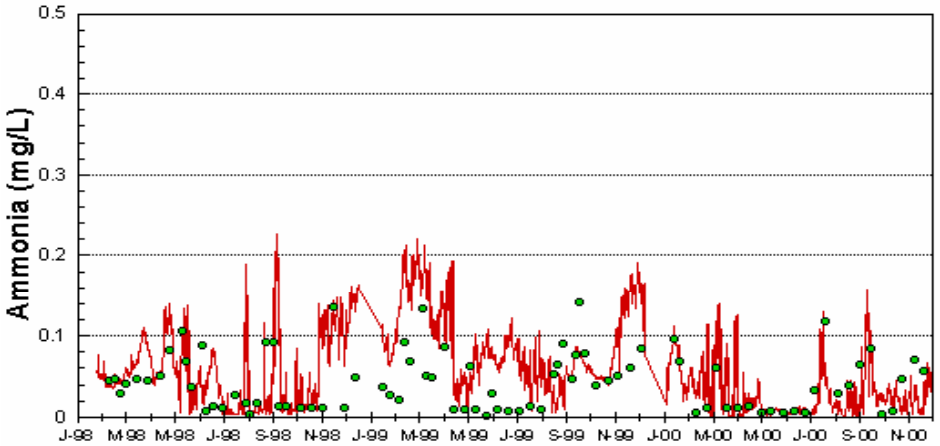

Nitrate (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

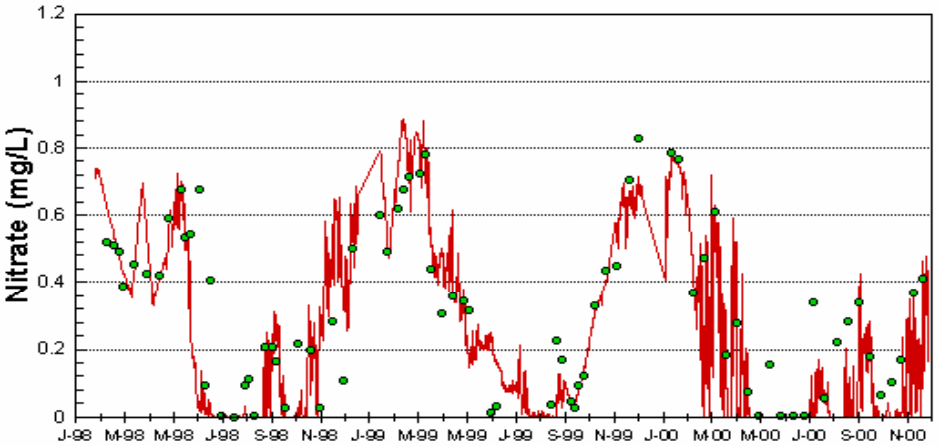

Chlorophyll-a (ug/L)
0
10
20
30
40
50
60
70
80
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

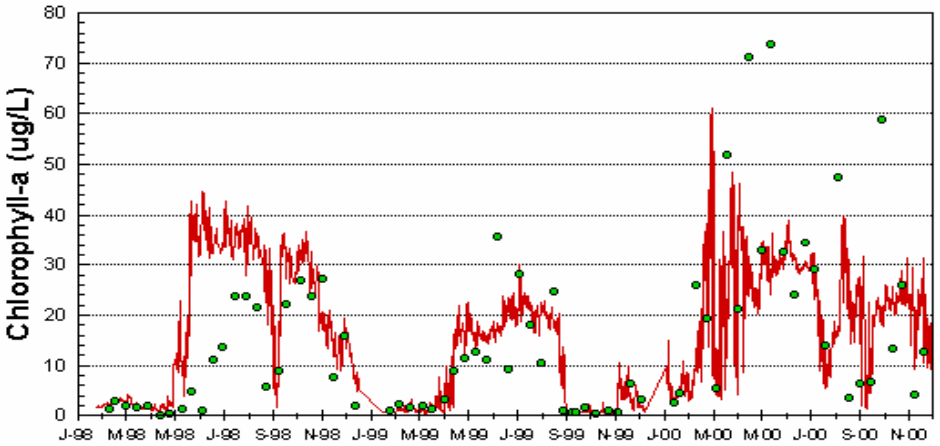

Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
14
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

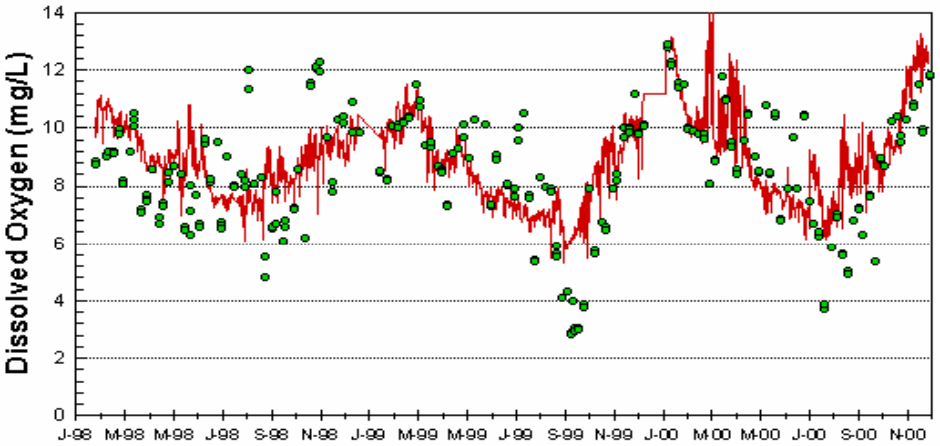

Salinity (ppt)
0
5
10
15
20
25
30
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

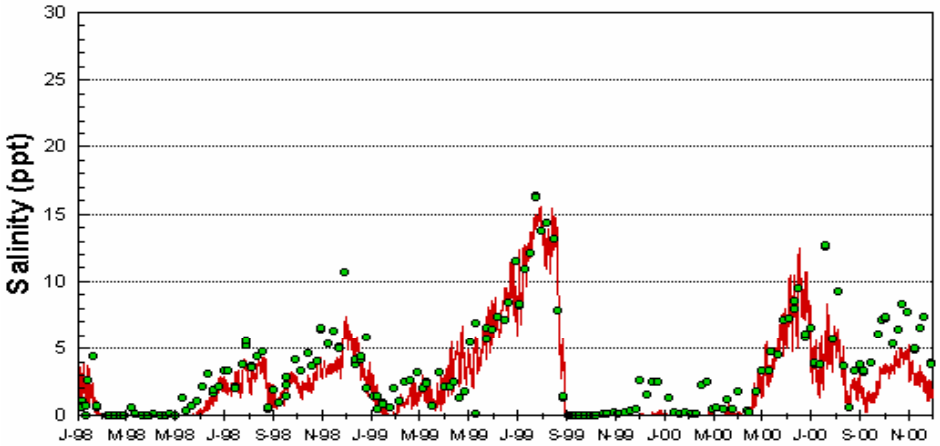

Temperature (deg C)
0
5
10
15
20
25
30
35
40
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

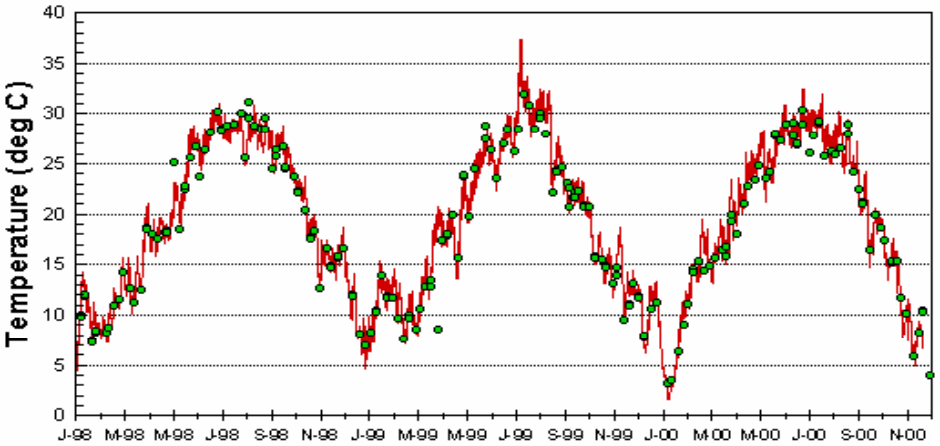

Ammonia (mg/L)
0
0.1
0.2
0.3
0.4
0.5
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

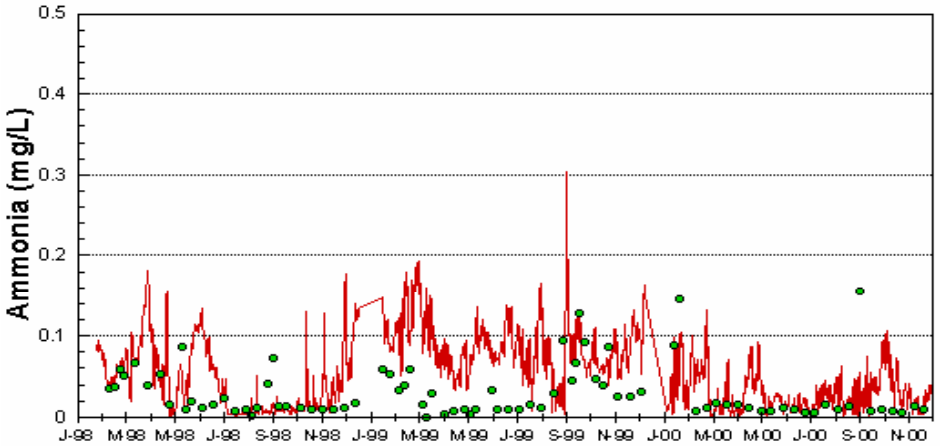

Nitrate (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

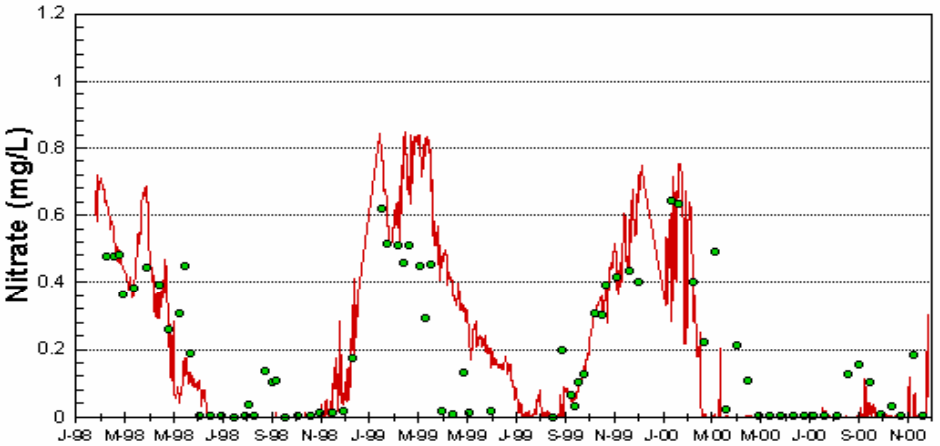

Chlorophyll-a (ug/L)
0
10
20
30
40
50
60
70
80
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

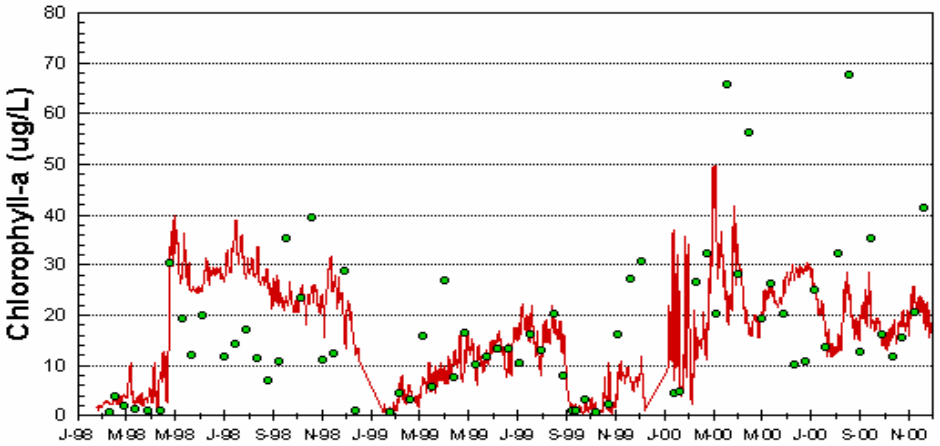

Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
14
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

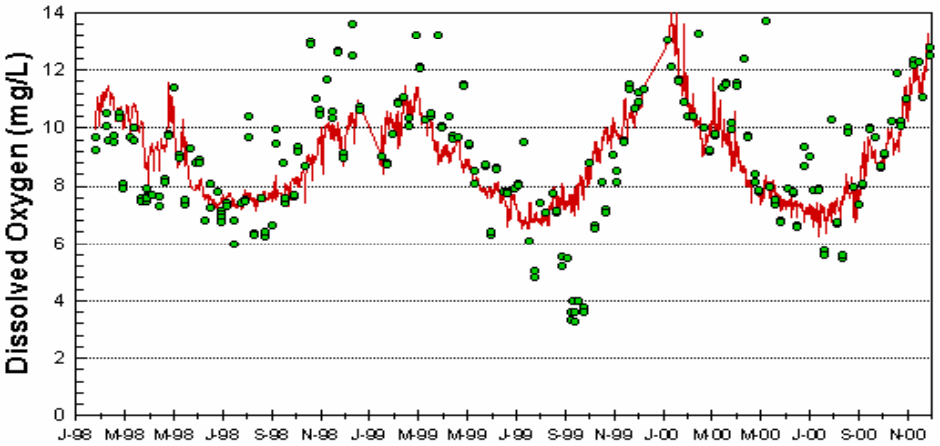

Salinity (ppt)
0
5
10
15
20
25
30
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

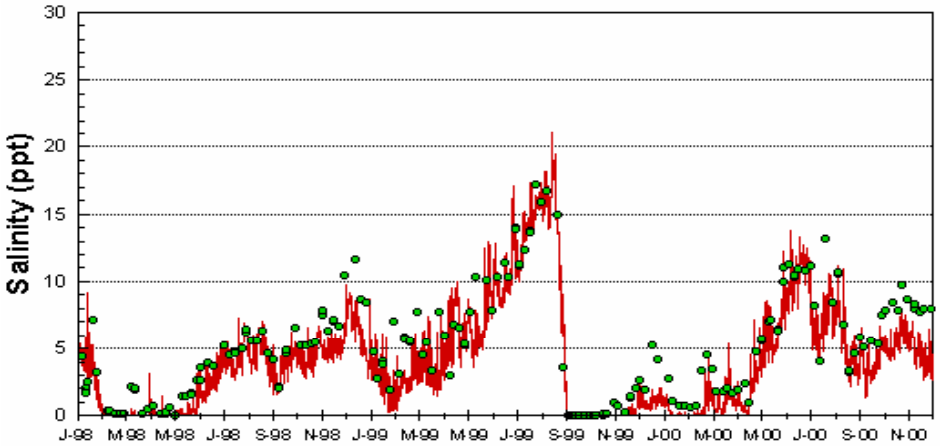

Temperature (deg C)
0
5
10
15
20
25
30
35
40
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

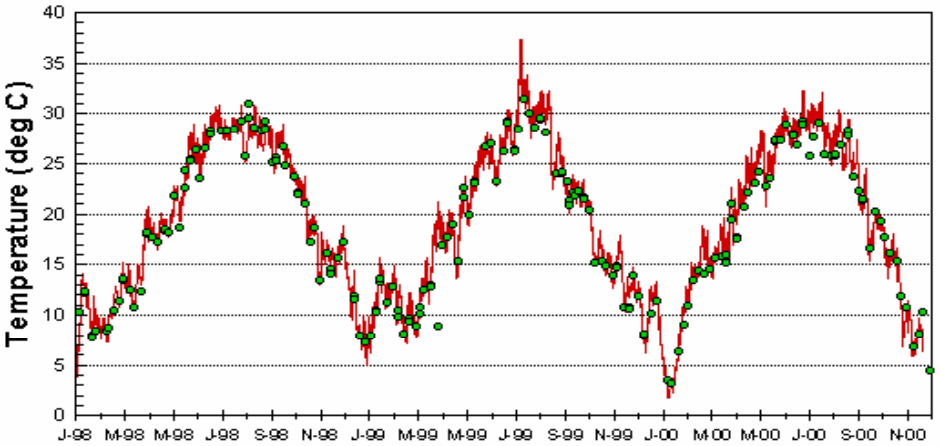

Ammonia (mg/L)
0
0.1
0.2
0.3
0.4
0.5
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

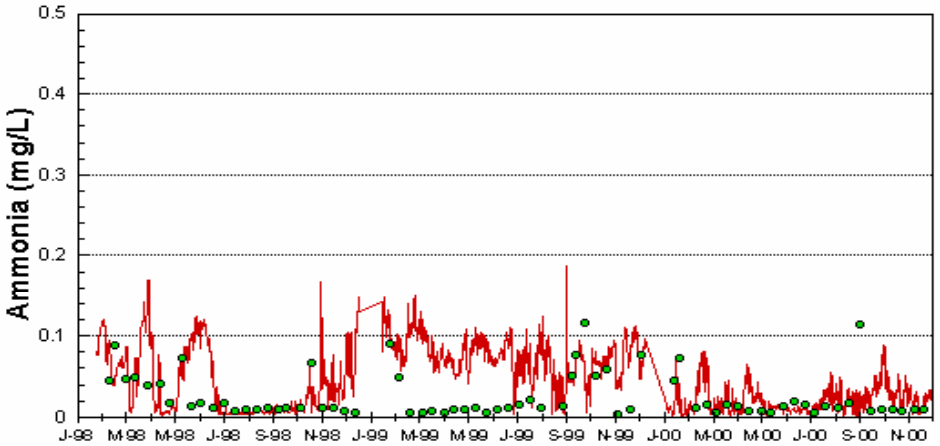

Nitrate (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

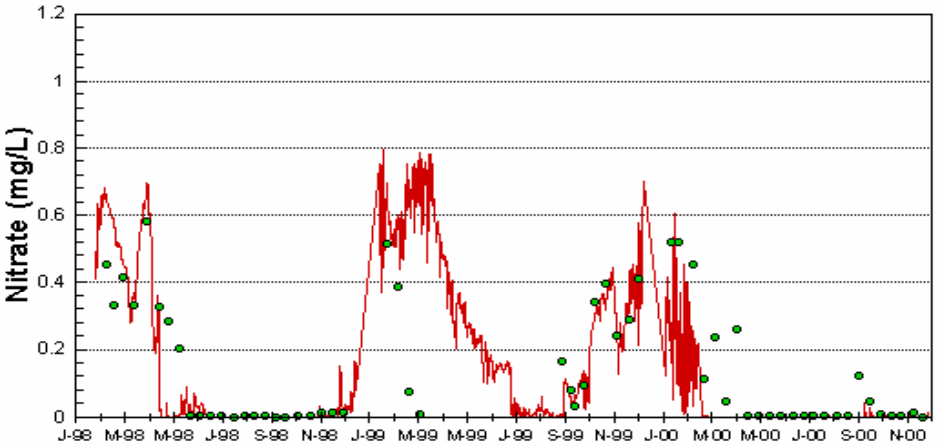

Chlorophyll-a (ug/L)
0
10
20
30
40
50
60
70
80
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

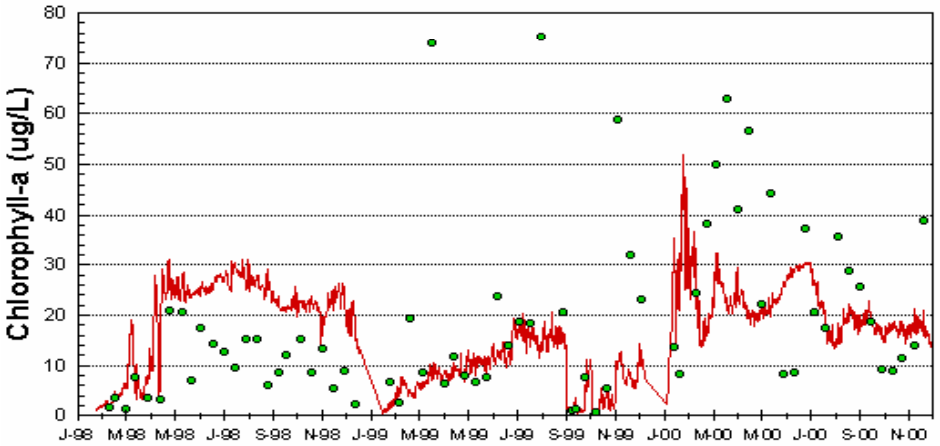

Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
14
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00

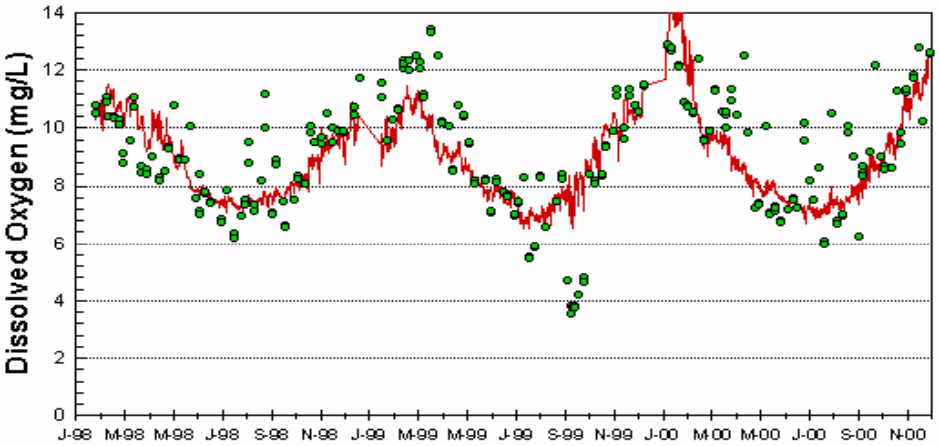

Salinity (ppt)
0
5
10
15
20
25
30
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00


Temperature (deg C)
0
5
10
15
20
25
30
35
40
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00


Ammonia (mg/L)
0
0.1
0.2
0.3
0.4
0.5
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00


Nitrate (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00


Chlorophyll-a (ug/L)
0
10
20
30
40
50
60
70
80
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00


Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
14
J-98 M-98 M-98 J-98 S-98 N-98 J-99 M-99 M-99 J-99 S-99 N-99 J-00 M-00 M-00 J-00 S-00 N-00