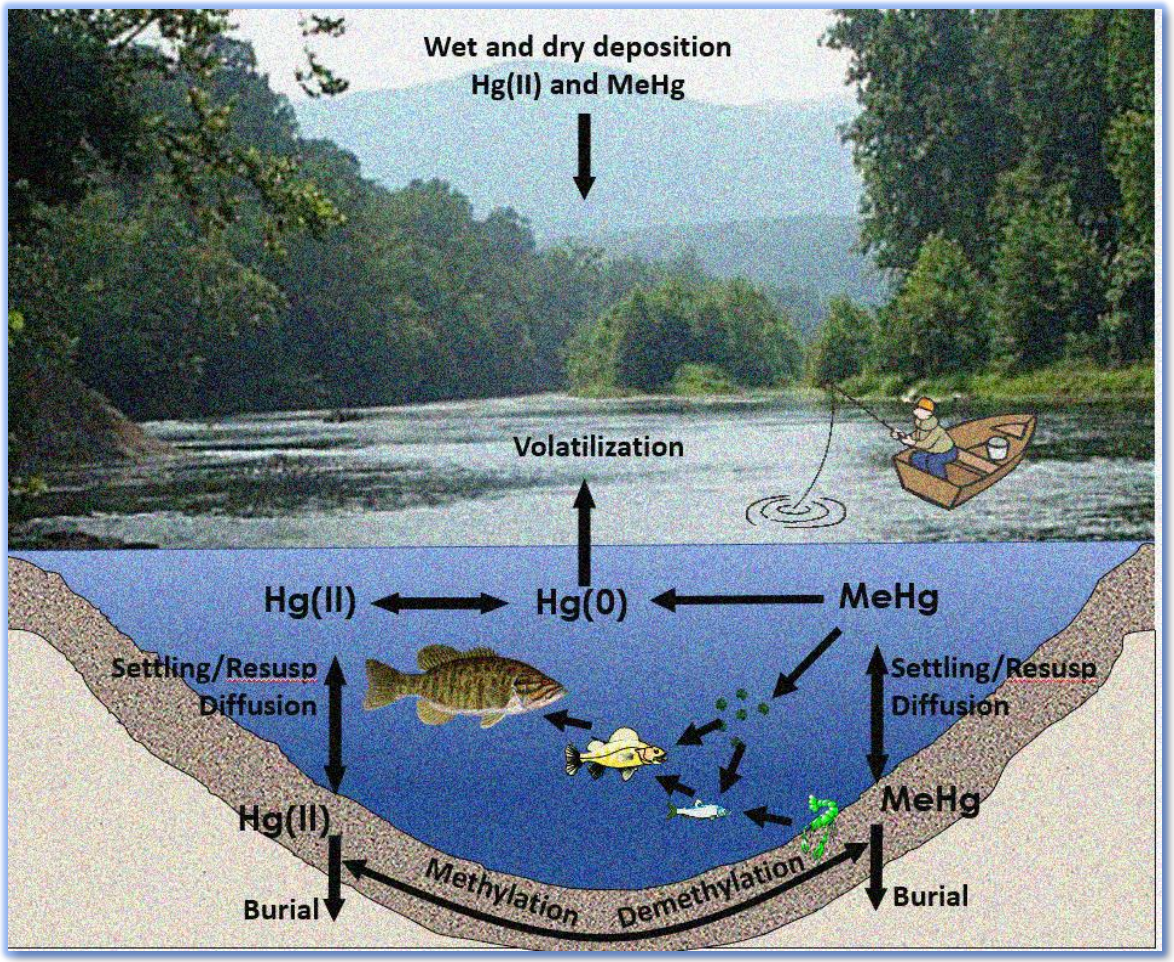
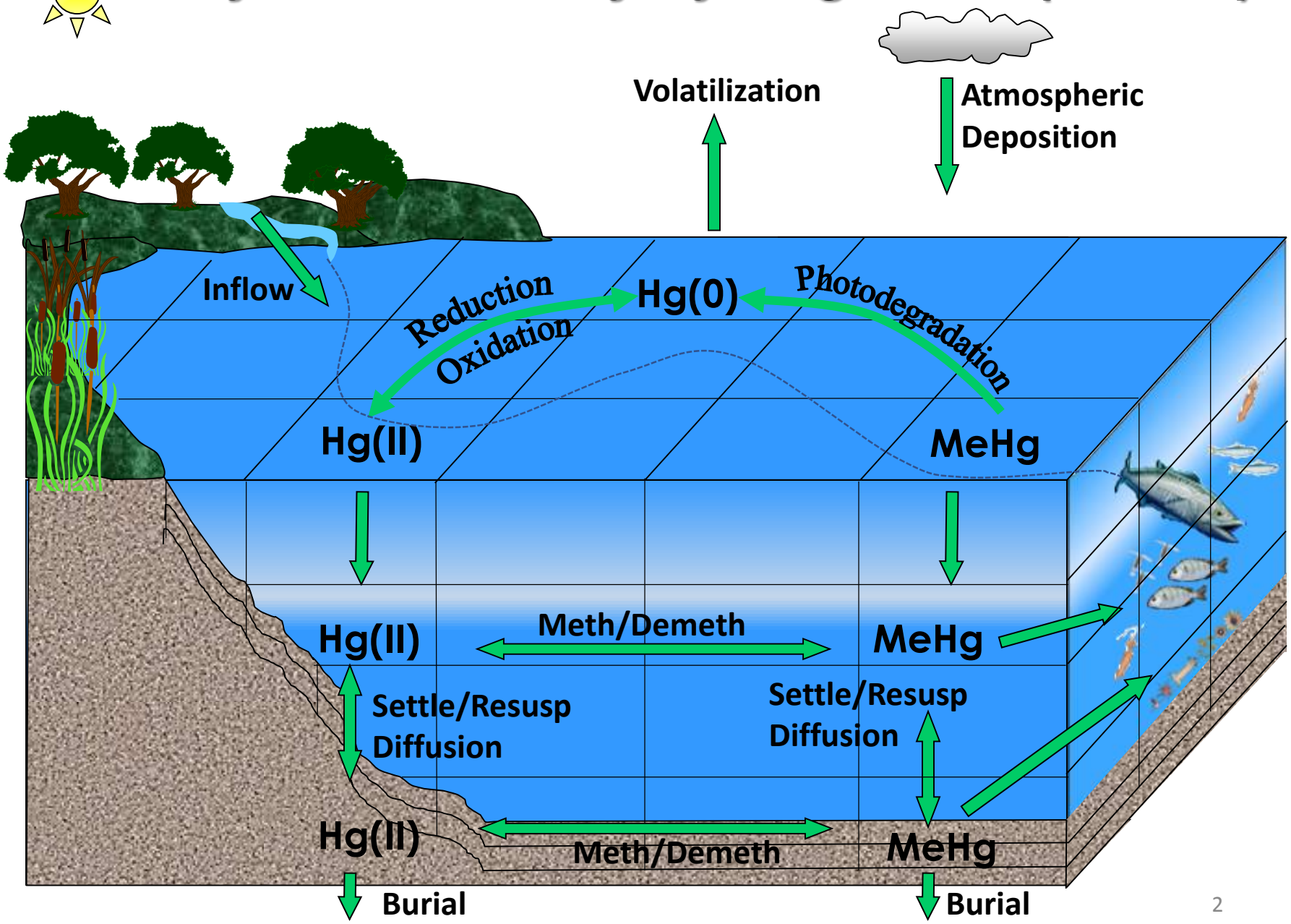
Application of a Mechanistic Mercury Model to the South River: Update

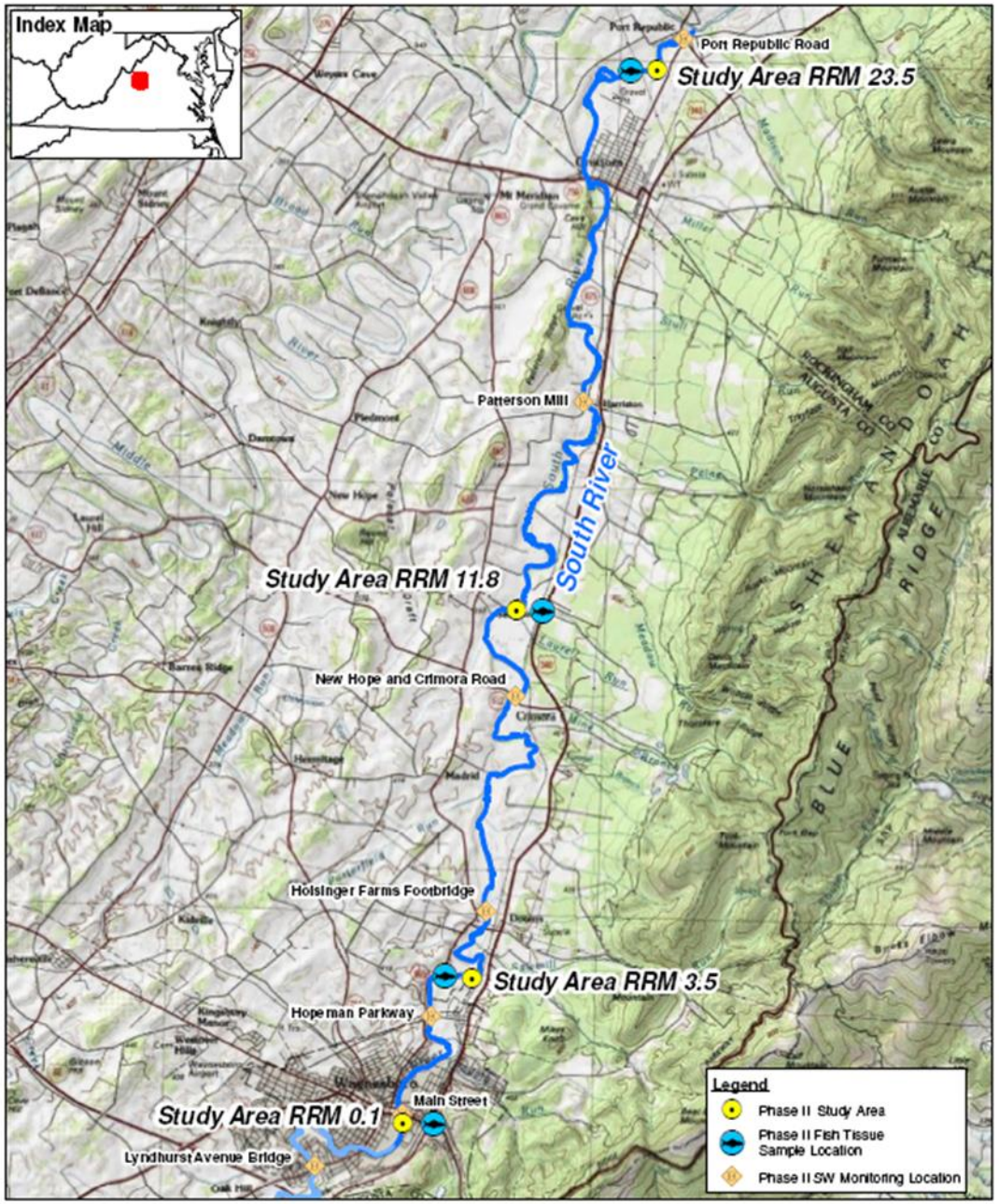


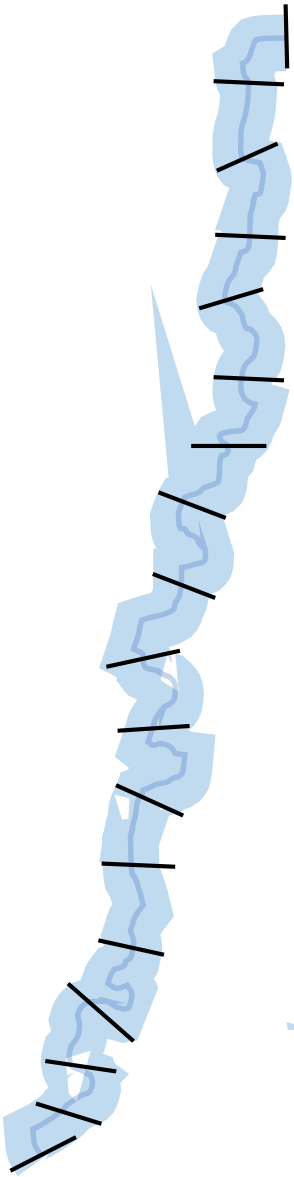
Reed Harris
RHE Ltd.

July 24, 2018

Dynamic Mercury Cycling Model (D-MCM)







Model setup

Set of connected cells

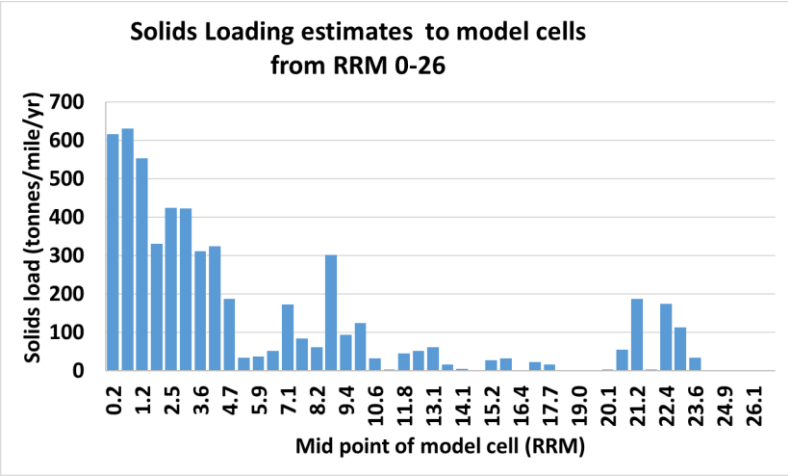
27 miles/43 km

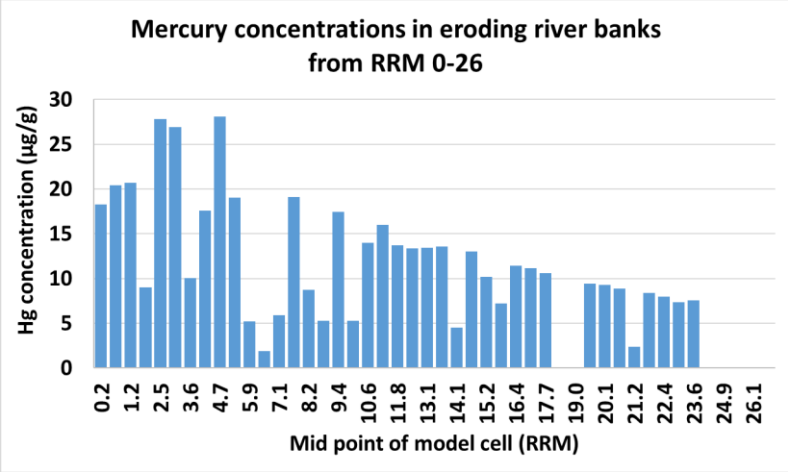
Simulating 2006-2014

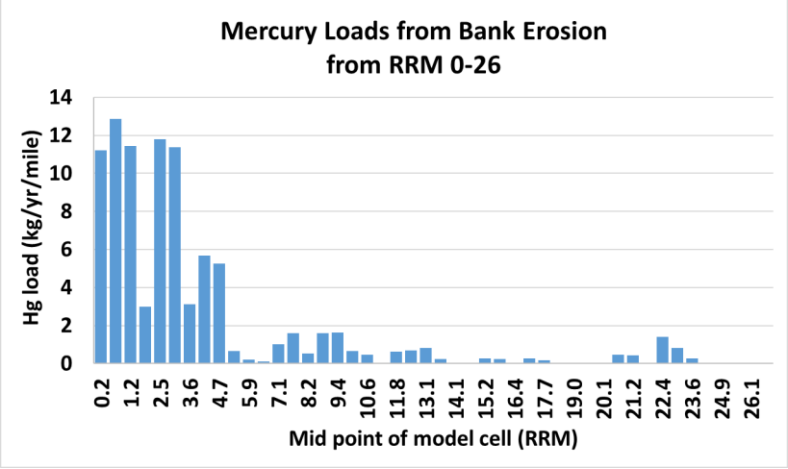
Model Calibration

A few assumptions applied for the results being shown….

- 95% of Hg contamination in banks and sediments is strongly bound to solids (quick to adsorb, slow to desorb)
- Background Hg is mostly exchangeable between solids and dissolved phase
- Model has 4 particle types (sand, silt/clay and two types of fine organics) but they currently have similar Hg partitioning in simulations.

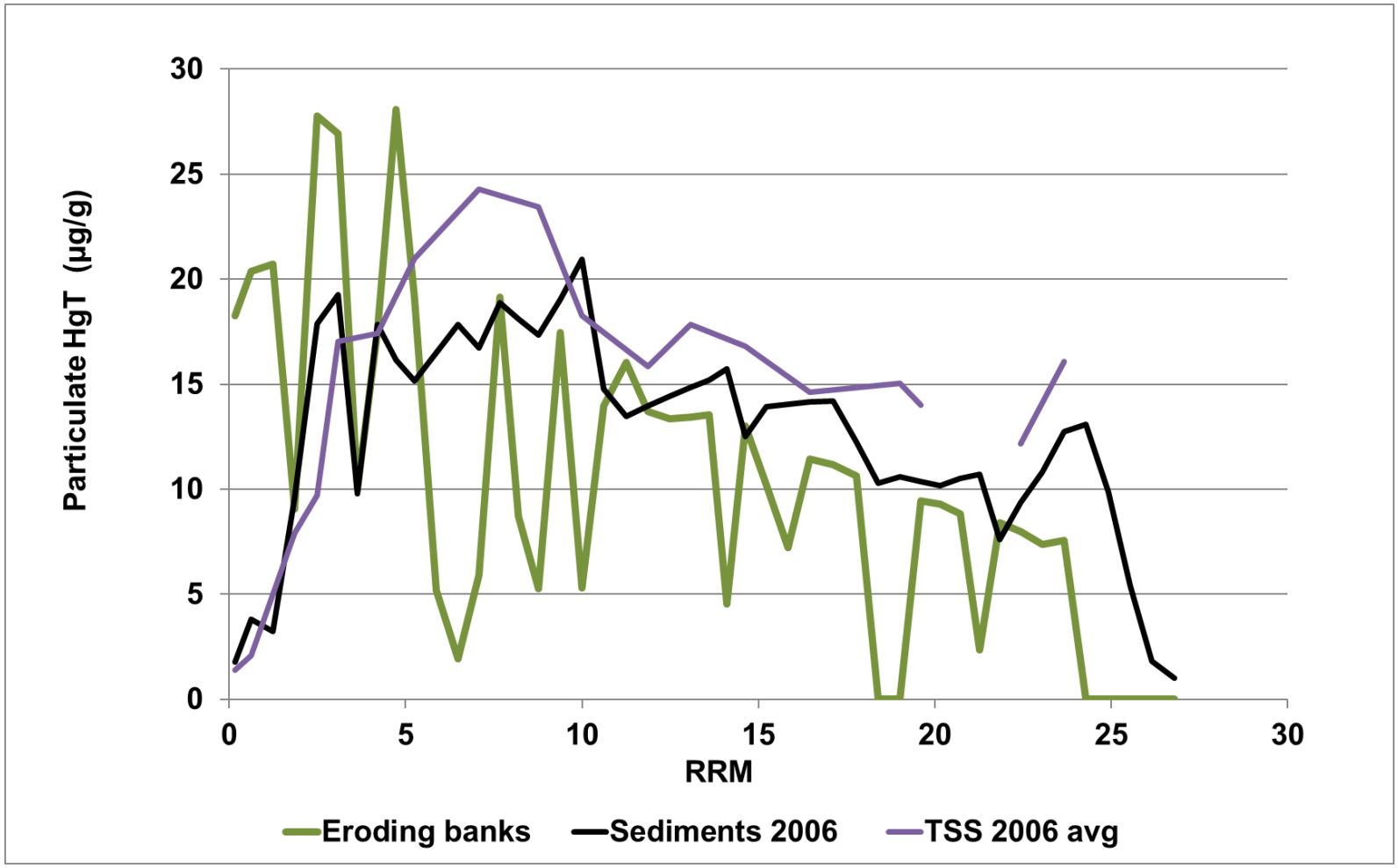




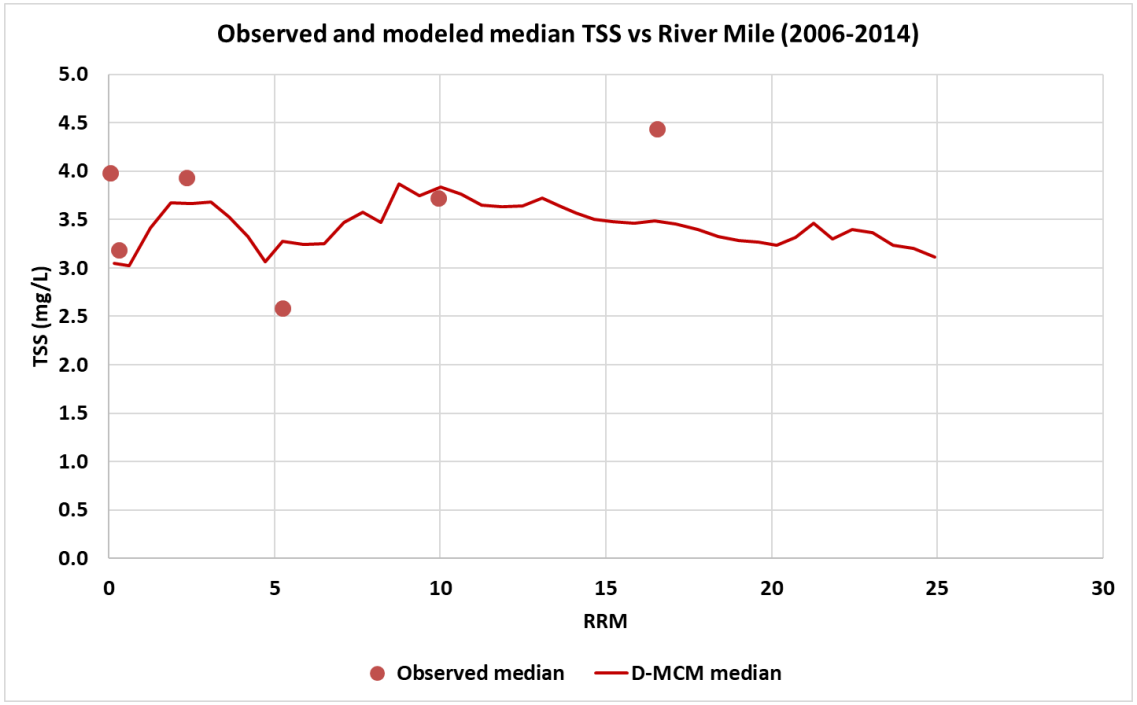


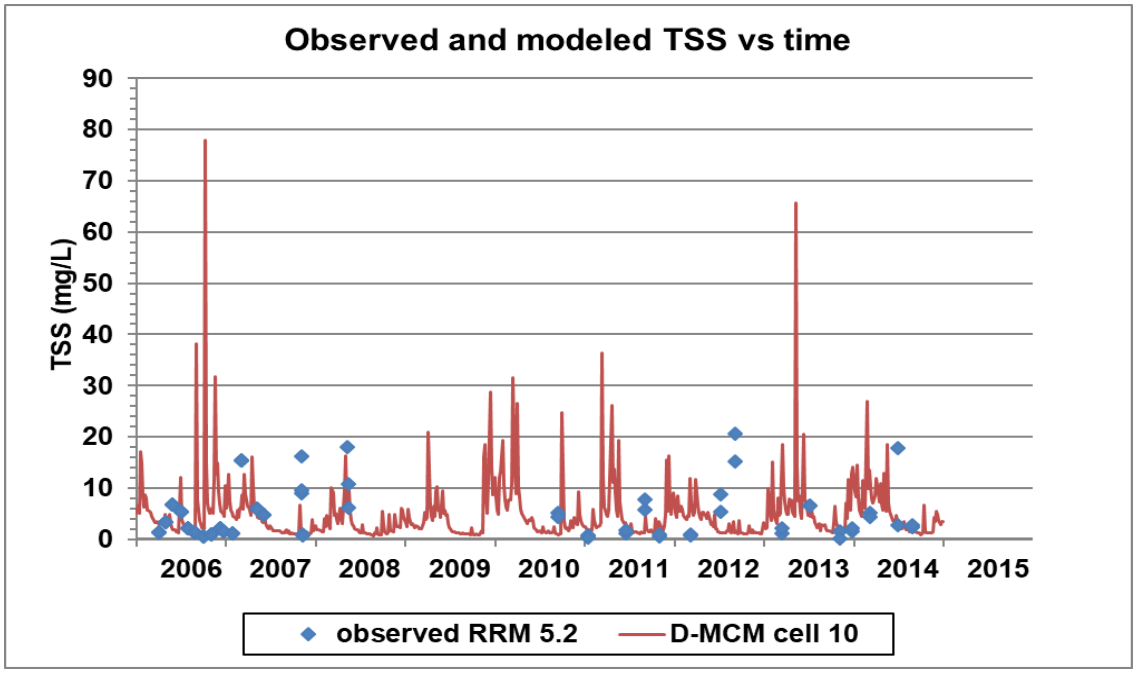
Estimated bank erosion rates for solids and mercury from RRM 0-26

THg concentrations on bank solids, sediment bed and TSS in 2006…..

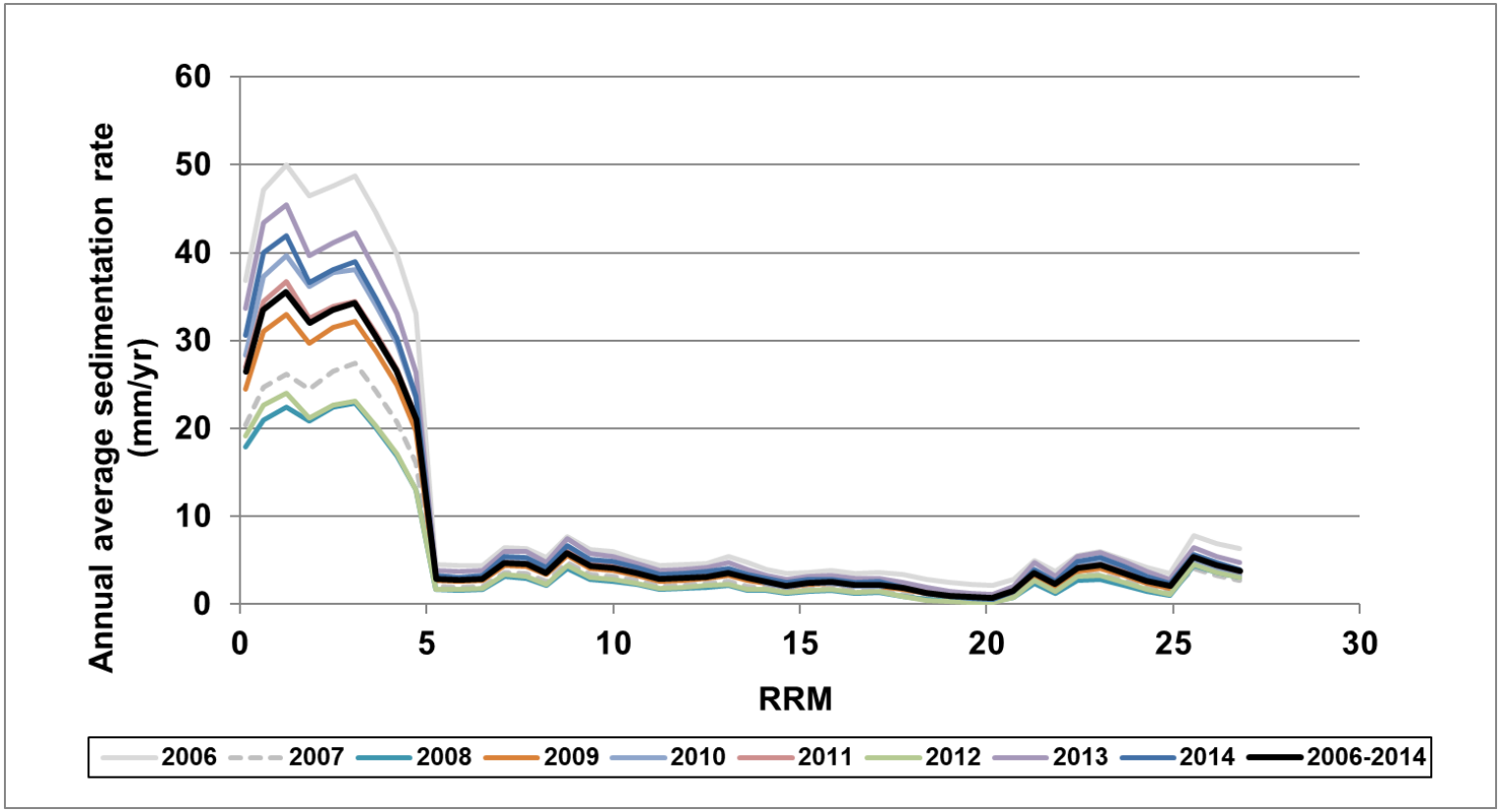


Model Calibration - Solids





Model calibration for suspended solids


Annual average sedimentation rate (mm/yr)
60
50
40
30
20
10
0
0
5
10
15
20
25
30
RRM
2006
2007
2008
2009
2010
2011
2012
2013
2014
2006-2014

Solids residence time in surface sediments (0-2 cm) is an indicator of how fast the system can replace contaminated particles…

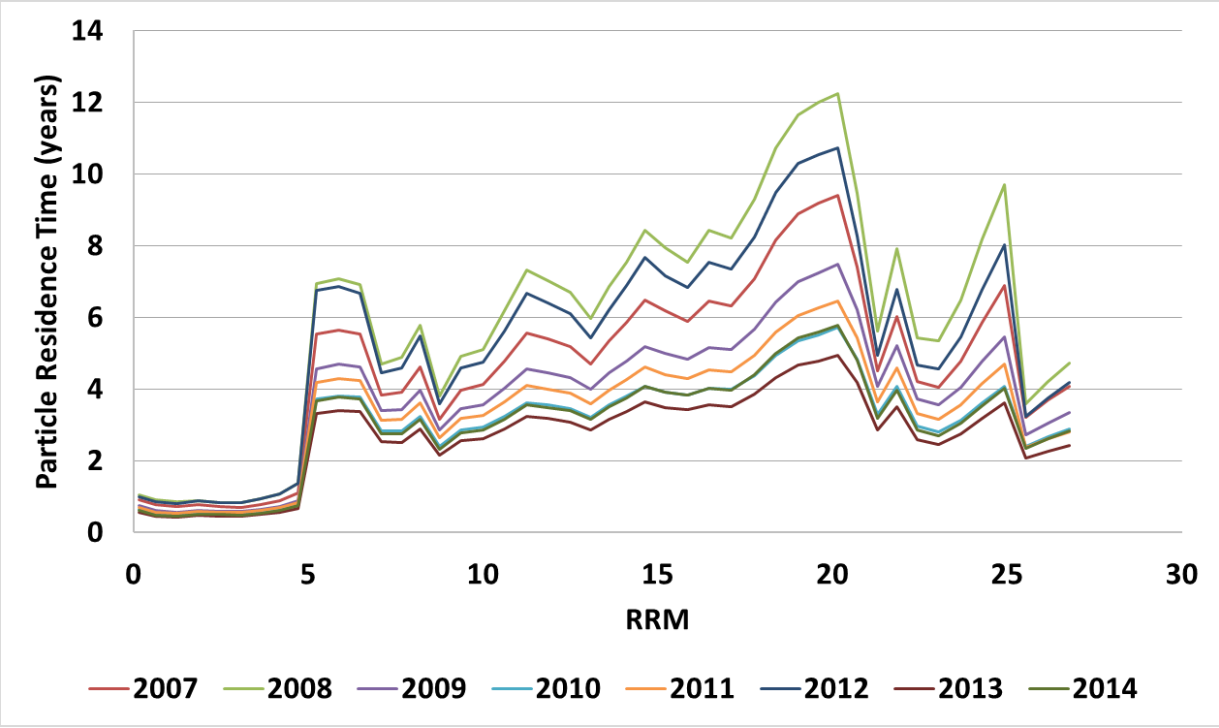


Table 5.8. Maximum age of FGCM deposits cored and dated using ^{14}C.

Core	Age at Base (years)
Core 1	> 55
H1A	19
H2A	14
H2C	13
D5A	10
D7A	11

From Pizzuto et al (2008)

- Average age at base of core was 13 years
- Average age for overall sample likely less.

What stage of solids conceptual model was the river in for the period simulated (2006-2014)?

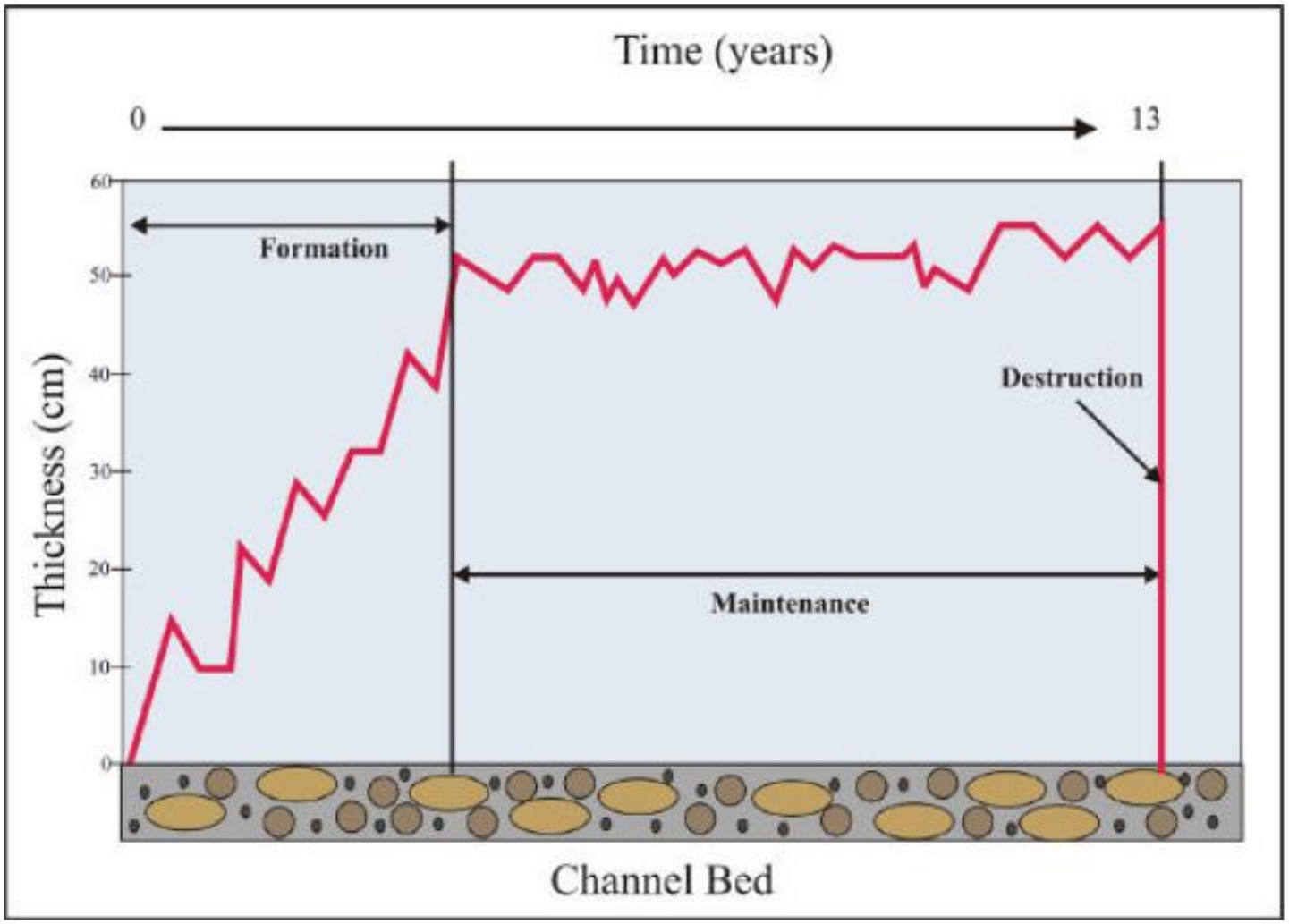


Figure 5.33. Idealized conceptual model for the temporal evolution of a FGCM deposit through time

Pizzuto conceptual model for particles in South River

Suspended solids fluxes estimated at Waynesboro for 1952-2014

From Pizzuto et al (2008)

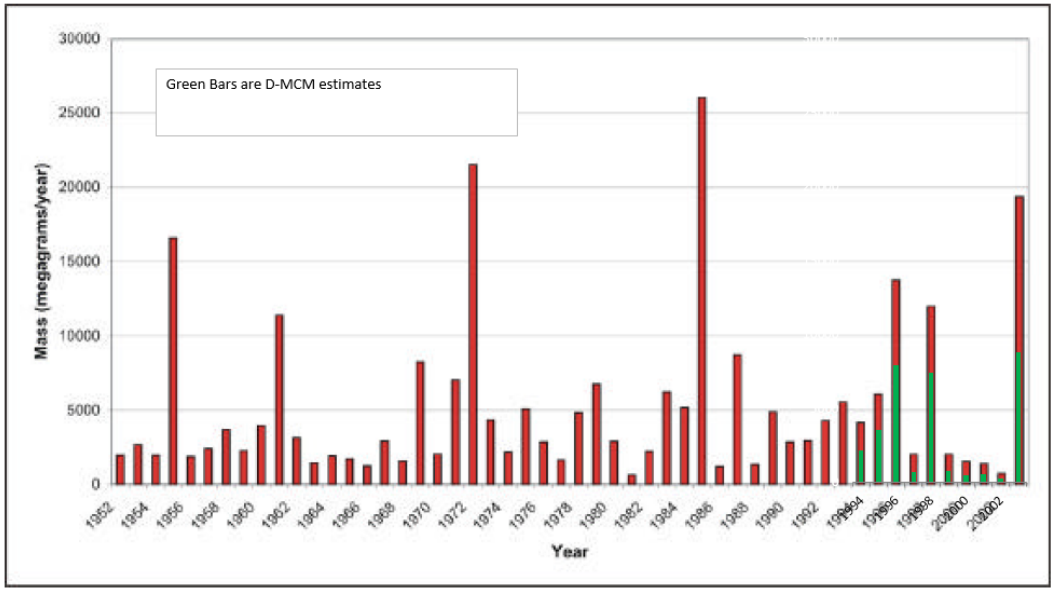
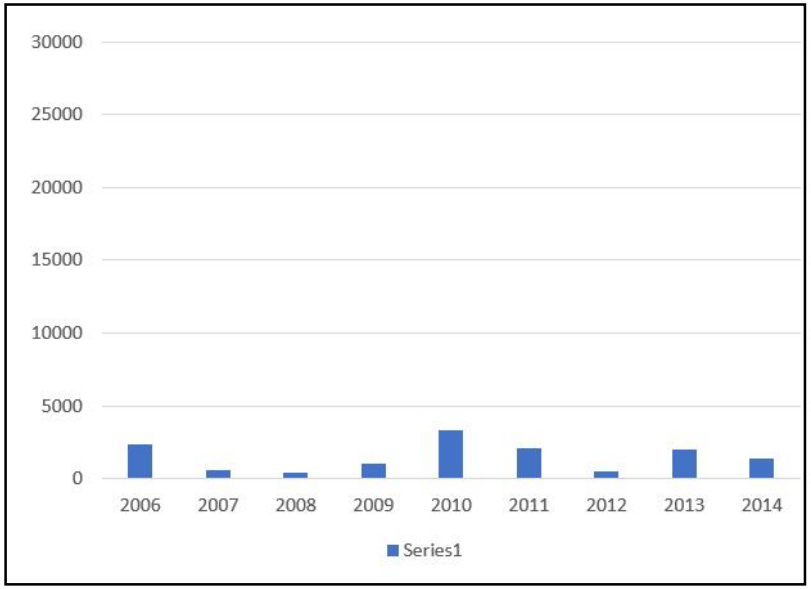


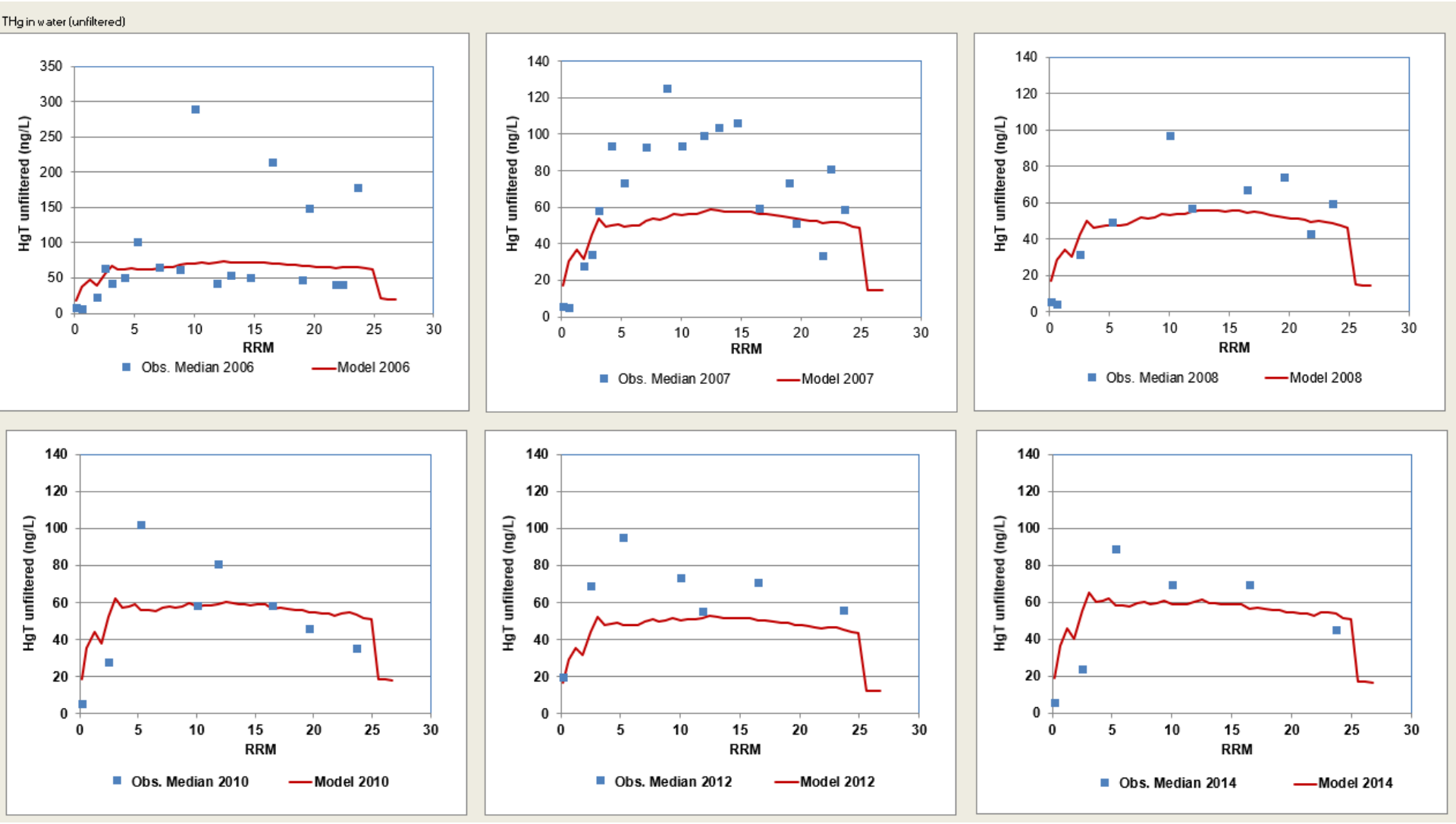
Figure 11.12. Total mass of suspended sediment for each year of discharge data on South River at Waynesboro

Estimated for modeling study

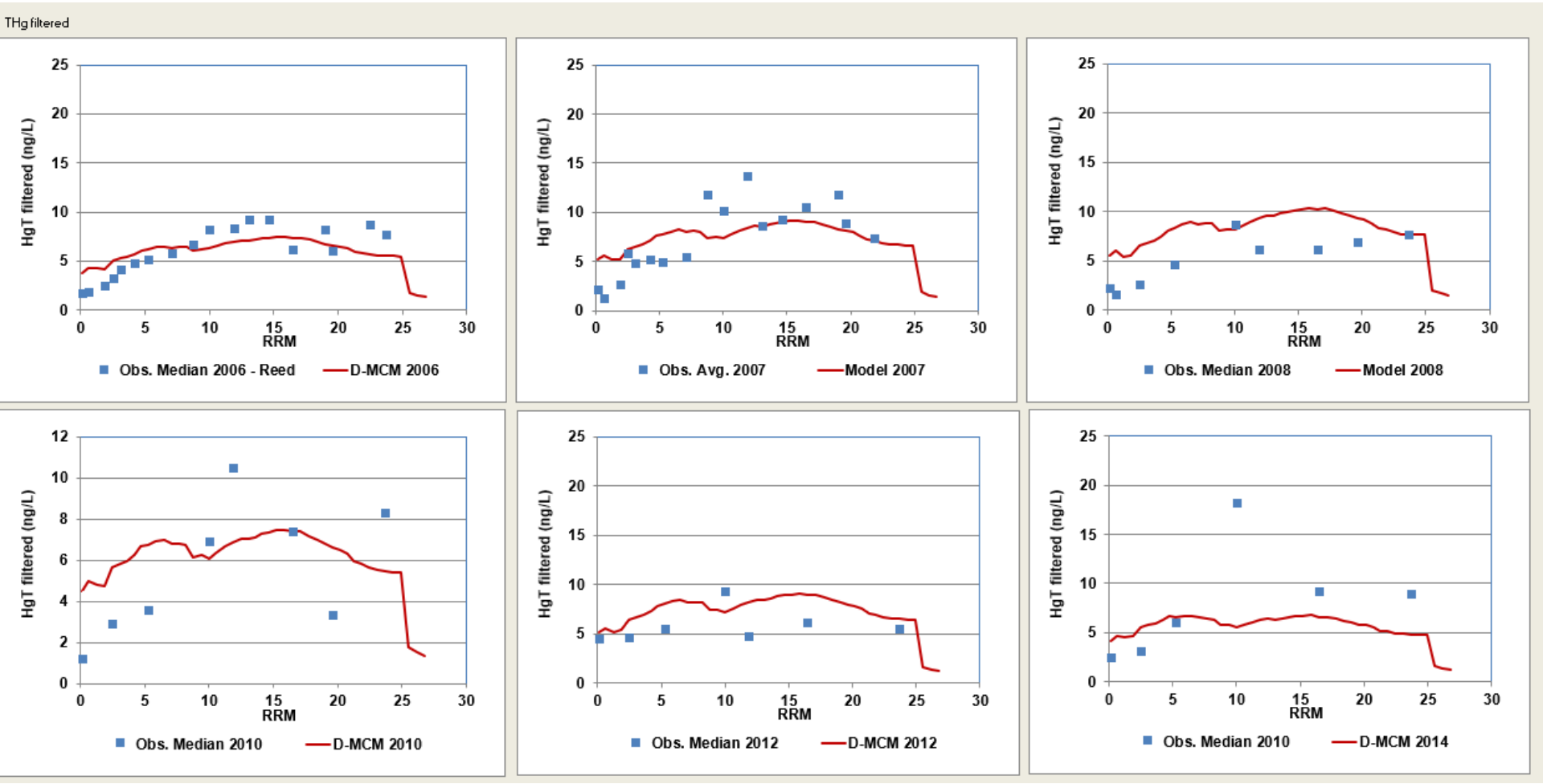


Spatial Patterns in Water - THg

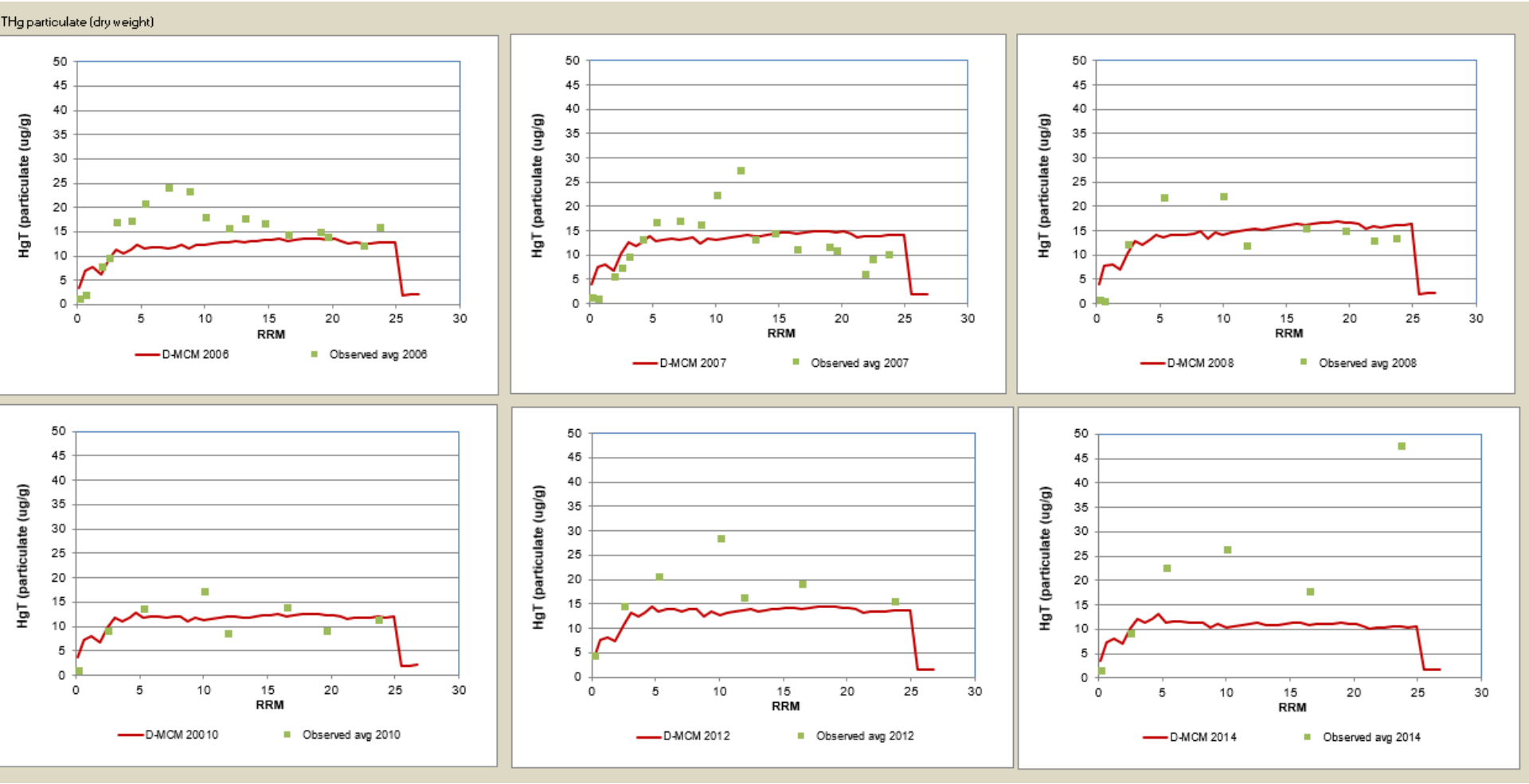
Model Calibration – Bulk Total Mercury in water (ng/L unfiltered)



Model Calibration – Filtered Total Mercury in water (ng/L unfiltered)

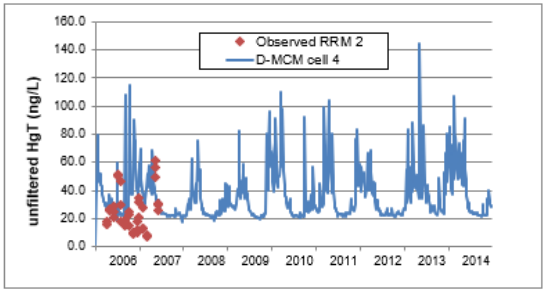
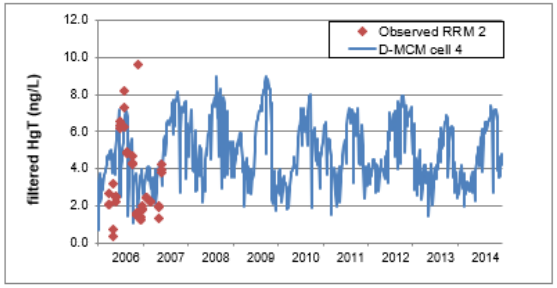
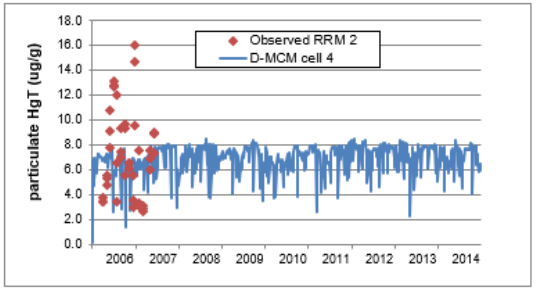
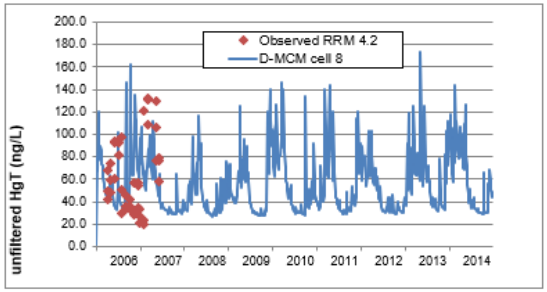
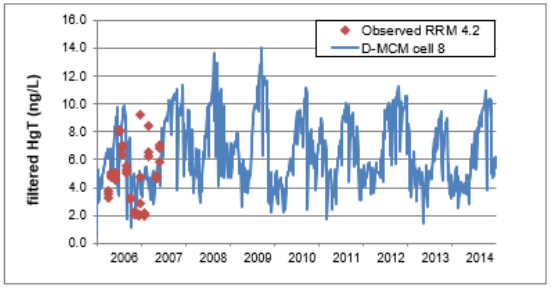
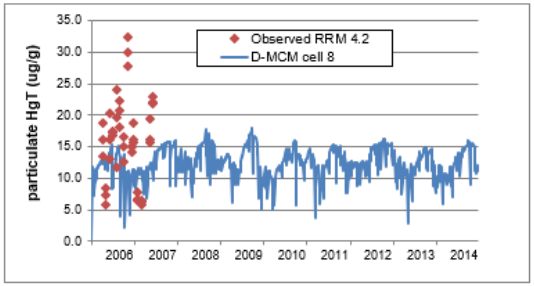
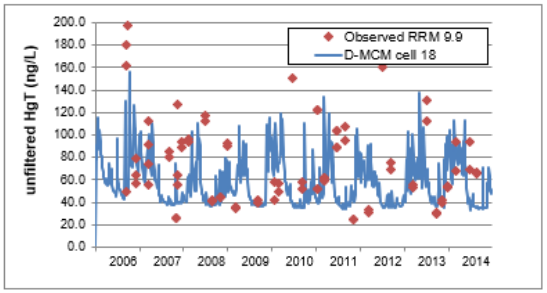
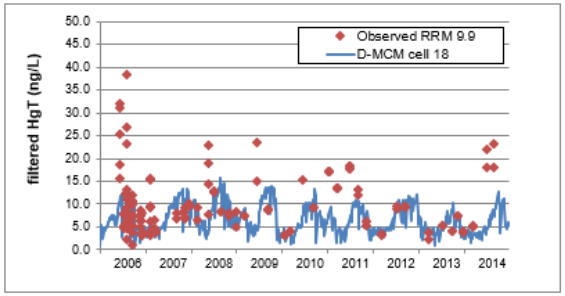
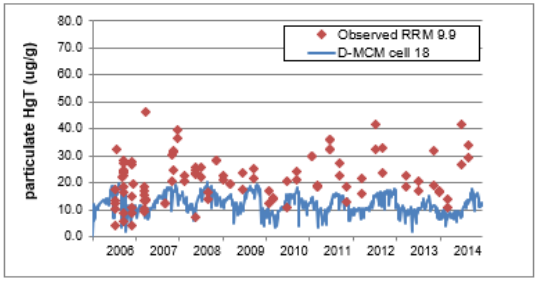


Model Calibration –Total Mercury in Suspended Solids (µg/g)



Temporal Patterns in Water - THg

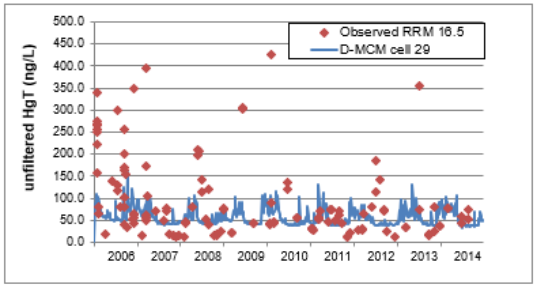
Model Calibration -
THg vs time at different locations

	Unfiltered	Filtered	Particulate (ug/g)
RRM 2			
RRM 4.2			
RRM 9			

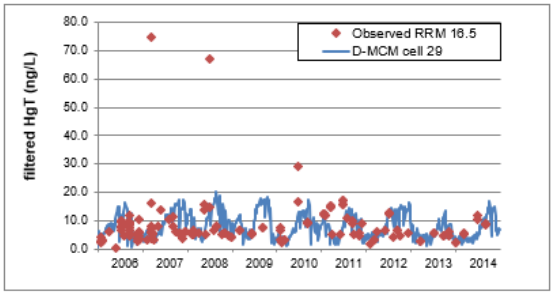
Model Calibration -
THg vs time at different locations

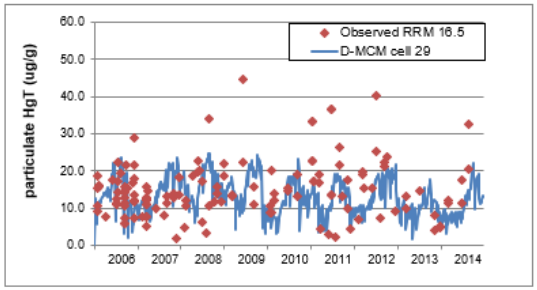
Unfiltered | **Filtered** | **Particulate (ug/g)**

RRM 16.5

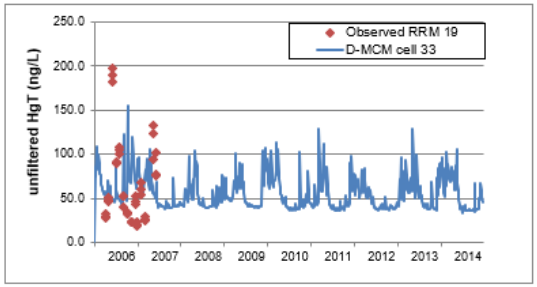


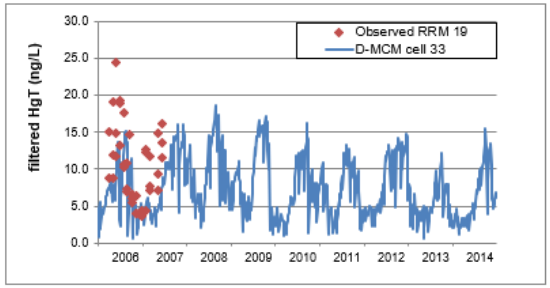
Note Y axis max imposed

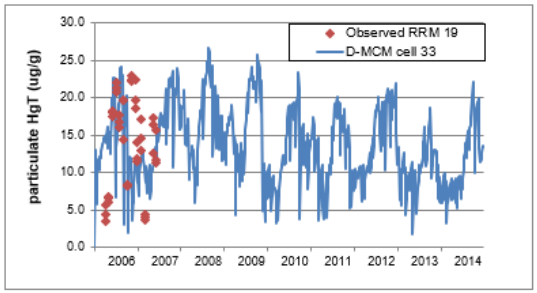




RRM 19

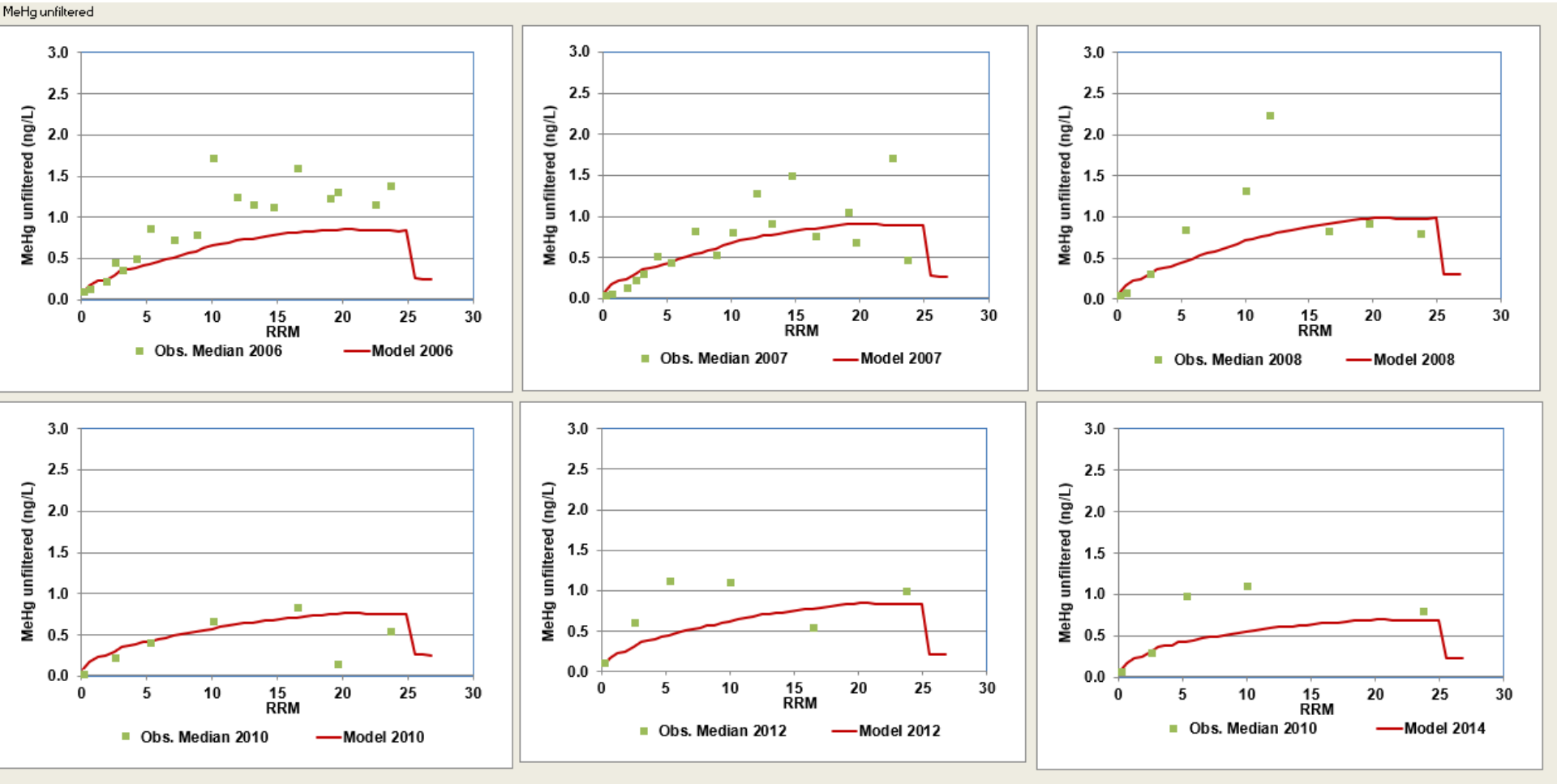




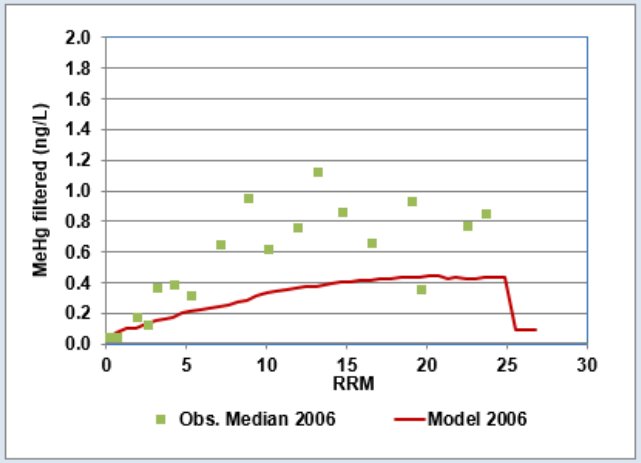


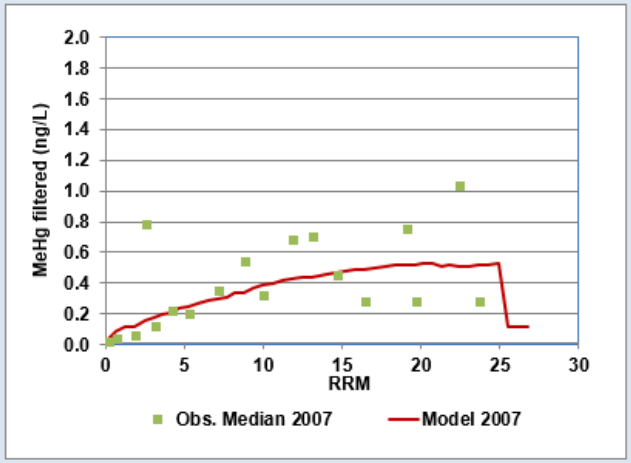
Spatial Patterns in Water - MeHg

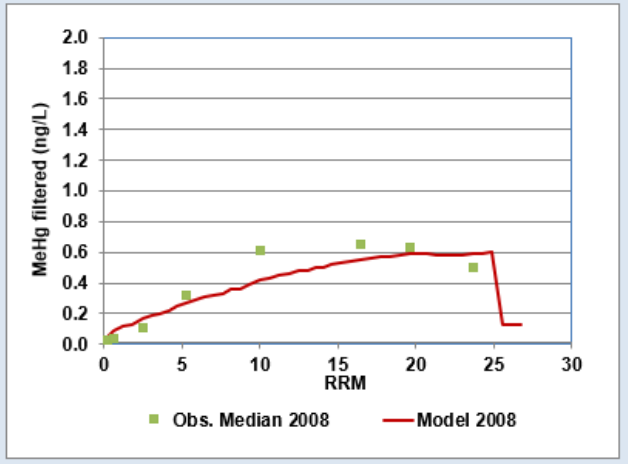
Model Calibration – MeHg in Water (Unfiltered)

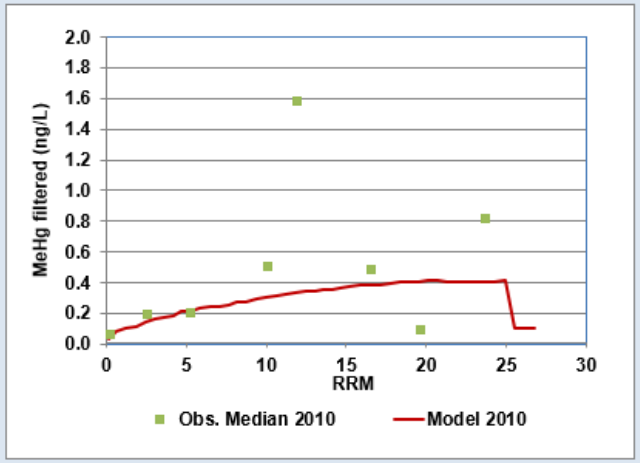


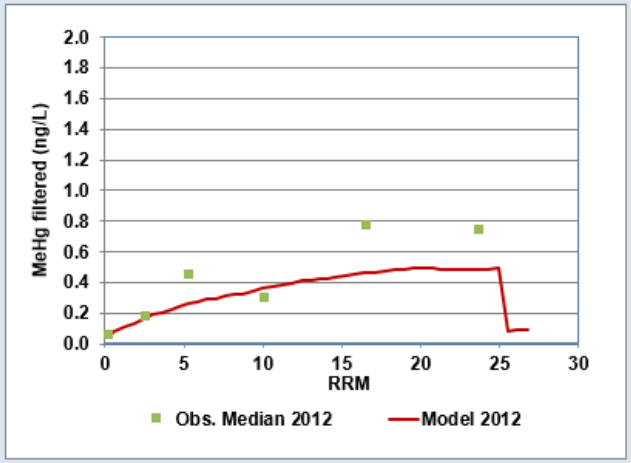
Model Calibration – MeHg in Water (Filtered)

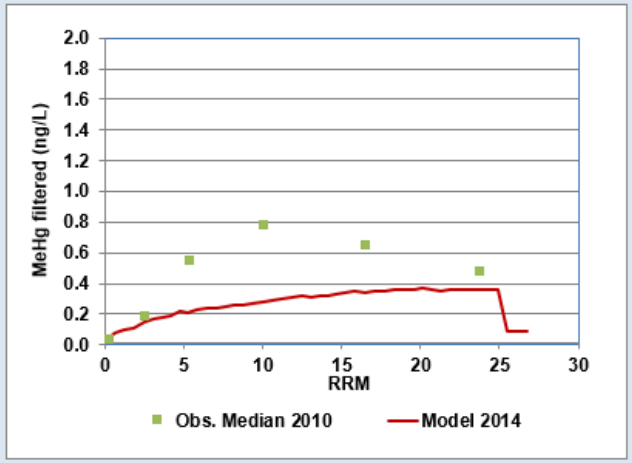






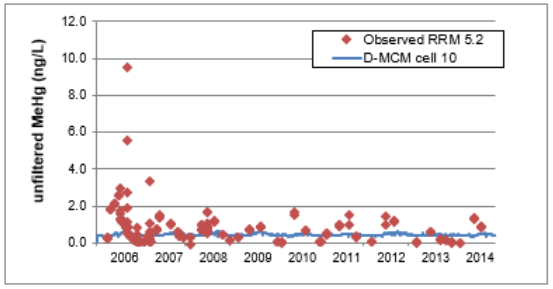
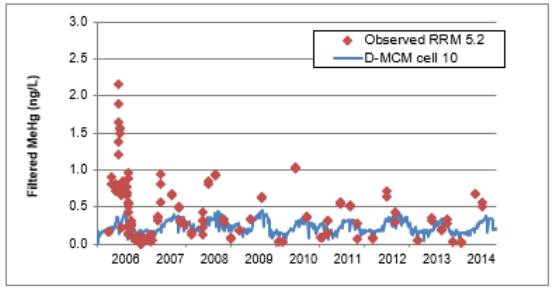
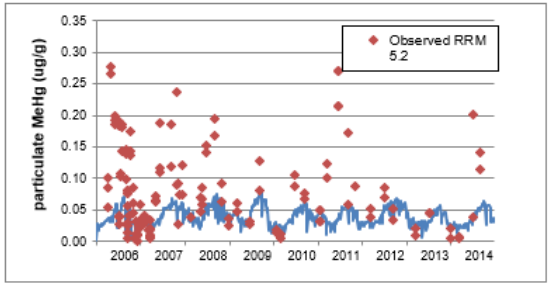
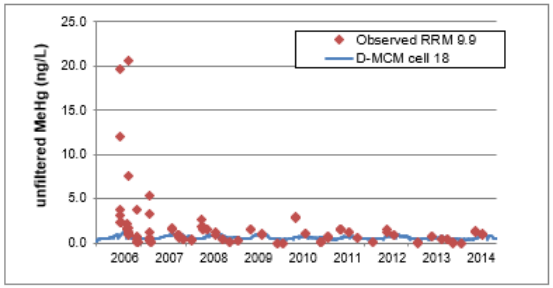
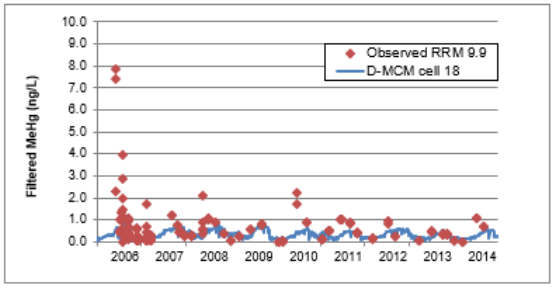
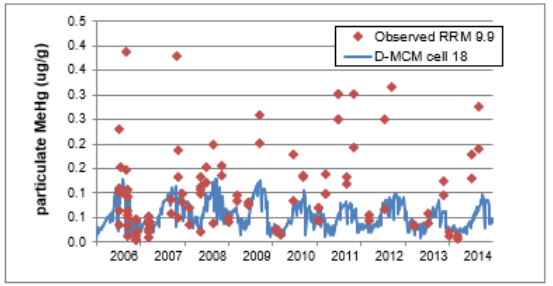
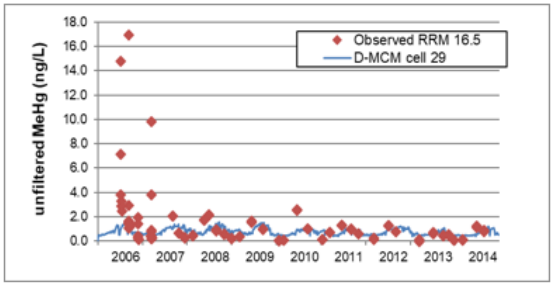
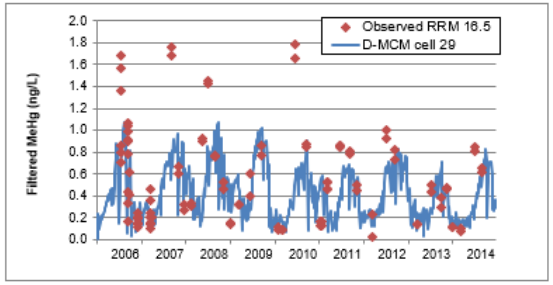
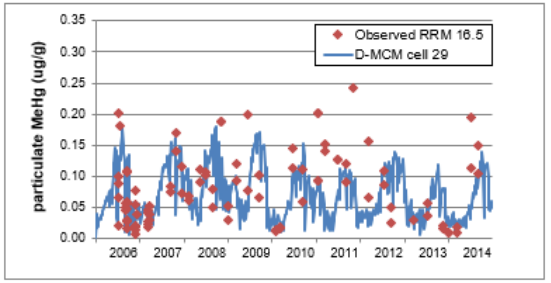




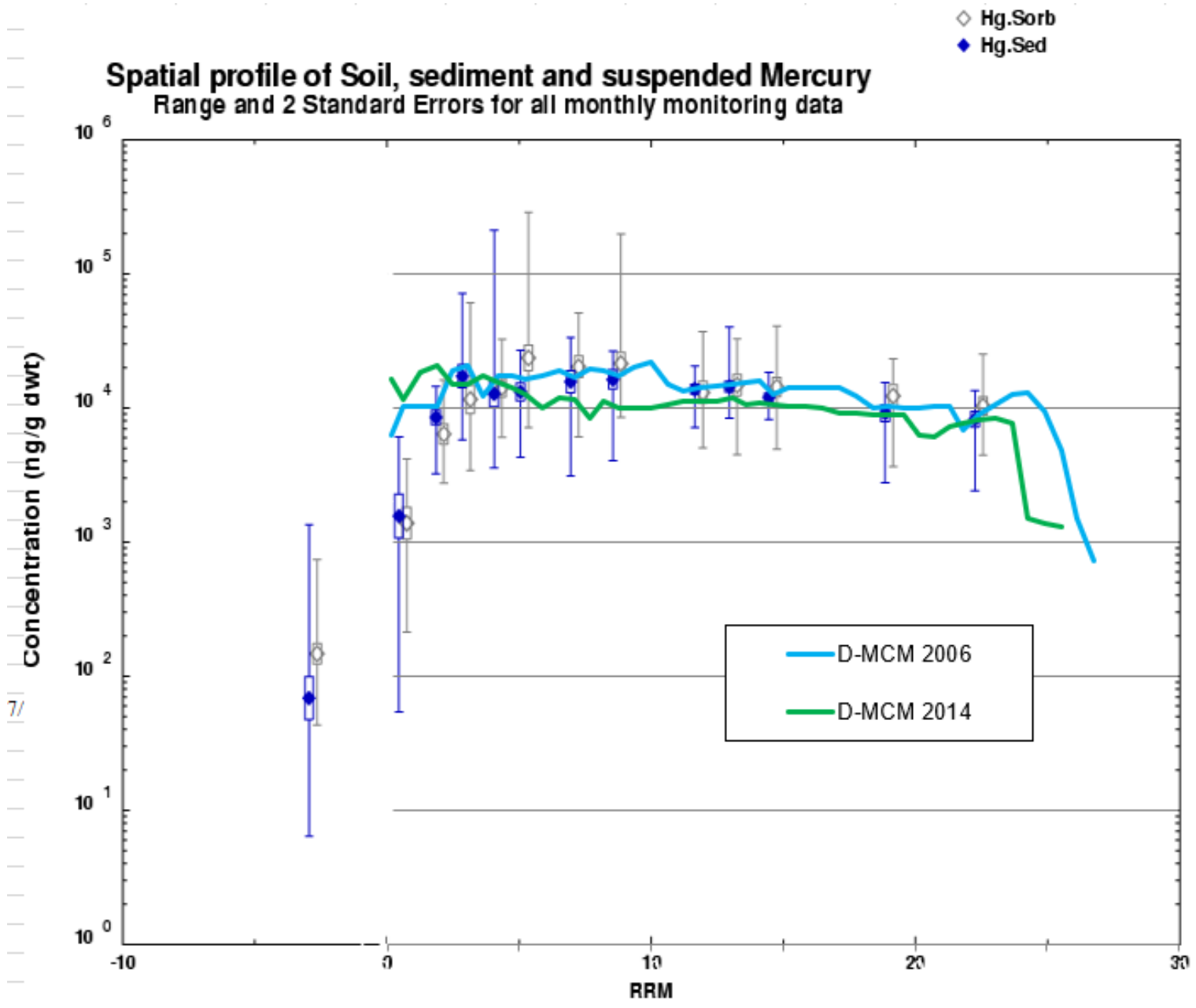


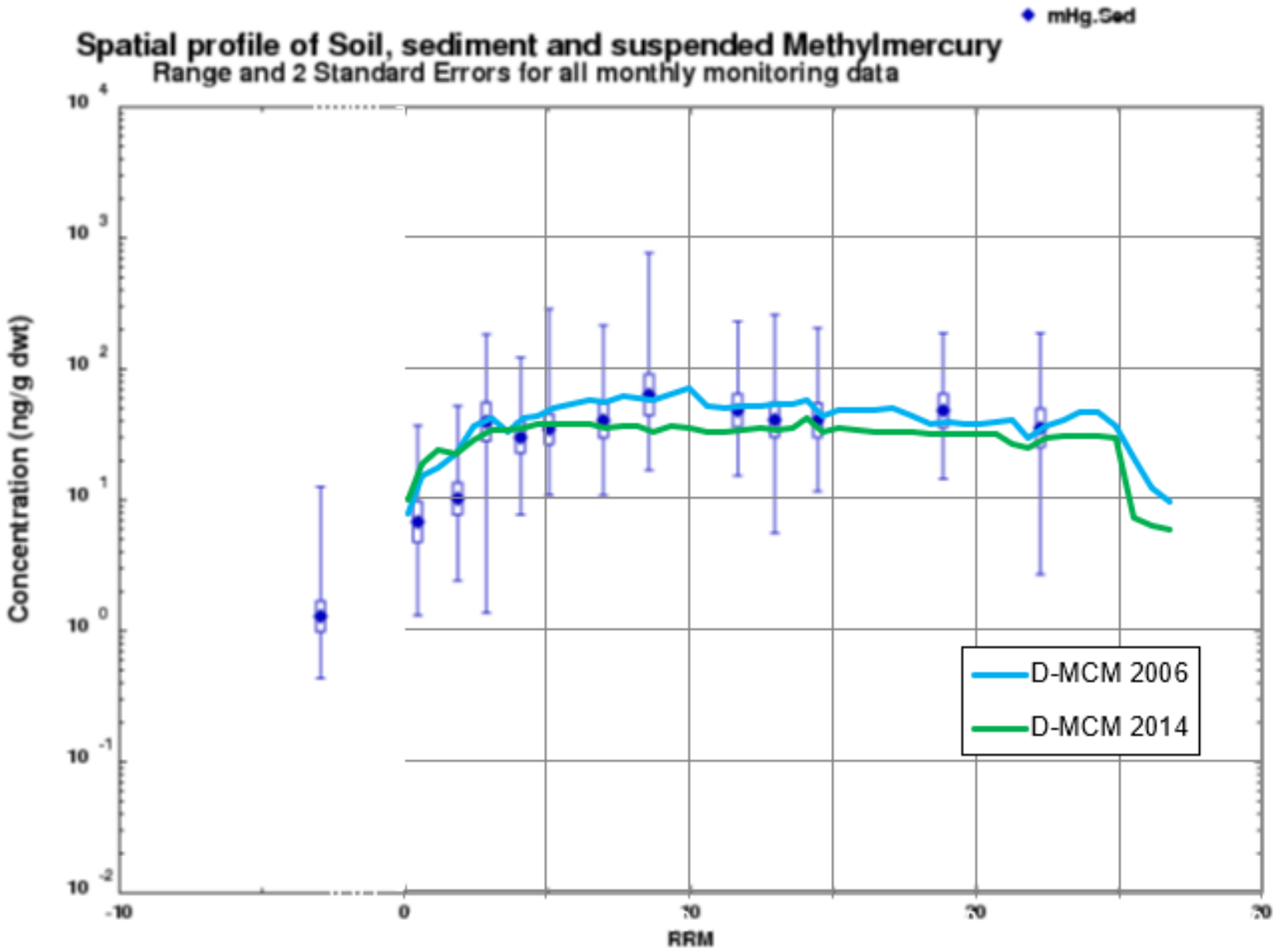
Temporal Patterns in Water - MeHg

Model Calibration -
MeHg vs time at different locations

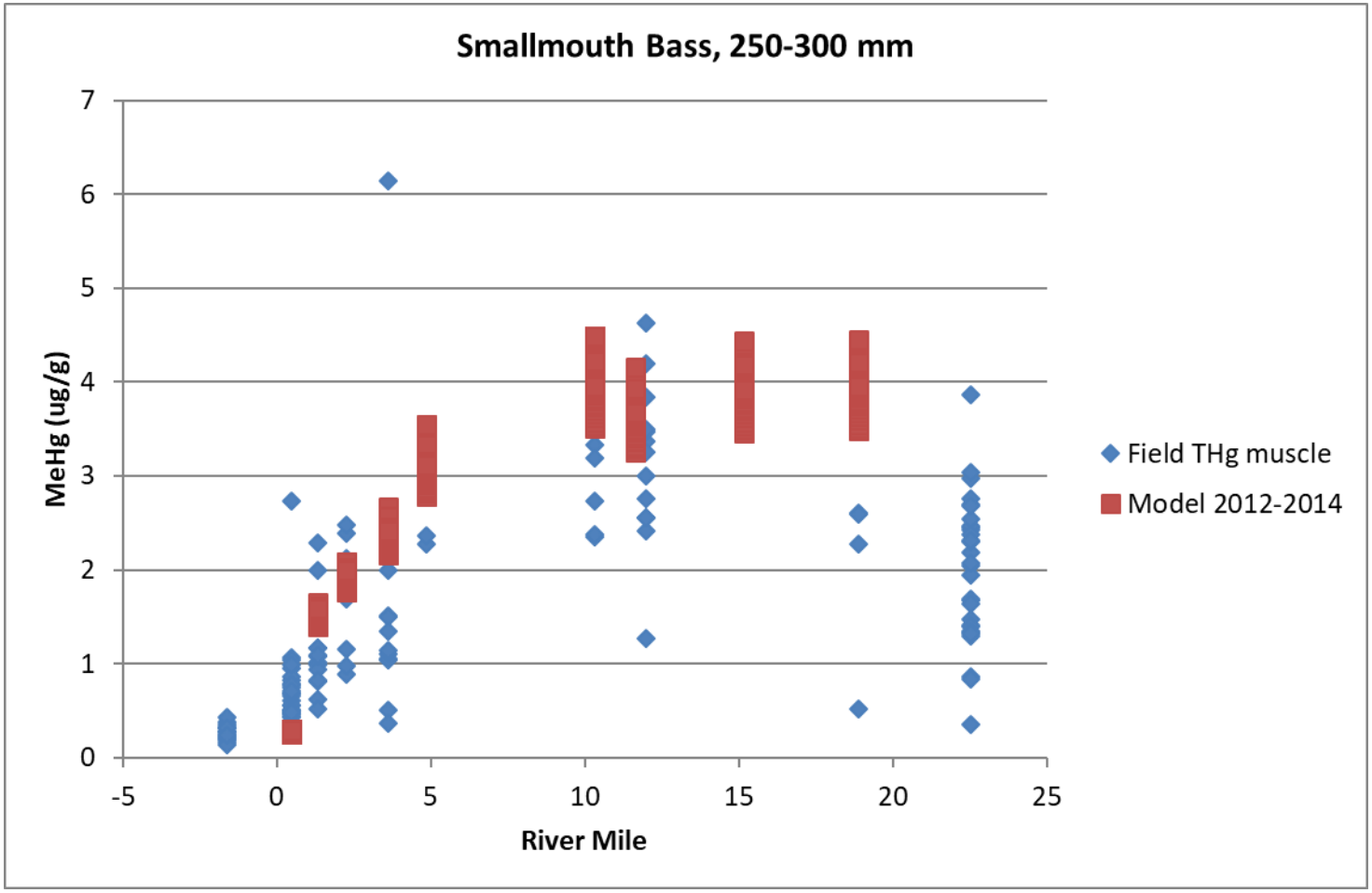
	Unfiltered	Filtered	Particulate (ug/g)
RRM 5.2			
RRM 9.9			
RRM 16.5			

THg and MeHg in sediments

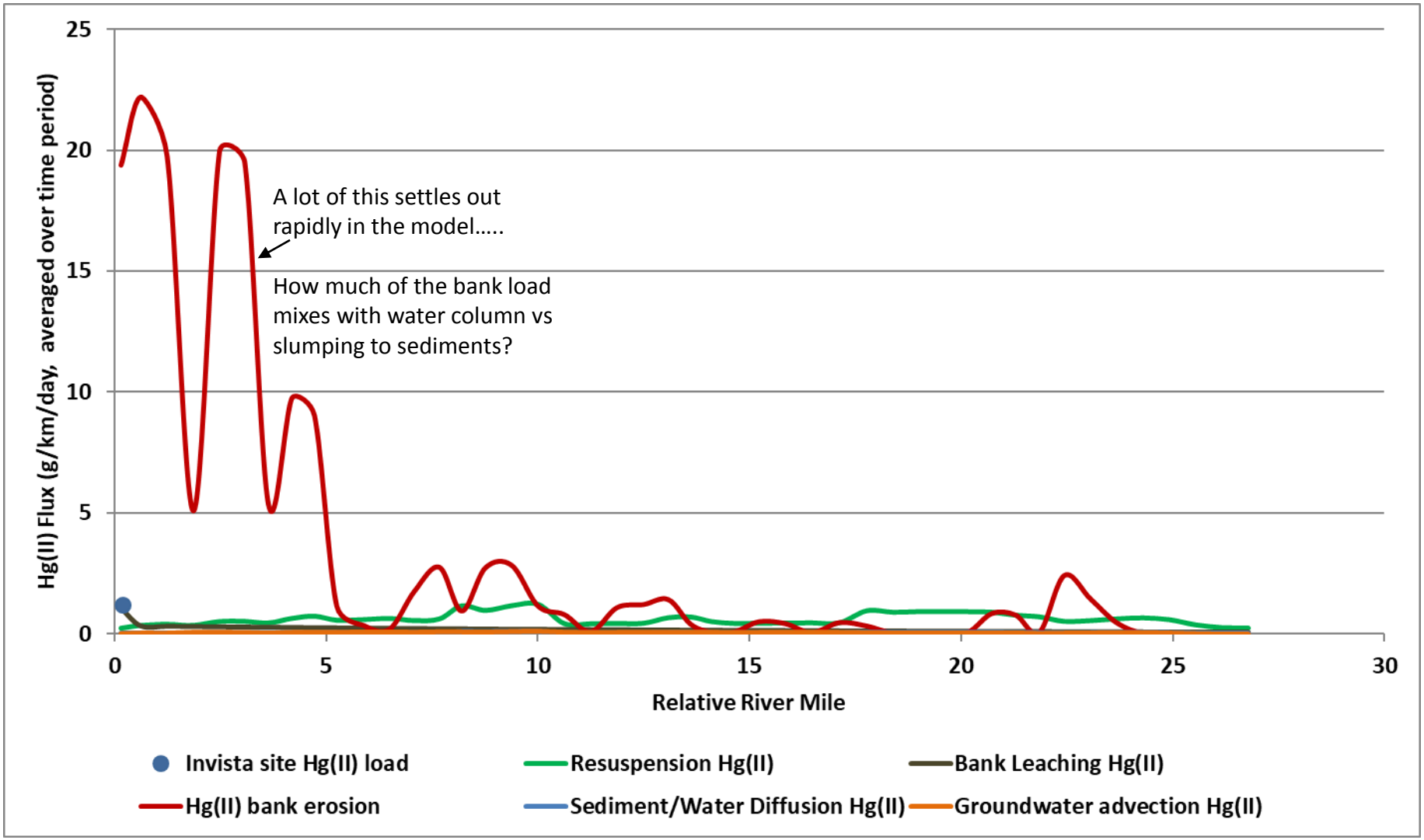

Hg.Sorb
Hg.Sed
Spatial profile of Soil, sediment and suspended Mercury
Range and 2 Standard Errors for all monthly monitoring data
Concentration (ng/g dwt)
10 6
10 5
10 4
10 3
10 2
10 1
10 0
-10
0
10
20
30
RRM
D-MCM 2006
D-MCM 2014


mHg.Sed
Spatial profile of Soil, sediment and suspended Methylmercury
Range and 2 Standard Errors for all monthly monitoring data
Concentration (ng/g dwt)
10 4
10 3
10 2
10 1
10 0
10 -1
10 -2
-10
0
10
20
30
RRM
D-MCM 2006
D-MCM 2014

Observed and predicted MeHg in Smallmouth Bass



Modeled Sources of Total Mercury to the Water Column (Averages for 2006-2014)



Bank Stabilization Scenario

~90% reduction in Hg loading for RRM 0-2 (from about 20 kg/yr to 2 kg/yr)

Before…

Model Cell	Solids Load (kg/yr)	THg load (kg/yr)	THg concentration (ug/g)
1	190,768	3.48	18.24
2	391,166	7.97	20.39
3	342,694	7.10	20.72
4	205,282	1.86	9.04
Total	1,129,910	20.41	

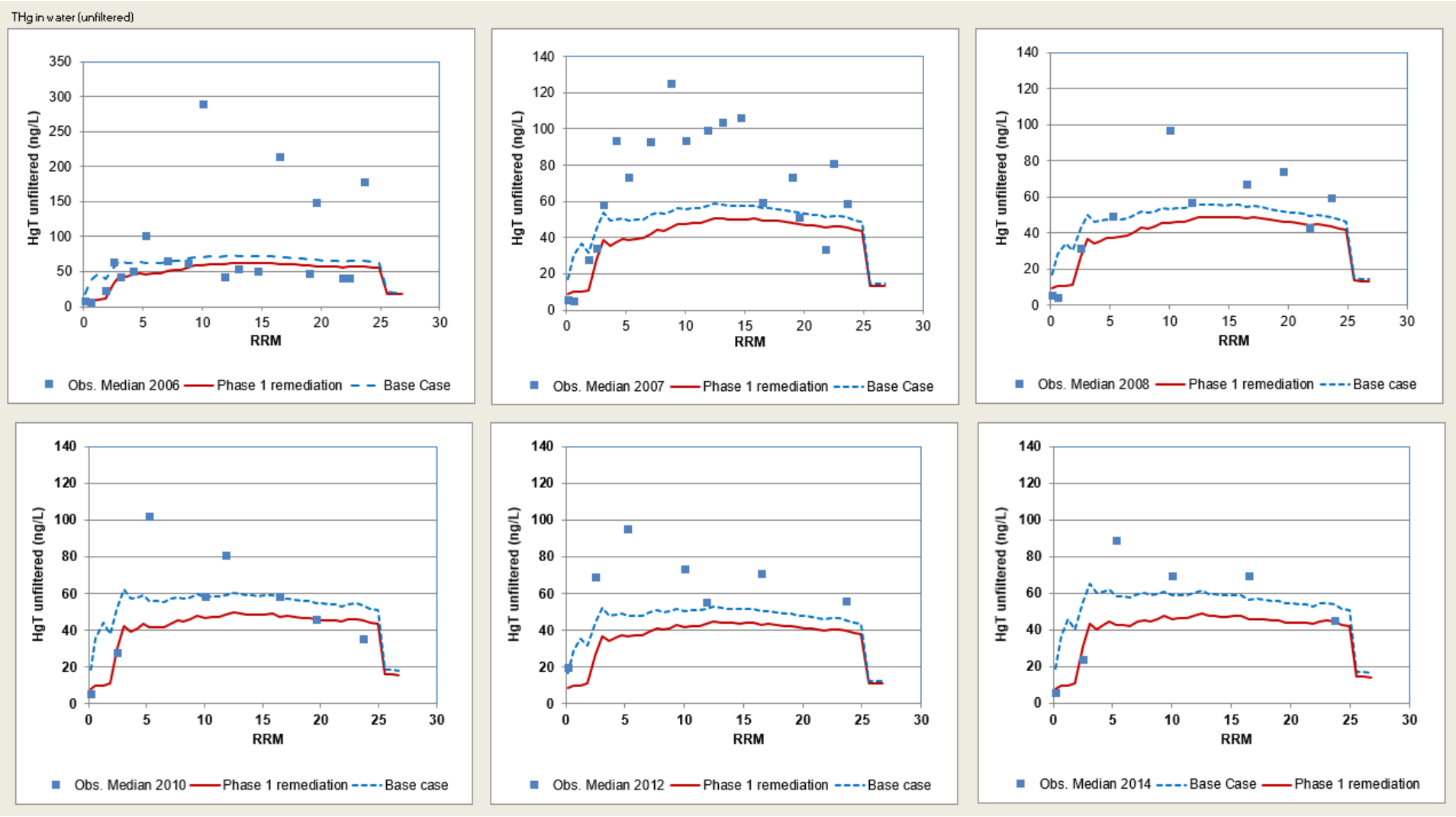
After…

Model Cell	Solids load (kg/yr)	THg load (kg/yr)	THg concentration (ug/g)
1	119,915	0.17	1.45
2	216,696	0.67	3.08
3	138,069	0.51	3.71
4	181,897	0.66	3.62
Total	656,578	2.01	

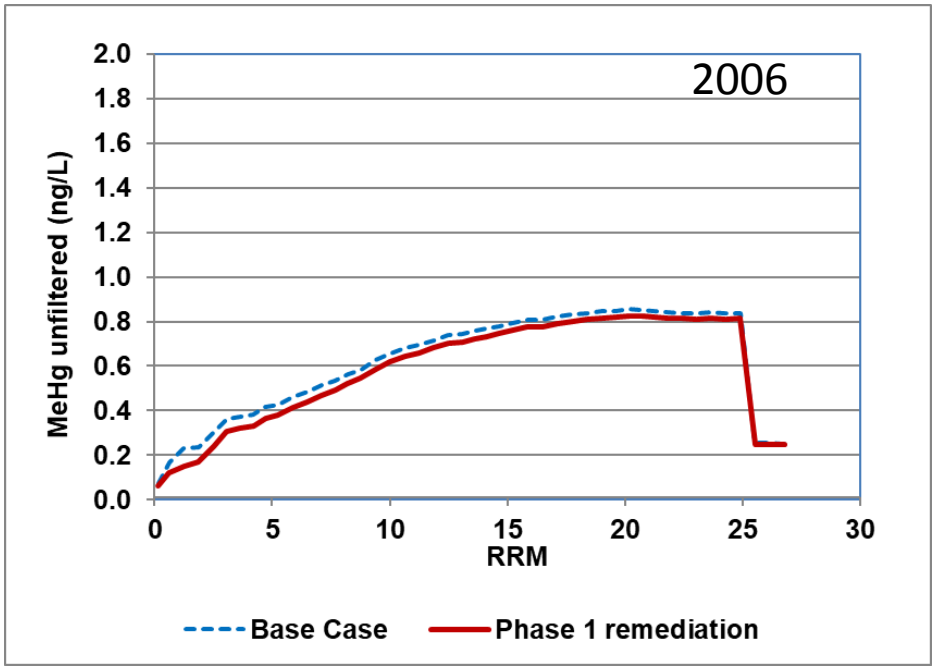
Imposed in 2006 in simulation

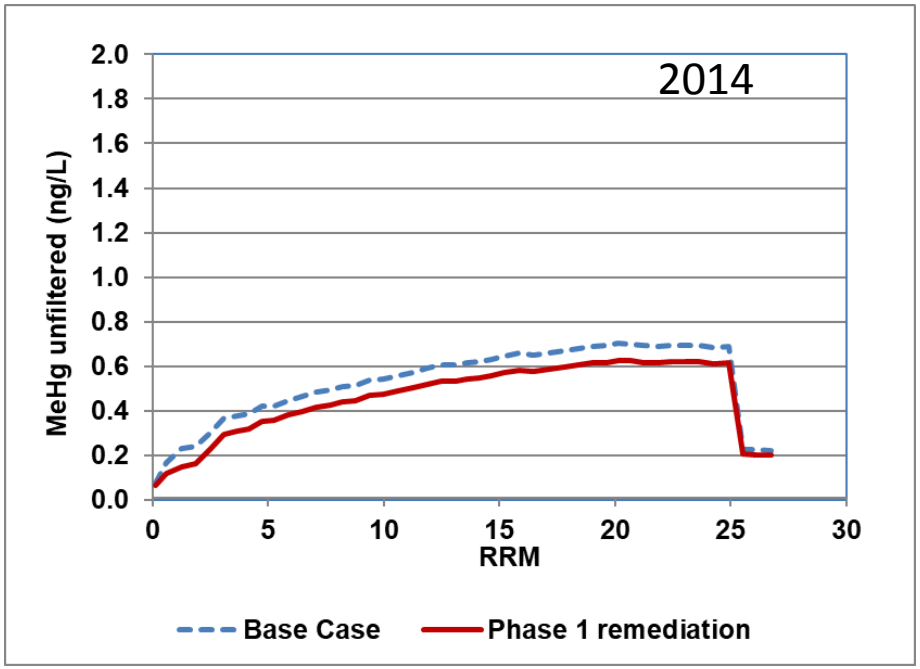
Predicted response of THg in water to 90% reduction in bank Hg load for RRM 0-2….

Effect depends on time and location:
- greater effect near remediated area, effect increases with time…



Currently predicted response of MeHg in water to 90% reduction in bank Hg load for RRM 0-2 ….

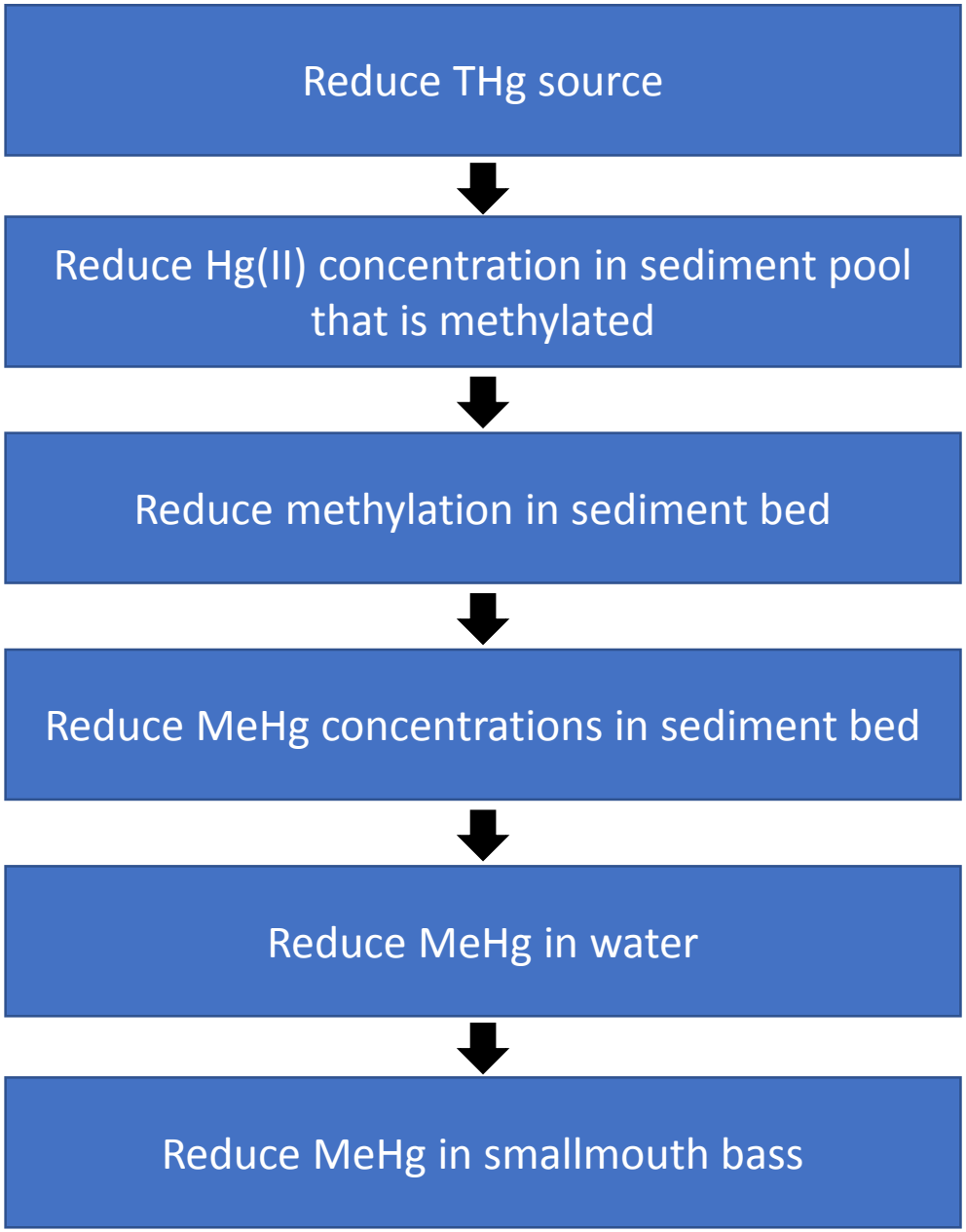




Some issues affecting the response to remediation in the model:

- Fate of eroded particles
  (buried vs travels downstream… and when)
- How quickly do sediment bed particles get replaced?
- How quickly does pool of Hg being methylated respond to change in Hg loading?
- Is methylation in sediments linear?

How fast do these steps occur?



Can be fast or slow in model..
Depends on assumptions

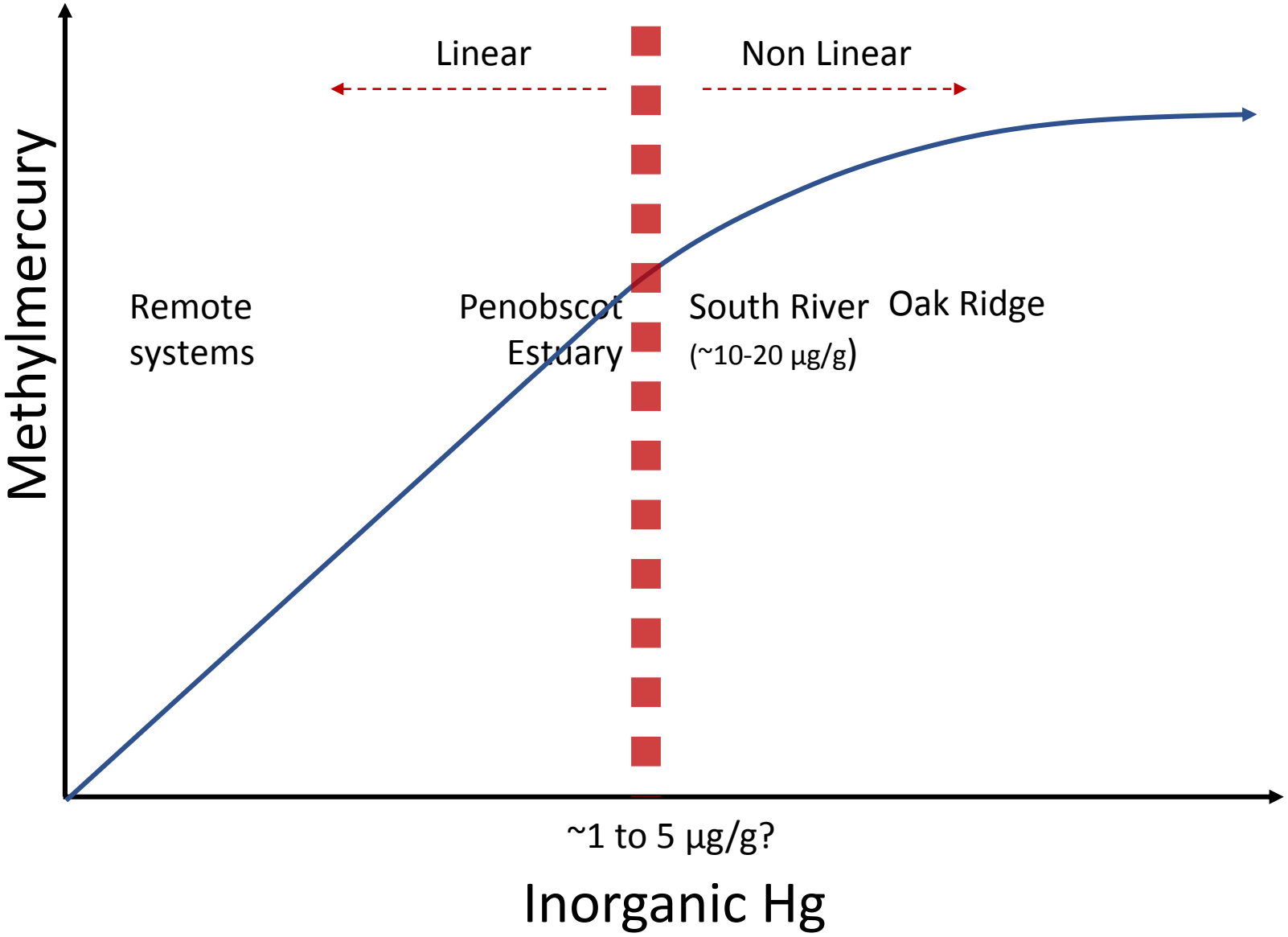
Almost immediate?

Seasonal?

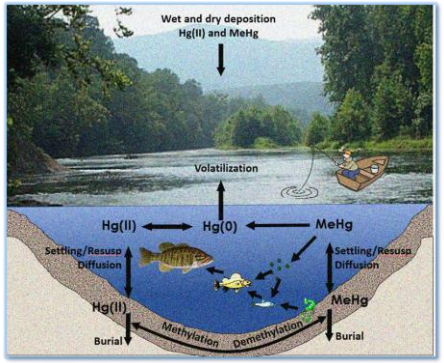
Fast…. Days?

< 1 yr for young fish,
a few years for adults?

Relationship between MeHg and inorganic Hg concentrations in sediments across ecosystems

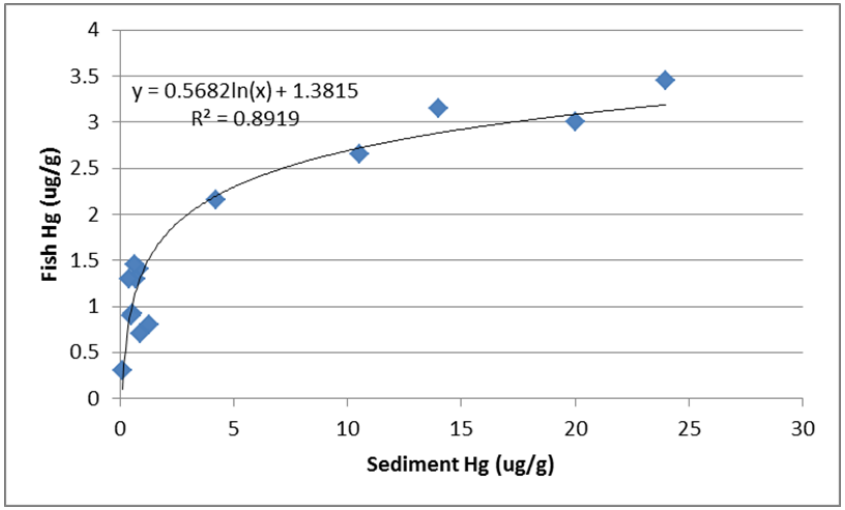


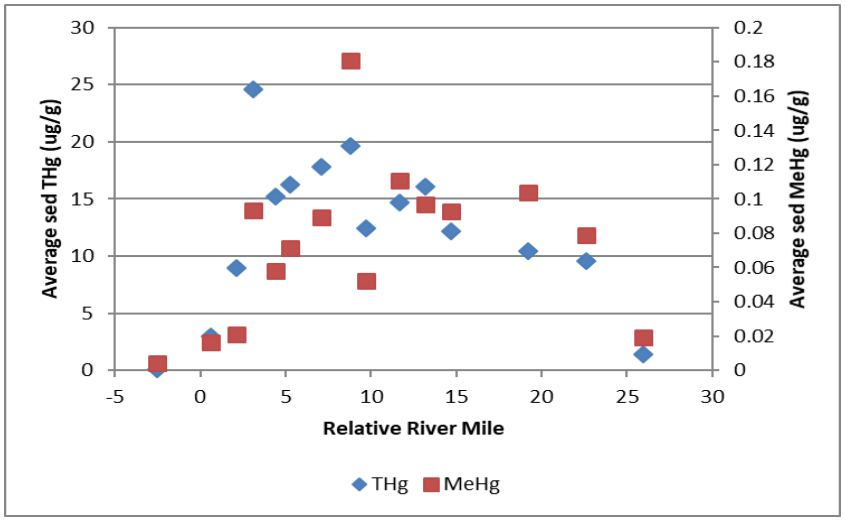
Summary



- River banks are primary source of inorganic Hg.
- Particle dynamics are important, affecting:
  - Natural rate of recovery
  - Downstream movement of contamination
  - Benefits of bank stabilization.
- Non-linearity is important issue.
- Infrequent events may be important.
- Sensitivity analyses being completed.
- Report being drafted.

Fish MeHg – sediment THg relationship is non linear…





…Where does MeHg/inorganic Hg non-linearity first appear?