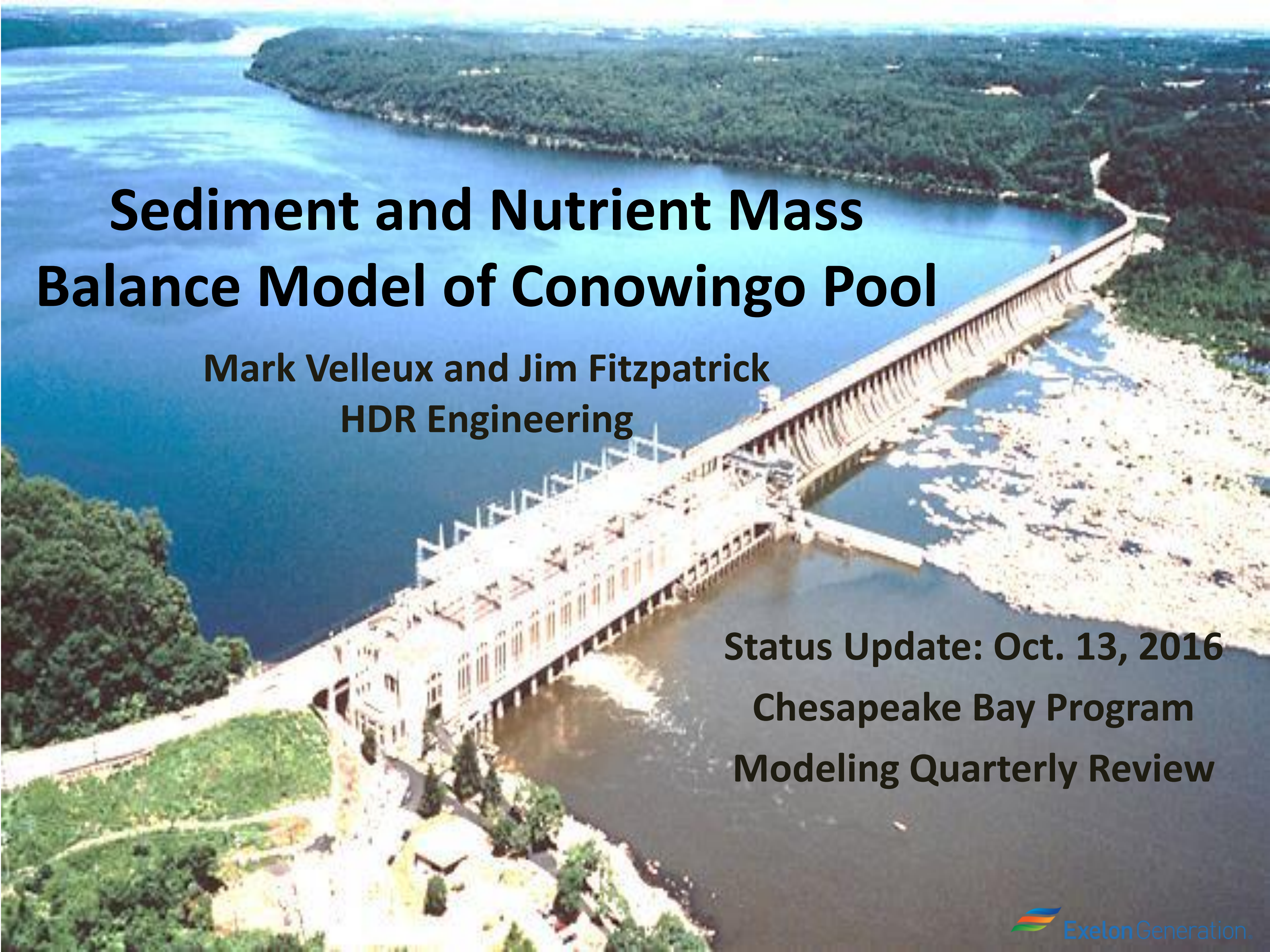


Sediment and Nutrient Mass Balance Model of Conowingo Pool

Mark Velleux and Jim Fitzpatrick
HDR Engineering

Status Update: Oct. 13, 2016
Chesapeake Bay Program
Modeling Quarterly Review

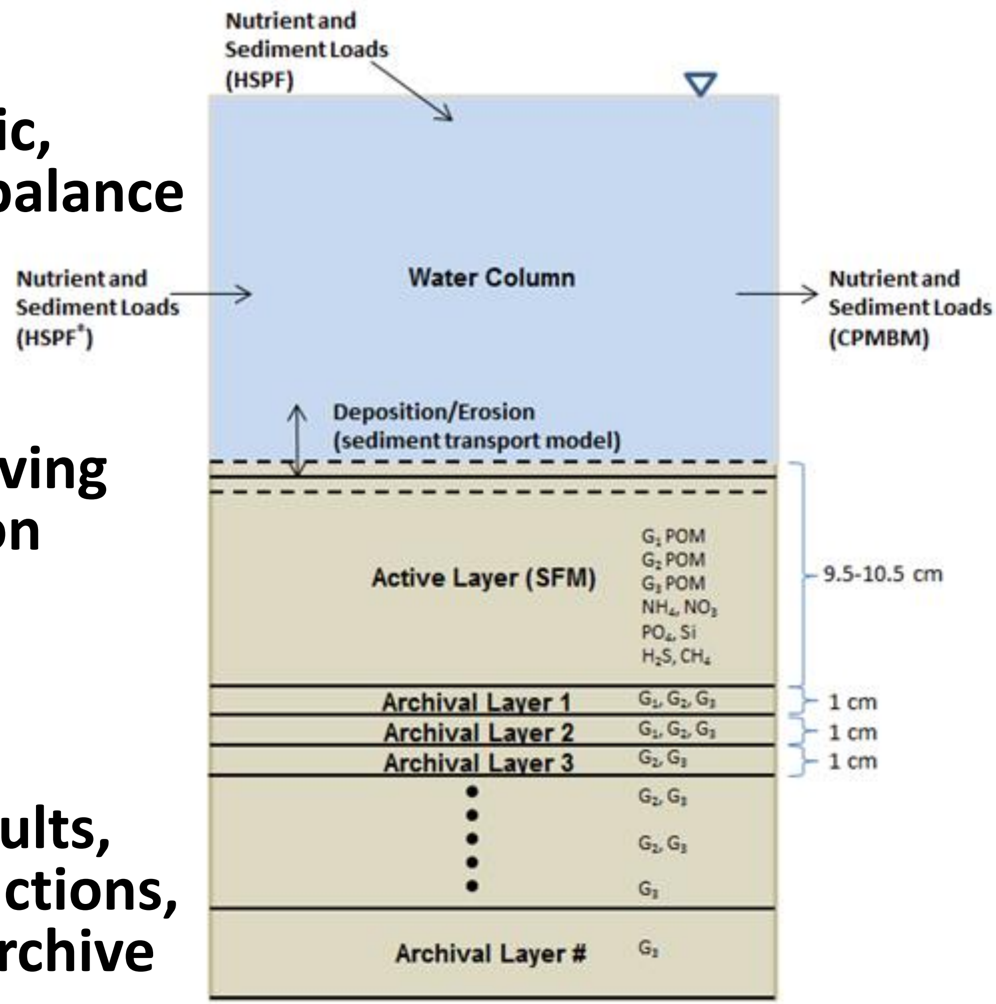
Conowingo Pond Mass Balance Model Update

Goals

- develop coupled hydrodynamic, sediment transport, nutrient balance model for Conowingo Pond
- determine composition/ bioavailability of nutrients leaving the pond during a resuspension event

Today

- Sediment transport model results, diagenesis data analysis, G-fractions, results from standalone and archive stack versions of SFM



Sediment Transport Model Update

- **Sediment Transport (same as before):**
  - **Five size classes: clay, silt, sand, gravel, coal**
- **Short-term and Long-term simulations completed**
  - **Calibration: 2008-2014 (short-term)**
  - **Confirmation: 1997-2014 (long-term)**
- **Sediment loads at Holtwood:**
  - **HEC-RAS (WEST) simulation results: 2008-2014**
  - **HEC-RAS rating curve: 1997-2007**
- **Watershed sediment loads (Muddy and Broad Creeks):**
  - **HSPF Phase 6 Beta 2**

Size Classes and Settling Speeds

- **Settling speeds for Conowingo by Sanford et al. (2016):**

Particle Size (mm)	.003	.009	.035	0.5
Ws (mm/s)	.0045	.07	1.2	50*

- **Large particles: Cheng (1997) settling speed relationship**
- **In the model (subject to revision):**

	Clay	Silt	Sand	Gravel	Coal
Diameter (µm)	3	35	500	4,000	354 (effective diameter)
Settling Speed (mm/s)	0.0004	1.2	50	273	42

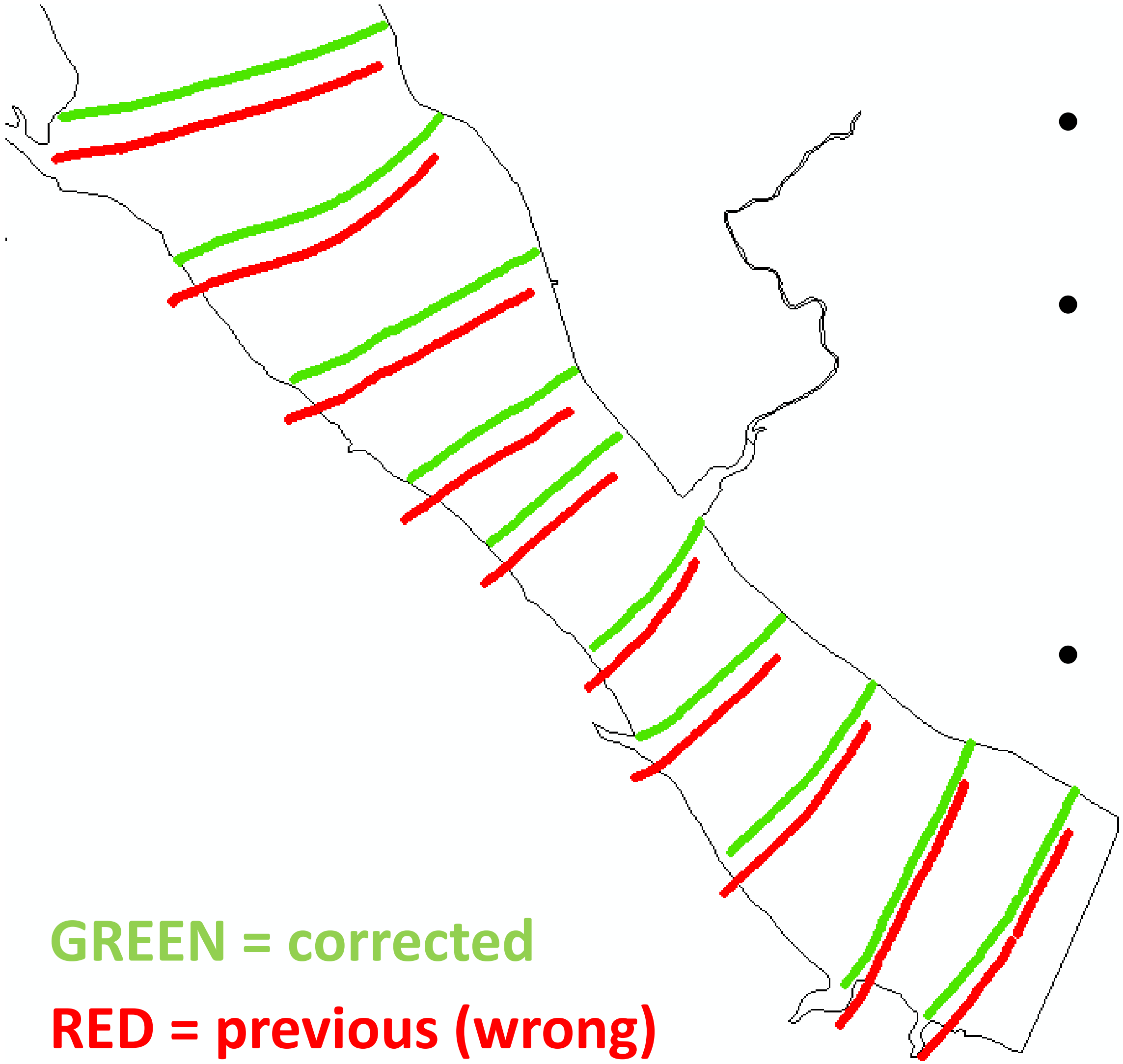
Updated Evaluation of 1996 Bathymetry

- Discovered that 1996 data were in wrong projection:
  - Received in NAD 1983 datum, should have been NAD 1927
- Points shift by ~400 ft and better align to riverbanks
- Changes affect bed elevations, elevation differences:

End	Start	Survey Type	Unweighted Average Difference (ft)	Area-Weighted Average Difference (ft)
2008	1996	Raw	2.38 (before: 0.705)	1.72 (before: 0.433)
2011	2008	Raw	0.204	0.064
2015	1996	Raw	2.69 (before: 1.022)	1.69 (before 0.642)
2015	2008	Raw	0.317	0.210
2015	2011	Raw	0.113	0.145

- However, sediment mass implied by bed elevation difference for 1996 appears to be unrealistically large

Locations Shift When Datum Is Corrected



GREEN = corrected

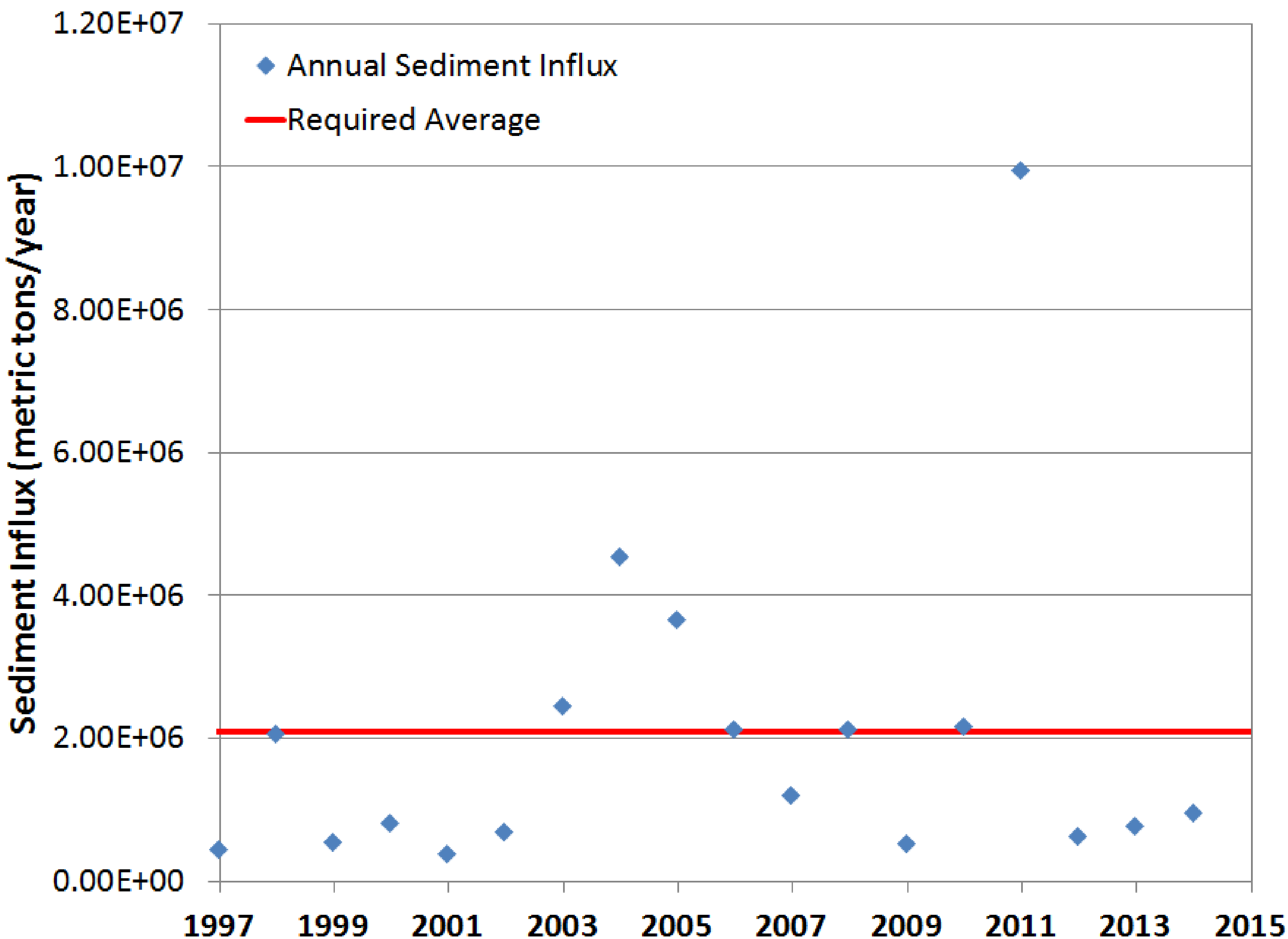
RED = previous (wrong)

- Survey points better aligned with shoreline
- Uncertainties exist because transects do not always go bank to bank
- Consequence: more uncertainty in kriging results because of extrapolation at edges

1996 Survey Results May Be Unrealistic

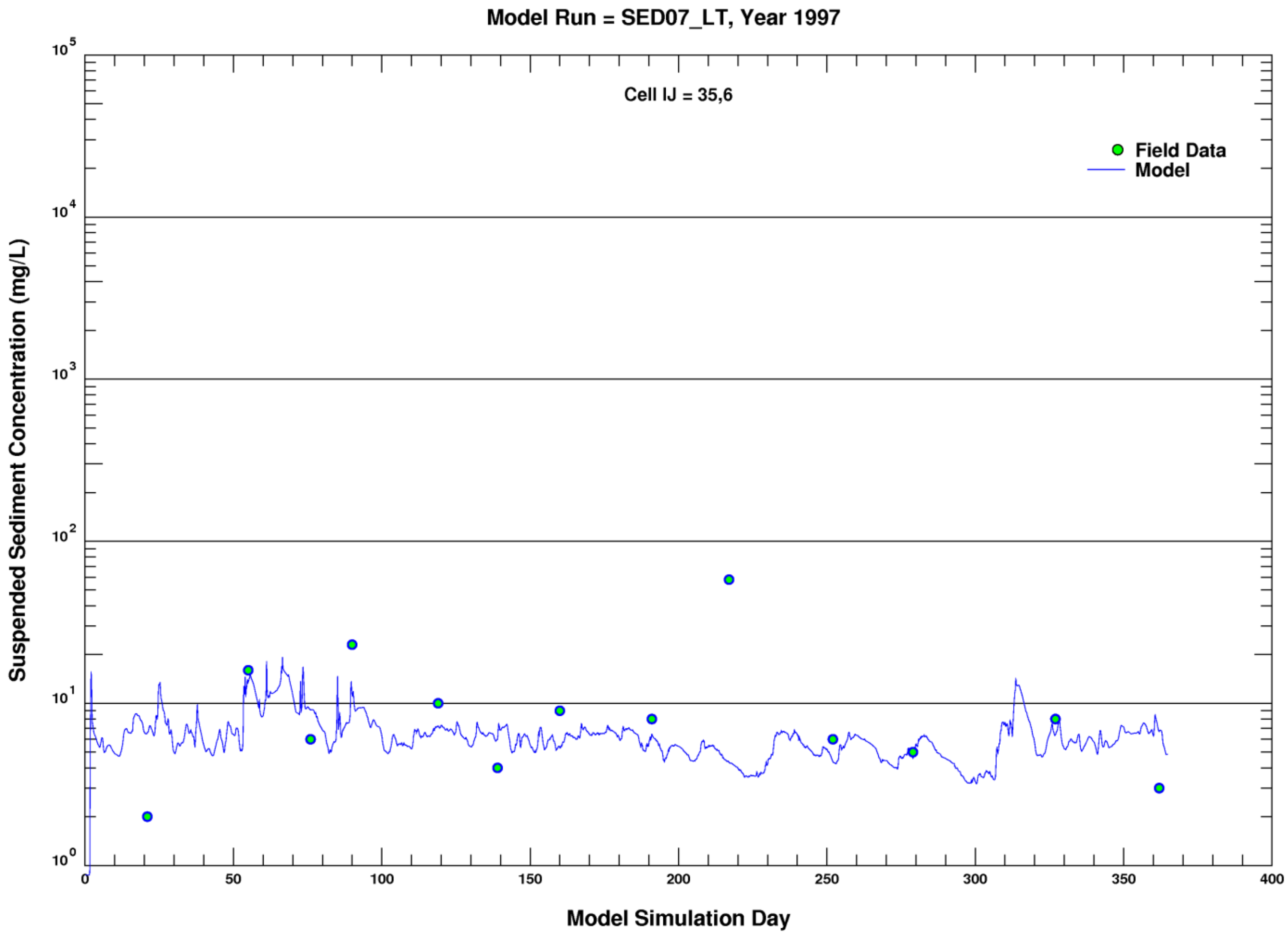
- **Assume differences implied by 1996 survey are right:**
  - **Estimated pond-wide elevation change: +2.69 ft**
  - **Surveyed area of pond: ~7,500 acres**
  - **Sediment volume change: +8.82E+08 ft^3 (+2.50E+07 m^3)**
  - **Average bulk density of bed: ~100 pcf (1,600 kg/m3)**
  - **Time between 2015 and 1996 surveys : ~19 years**
- **Implied deposition rate is unrealistically large:**
  - **2.1 million metric tons/year (2.32 million tons/year)**
  - **Average sediment influx to Pond:**
    - **1997-2014: ~2.0 million metric tons/year**
  - **Would require 105% trapping efficiency if sediment load over Conowingo Dam were zero…**

Net Accumulation and Sediment Influx



Exelon Generation.

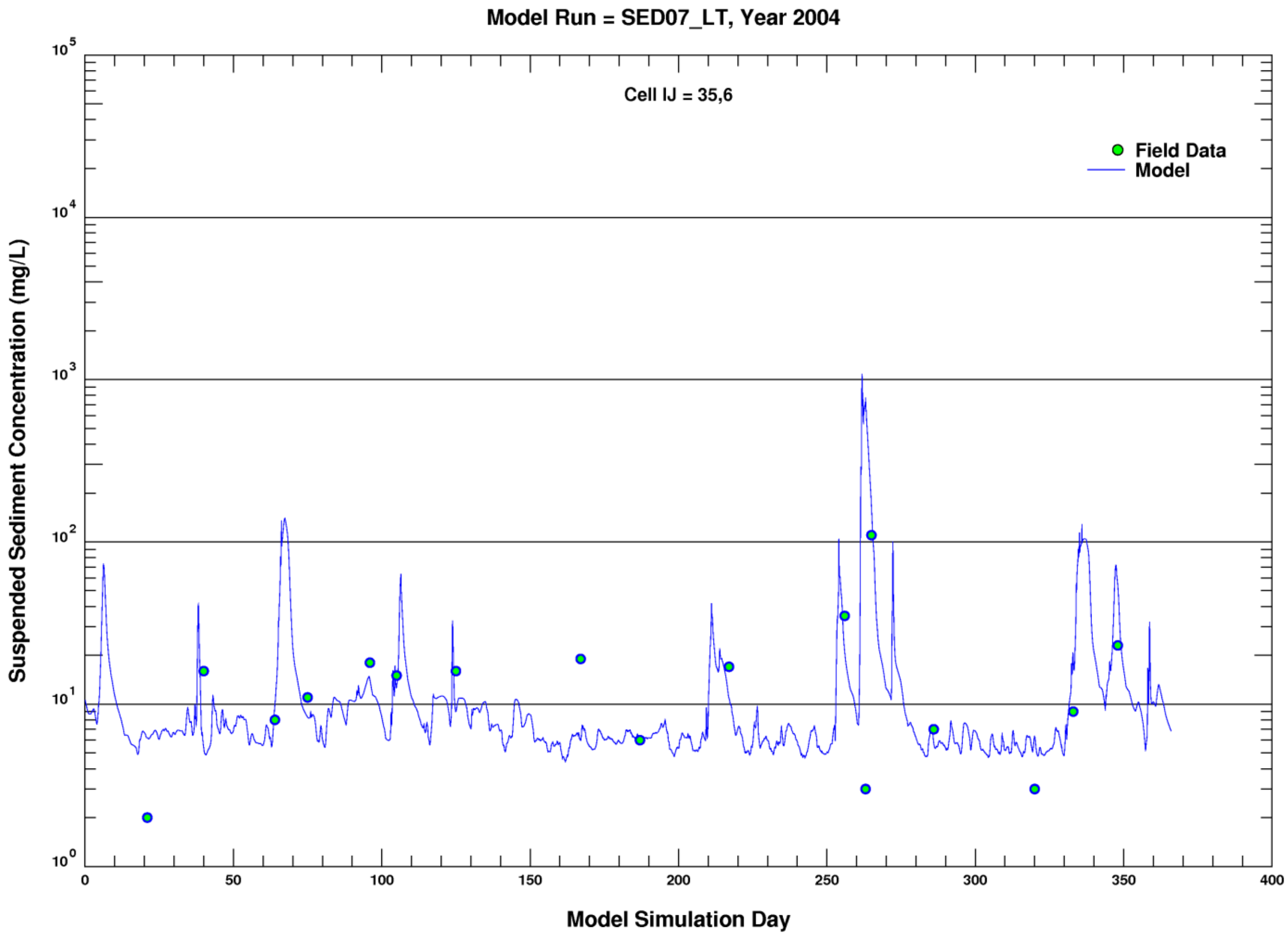
Long-Term Model: SSC at Conowingo 1997



Note: log scale for concentration (maximum for TS Lee in 2011 for short-term run)

Exelon Generation.

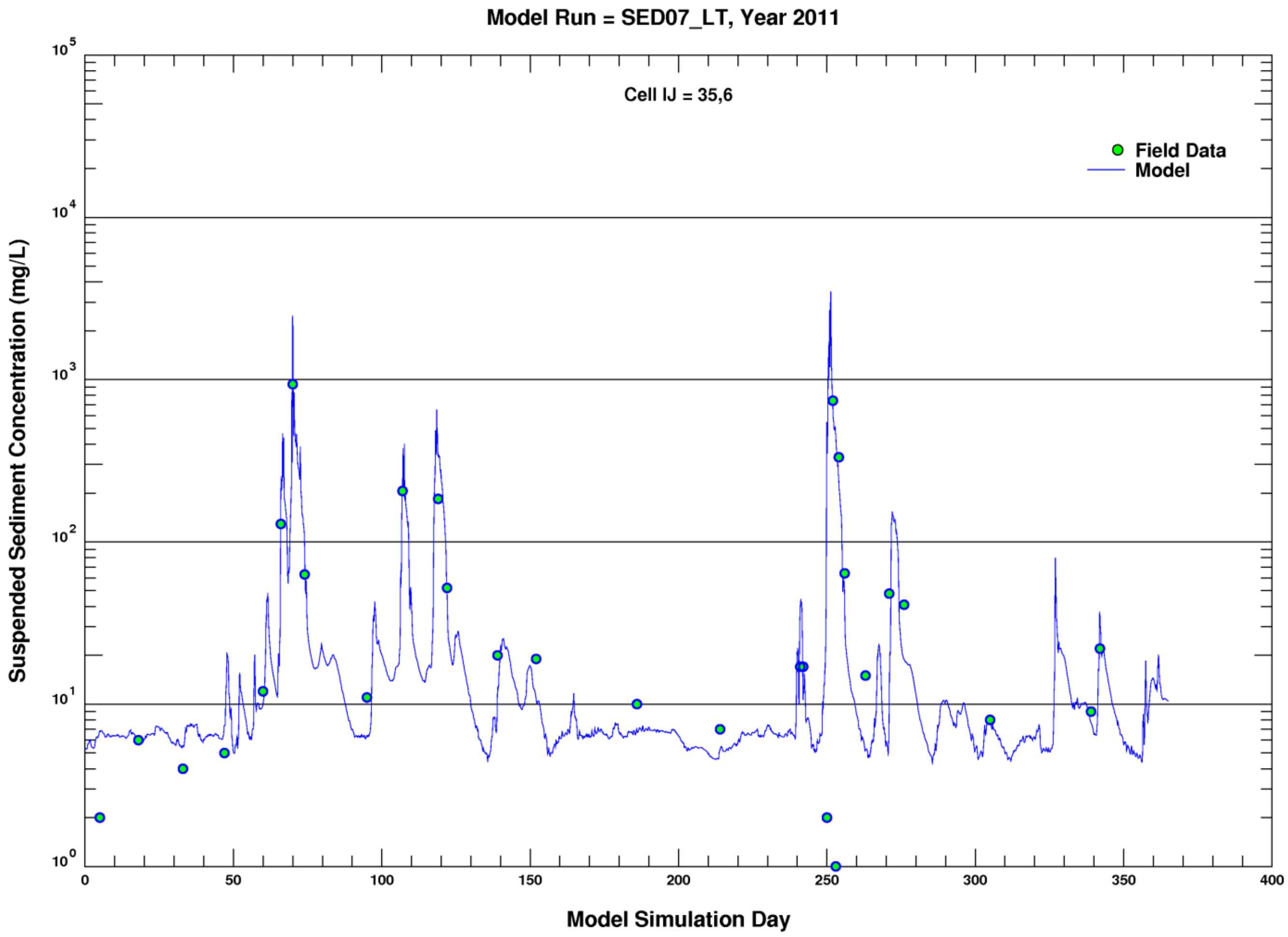
Long-Term Model: SSC at Conowingo 2004



Note: log scale for concentration (maximum for TS Lee in 2011 for short-term run)

Exelon Generation.

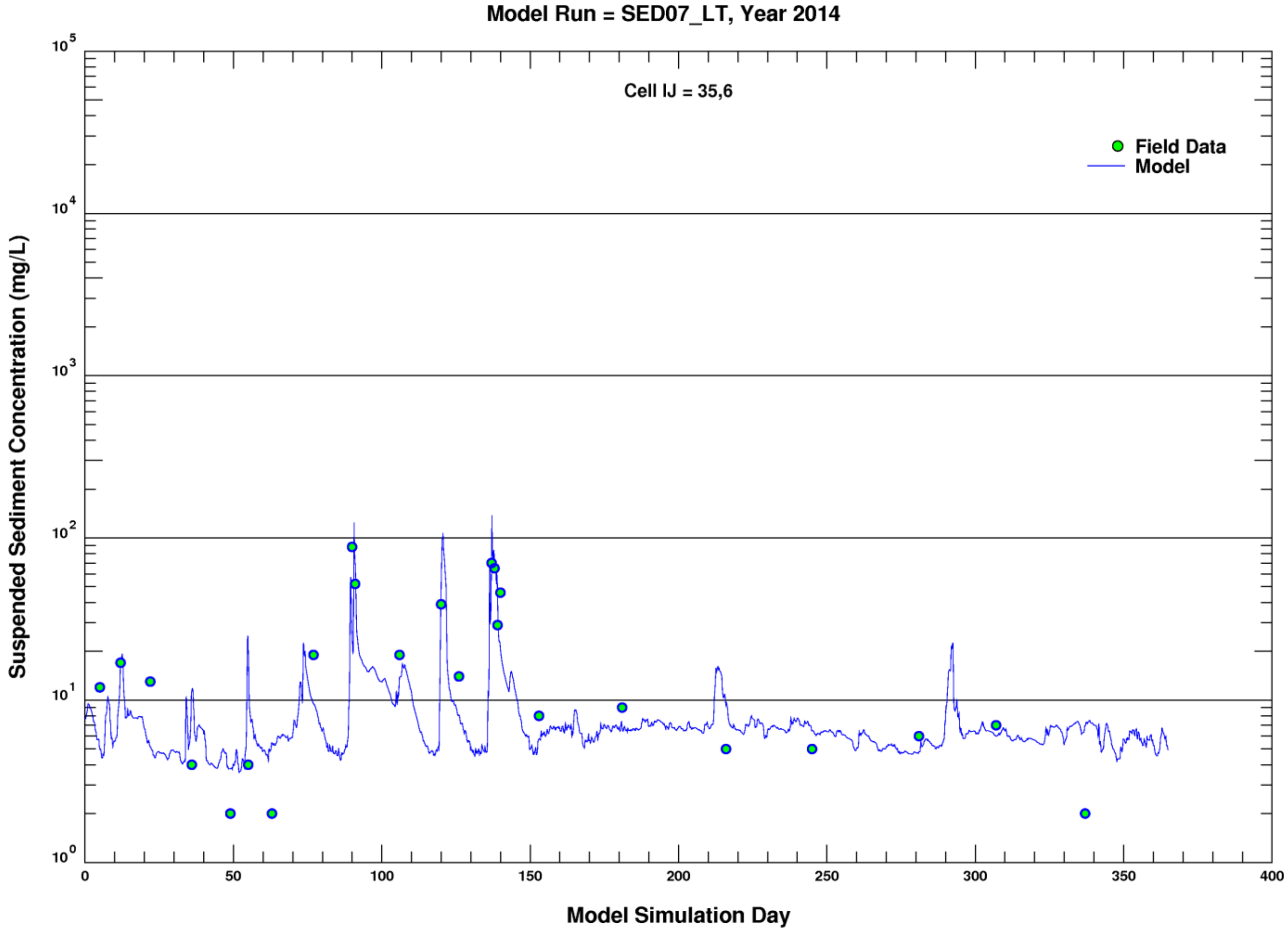
Long-Term Model: SSC at Conowingo 2011



Note: log scale for concentration (maximum for TS Lee in 2011 for short-term run)

Exelon Generation

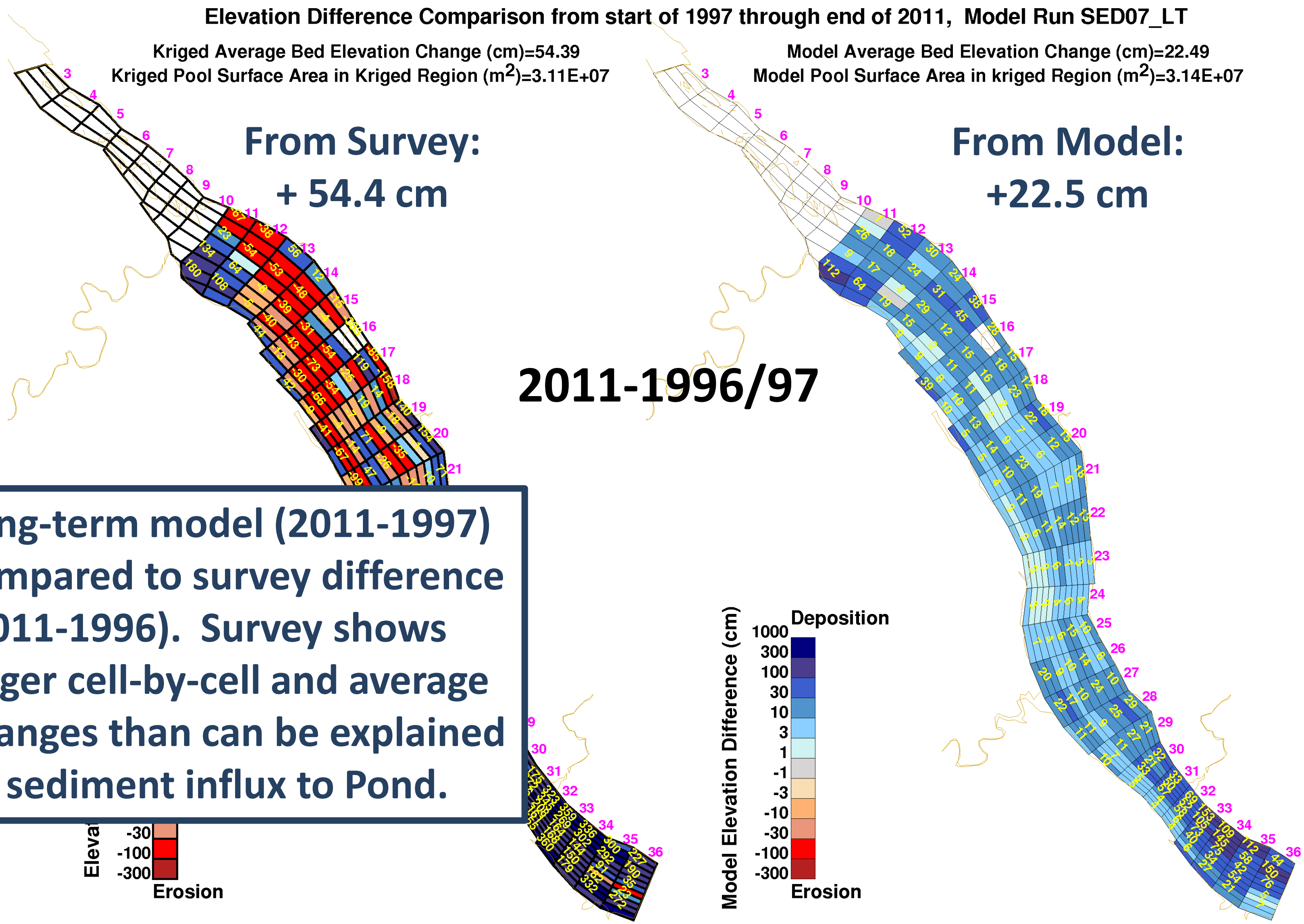
Long-Term Model: SSC at Conowingo 2014



Note: log scale for concentration (maximum for TS Lee in 2011 for short-term run)

Exelon Generation

Long-Term Model: Bed Elevation Changes



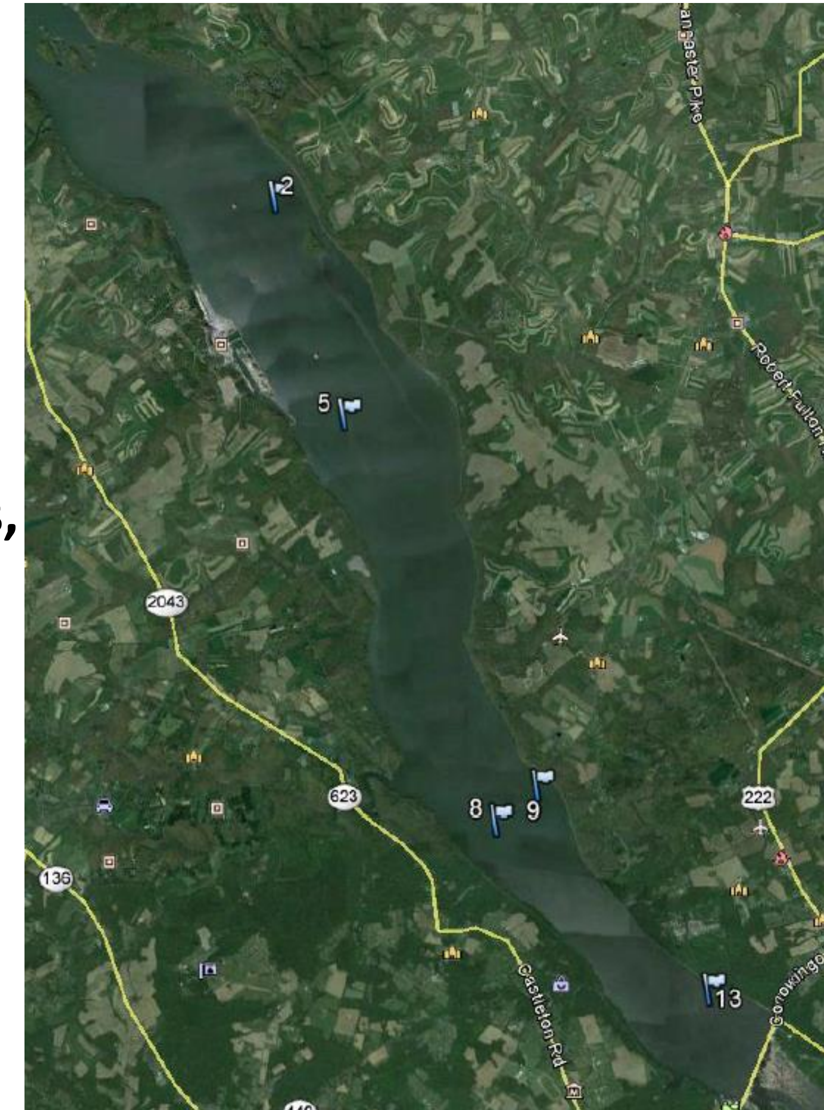
Long-term model (2011-1997) compared to survey difference (2011-1996). Survey shows larger cell-by-cell and average changes than can be explained by sediment influx to Pond.

Diagenesis Analysis

Long and Short Core Diagenesis Data Provided by Jeff Cornwell and Mike Owens (UMCES)

Long cores

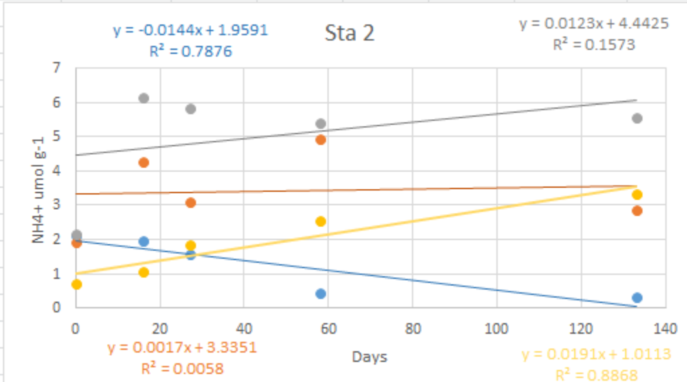
- Incubations of 5 long-cores at 4-5 depth intervals, using 10 cm slices, over a 252-day incubation period (t = 0, 16, 27, 58, 133, 252 days)
- Looked at C, N, P
- NH_4 data is most reasonable, CO_2 too problematic, PO_4 also problematic due to high iron content of cores



Long Core N Diagenesis Analysis

Long core diagenesis collected August 2015
Not amemded with Sulfate

Site	Depth Section	Days	NH4+ umol g-1
Sta 2	5-15	0	2.13741
Sta 2	5-15	16	1.948815
Sta 2	5-15	27	1.587341
Sta 2	5-15	58	0.440055
Sta 2	5-15	133	0.311986
Sta 2	5-15	252	0.131349
Sta 2	25-35	0	1.923955
Sta 2	25-35	16	4.251537
Sta 2	25-35	27	3.107927
Sta 2	25-35	58	4.937703
Sta 2	25-35	133	2.857776
Sta 2	25-35	252	0.084333
Sta 2	45-55	0	2.139464
Sta 2	45-55	16	6.123829
Sta 2	45-55	27	5.844769
Sta 2	45-55	58	5.410675
Sta 2	45-55	133	5.570448
Sta 2	45-55	252	2.283672
Sta 2	75-85	0	0.69927
Sta 2	75-85	16	1.082204
Sta 2	75-85	27	1.864721
Sta 2	75-85	58	2.555667
Sta 2	75-85	133	3.313338
Sta 2	75-85	252	0.521802



					C (mg/g)	N (mg/g)	C/N
Aug-15	Conowingo	2	5-15	0-60	94.95	3.25	34.1
Aug-15	Conowingo	2	25-35	0-60	58.1	2.6	26.1
Aug-15	Conowingo	2	45-55	0-60	119.9	3.85	36.3
Aug-15	Conowingo	2	75-85	60-120	60.3	1.8	39.1
Aug-15	Conowingo	2	75-85	60-120	*	*	*
Aug-15	Conowingo	2	145-155	120-180	89.7	2.1	49.8
Aug-15	Conowingo	2	205-215	180-240	88.2	2.8	36.8
Aug-15	Conowingo	2	265-275	240-300	68.1	3	26.5

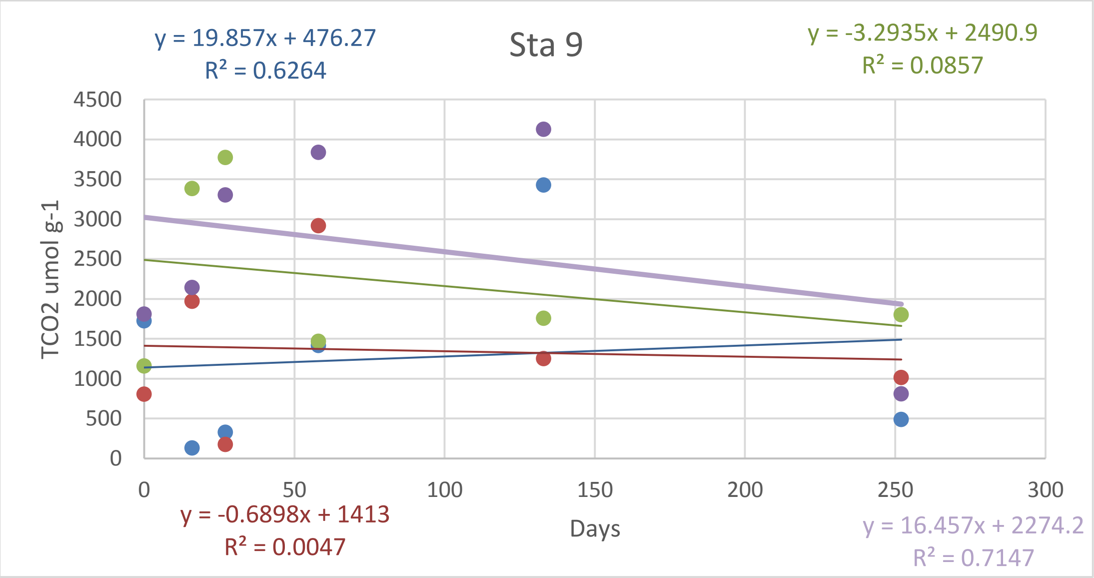
Rates						
		umol/g/d	mg N/g	umol/g	/day	/yr
10	5-15	0	3.25	232.14	0.0000000	0.0000
30	25-35	0.0017	2.6	185.71	0.0000092	0.0033
50	45-55	0.0123	3.85	275.00	0.0000447	0.0163
80	75-85	0.0191	1.8	128.57	0.0001486	0.0542
				Ave	0.0000506	0.0185
				K_{G3}/K_{G2}	2.81%	
				K_{G3max}/K_{G2}	8.25%	

Core	Ave Rate	Max Rate
	/day	/day
2	0.000051	0.000148
5	0.000018	0.000061
8	0.000088	0.000155
9	0.000108	0.000134
13	0.000062	0.000107

Core	Ave Rate	Max Rate
	% G2	%G2
2	2.8	8.2
5	1.0	3.4
8	4.9	8.6
9	6.0	7.5
13	3.4	5.9

Exelon Generation.

Long Core C Diagenesis Analysis



Exelon Generation.

Short Core N and C Diagenesis Analysis

Short cores analyzed at 13 stations, 3 of which had replicate analysis; 0-2 cm depth, over a 252 day period (t = 0, 14, 42, 106, 190, 252)

Fitting equation: $C(t) = f_{meta} * C_{org}(0) * (1 - e^{-k_{diag} t})$

Where

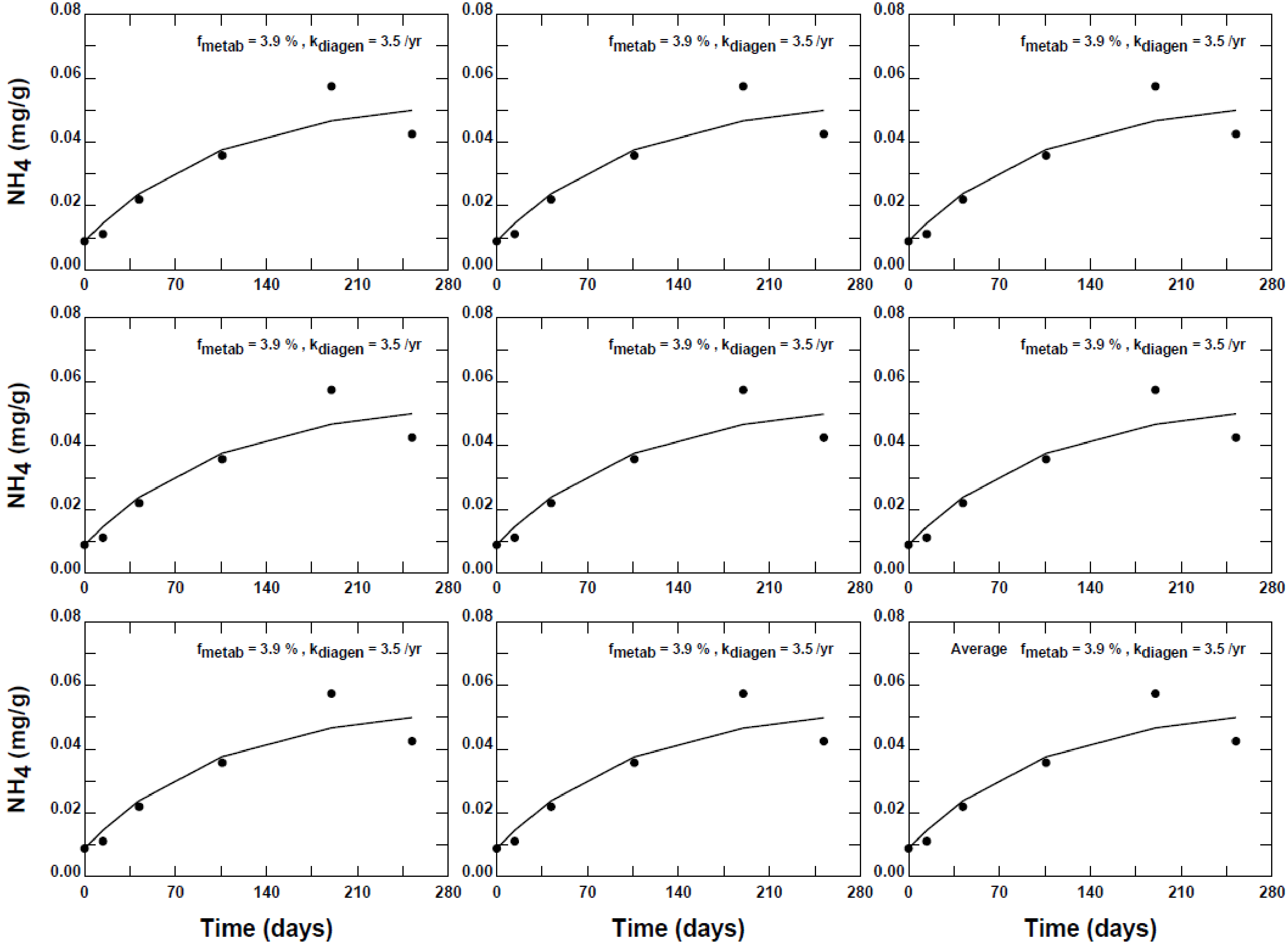
$C(t)$ = concentration of nutrient at time = t

f_{meta} = metabolizable fraction

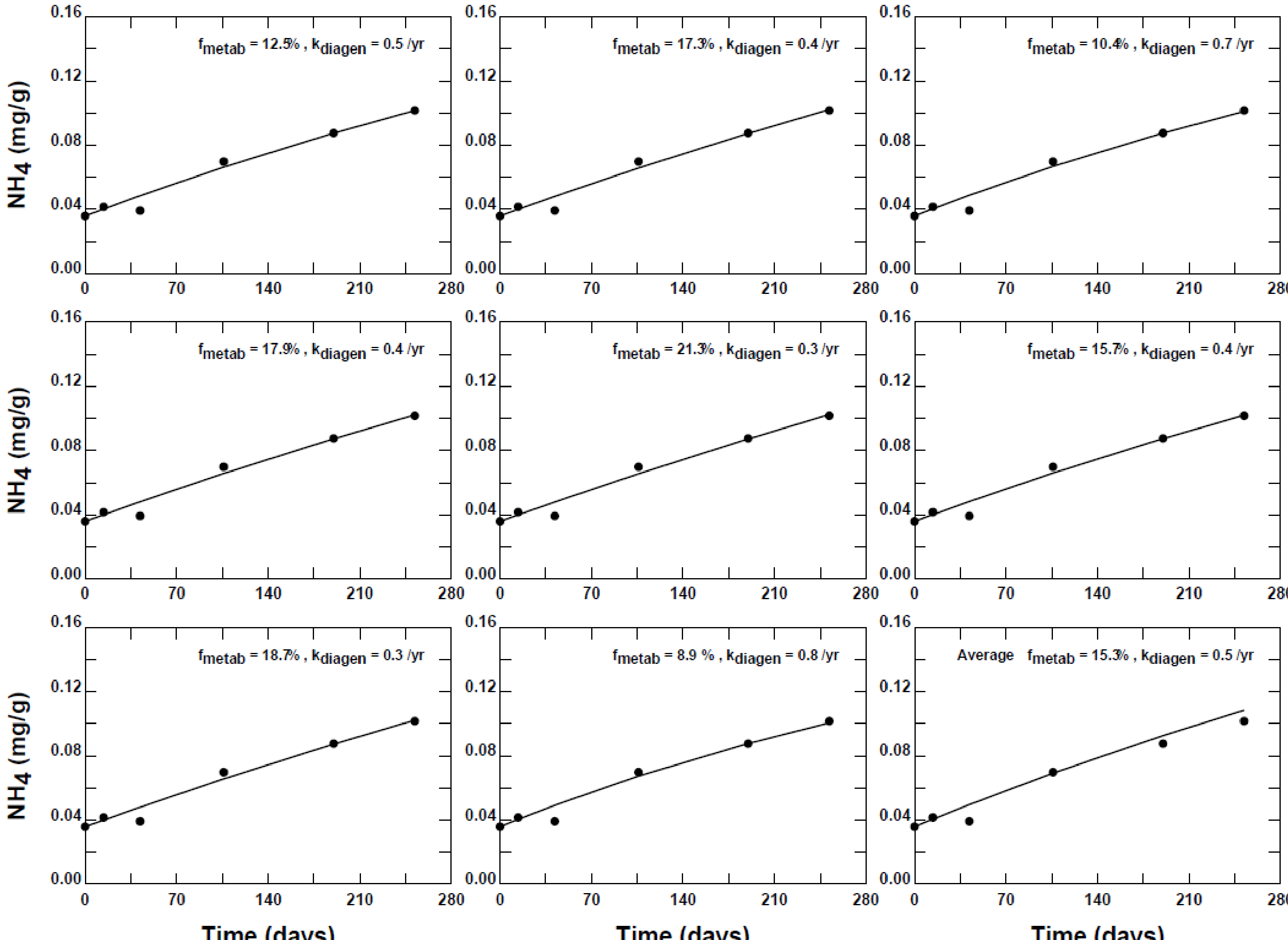
$C_{org}(0)$ = concentration of organic matter at time = 0

k_{diag} = diagenesis rate

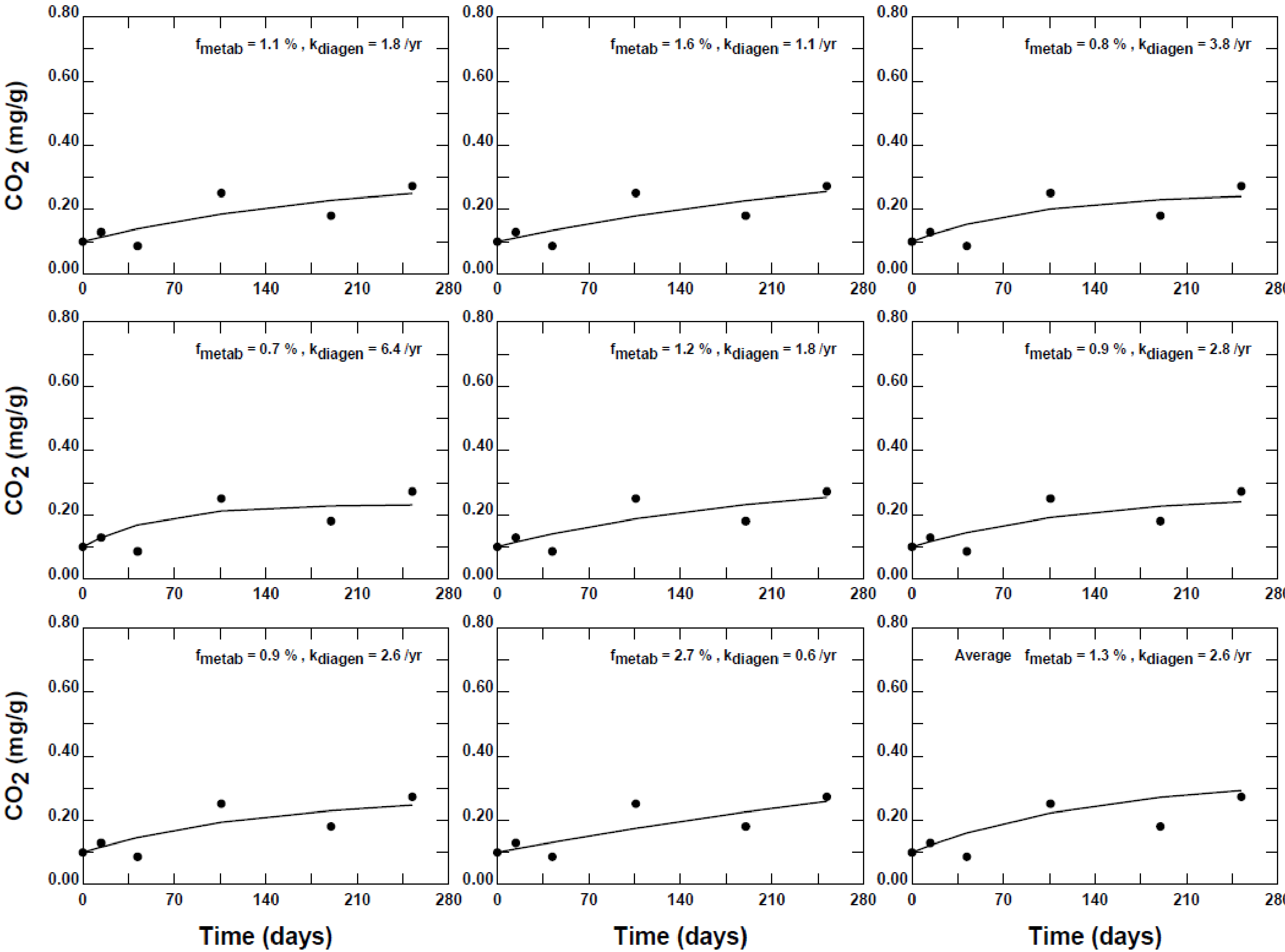
Short Core N Diagenesis Analysis



Short Core N Diagenesis Analysis



Short Core C Diagenesis Analysis



Short Core Diagenesis Analysis Summary

	Nitrogen		Carbon	
Core	f_{meta}	k_{diag} (yr^{-1})	f_{meta}	k_{diag} (yr^{-1})
	3.9	3.5	0.7-2.7	0.6-6.4
2	6.4-6.5	2.7-2.8	1.0-1.1	9.8-10.8
3	9.1-9.2	3.1-3.2	3.8-12.9	0.3-1.5
4	5.6-5.7	1.5-1.6	0.5-1.2	1.7-19.3
4rep	23.7-100	0.1-0.5	1.2-1.3	4.7-7.1
5	23.2-24.3	1.8-2.0	3.9-17.9	0.3-1.6
5rep	10.5	4.1	4.2-13.5	0.2-0.9
6	27.6	0.3-0.7	4.5-9.1	0.4-0.9
7	16.4-16.5	3.4	2.1-6.6	0.9-21.0
8	27.8-41.7	0.7-1.2	1.9-4.7	1.0-14.3
8rep	8.9-21.3	0.3-0.8	1.2-2.4	0.5-1.1
9	31.7-38.7	0.7-1.0	1.5	9.9-14.0
10	15.0	2.5	1.4-4.2	0.8-10.0
11	12.9-13.2	2.1-2.2	4.4-12.8	0.3-1.2
12	15.4	3.7	1.7-3.8	0.8-2.6
13	30-100	0.1-0.4	0.8-3.2	0.6-58.1

SFM

G_1=3.7-12.8 yr^{-1}

G_2=0.66 yr^{-1}

Short Core Diagenesis Summary

Table 2. Rate constants for organic matter remineralization in Southern Chesapeake Bay sediments.*

Expt.	Depth (cm)	SO_4 k_s	ΣCO_2 k_c	PO_4 k_p	NH_4 k_n	Average	Metabolizable Fractions C $G_{m,c}$ (g)	N $G_{m,n}$ (g)	P $G_{m,p}$ (g)
17-1	0–2	3.76	2.01	5.66	3.39	3.70 ± 1.30	21%	26%	20%
17-2	5–7	1.72	0.77	2.34	2.88	1.93 ± 0.79	27%	12%	12%
17-3	12–14	0.22	0.17	0.69	0.47	0.39 ± 0.21	86%	1%	24%
21-1	0–2	5.13	2.42	9.86	8.40	6.45 ± 2.89	3%	5%	1%
21-2	5–7	2.07	1.46	4.60	4.27	3.10 ± 1.36	10%	9%	2%
21-3	12–14	0.37	0.16	0.09	0.30	0.23 ± 0.11	19%	3%	5%
23-1	0–2	4.89	8.10	5.29	14.64	8.23 ± 3.90	2%	4%	5%
23-2	5–7	5.11	3.18	5.07	6.68	5.01 ± 1.24	2%	2%	3%
23-3	12–14	3.10	1.13	2.81	1.46	2.13 ± 0.84	9%	2%	13%
25-1	0–2	0.80	0.51	8.40	6.42	4.03 ± 3.45	25%	13%	43%
25-2	5–7	0.18	0.18	1.10	3.03	1.12 ± 1.16	34%	3%	5%
25-3	12–14	0.35	0.39	1.64	0.00	0.80 ± 0.60	15%	0%	3%
26-1	0–2	1.17	0.70	12.05	6.79	5.18 ± 4.63	44%	38%	14%
26-2	5–7	0.49	0.28	2.70	2.77	1.56 ± 1.18	78%	13%	2%
26-3	12–14	0.58	0.24	1.88	0.47	0.79 ± 0.64	43%	26%	1%

All rate constants are yr^{-1}.

Burdige, 1991

Exelon Generation.

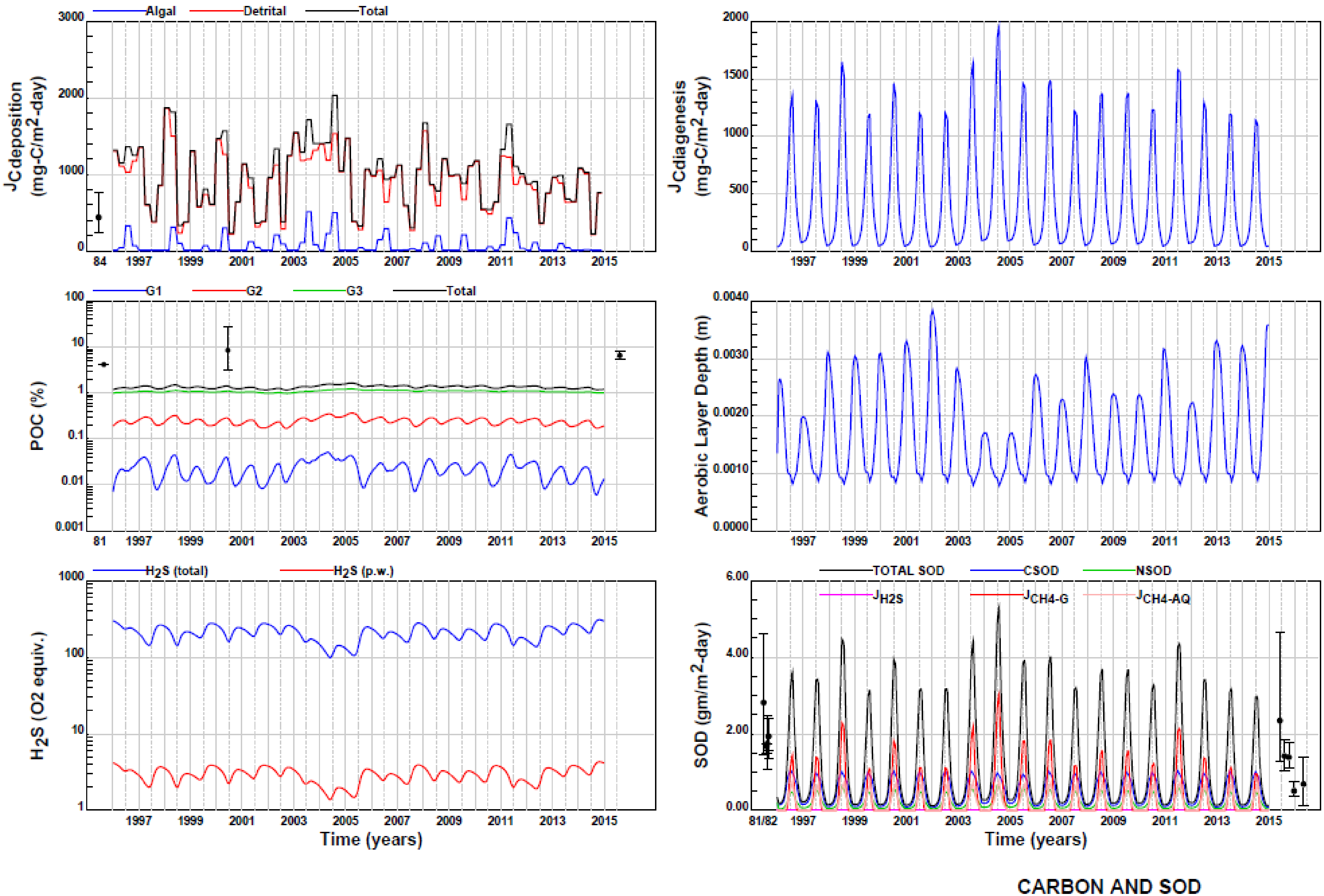
Non- Algal POM G-fractions from Standalone SFM

Estimated from SFM

	Carbon			Nitrogen			Phosphorus		
Run	fG1	fG2	fG3	fG1	fG2	fG3	fG1	fG2	fG3
05	0.10	0.40	0.50	0.10	0.50	0.40	0.25	0.45	0.30
10	0.15	0.35	0.50	0.15	0.45	0.40	0.30	0.40	0.30
11	0.15	0.50	0.35	0.15	0.55	0.30	0.30	0.50	0.20

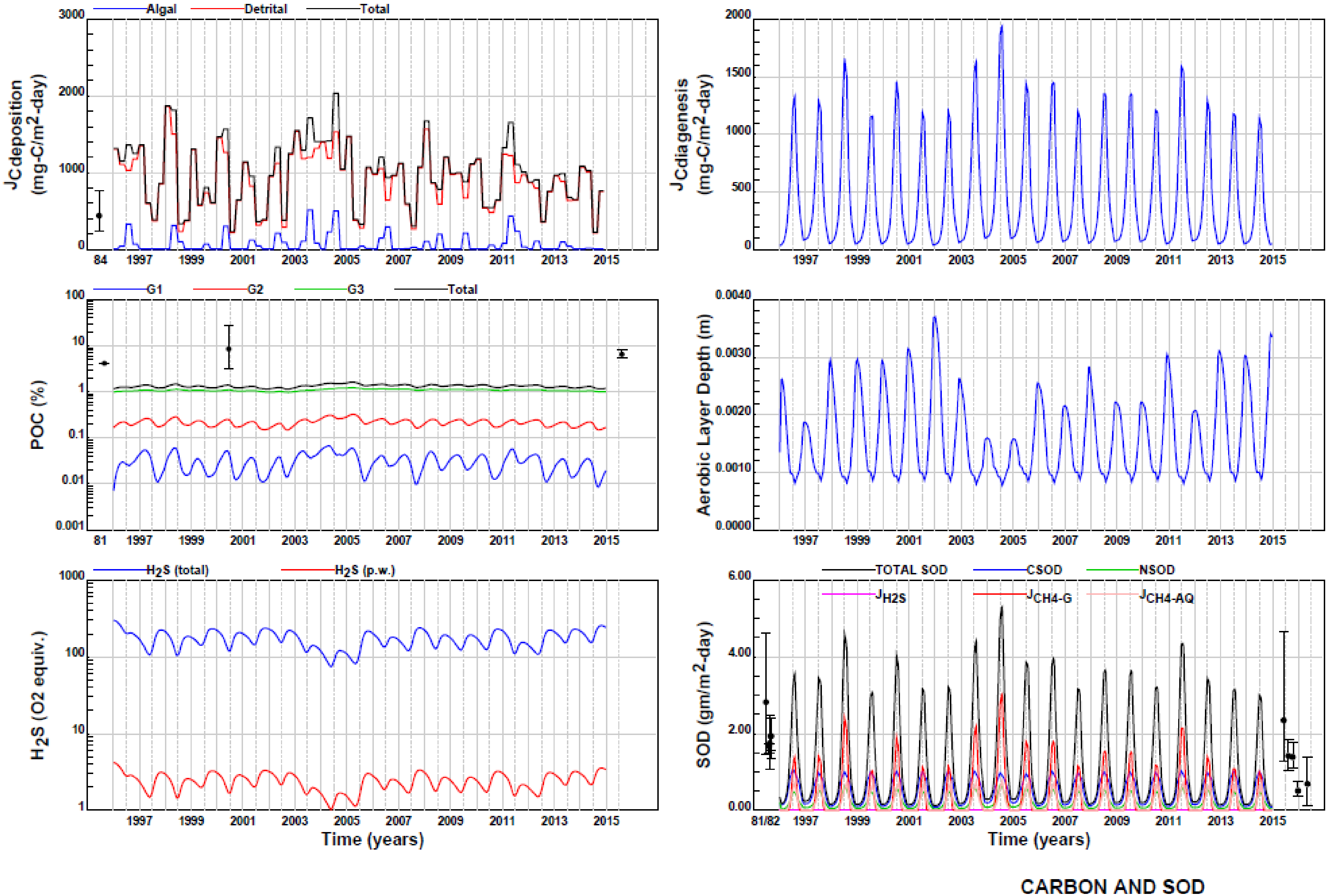
No significant differences in SFM behavior between runs 05 and 10. similar to the findings of Carl Cerco using the Bay water quality model

Run 11 suggests too great an allocation of POM to G_1 and G_2 carbon pools, but more difficult to conclude for N and P



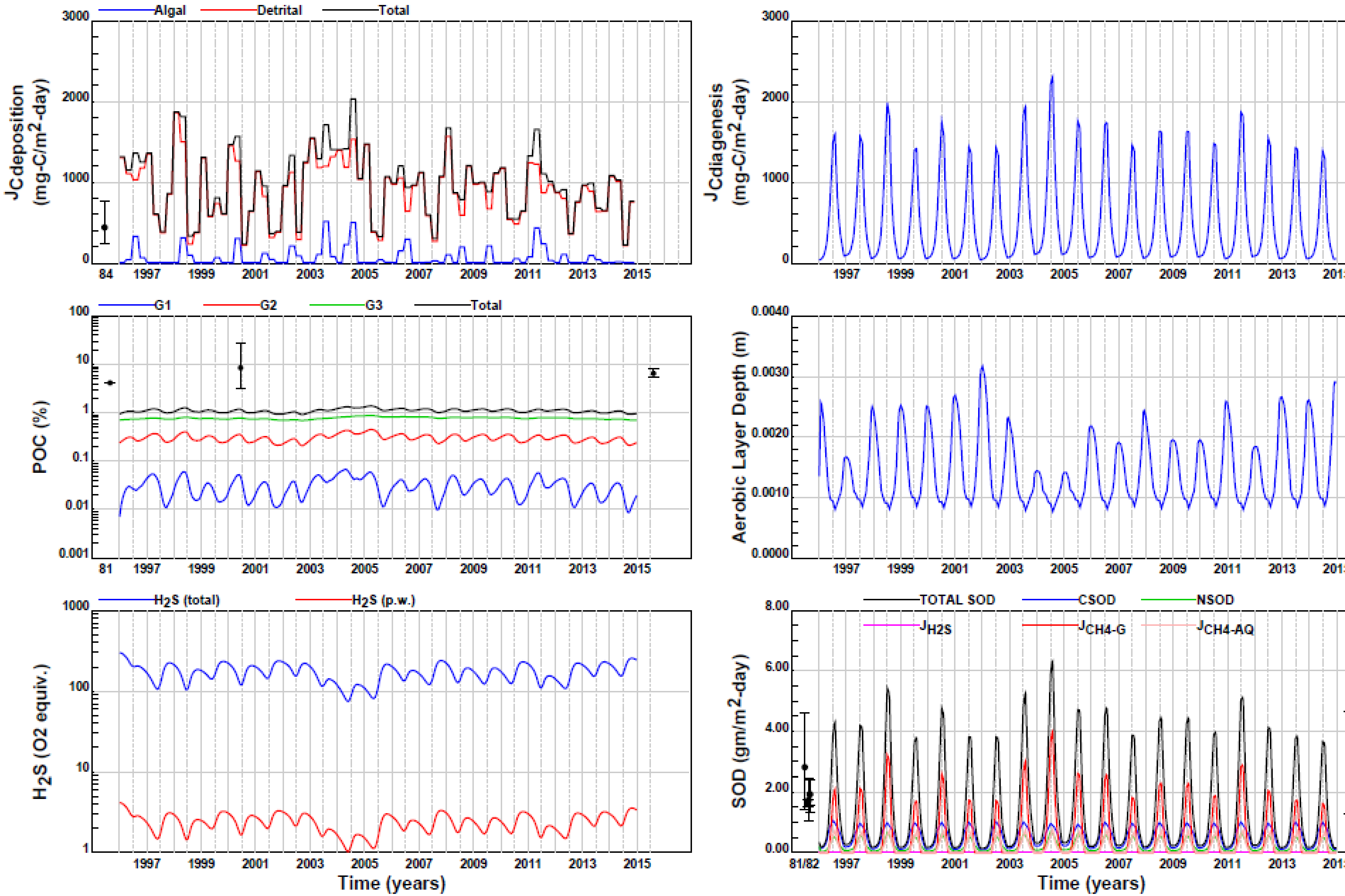
CONOWINGO POND STAND ALONE SFM

05, RUN05



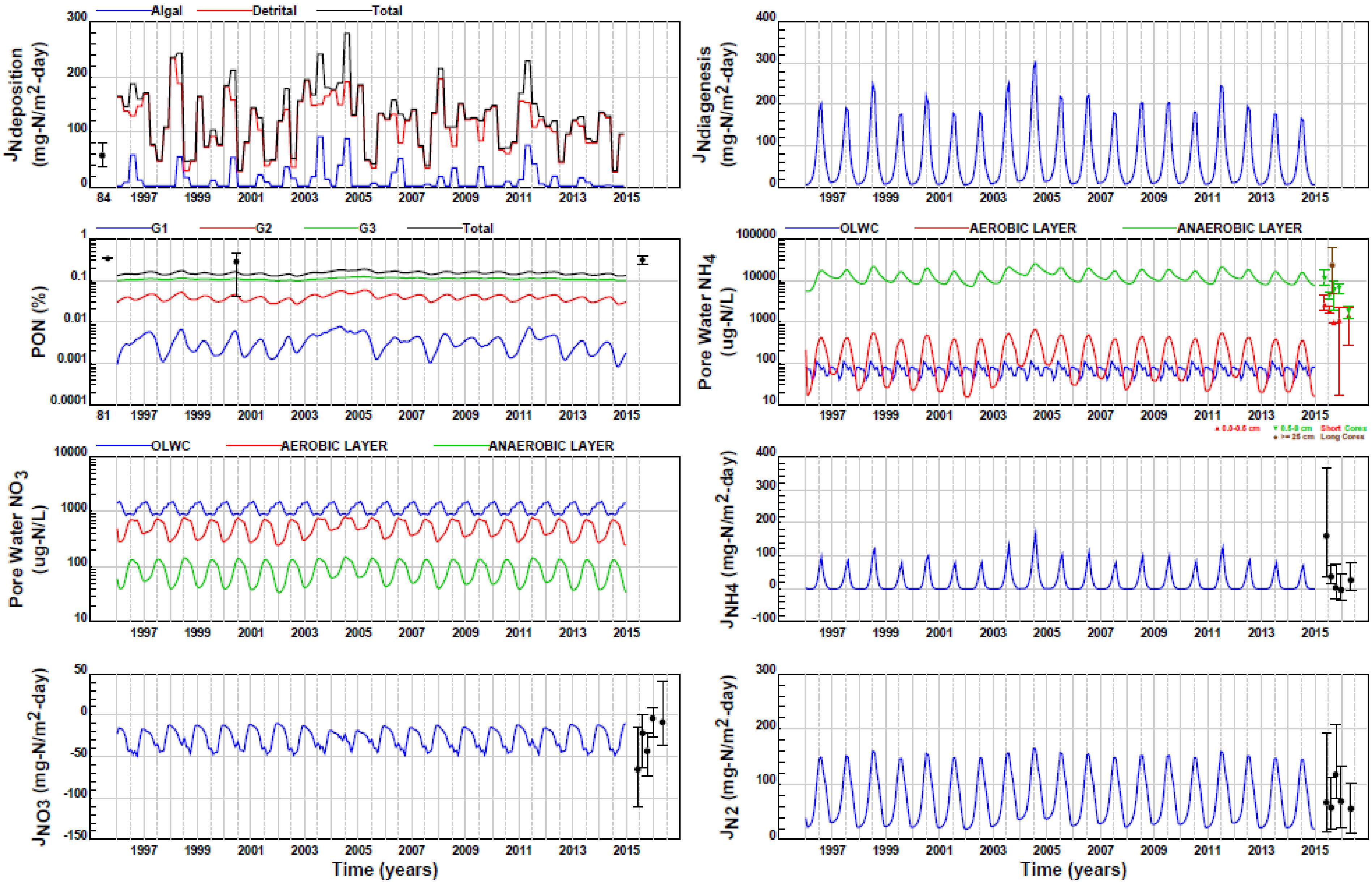
CONOWINGO POND STAND ALONE SFM

10, Kg1=0.010,fG1,fG2



CARBON AND SOD

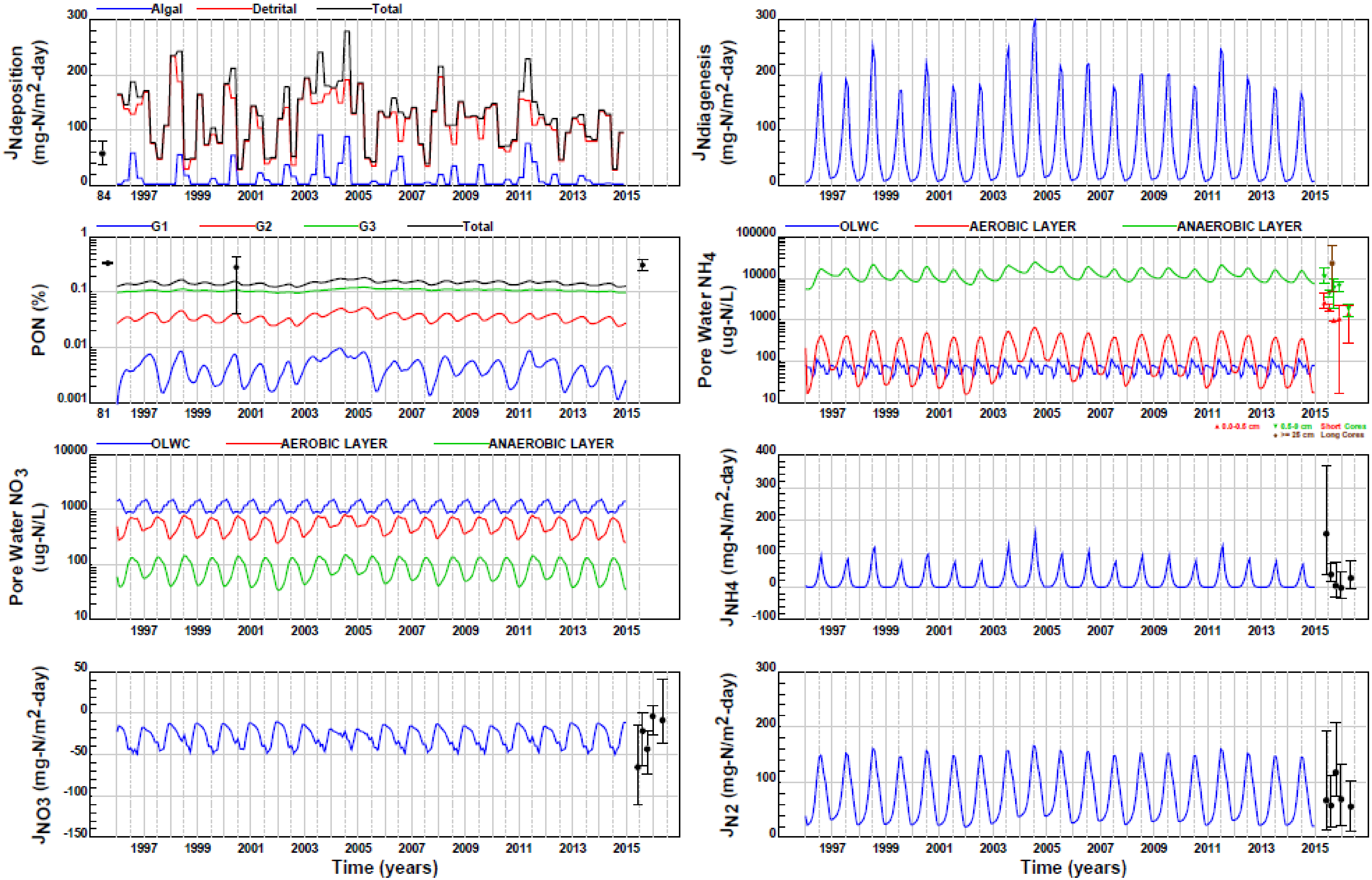
CONOWINGO POND STAND ALONE SFM



NITROGEN

CONOWINGO POND STAND ALONE SFM

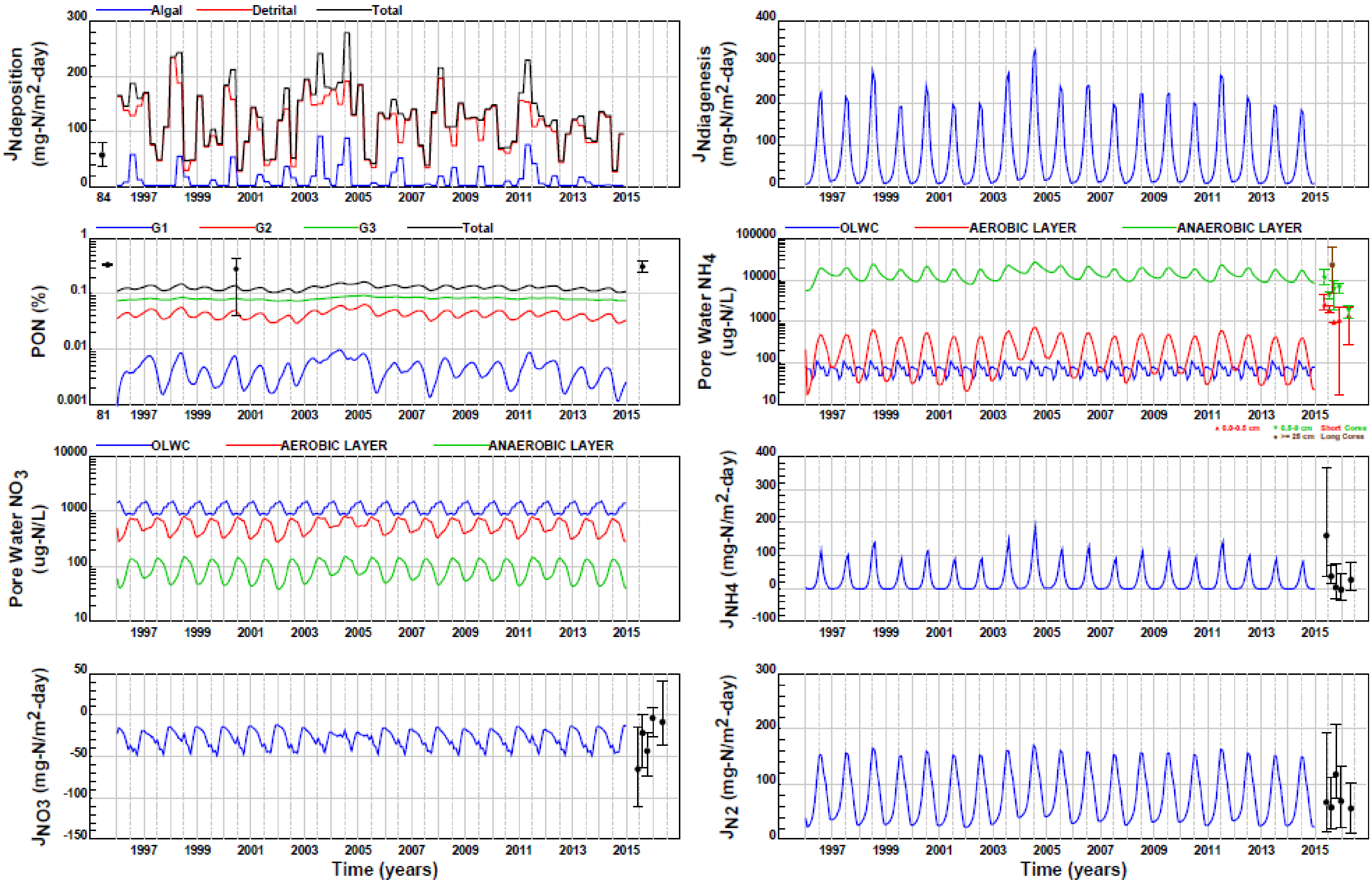
05, RUN05



NITROGEN

CONOWINGO POND STAND ALONE SFM

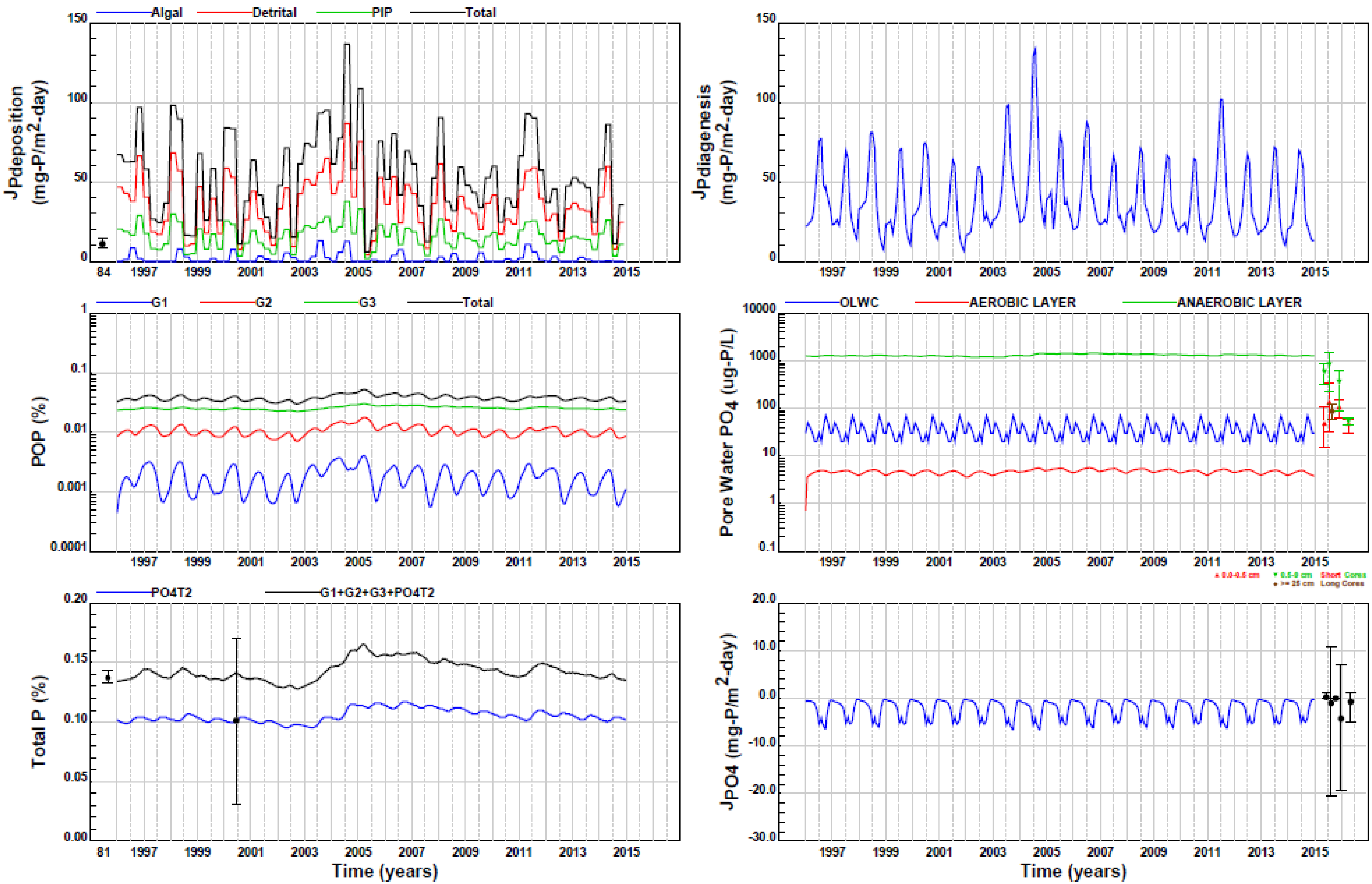
10, Kg1=0.010,fG1,fG2



NITROGEN

CONOWINGO POND STAND ALONE SFM

11, Kg1=0.010,fG1,fG2,fG3



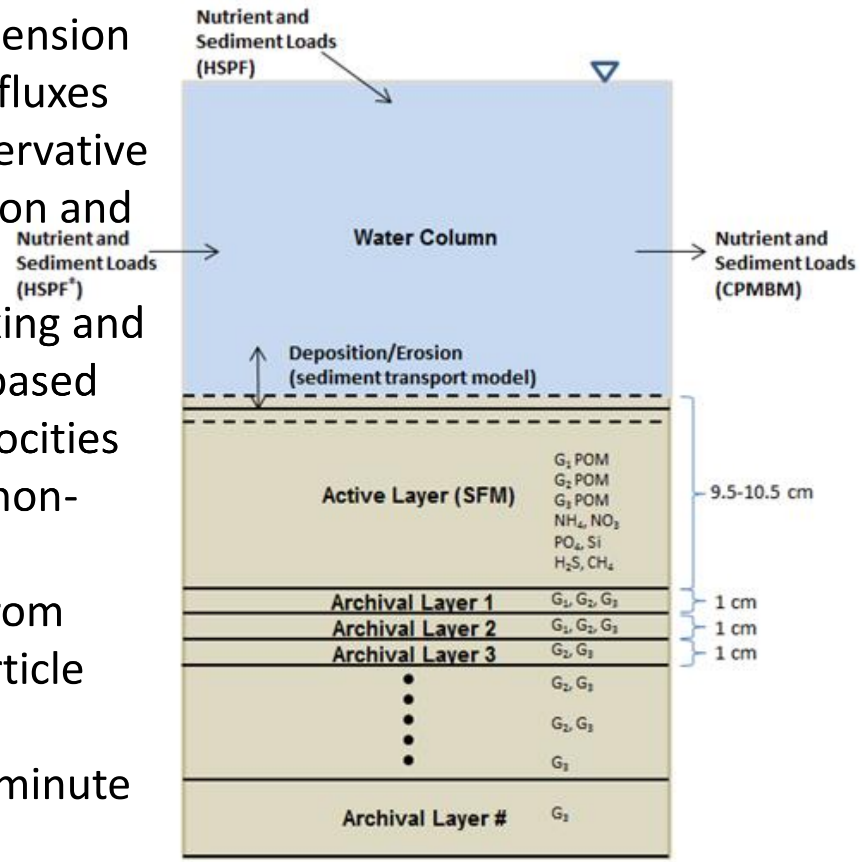
PHOSPHORUS

CONOWINGO POND STAND ALONE SFM

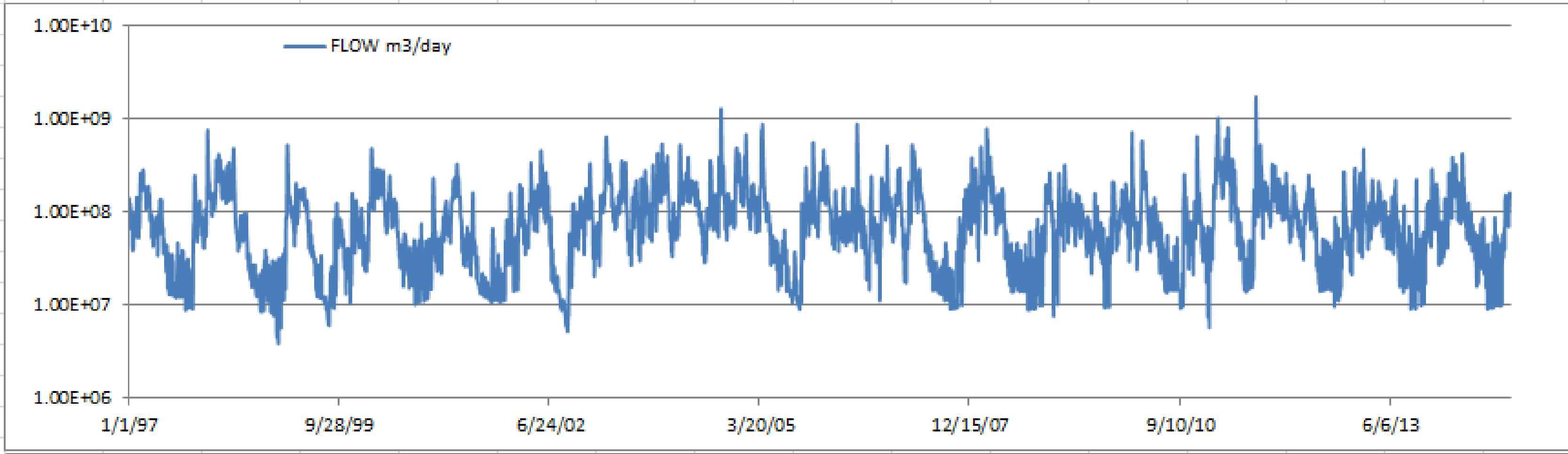
05, RUN05

CPMBM - Archive Stack SFM

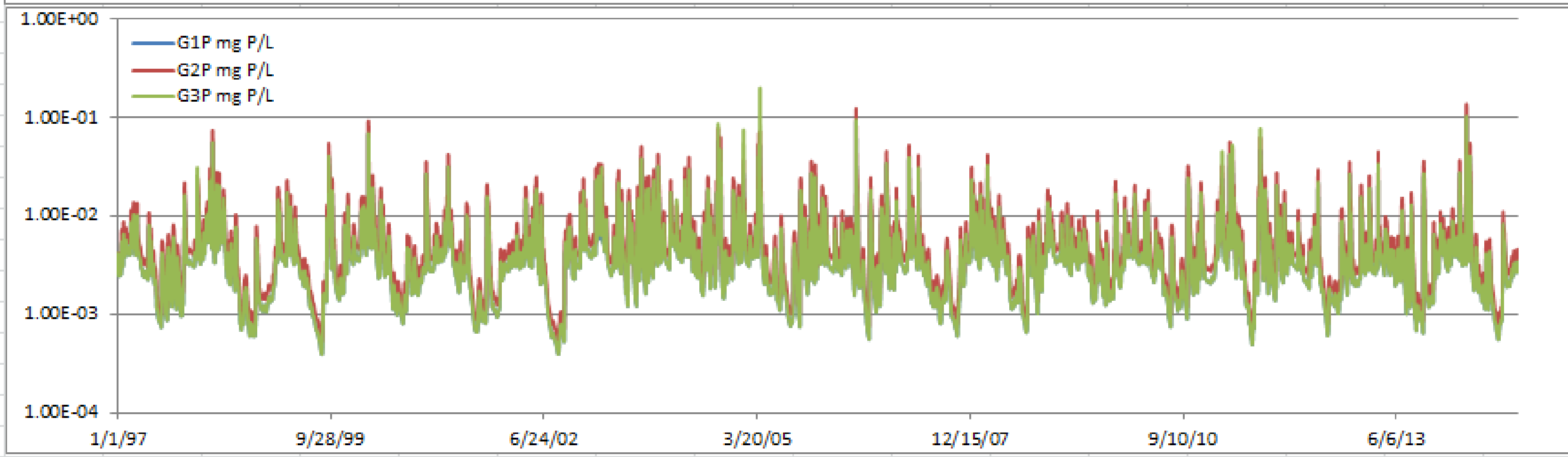
- The water quality portion of the CPMBM uses an archive stack version of the SFM
- Provides spatial detail of deposition and resuspension of POM and PIP as well as SFM driven nutrient fluxes
- Water column constituents are treated as conservative variables and only consider settling, resuspension and flux of inorganic nutrients
- Information from ECOMSED: ECOM – flow, mixing and temperature; SED – settling velocities of POM based on settling rates of cohesives, resuspension velocities based on gross resuspension of cohesives and non-cohesives
- Changes in active layer thickness determined from deposition of cohesives, non-cohesives and particle size bulk densities
- ECOMSED information passed to RCA using 15 minute averages
- Holtwood flows from ECOMSED with concentrations based on EPA watershed model



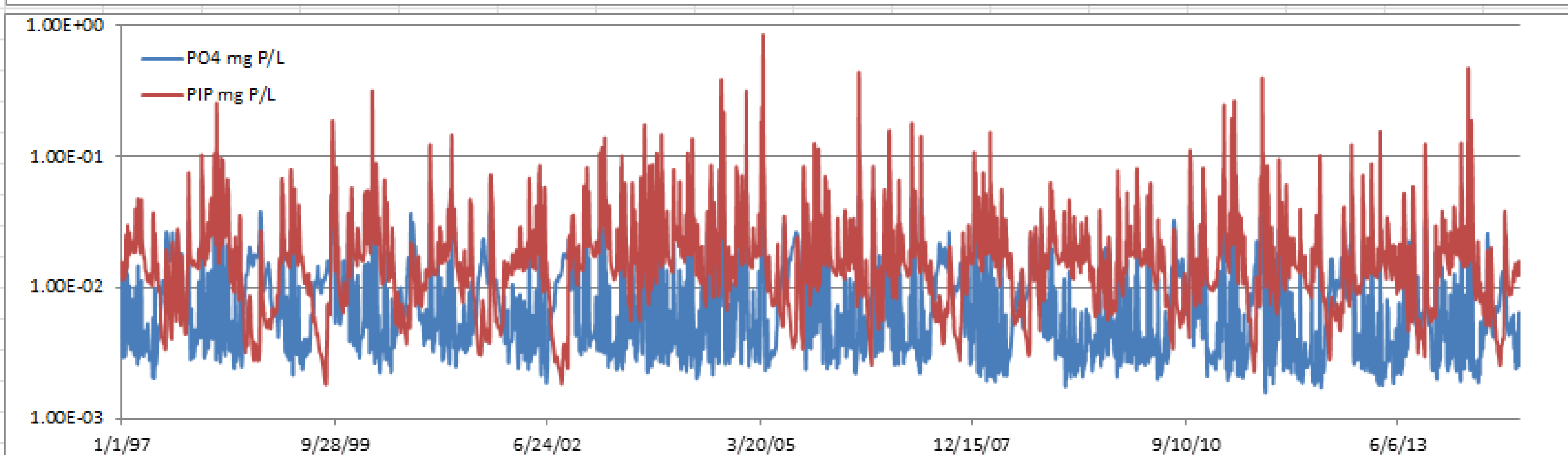
Exelon Generation.



FLOW m3/day
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1/1/97
9/28/99
6/24/02
3/20/05
12/15/07
9/10/10
6/6/13

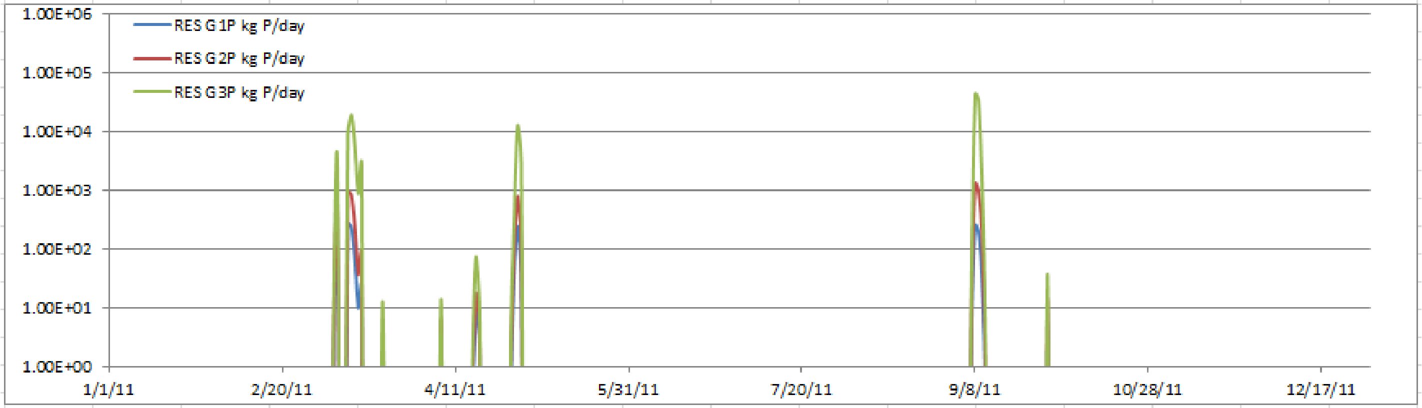


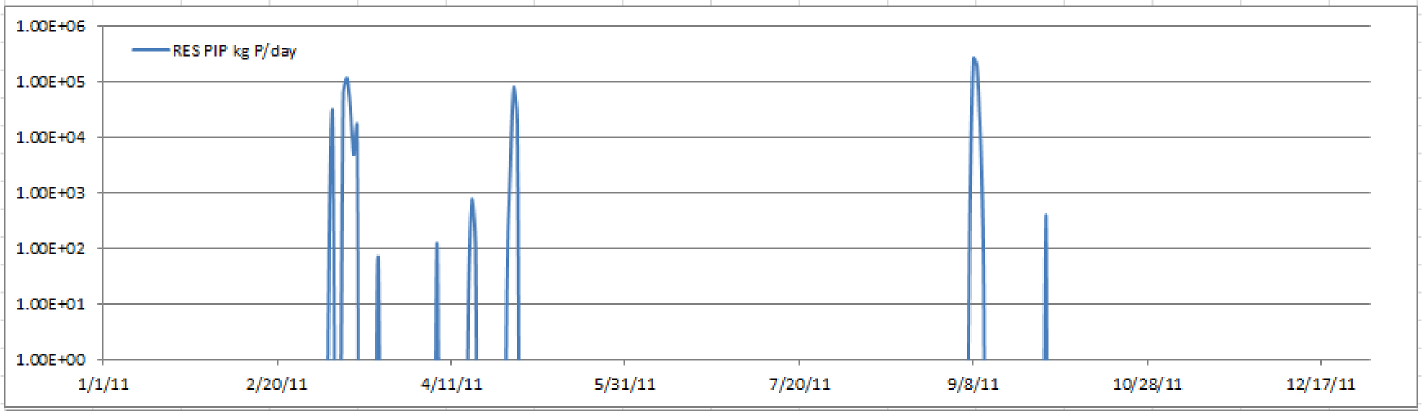
G1P mg P/L
G2P mg P/L
G3P mg P/L
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1/1/97
9/28/99
6/24/02
3/20/05
12/15/07
9/10/10
6/6/13

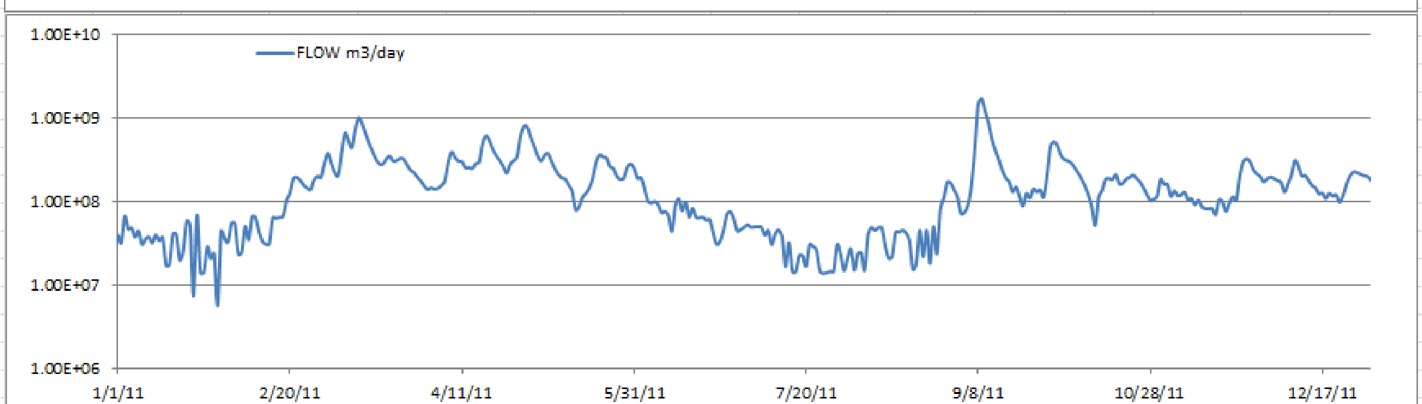


PO4 mg P/L
PIP mg P/L
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1/1/97
9/28/99
6/24/02
3/20/05
12/15/07
9/10/10
6/6/13

Archive Stack SFM







Ion Generation


Questions?
Exelon Generation