Exhibit CSPA-75
vanNieuwenhuyse (2008)

Response of chlorophyll to reduced phosphorus concentration in the Delta and the Rhine River

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Bureau of Reclamation

CWEMF Technical Workshop
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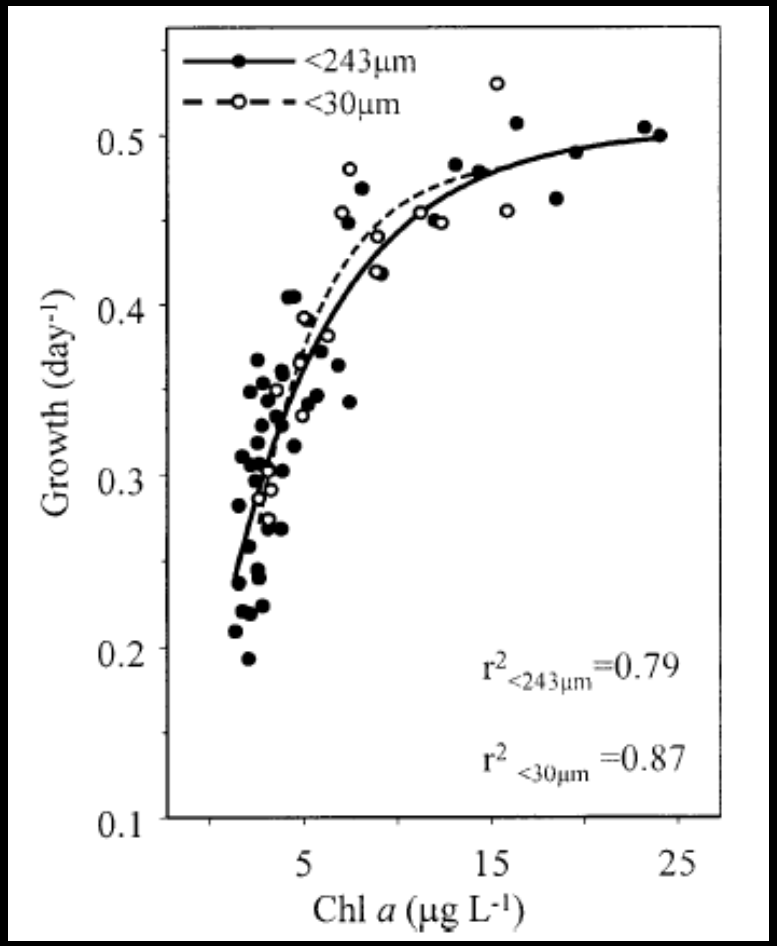
Secretary of State Bldg Auditorium, Sacramento, CA



Source: Mueller-Solger et al 2002, Limnol. Oeanogr. 47(5): 1468-1476

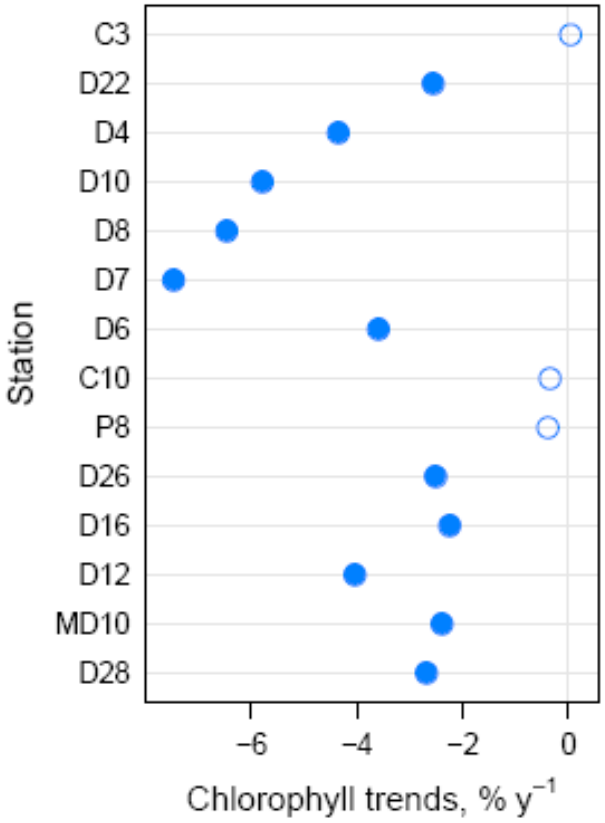


Figure 4. Long-term trends in Chl-*a* for 1975–2005. Trends are expressed as the Theil-Sen slope divided by the long-term median for the station. Trends are adjusted for river inflow, and *p*-values are corrected for seasonal serial correlation. Stations are arranged as in Figure 5 but with the left-column stations stacked on top of the right-column stations. *Solid circles*, $p < 0.05$ level according to the Seasonal Kendall test.

Alan Jassby. Phytoplankton in the Upper San Francisco Estuary:

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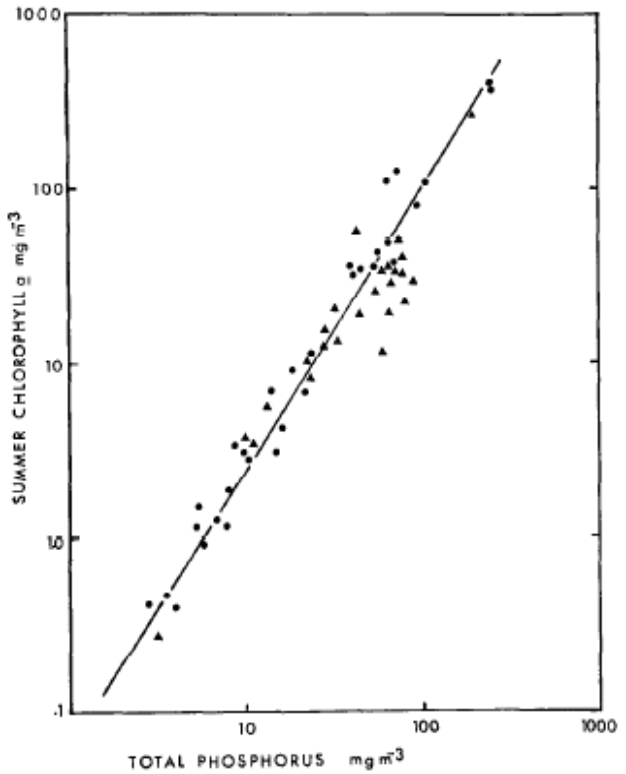
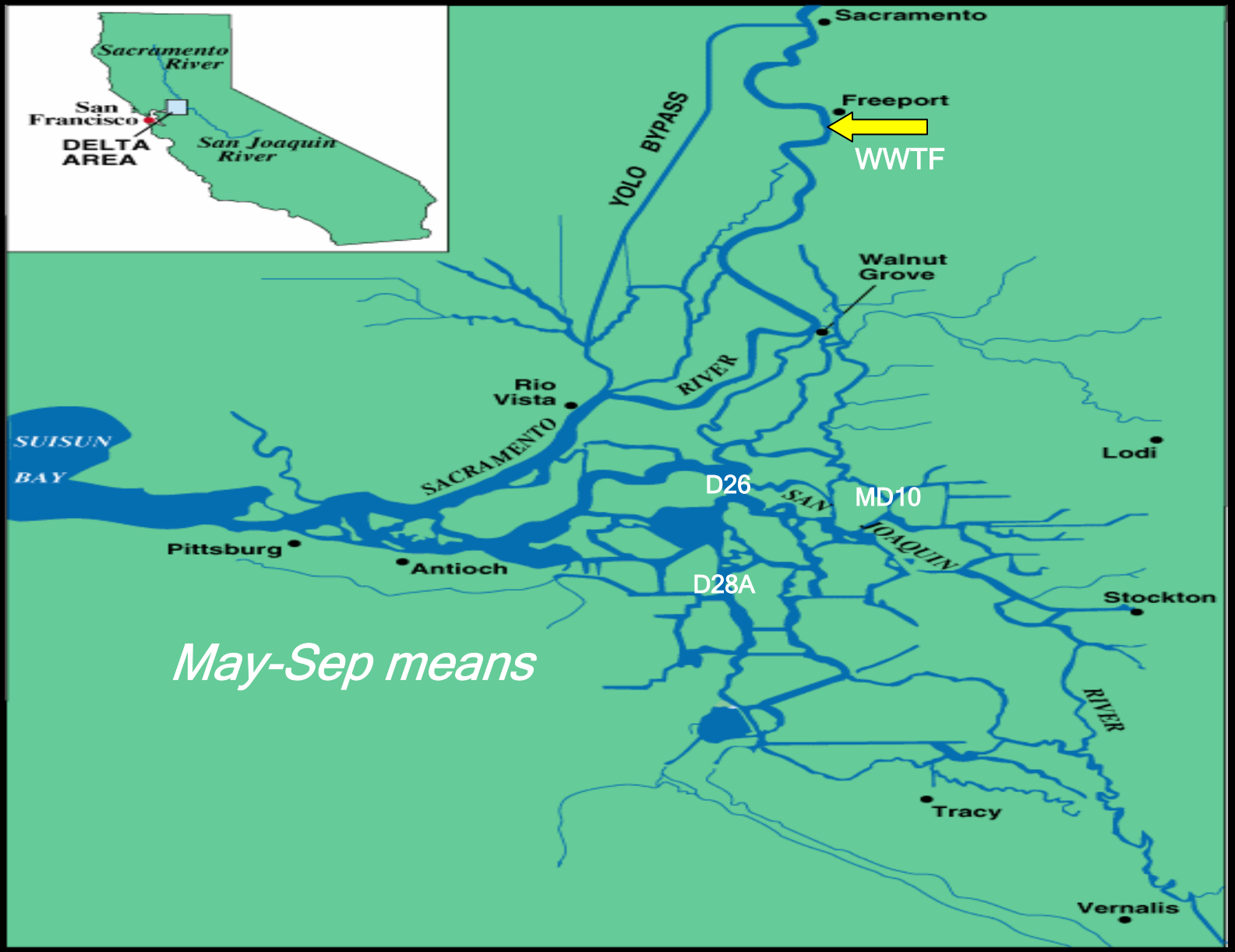


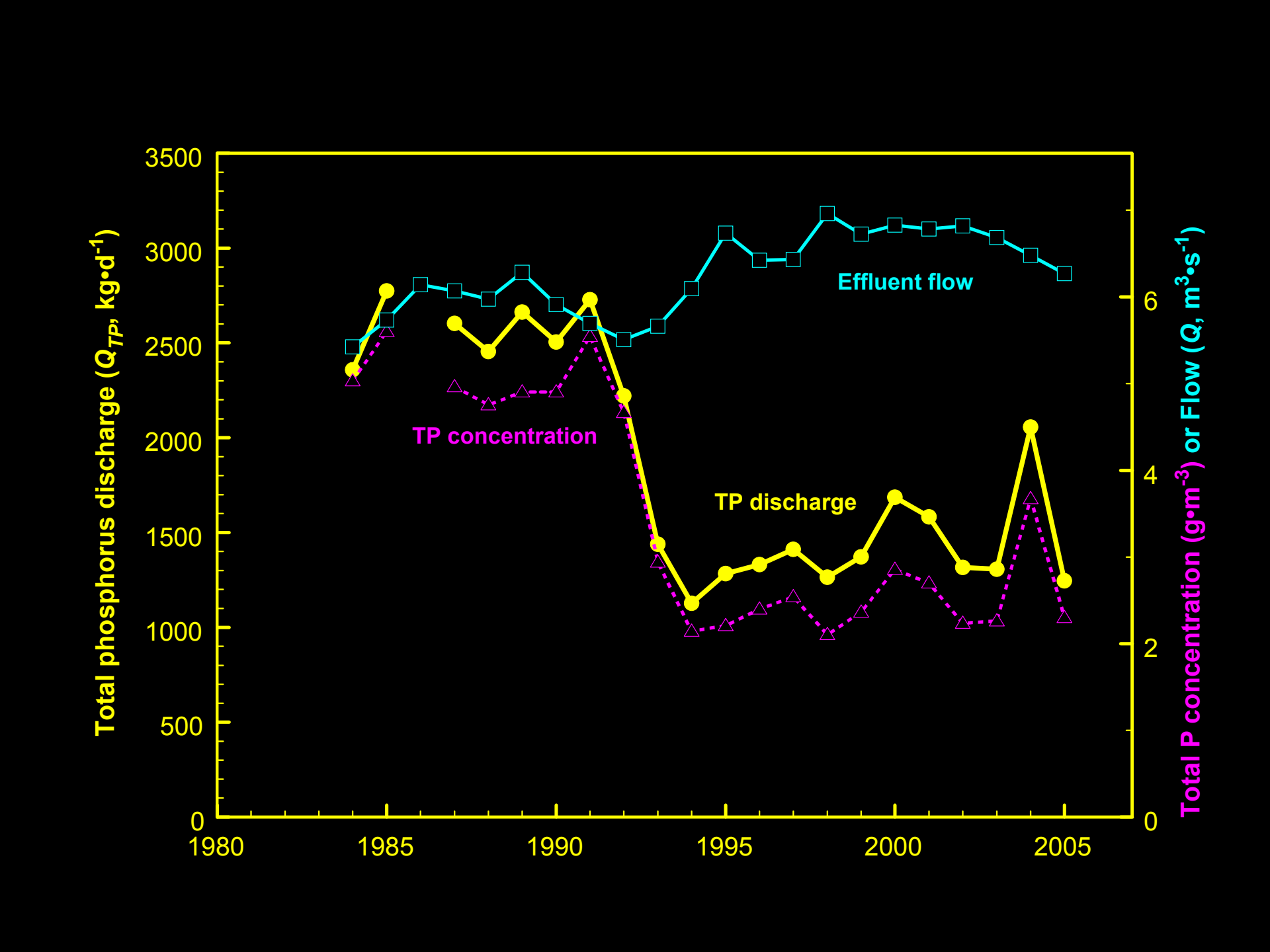
Fig. 1. Summer average chlorophyll concentration vs. total phosphorus concentration at spring overturn. Circles—data from Sakamoto (1966), chlorophyll measured by the method of Hogetsu and Ichimura (1954) and Ichimura (1956); triangles—data for other lakes reported in the literature, chlorophyll measured as chlorophyll *a*. The line shown is the regression line for Sakamoto's data.

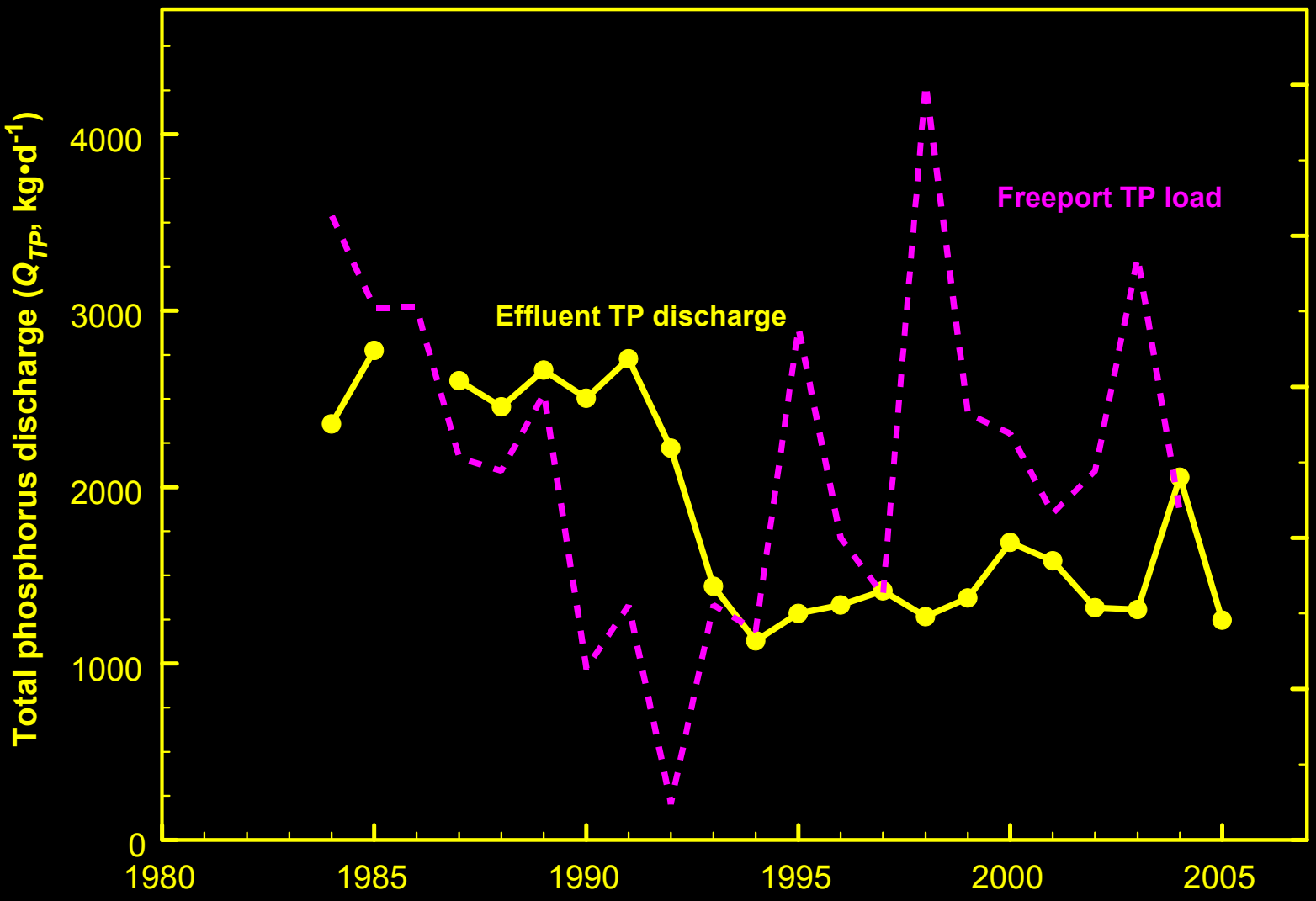
Dillon and Rigler 1974

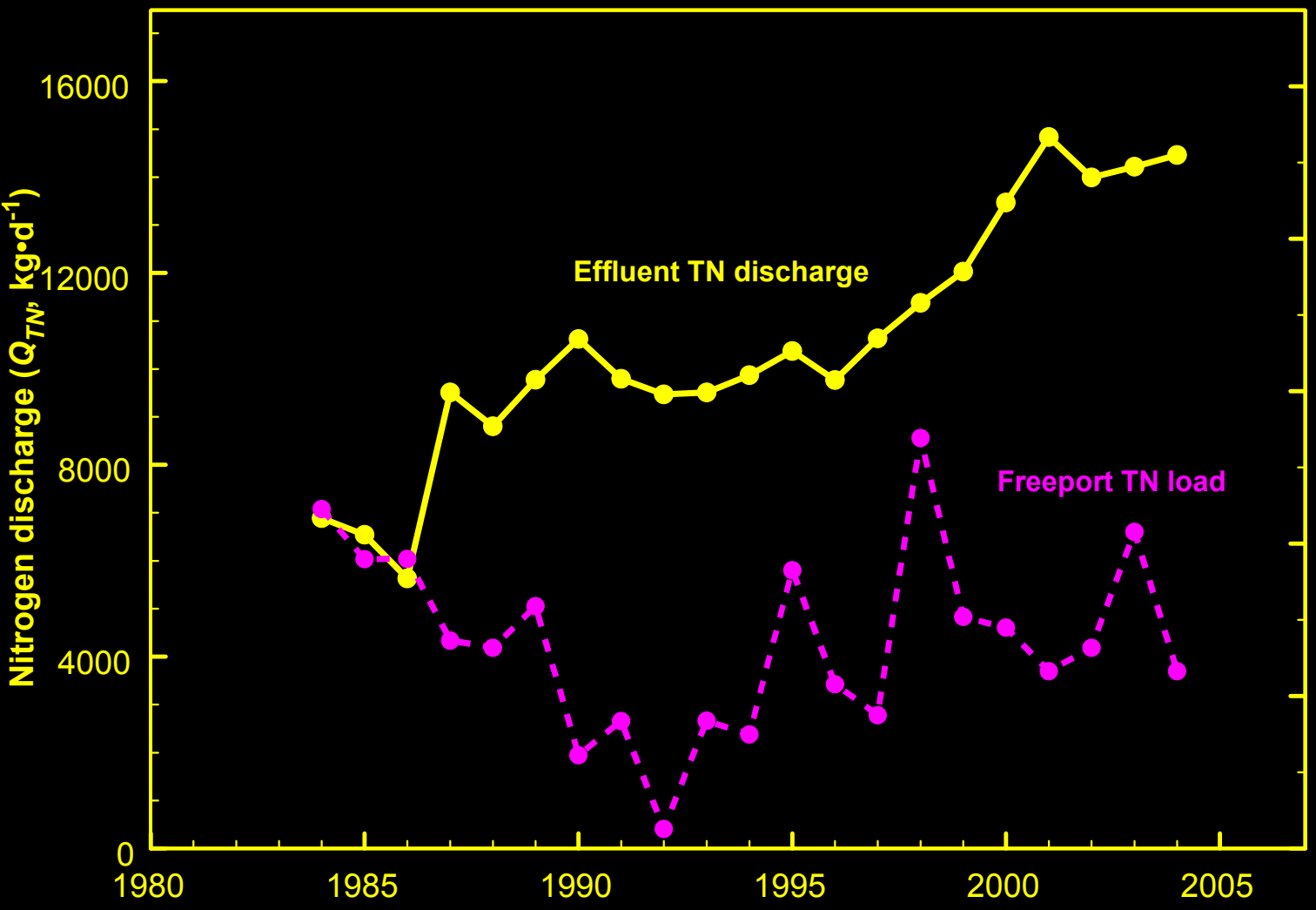
Outline

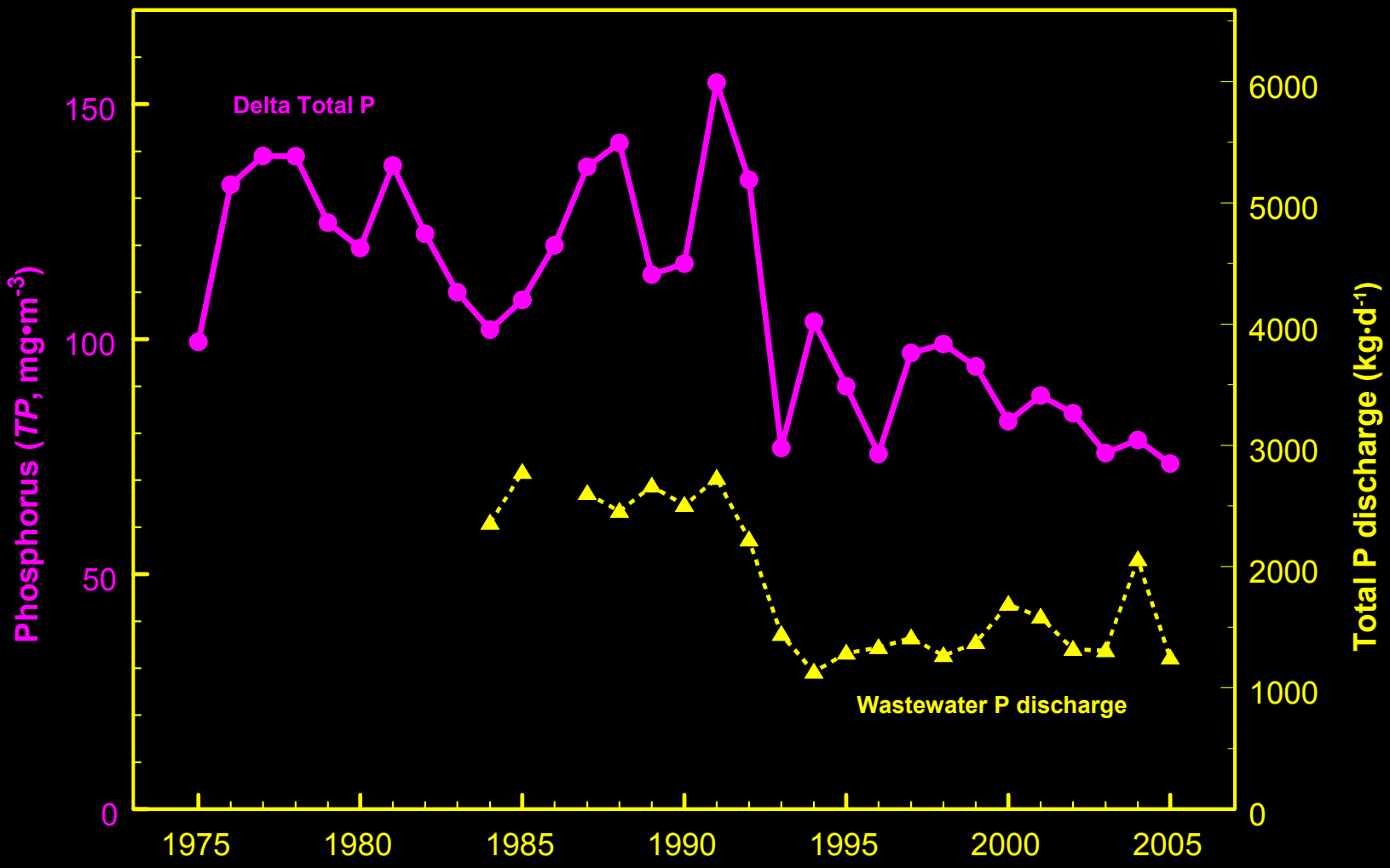
- Document Delta's chlorophyll response to phosphorus reduction
- Compare to the Rhine River's response
- Compare to an empirical model for flowing waters

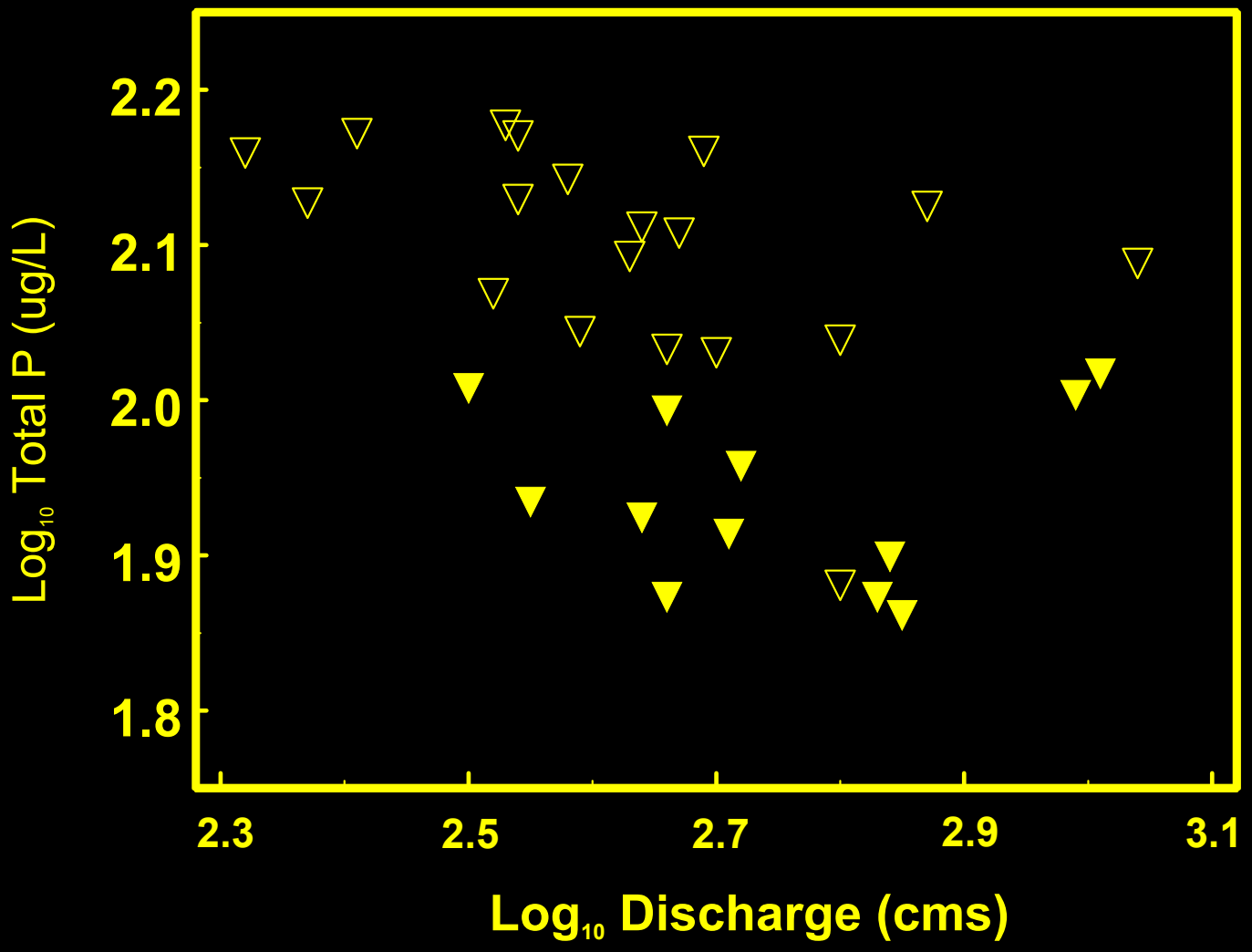

Sacramento River
San Francisco
DELTA AREA
San Joaquin River
Sacramento
Freeport
WWTF
YOLO BYPASS
Walnut Grove
RIVER
Rio Vista
SACRAMENTO
SUISUN BAY
Lodi
D26
SAN
MD10
JOAQUIN
Pittsburg
Antioch
D28A
Stockton
May-Sep means
RIVER
Tracy
Vernalis

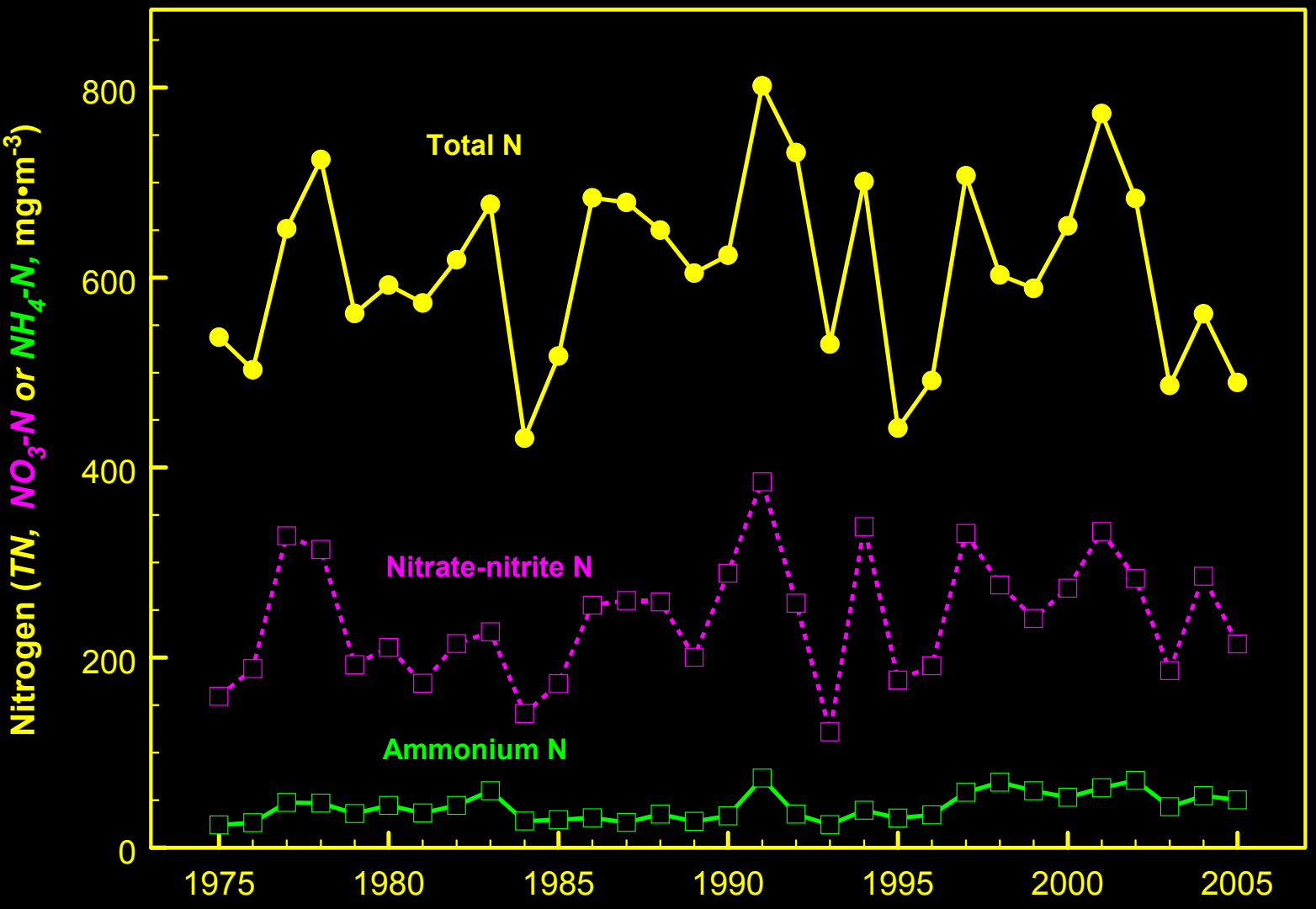

Total phosphorus discharge (Q_{TP}, kg•d^{-1})
Total P concentration (g•m^{-3}) or Flow (Q, m^3•s^{-1})
Effluent flow
TP concentration
TP discharge
3500
3000
2500
2000
1500
1000
500
0
6
4
2
0
1980
1985
1990
1995
2000
2005

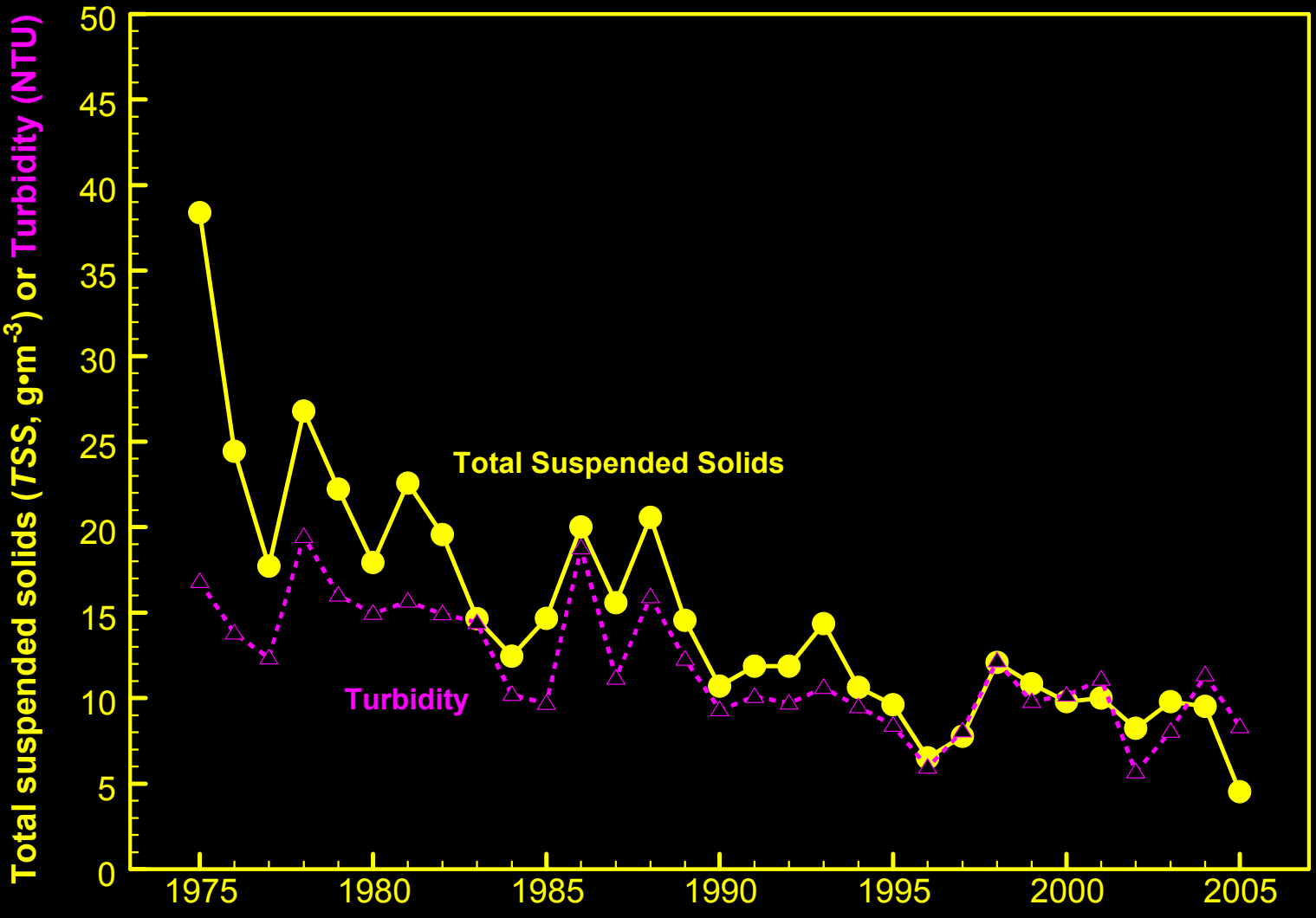

Total phosphorus discharge (Q_{TP}, kg•d^{-1})
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
2005
Freeport TP load
Effluent TP discharge

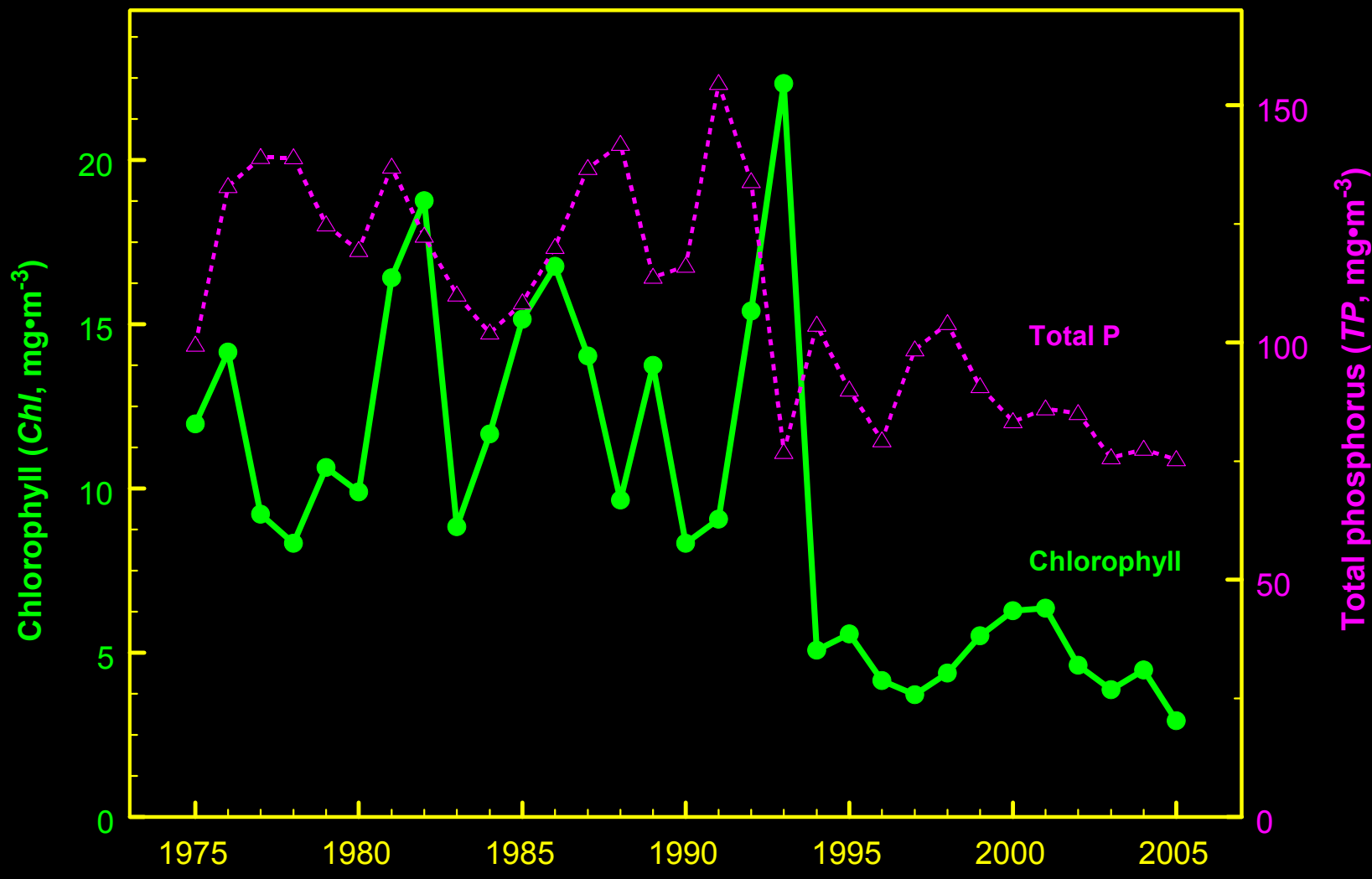

16000
12000
8000
4000
0
1980
1985
1990
1995
2000
2005
Nitrogen discharge (Q_{TN}, kg•d^{-1})
Effluent TN discharge
Freeport TN load

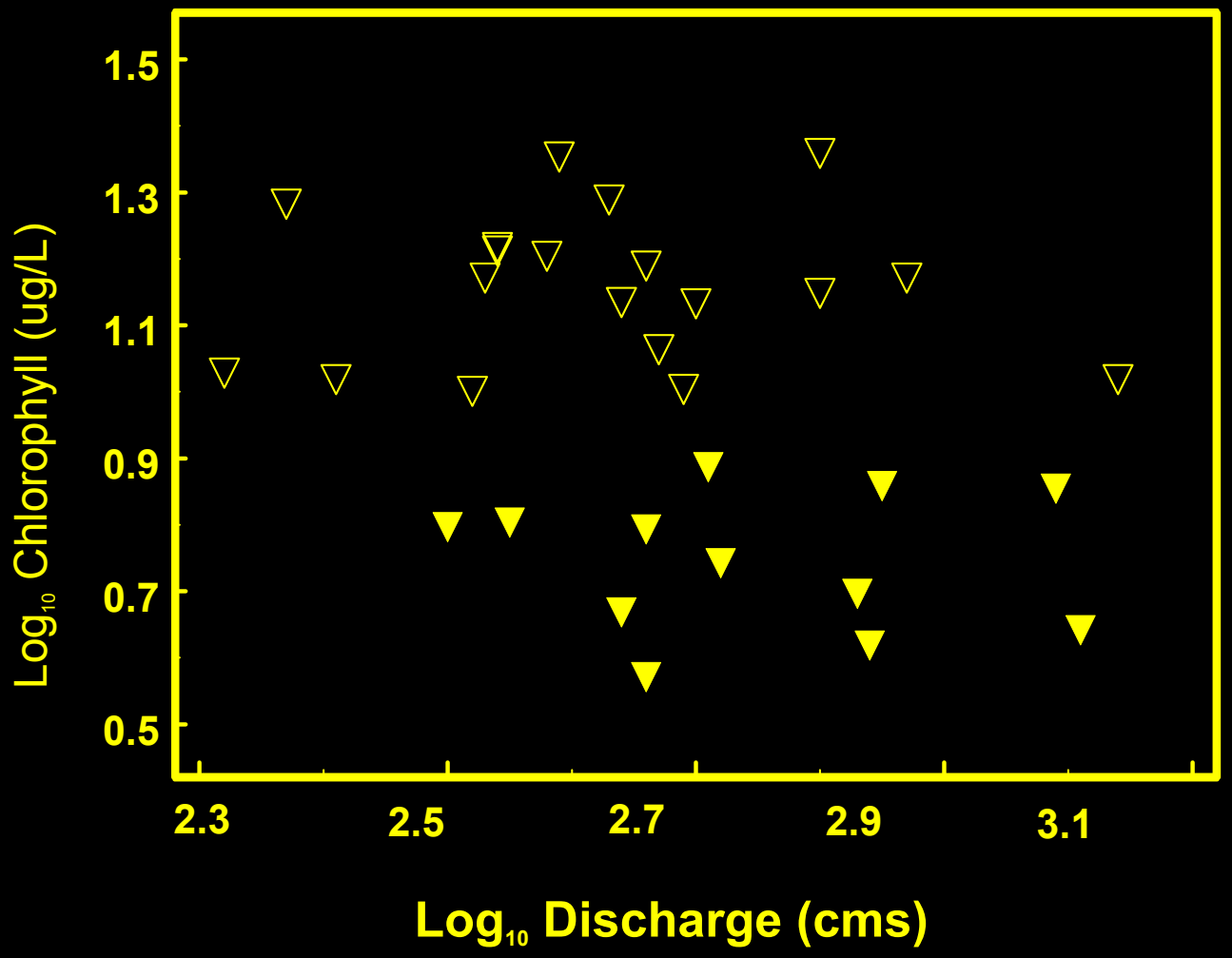

Delta Total P
Wastewater P discharge
Phosphorus (TP, mg•m-3)
Total P discharge (kg•d-1)
0
50
100
150
0
1000
2000
3000
4000
5000
6000
1975
1980
1985
1990
1995
2000
2005


2.2
2.1
2.0
1.9
1.8
Log10 Total P (ug/L)
2.3
2.5
2.7
2.9
3.1
Log10 Discharge (cms)

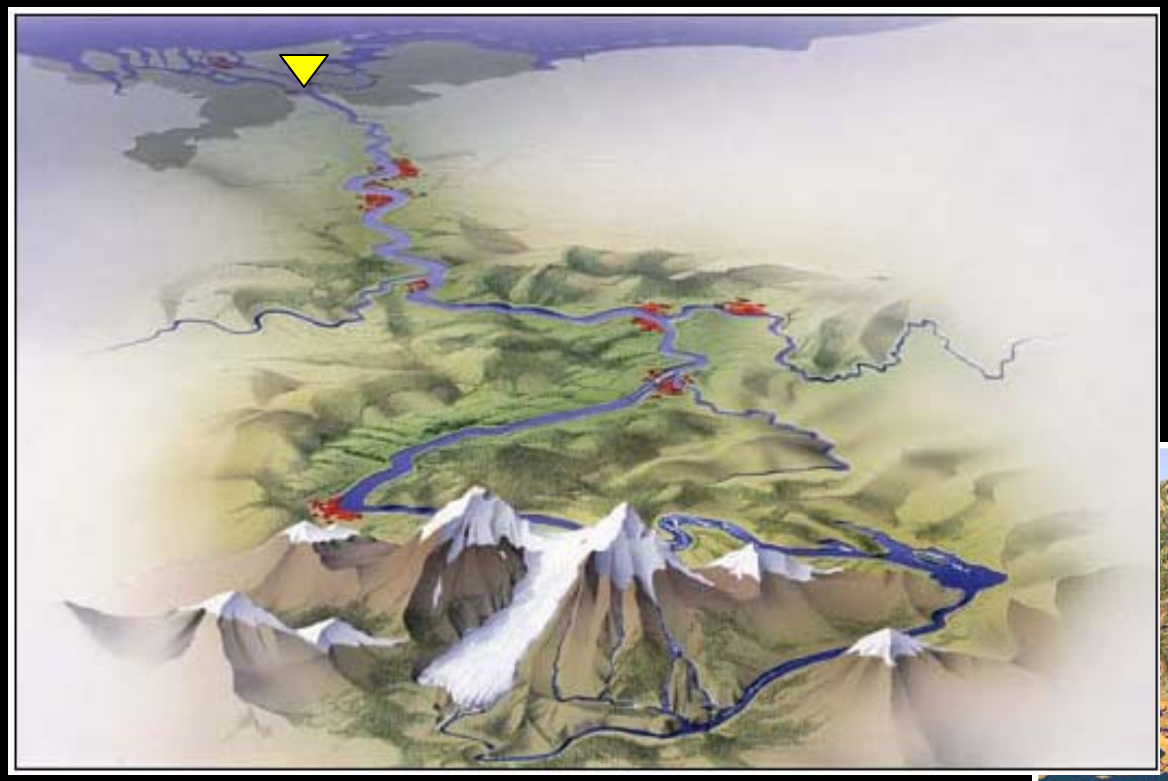

Nitrogen (TN, NO3-N or NH4-N, mg•m-3)
800
600
400
200
0
1975
1980
1985
1990
1995
2000
2005
Total N
Nitrate-nitrite N
Ammonium N


Total suspended solids (TSS, g•m-3) or Turbidity (NTU)
50
45
40
35
30
25
20
15
10
5
0
1975
1980
1985
1990
1995
2000
2005
Total Suspended Solids
Turbidity

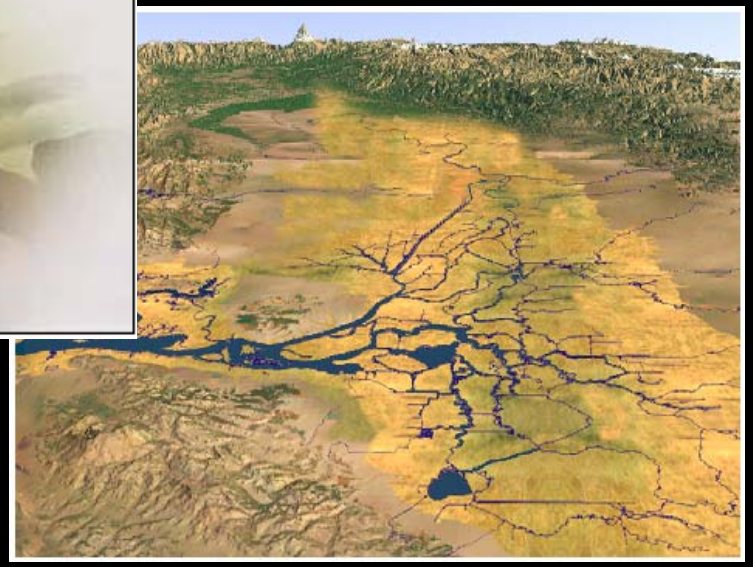

Chlorophyll (Chl, mg•m-3)
Total phosphorus (TP, mg•m-3)
Total P
Chlorophyll
0
5
10
15
20
0
50
100
150
1975
1980
1985
1990
1995
2000
2005


1.5
1.3
1.1
0.9
0.7
0.5
Log10 Chlorophyll (ug/L)
2.3
2.5
2.7
2.9
3.1
Log10 Discharge (cms)

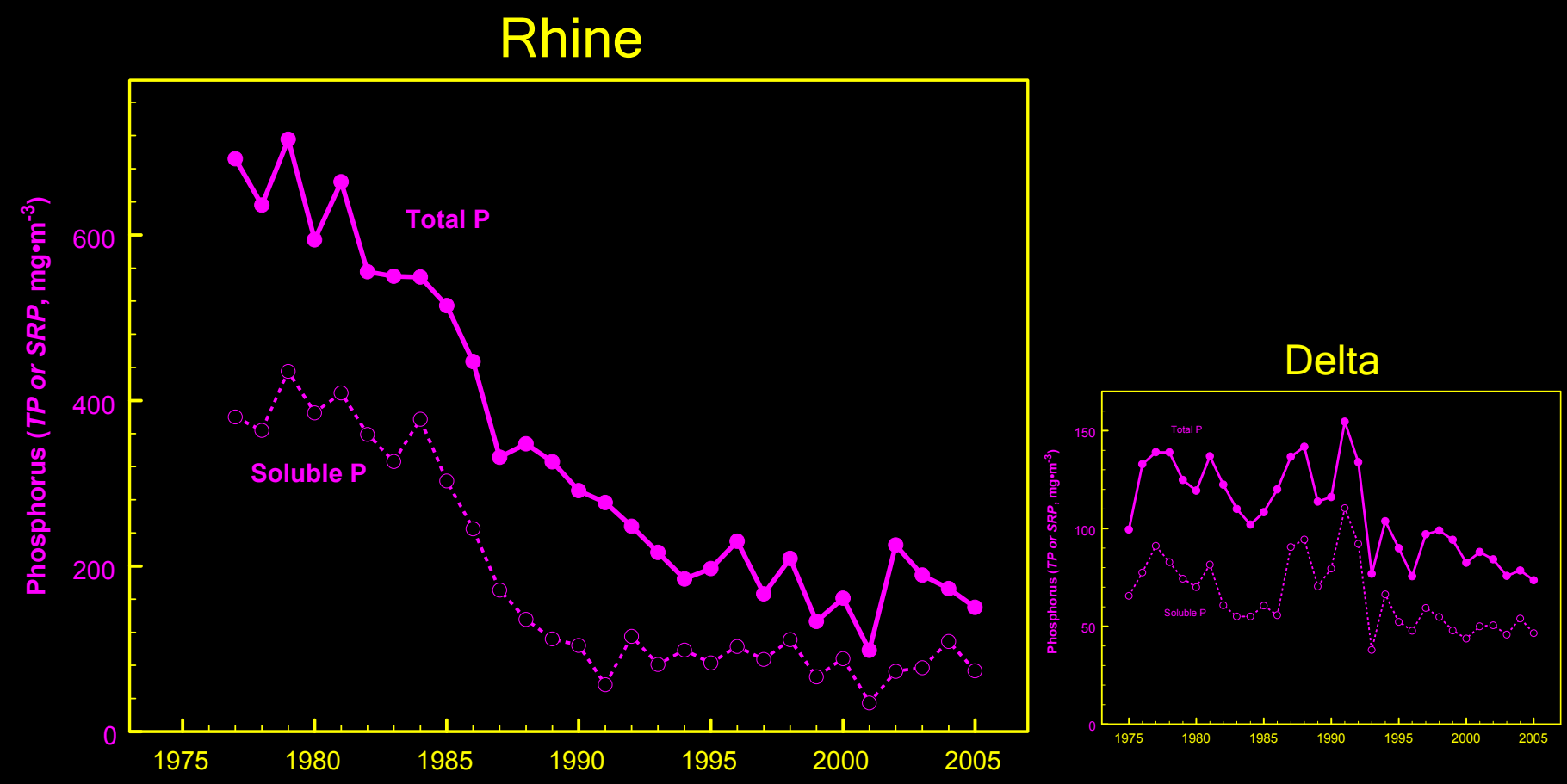
Lobith, Netherlands



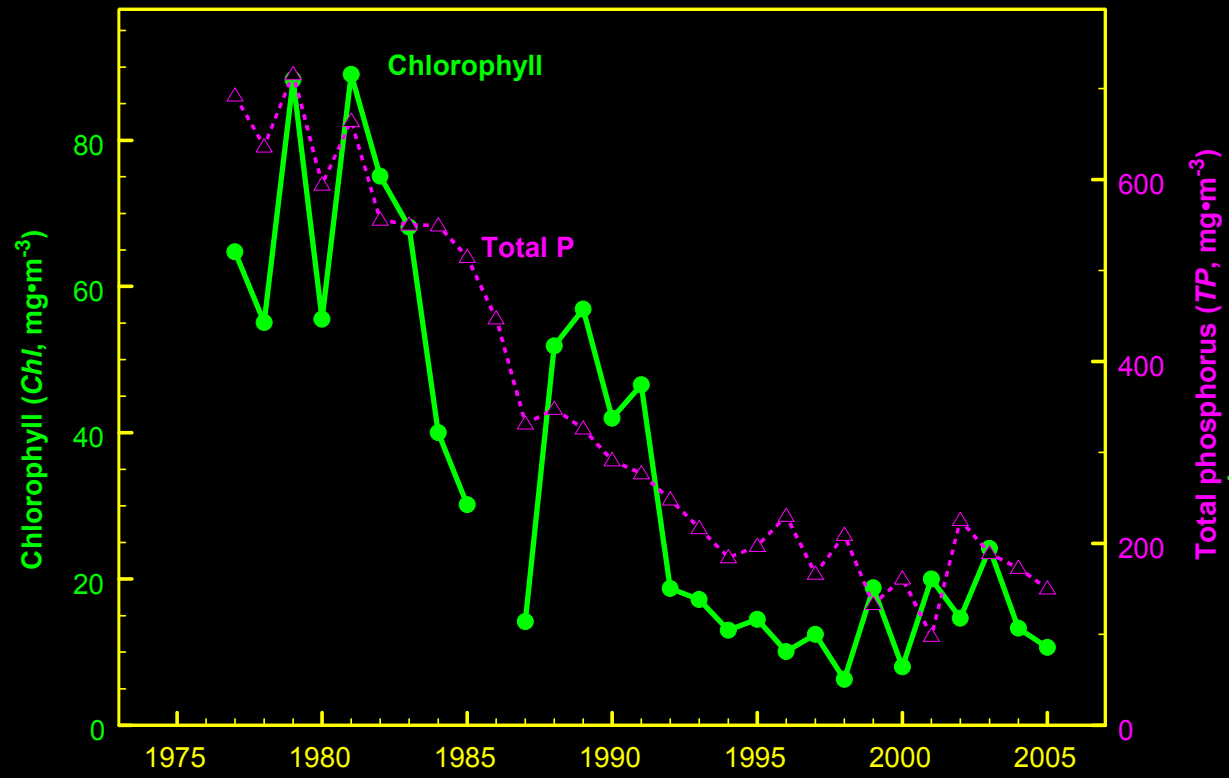
Delta



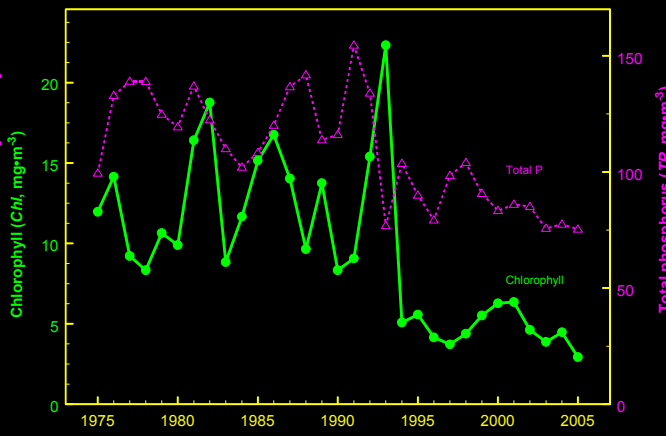
System	Area (km^2)	Flow (cms)	Depth (m)	*TSS* (mg/L)
Rhine	185,000	2,052	6.0	31
Delta	90,650	561	5.5	15

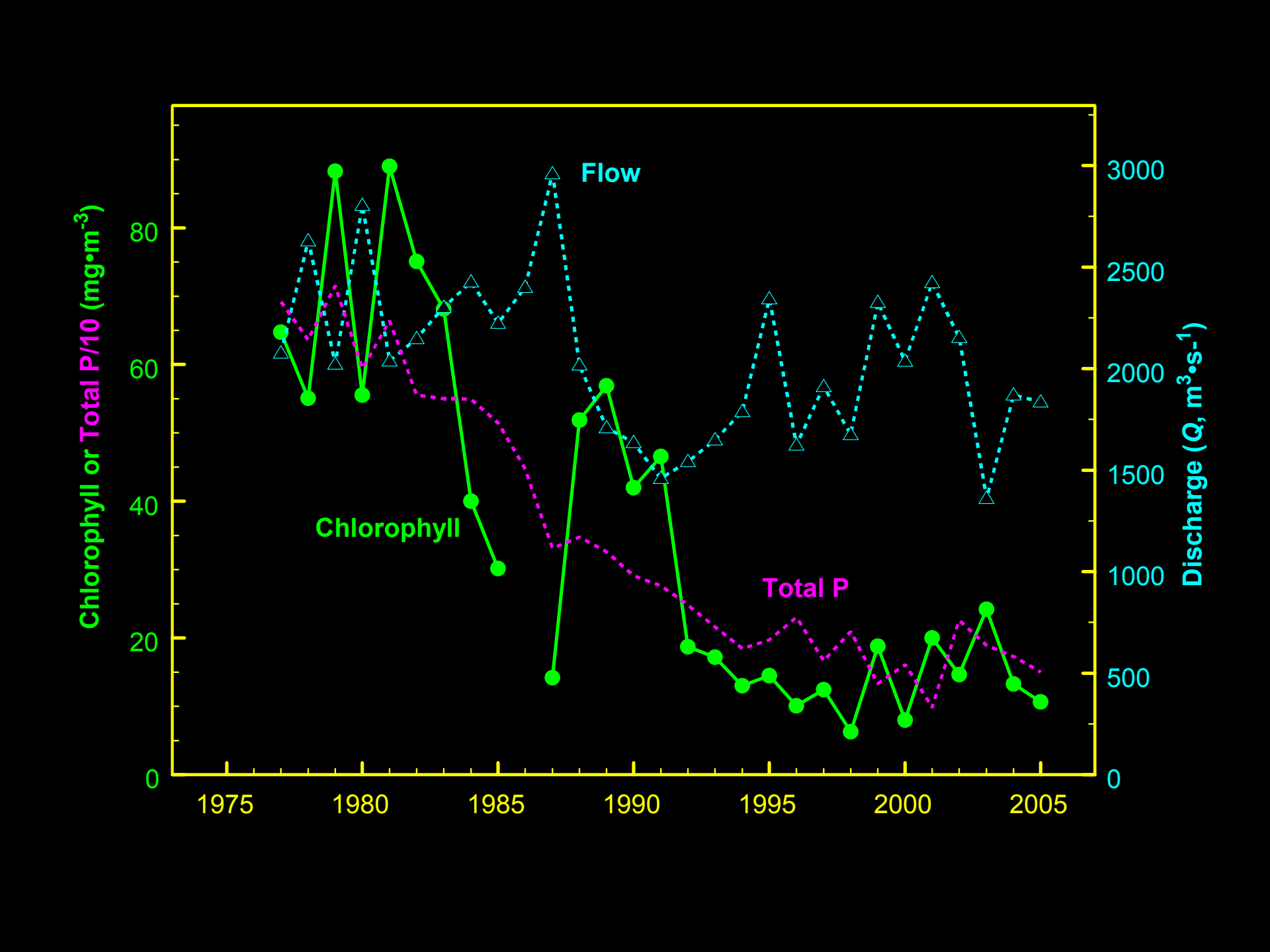

Rhine
Total P
Soluble P
Phosphorus (TP or SRP, mg•m-3)
0
200
400
600
1975
1980
1985
1990
1995
2000
2005
Delta
Total P
Soluble P
Phosphorus (TP or SRP, mg•m-3)
0
50
100
150
1975
1980
1985
1990
1995
2000
2005

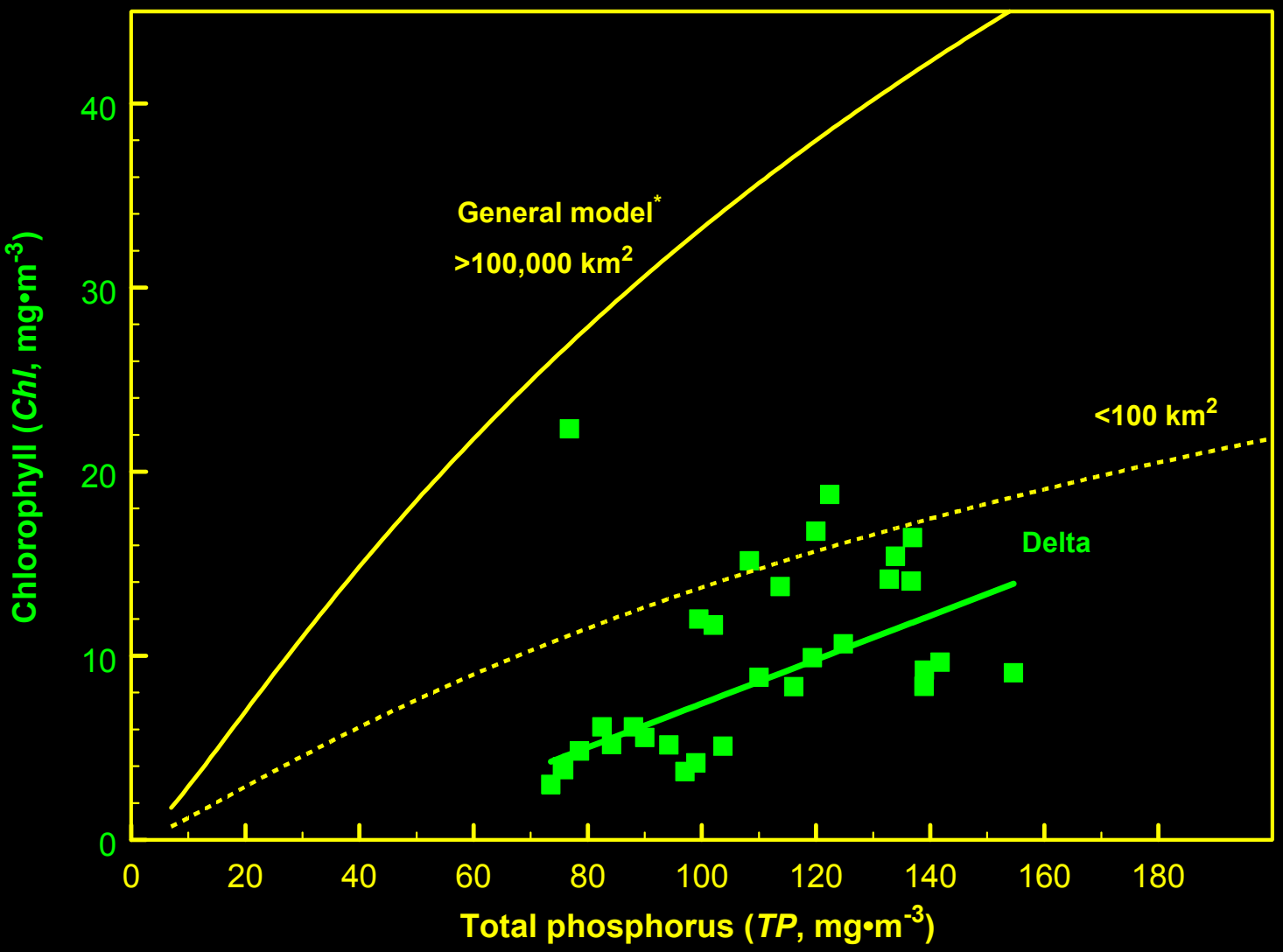
Rhine


Chlorophyll
Total P
Chlorophyll (*Chl*, mg•m^{-3})
Total phosphorus (*TP*, mg•m^{-3})
0
20
40
60
80
0
200
400
600
1975
1980
1985
1990
1995
2000
2005

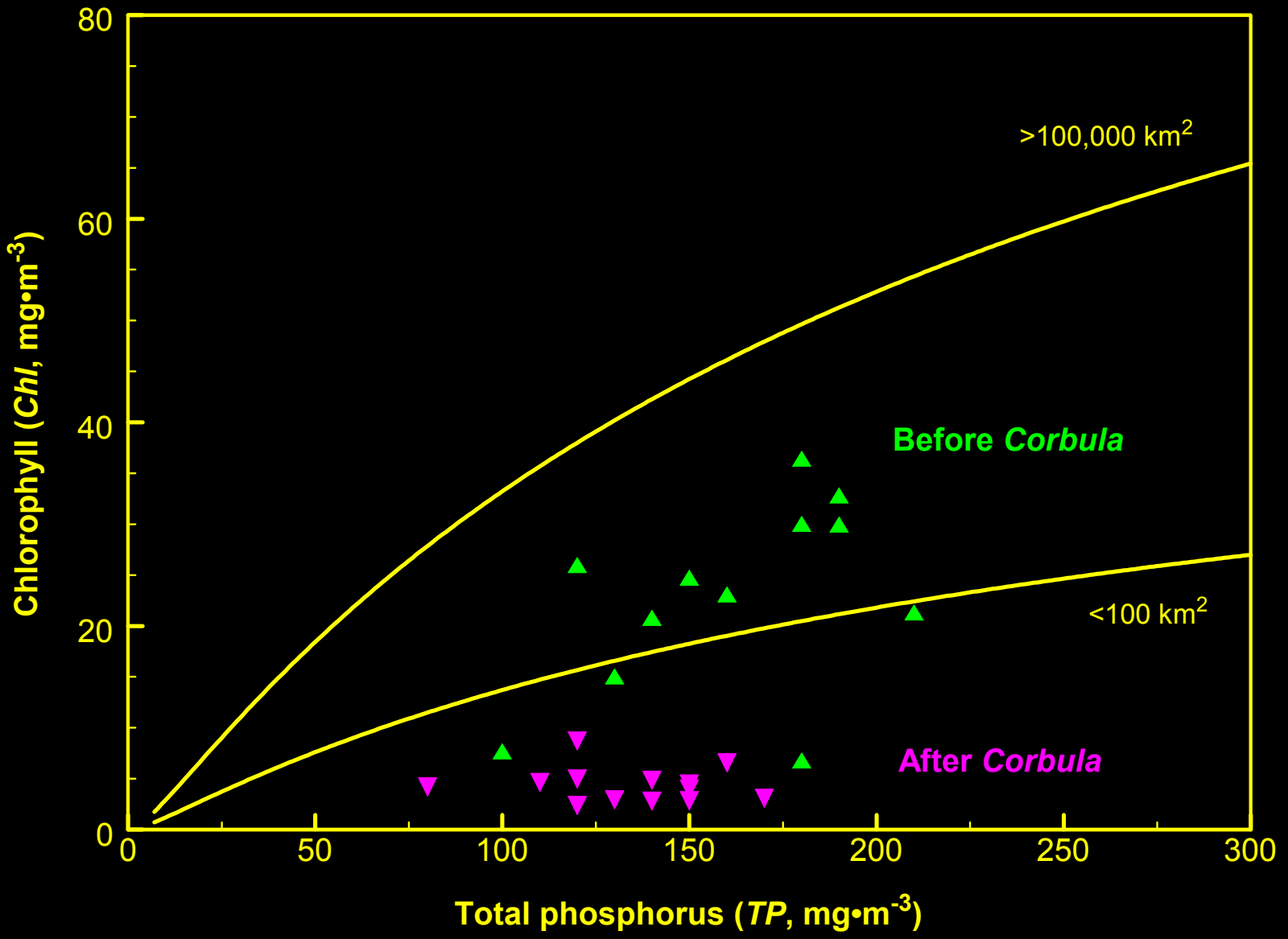
Delta

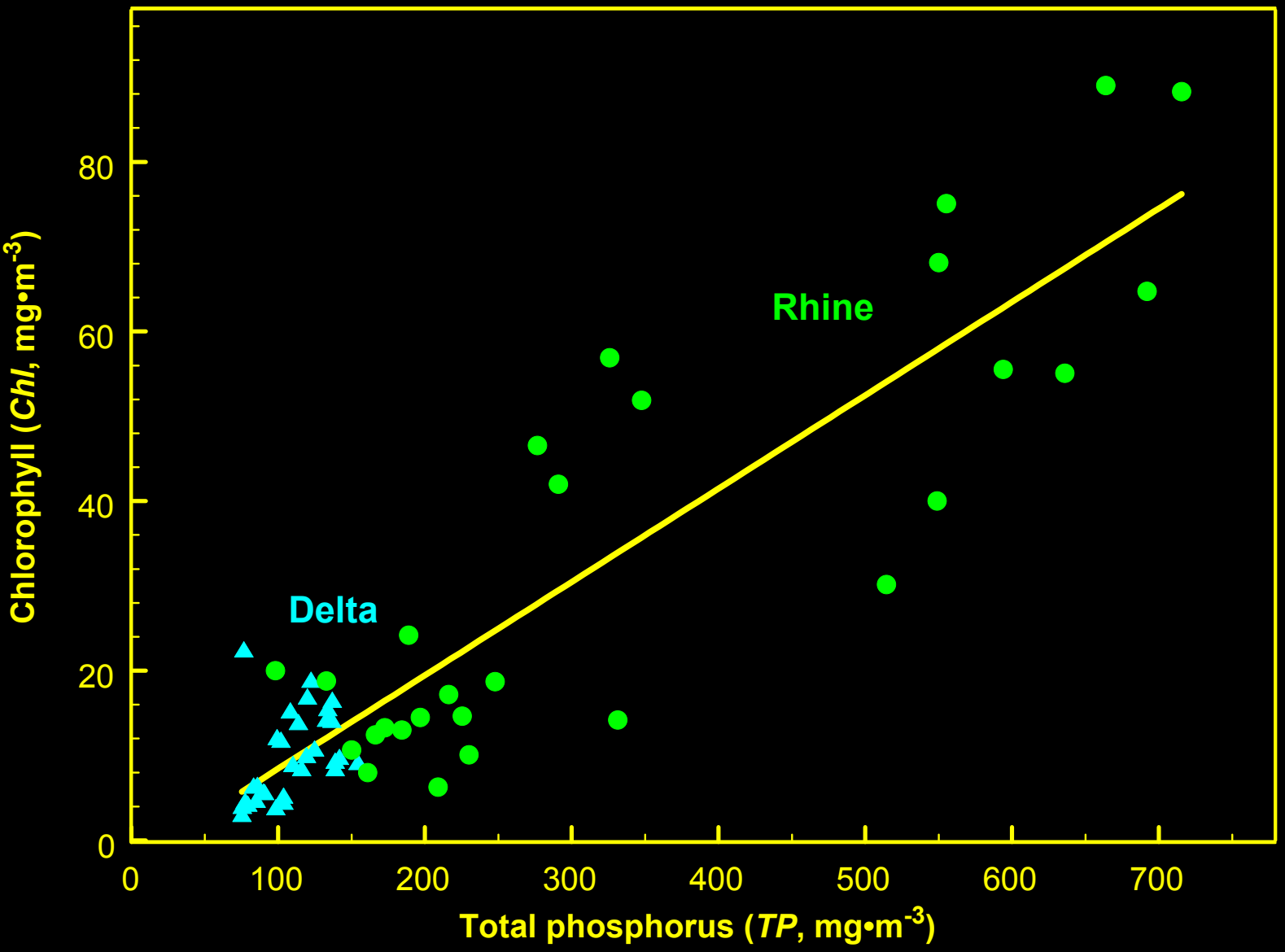

Total P
Chlorophyll
Chlorophyll (*Chl*, mg•m^{-3})
Total phosphorus (*TP*, mg•m^{-3})
0
5
10
15
20
0
50
100
150
1975
1980
1985
1990
1995
2000
2005

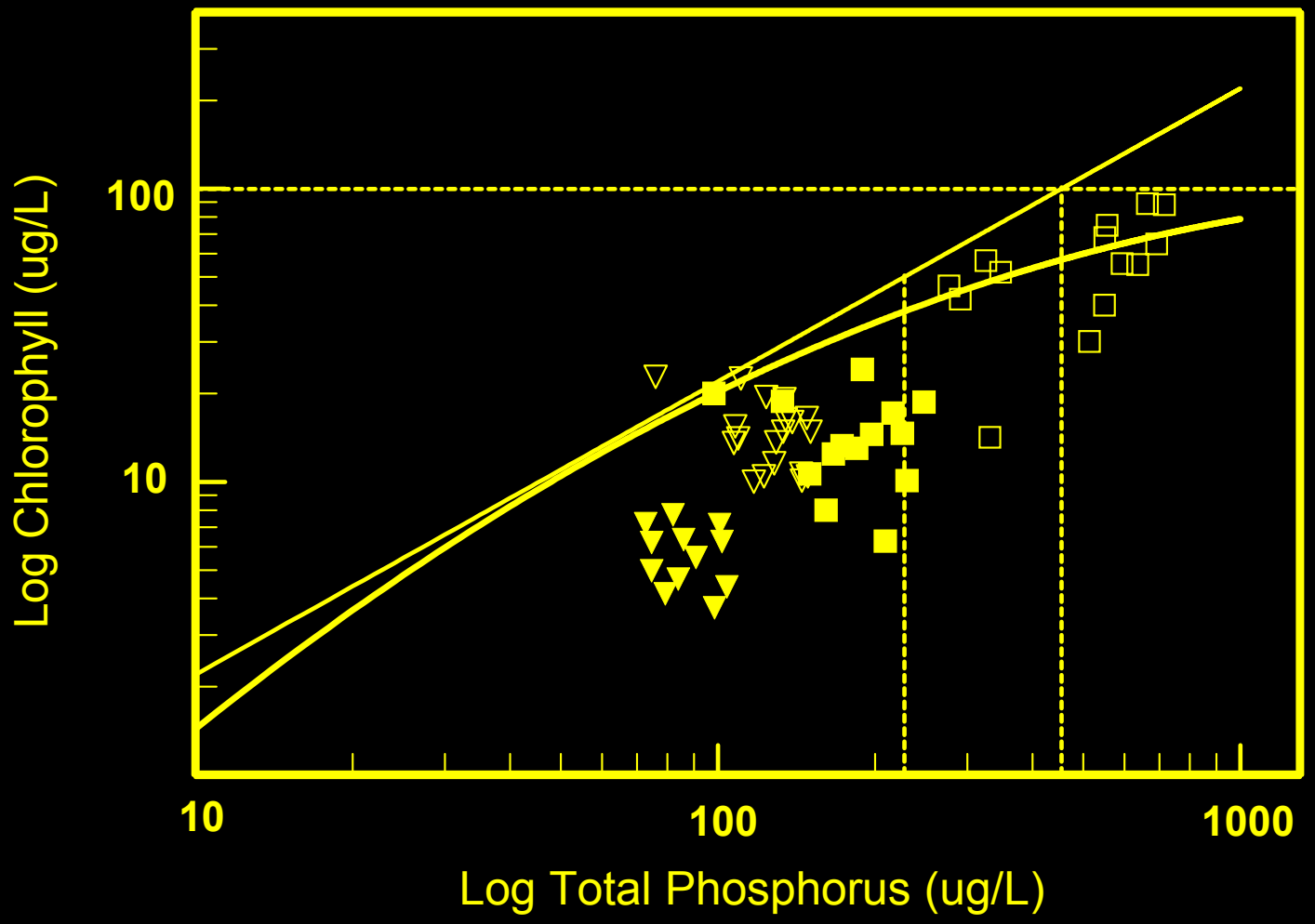

Flow
Chlorophyll
Total P
Chlorophyll or Total P/10 (mg•m-3)
Discharge (Q, m3•s-1)
0
20
40
60
80
0
500
1000
1500
2000
2500
3000
1975
1980
1985
1990
1995
2000
2005



*Van Nieuwenhuyse, E.E., and J.R. Jones. 1996. Phosphorus-chlorophyll relationship in temperate streams and its variation with catchment area. Can. J. Fish. Aquat. Sci. 53: 99 - 105


80
60
40
20
0
0
50
100
150
200
250
300
Chlorophyll (*Chl*, mg•m^{-3})
Total phosphorus (*TP*, mg•m^{-3})
>100,000 km^2
<100 km^2
Before *Corbula*
After *Corbula*


Chlorophyll (Chl, mg•m-3)
Total phosphorus (TP, mg•m-3)
Rhine
Delta
0
20
40
60
80
0
100
200
300
400
500
600
700


Log Chlorophyll (ug/L)
100
10
10
100
1000
Log Total Phosphorus (ug/L)

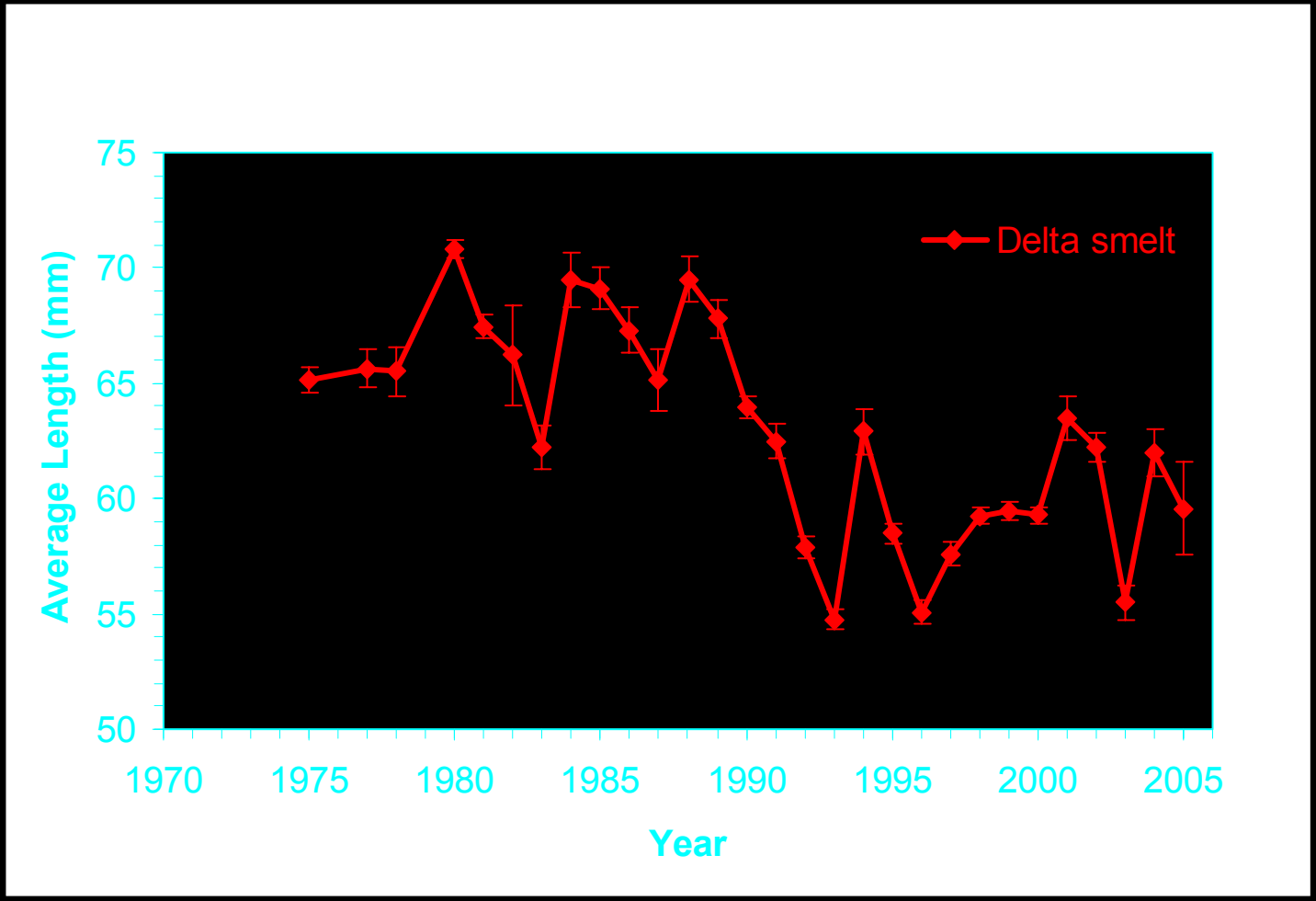
Conclusions

- Delta is phosphorus-limited
- Delta *Chl:TP* is low because loss is high
- To boost Delta *Chl*, increase *TP* and reduce loss
- Need whole-system scale experiment

Acknowledgements

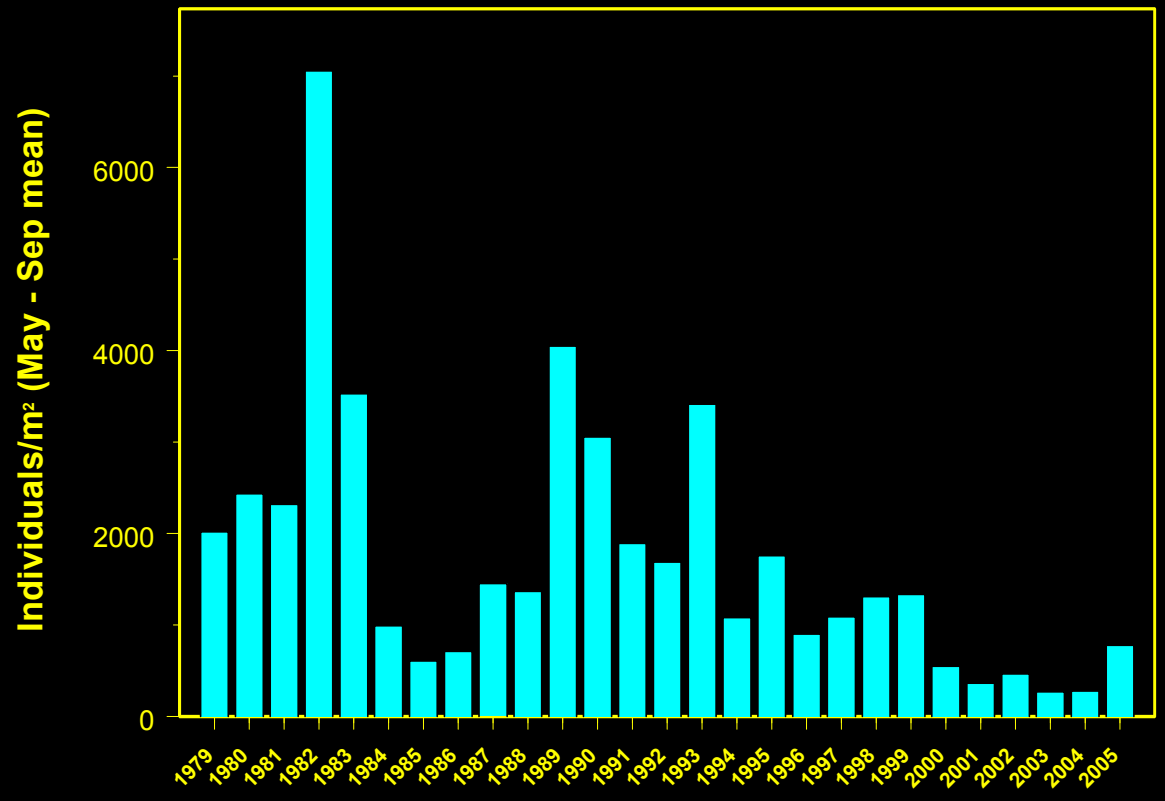
- IEP-Environmental Monitoring Program
- Milton Preszler, Sacramento Regional County Sanitation District
- Leo van Ballegooijen, Dutch Governmental Institute on Inland Water Management and Waste Water Treatment

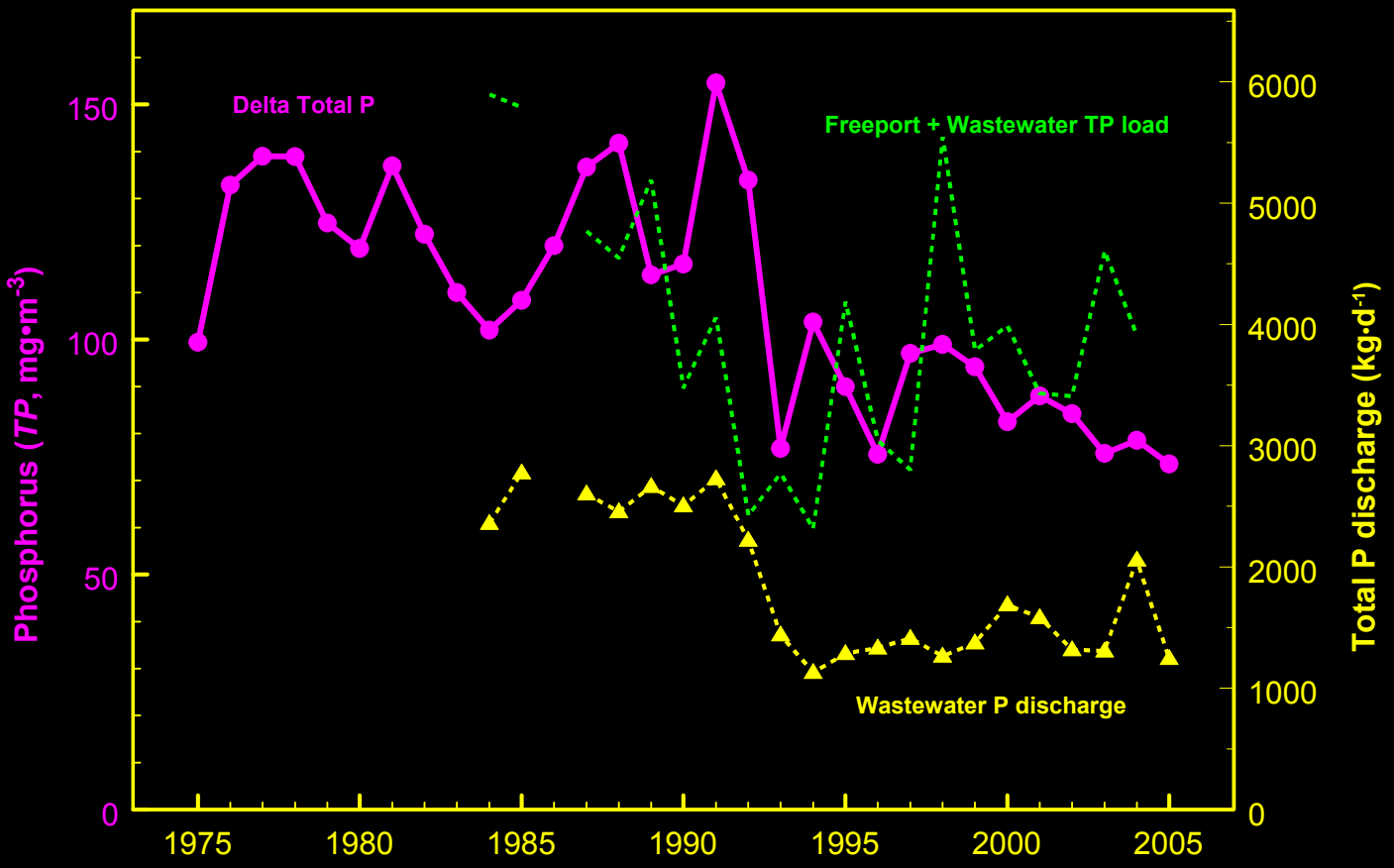

Questions?

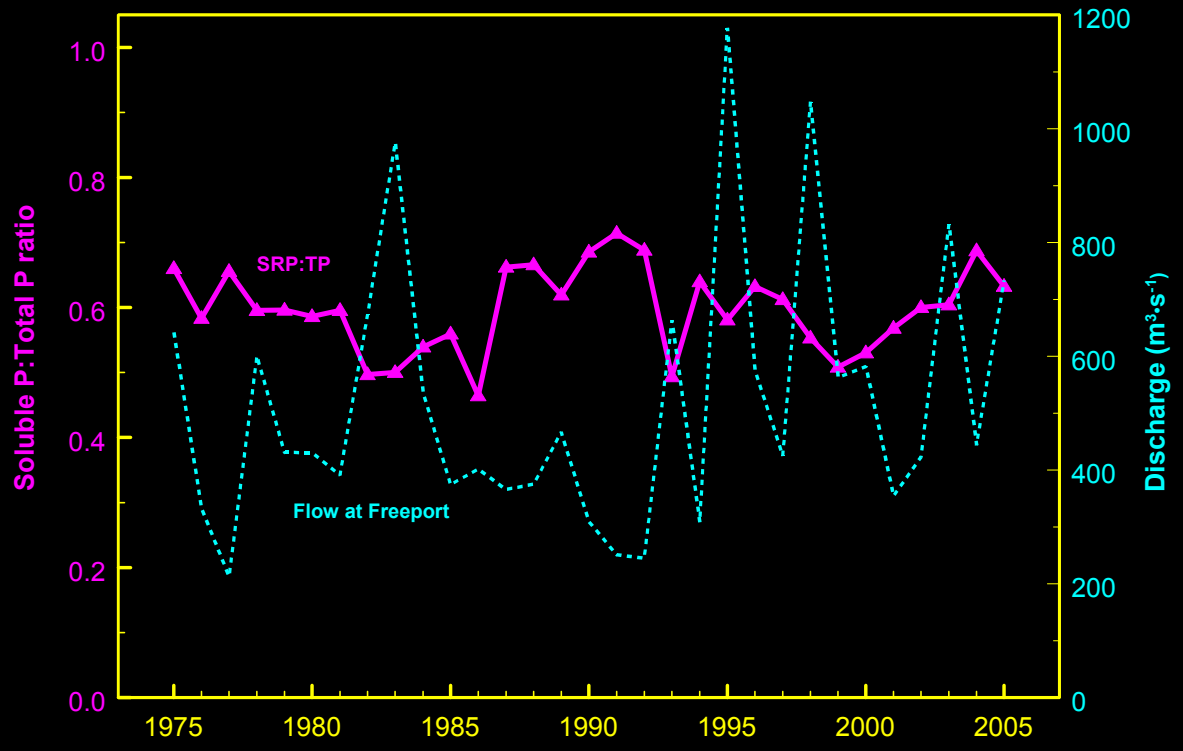


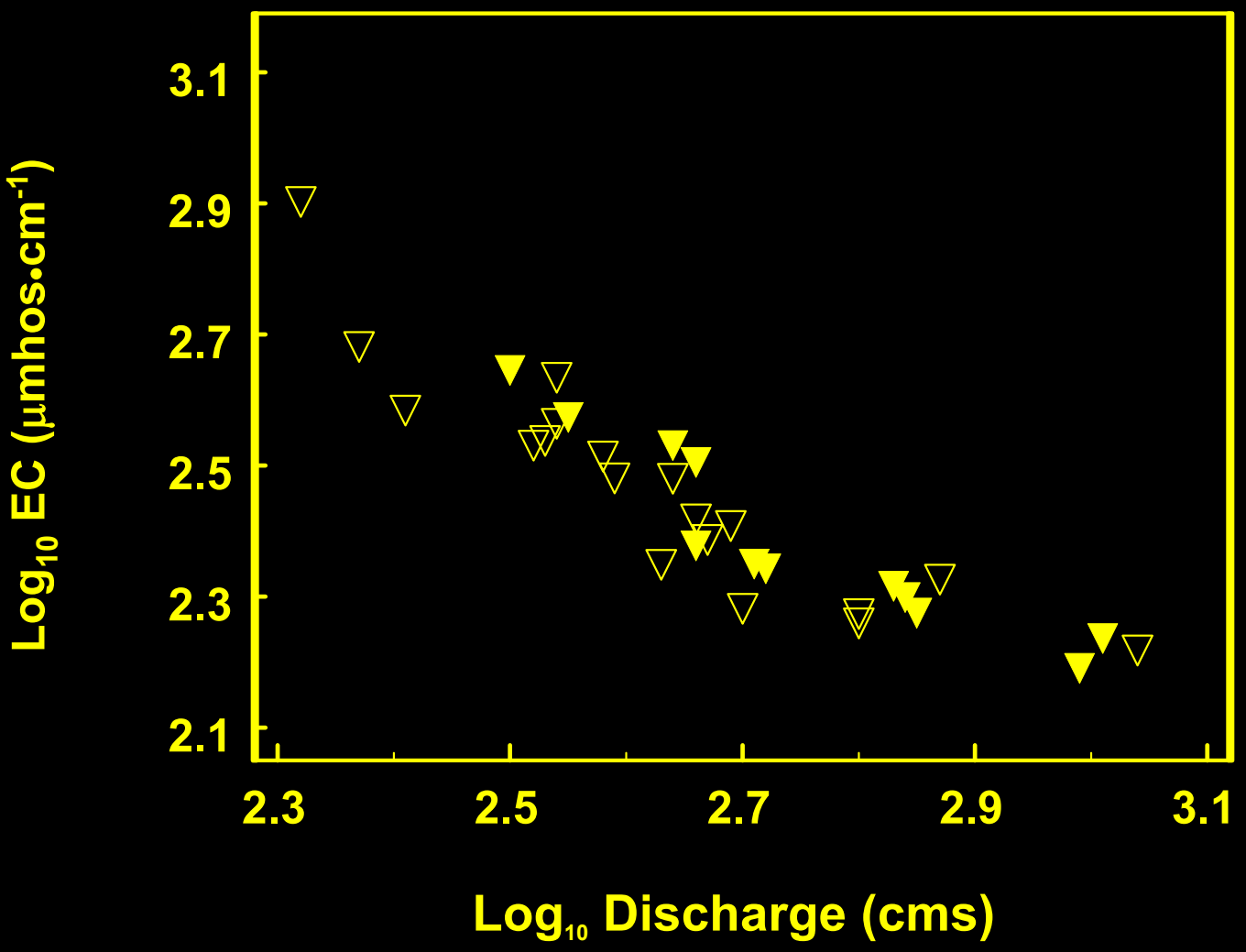
Source: California Department of Fish and Game

Corbicula fluminea at D-28A




Delta Total P
Freeport + Wastewater TP load
Wastewater P discharge
Phosphorus (TP, mg•m-3)
Total P discharge (kg•d-1)
0
50
100
150
0
1000
2000
3000
4000
5000
6000
1975
1980
1985
1990
1995
2000
2005


Soluble P:Total P ratio
Discharge (m³·s⁻¹)
SRP:TP
Flow at Freeport
0.0
0.2
0.4
0.6
0.8
1.0
0
200
400
600
800
1000
1200
1975
1980
1985
1990
1995
2000
2005


3.1
2.9
2.7
2.5
2.3
2.1
Log10 EC (µmhos•cm-1)
2.3
2.5
2.7
2.9
3.1
Log10 Discharge (cms)

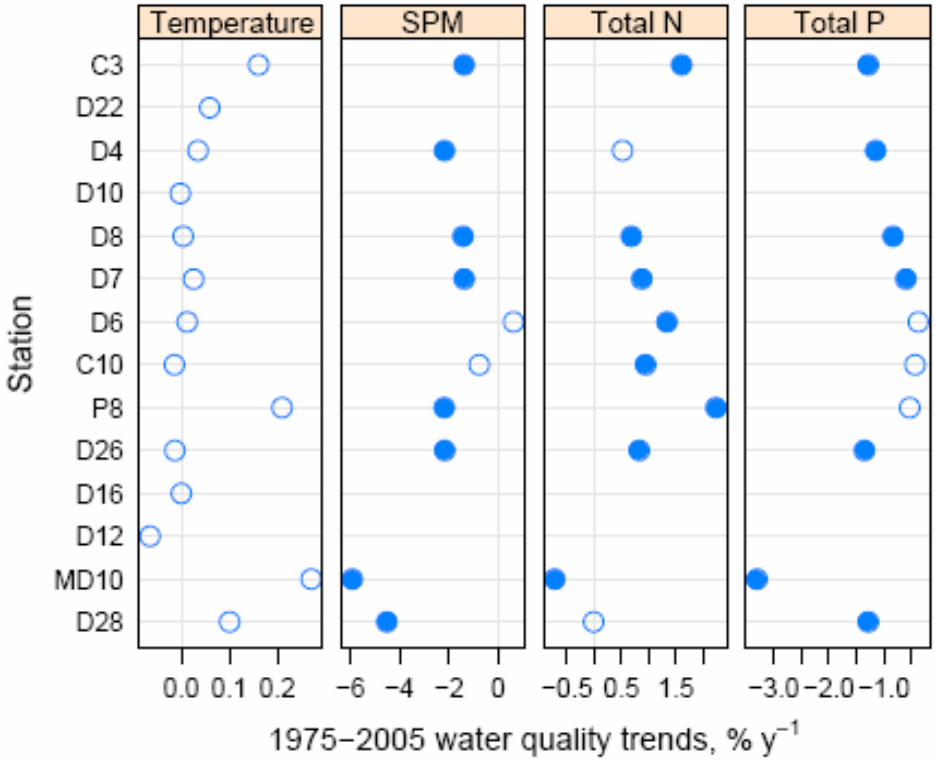


Figure 12. Long-term trends in water quality variables during 1975–2005. Trends are expressed as the Theil-Sen slope divided by the long-term median for the station. Trends are adjusted for river inflow and *p*-values are corrected for seasonal serial correlation. Trends are not plotted for stations with inadequate data during this period. *Solid circles*, $p < 0.05$ level according to the Seasonal Kendall test.

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