Phase 6 Watershed Model – Beta 3

Modeling Quarterly Review Meeting

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Presentation Outline

- A brief summary of data / model updates
- Beta 3 land-use export rates (targets)
- Evaluation of river inputs to WRTDS
- Model calibration
- rSAS prototype
- A few key scenarios
- Next steps

1. A brief summary of data / model updates

- Phase 6 Land-River segmentation were updated to include a few small reservoirs.
- Scenario builder team provided updated inputs
- Land-use export targets were updated
- Updated SPARROW *land-to-water* delivery variance factors and *stream-to-river* delivery factors
- *Land-to-water* delivery variance factors were renormalized.
- CSO data was expanded from 2005 to 2014.

2. Beta 3 land-use export rates (targets)

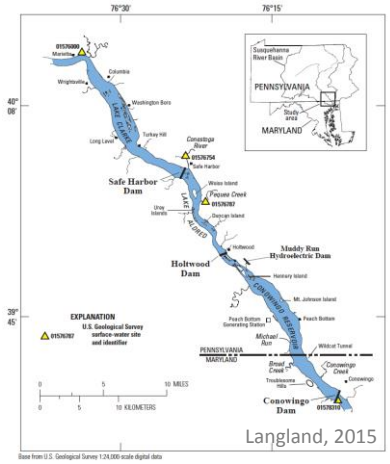
- Updated inputs
  - Large river delivery factor from SPARROW
  - Beta 3 Scenario Builder inputs
  - Soil Mehlich 3 reanalysis using APLE

Beta 3 Edge of Small Stream Load (for RIMshed)

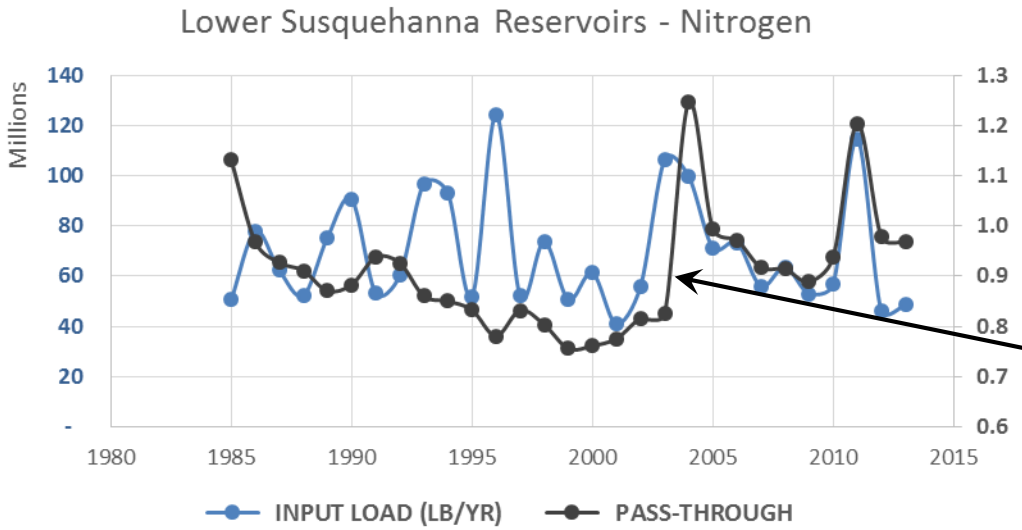
	Total Nitrogen		Total Phosphorus	
	Beta 2	Beta 3	Beta 2	Beta 3
RIM Loads	213 Mlb	213 Mlb	14.5 Mlb	14.5 Mlb
BMP efficiency	5.79%	5.79%	7.60%	7.60%
Large river losses	**53.30%**	**21.90%**	**54.30%**	**16.90%**
Direct Loads	44.98 Mlb	53.13 Mlb	5.41 Mlb	5.91 Mlb
AFO/CFO loads	**22.92 Mlb**	**58.75 Mlb**	3.72 Mlb	1.99 Mlb
Small stream losses	6.20%	6.30%	6.70%	4.30%
EOSS LOAD	**444 Mlb**	**189 Mlb**	**27.2 Mlb**	**11.5 Mlb**

A web based visual-analytics for AFO/CFO loads (Devereux): http://tiny.cc/beta3afocfo

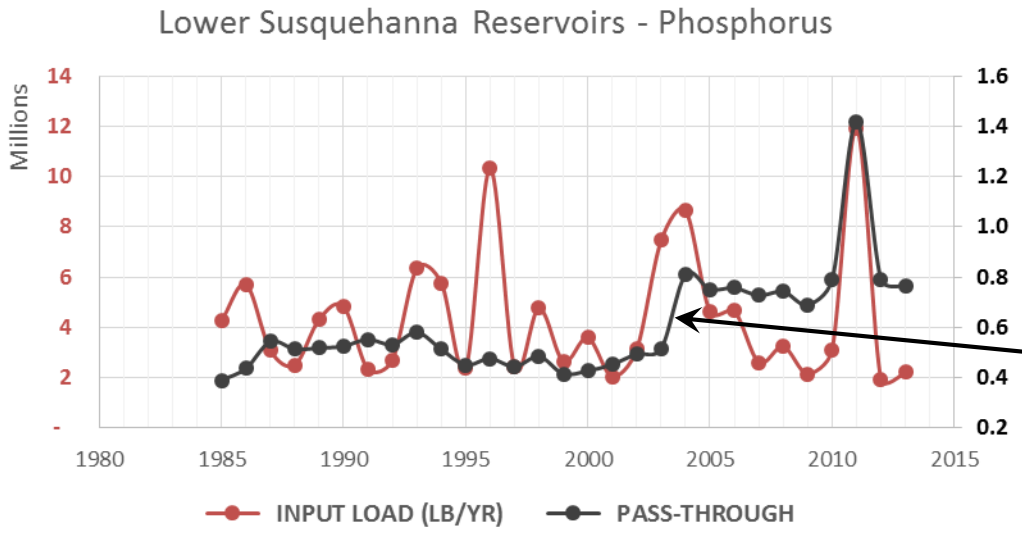
Mass balance of Lower Susquehanna Reservoirs



Langland, 2015

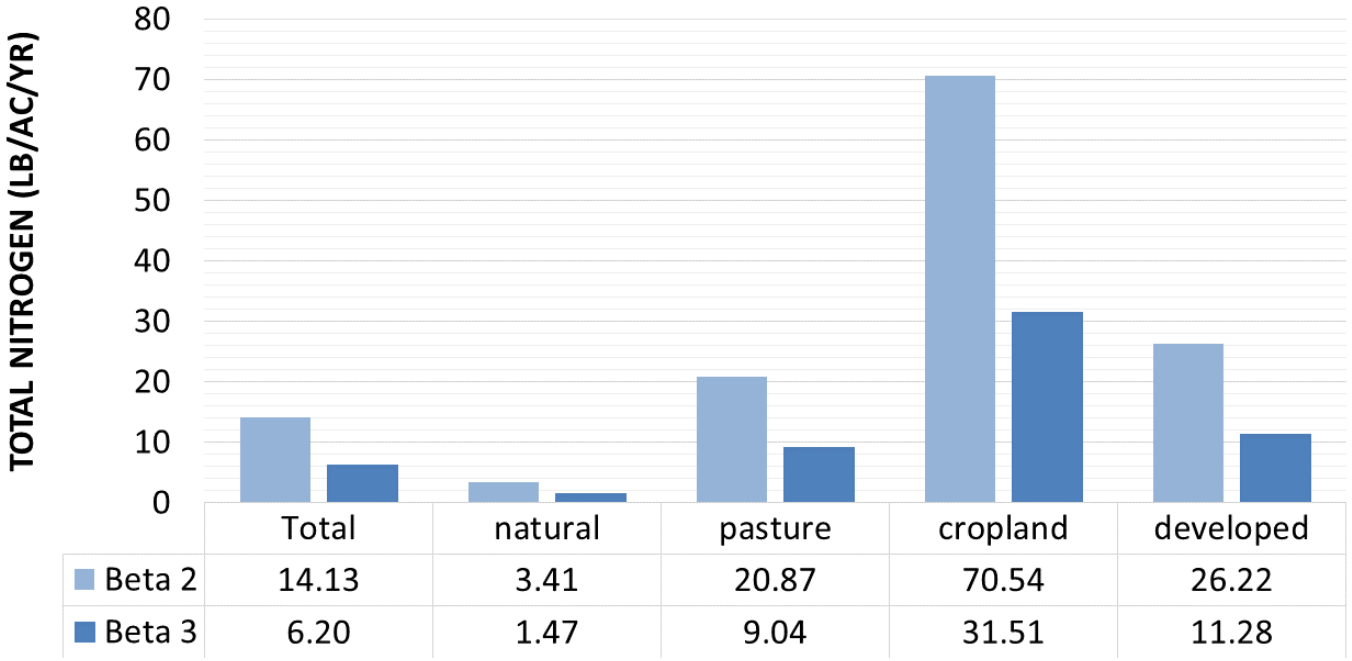


An average loss of **34.83%** over a 30-year period.

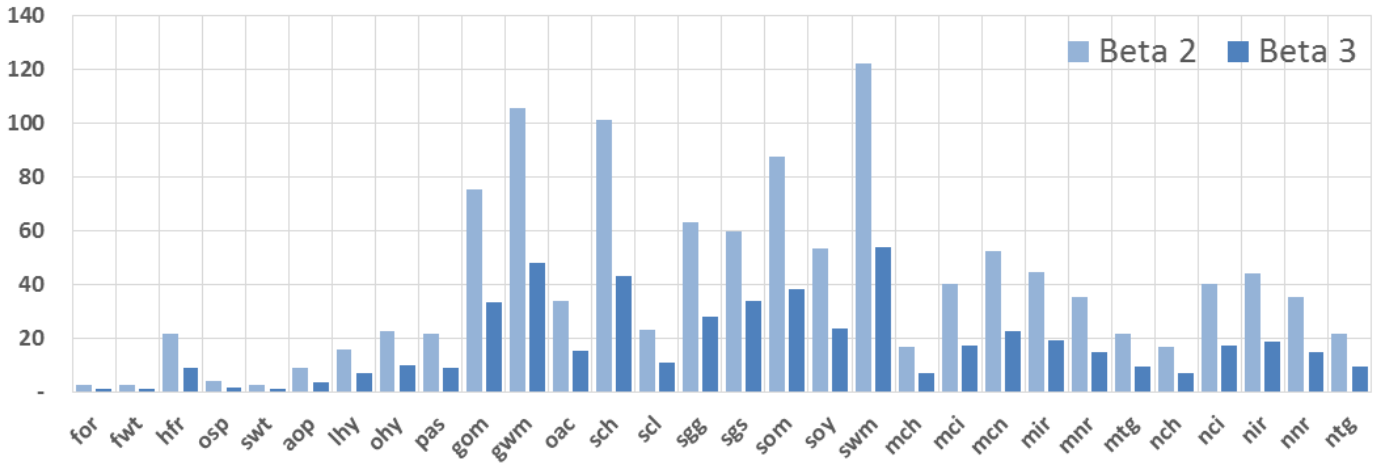


An average loss of **8.03%** over a 30-year period.

Nitrogen export rates (targets)

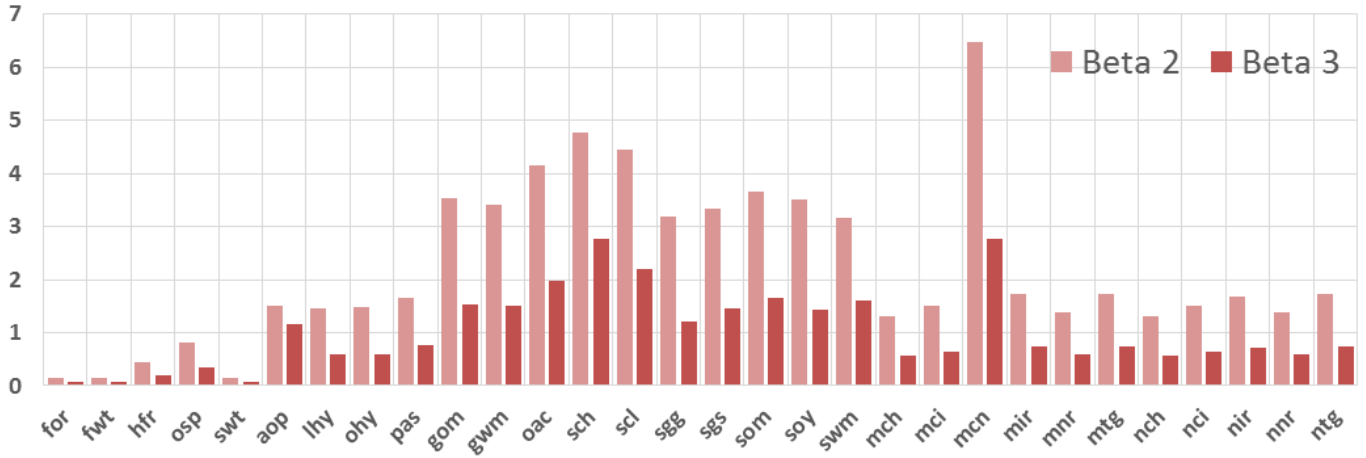


	Total	natural	pasture	cropland	developed
Beta 2	14.13	3.41	20.87	70.54	26.22
Beta 3	6.20	1.47	9.04	31.51	11.28



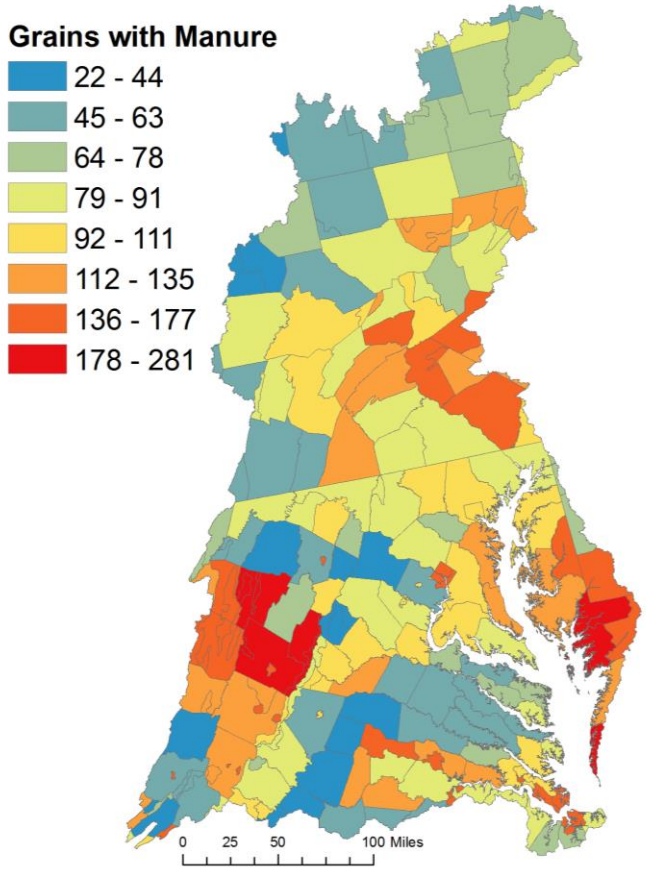
Phosphorus export rates (targets)

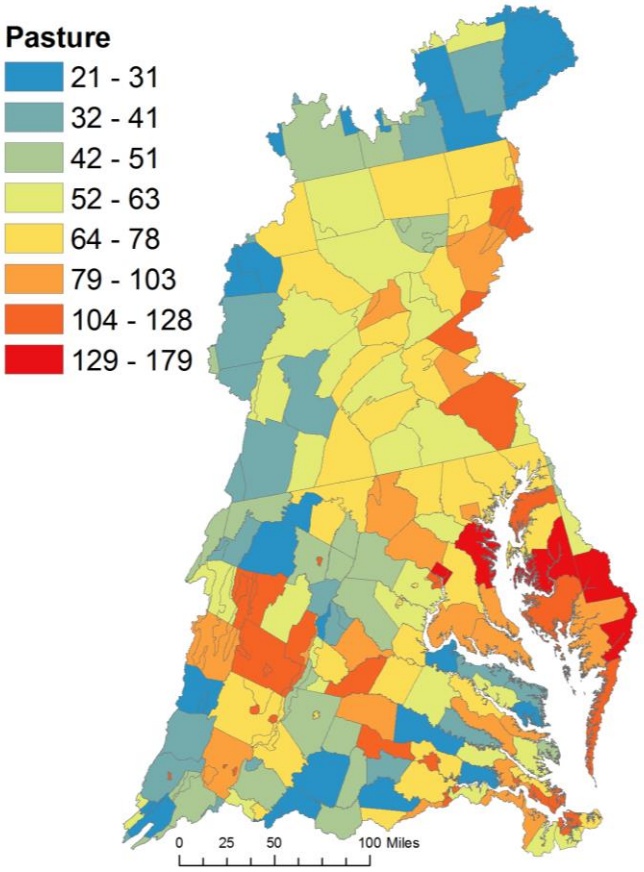
	Total	natural	pasture	cropland	developed
Beta 2	0.85	0.19	1.57	3.61	1.71
Beta 3	0.37	0.08	0.70	1.60	0.73



Soil Mehlich 3 reanalysis using APLE

- APLE model was calibrated against observed soil Mehlich 3 data using Beta 3 nutrient inputs.





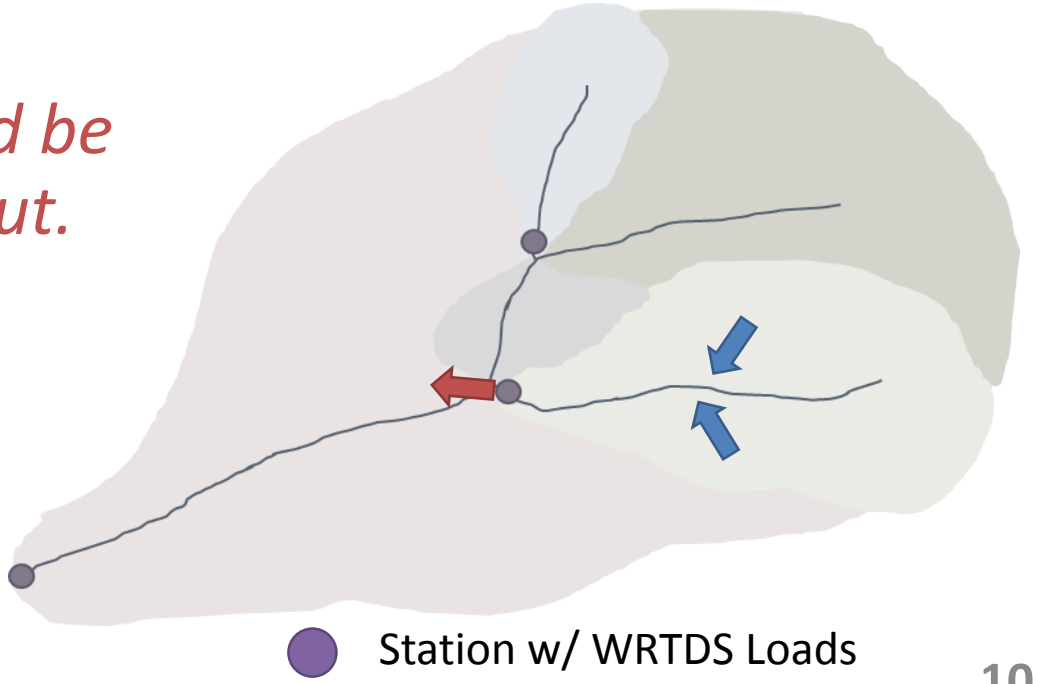
See appendix for variability in Soil Mehlich 3 for P6 agricultural land uses, and across P6 land segments

3. Evaluation of river inputs to WRTDS

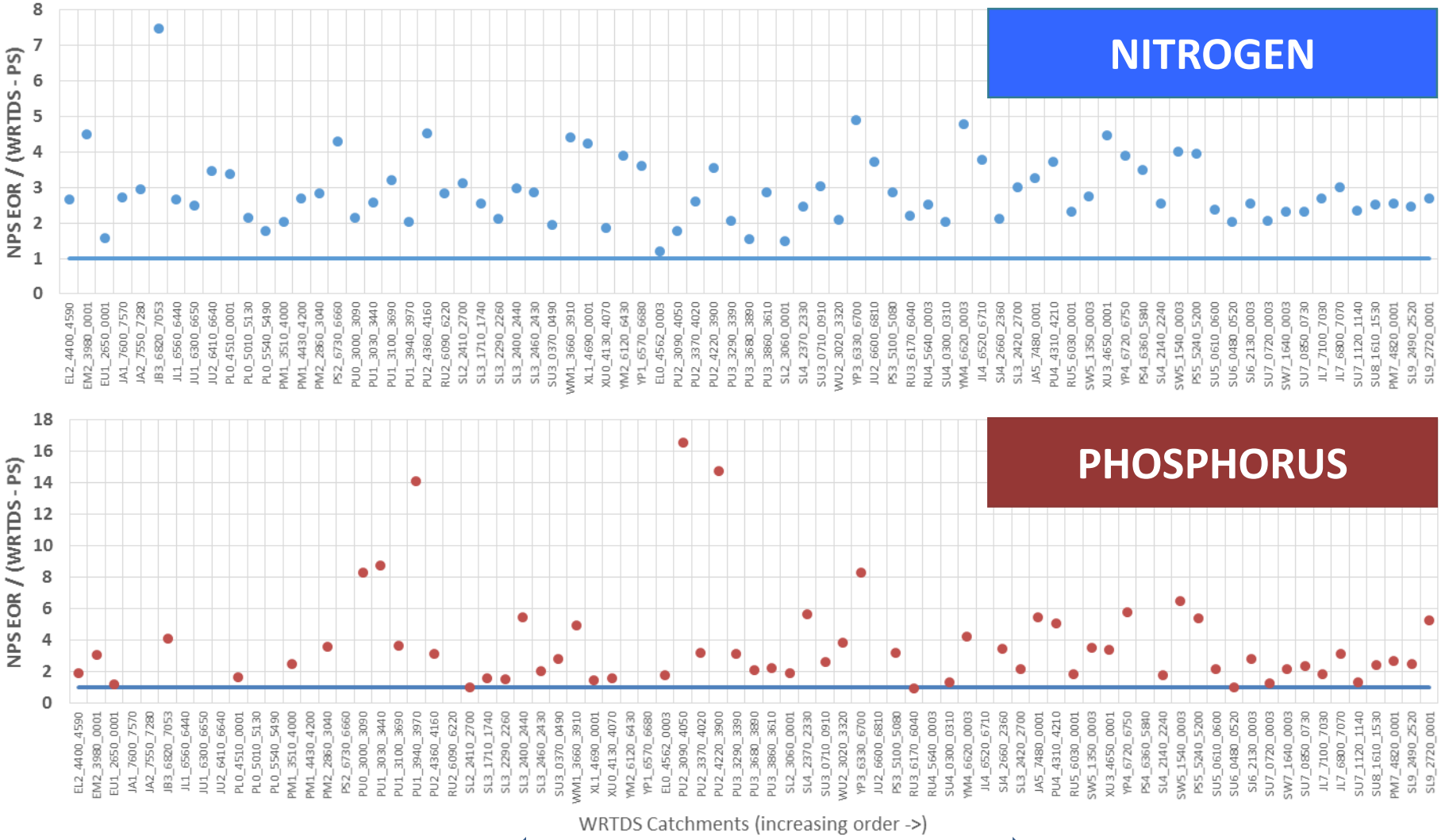
- Average non-point source yield [**input**] was calculated using Beta 3 targets, and compared to WRTDS yield (the difference of WRTDS and point source) [**output**]

- *The river inputs should be greater than the output.*

- The goal is to identify where it did not, and potentially why if that was the case.



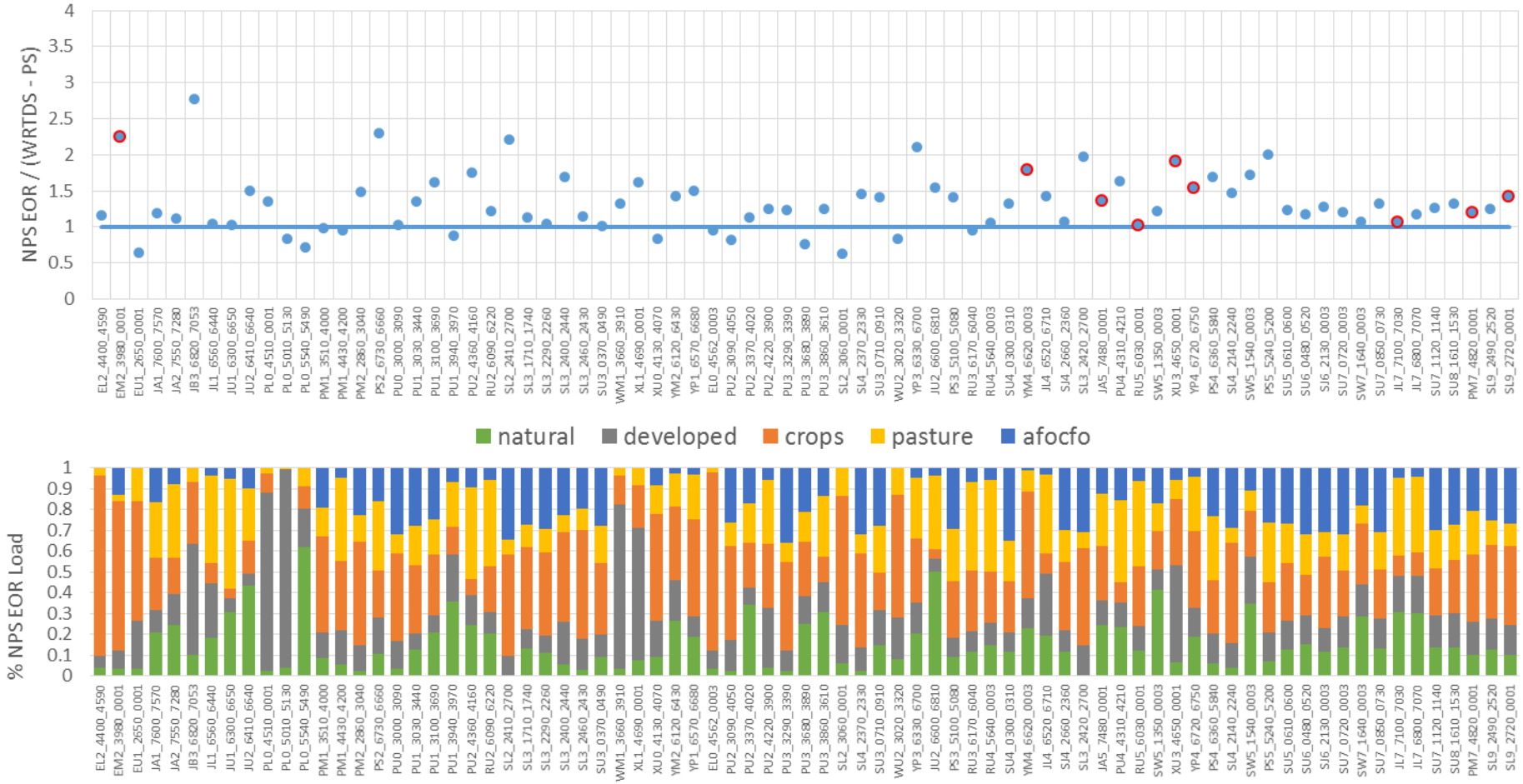
Beta 2 river inputs (EOR) vs. WRTDS



smaller catchments ← → **larger river basins**

Beta 3 river inputs (EOR) vs. WRTDS

Landuse	RATIO
crops	1.00
developed	0.37
natural	0.05
pasture	0.30



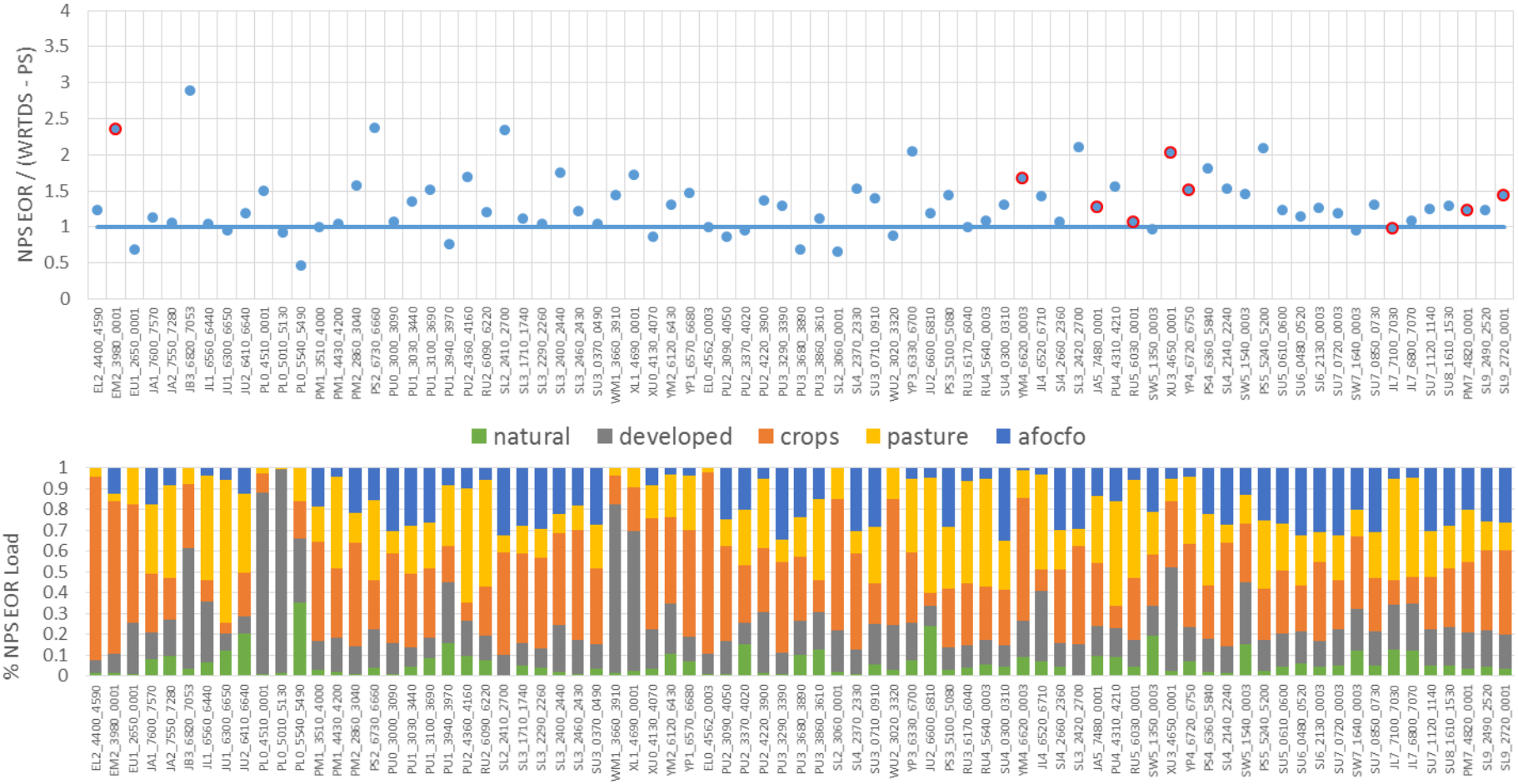
NITROGEN

larger river basins

SPARROW loading rate ratios

Landuse	RATIO
crops	1.00
developed	0.39
natural	0.02
pasture	0.34

less nitrogen loads from natural land-use

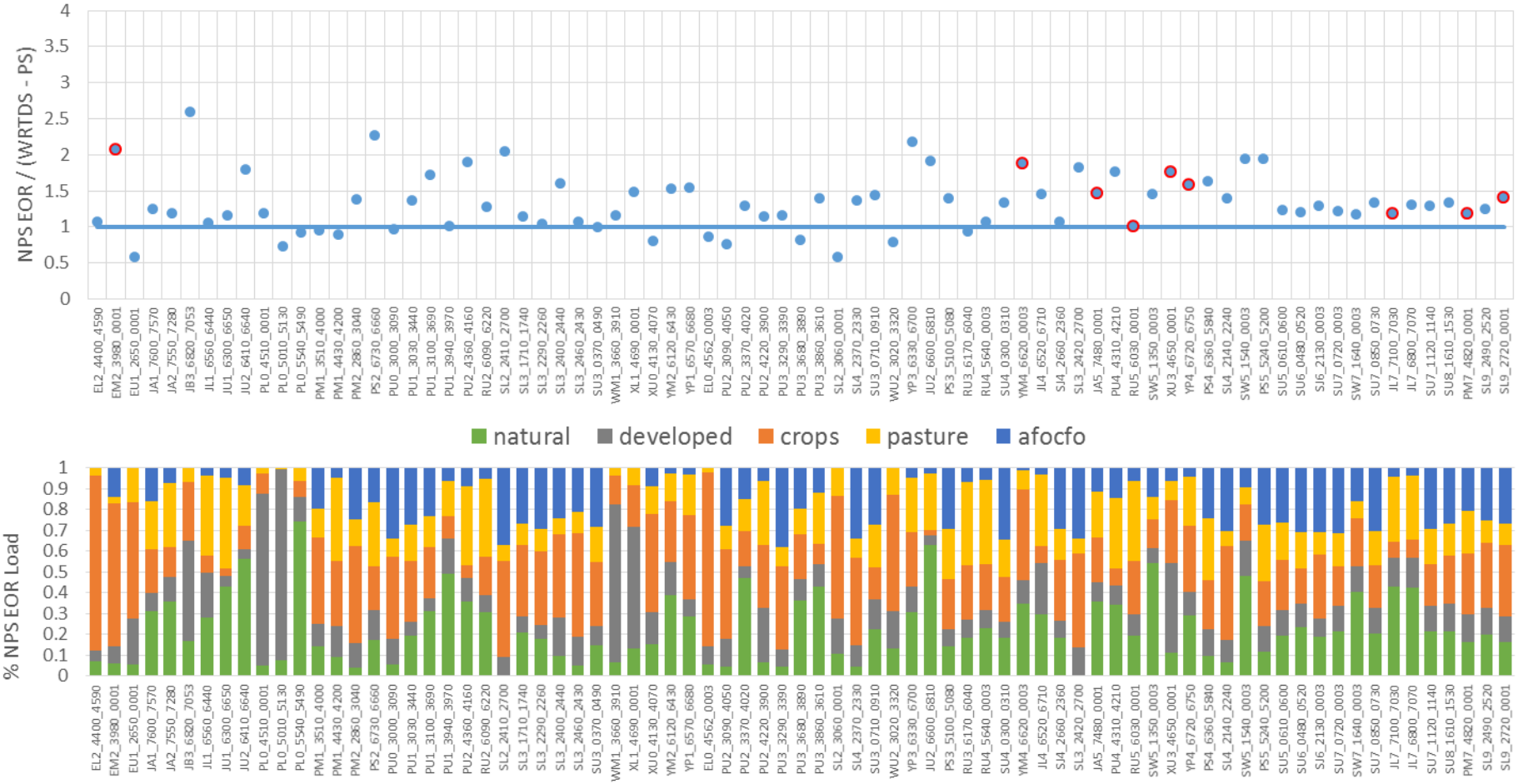


NITROGEN

P532 loading rate ratios

Landuse	RATIO
crops	1.00
developed	0.35
natural	0.09
pasture	0.32

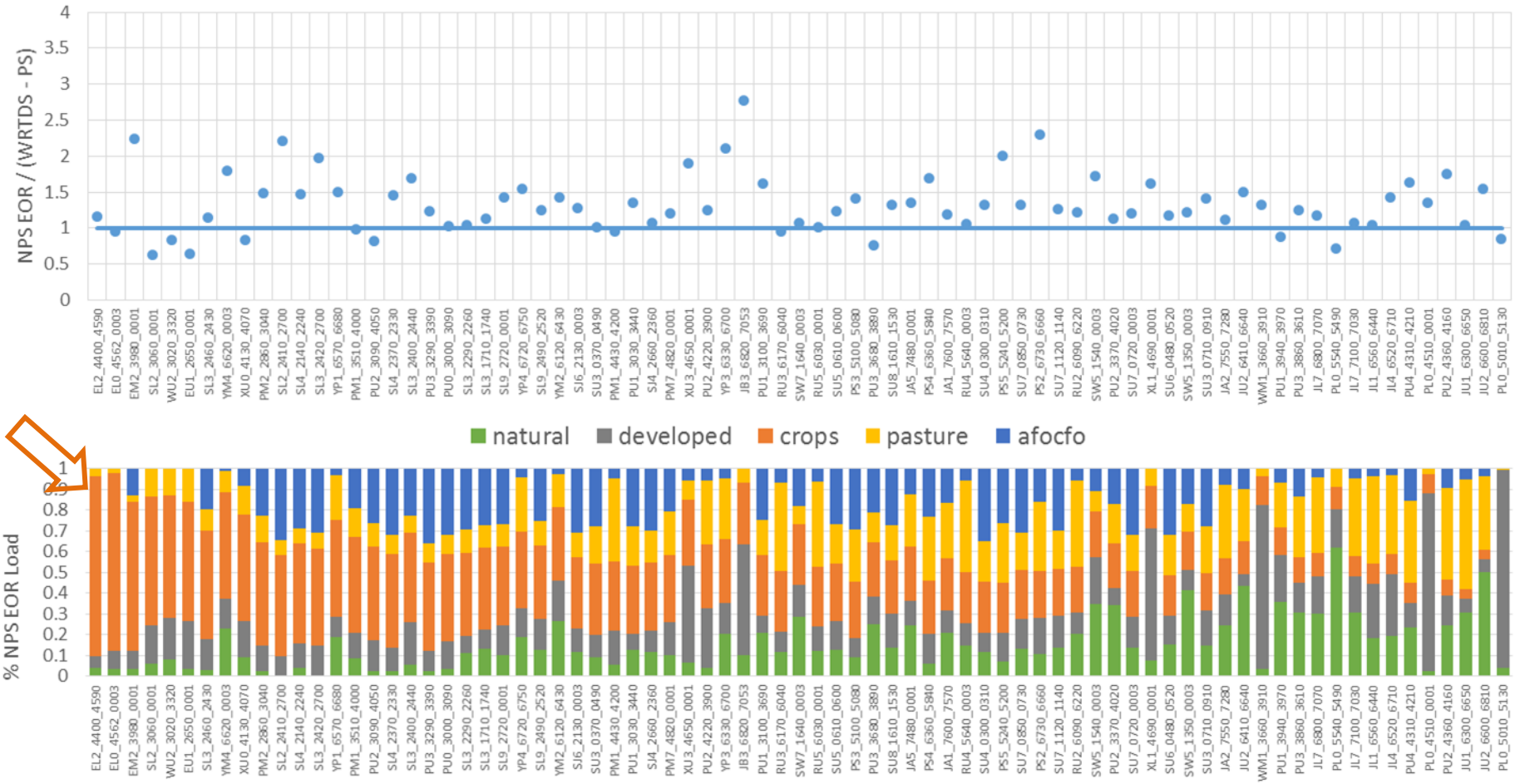
more nitrogen loads from natural land-use



NITROGEN

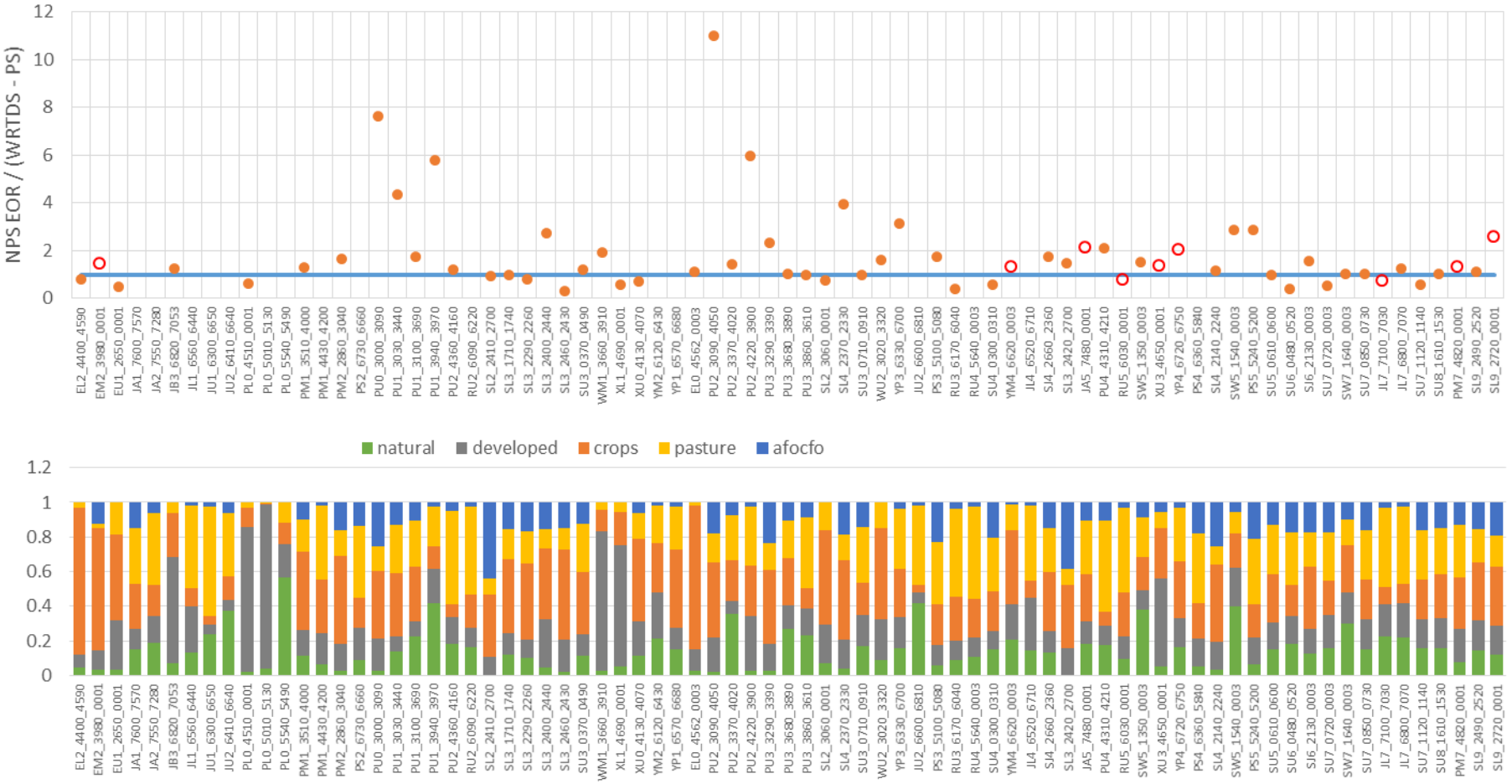
Investigated patterns

Left to right: decreasing % contribution from crop lands



NITROGEN

Beta 3 river inputs (EOR) vs. WRTDS



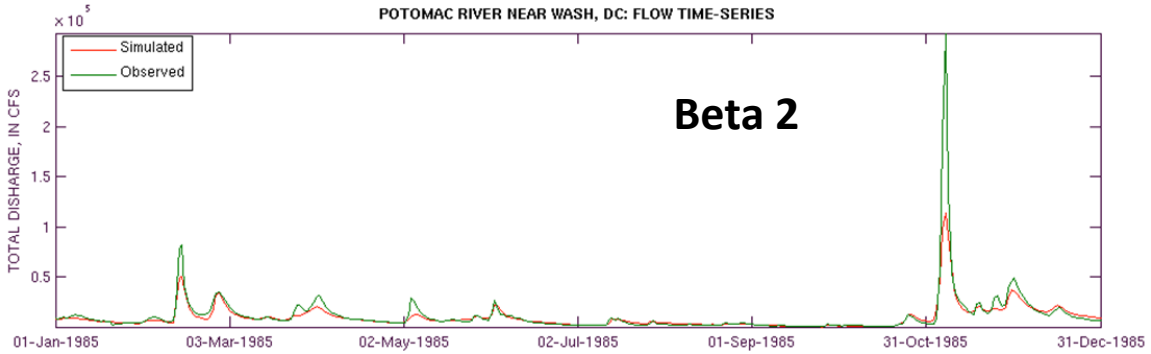
PHOSPHORUS

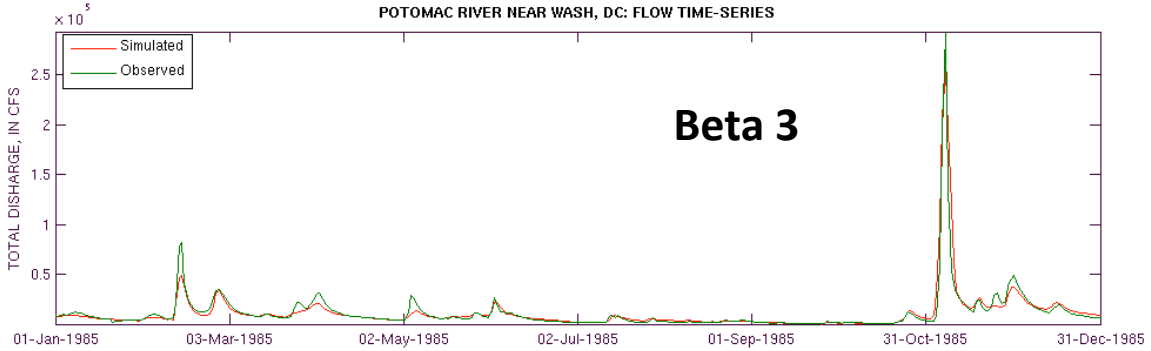
4. Beta 3 Model Calibration

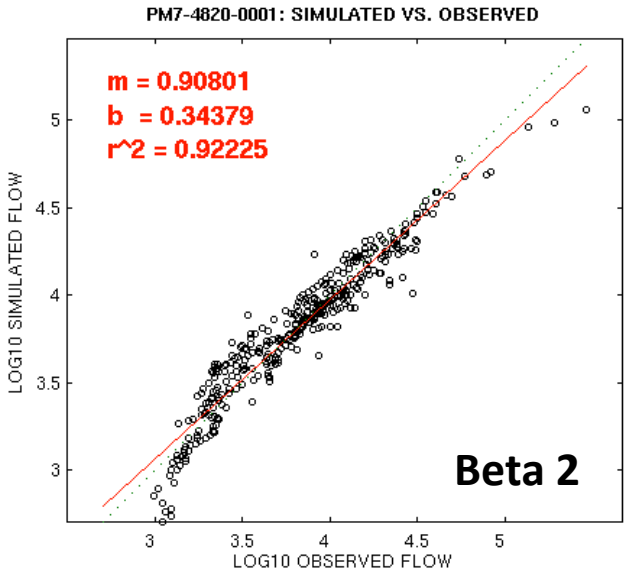
- Hydrology Calibration
  - Diversion data was updated in Beta 2 model.
  - Diversion data was reexamined for a few basins where low flow calibration had deteriorated.
  - Hurricane Juan (November 1985)

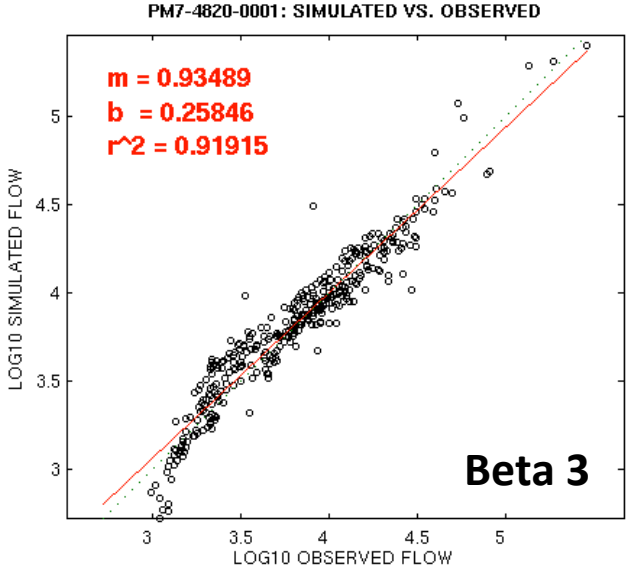
Hurricane Juan November 1985

Phase 5 Section 2.4.1



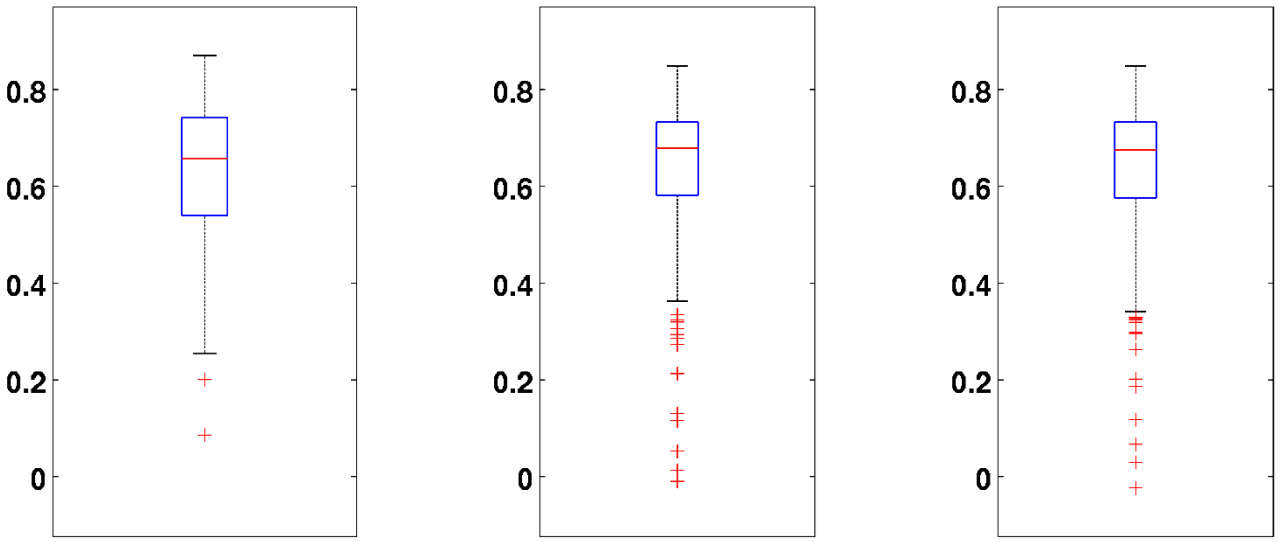






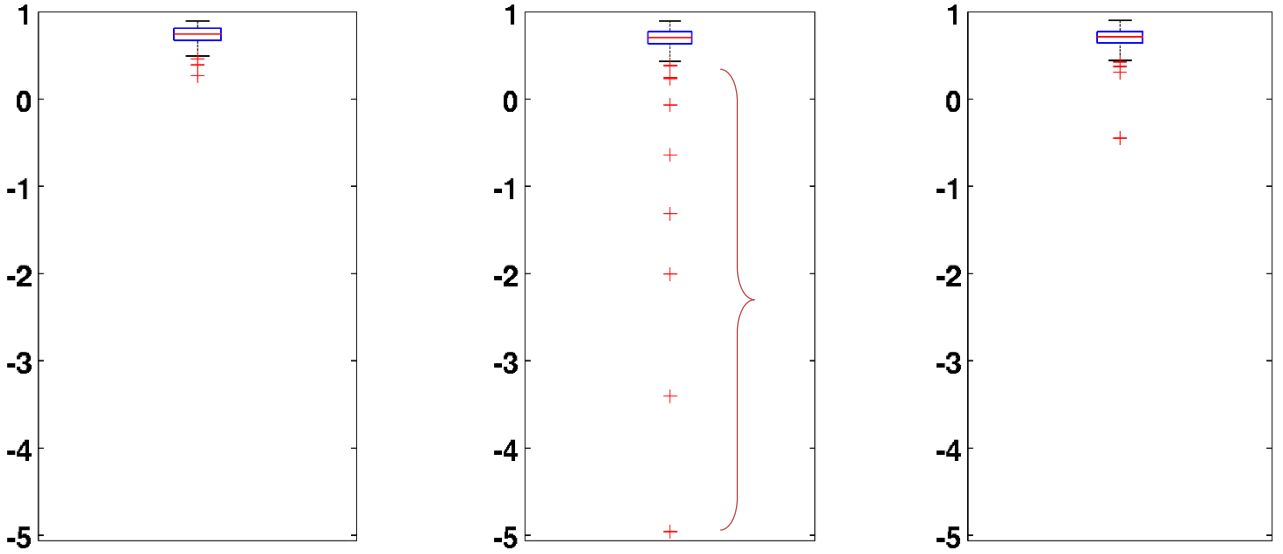
Model Performance (Hydrology)

Nash-Sutcliffe Efficiency at 191 Calibration Stations



Phase 5 | Phase 6 Beta 2 | Phase 6 Beta 3

Log Nash-Sutcliffe Efficiency at 191 Calibration Stations



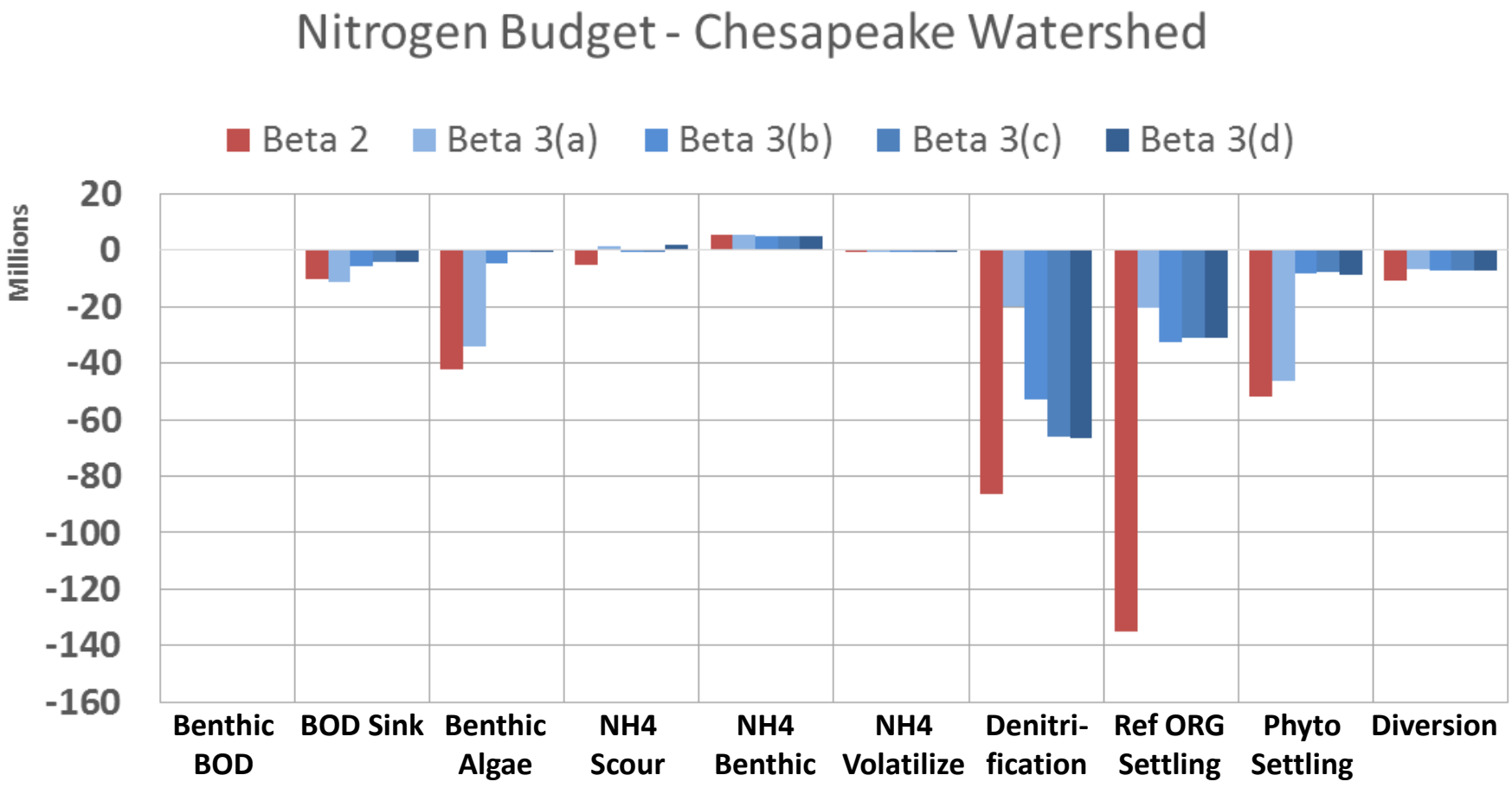
Phase 5 | Phase 6 Beta 2 | Phase 6 Beta 3

NSE closer to 1 the better

4. Beta 3 Model Calibration

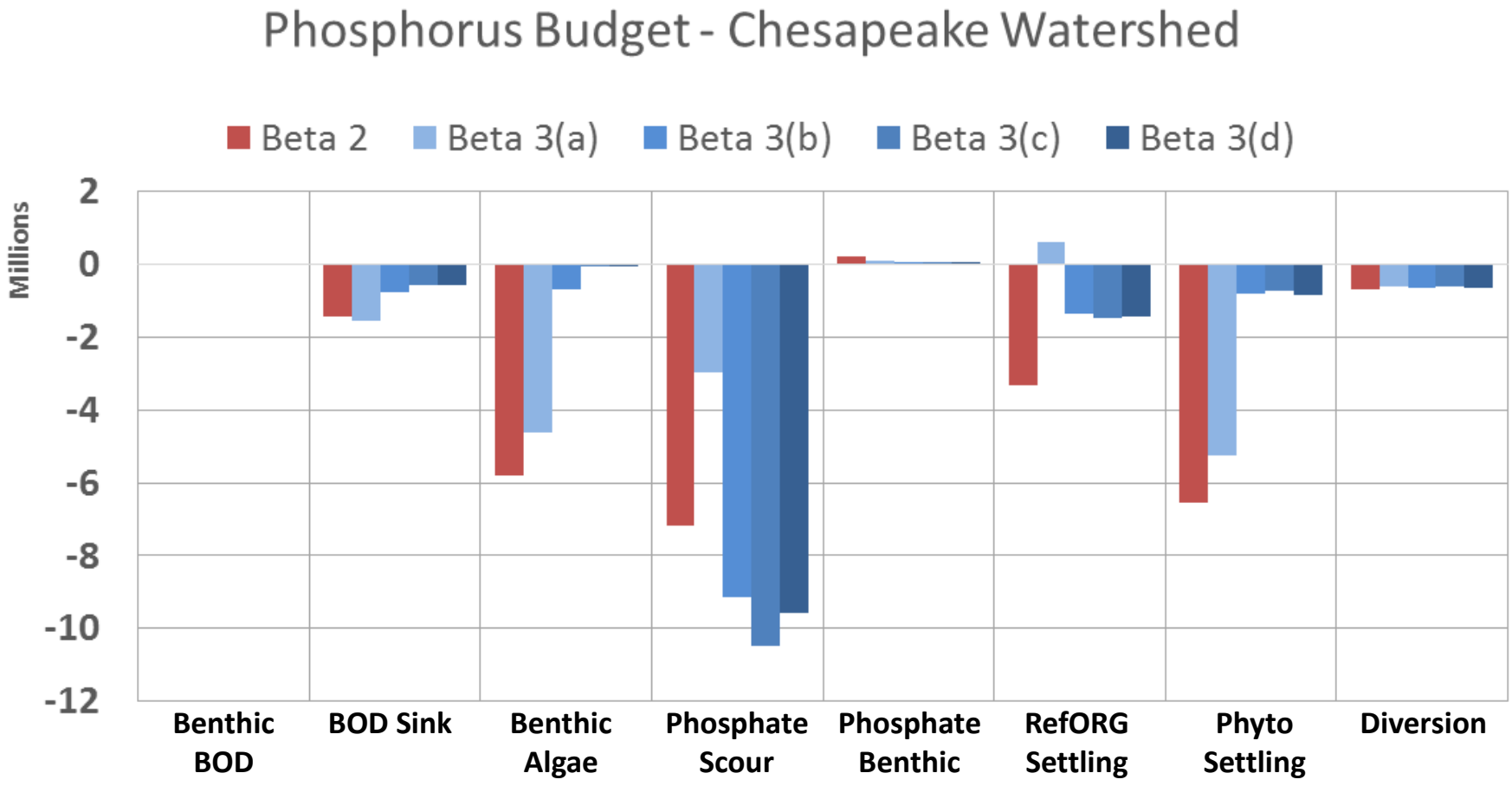
- Sediment Calibration
  - Beta 2 sediment export rates
- Nutrient Calibration
  - Beta 3 Scenario Builder inputs
  - New input dataset for biosolids
  - Legume fixation for pasture and hay land uses
  - Revised land use export rates

Simulation of nitrogen in large rivers



In Beta 3, denitrification is the strongest loss mechanism.

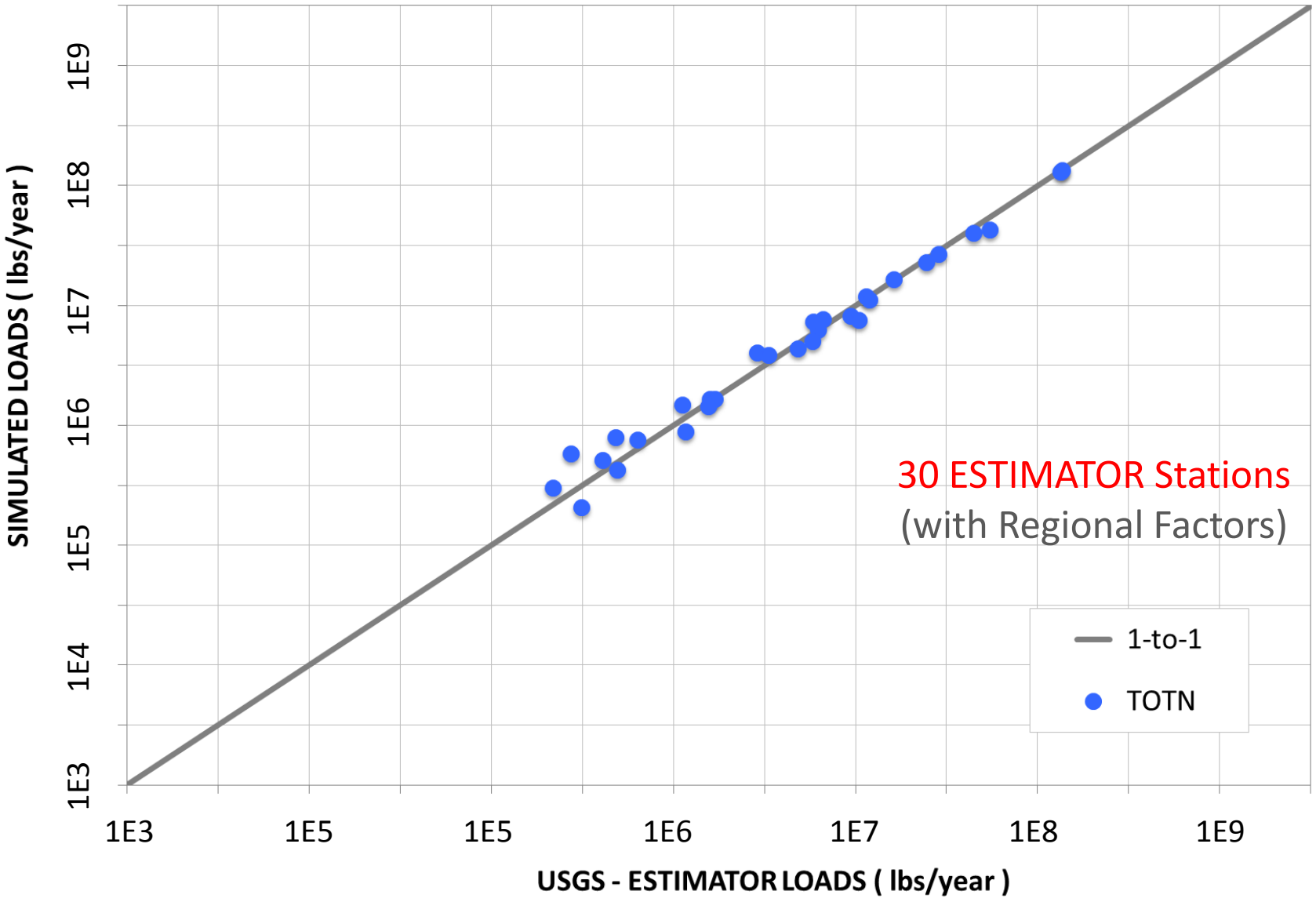
Simulation of phosphorus in large rivers



In Beta 3, settling of phosphate is the strongest loss mechanism.

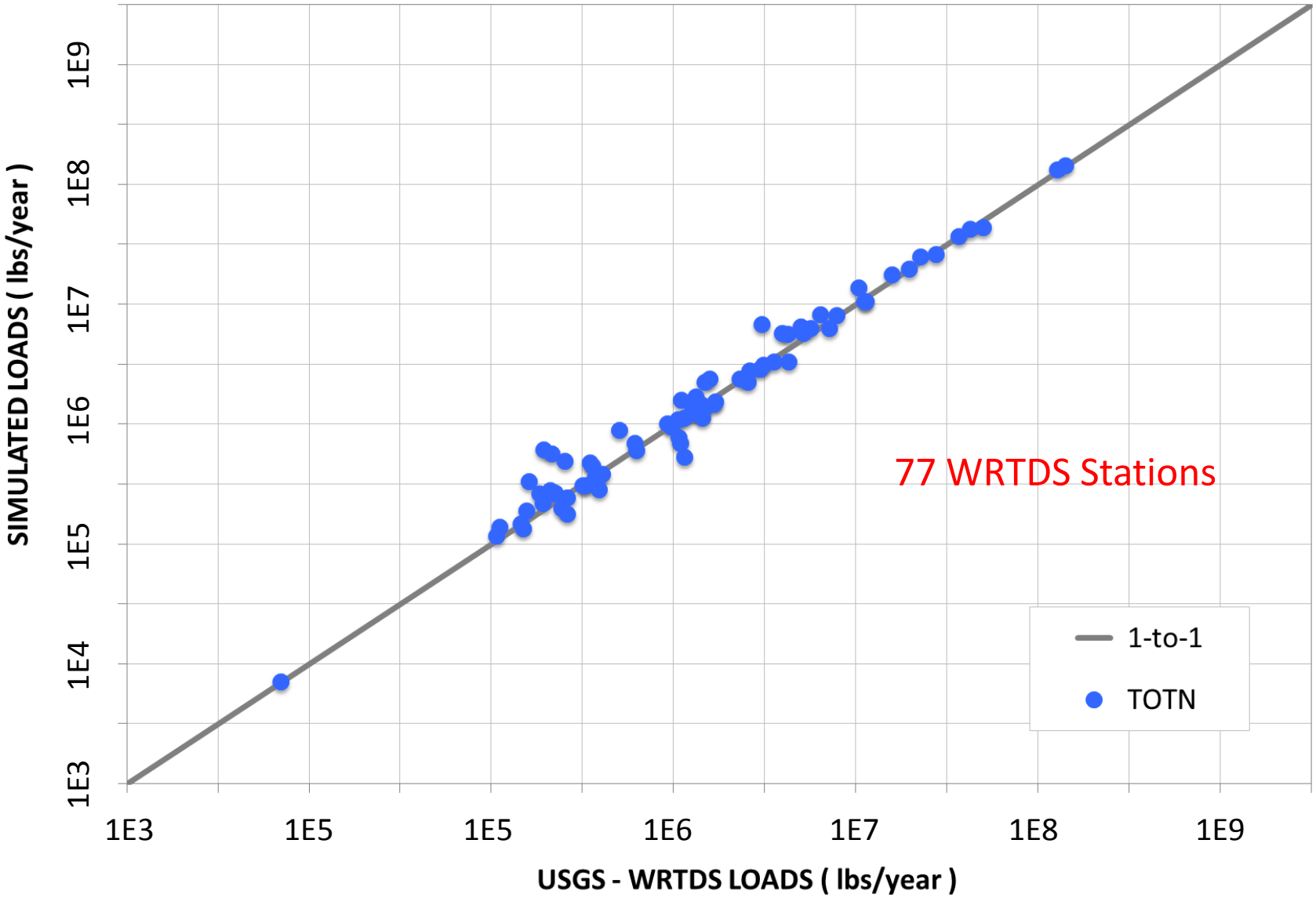
PHASE 5

NITROGEN



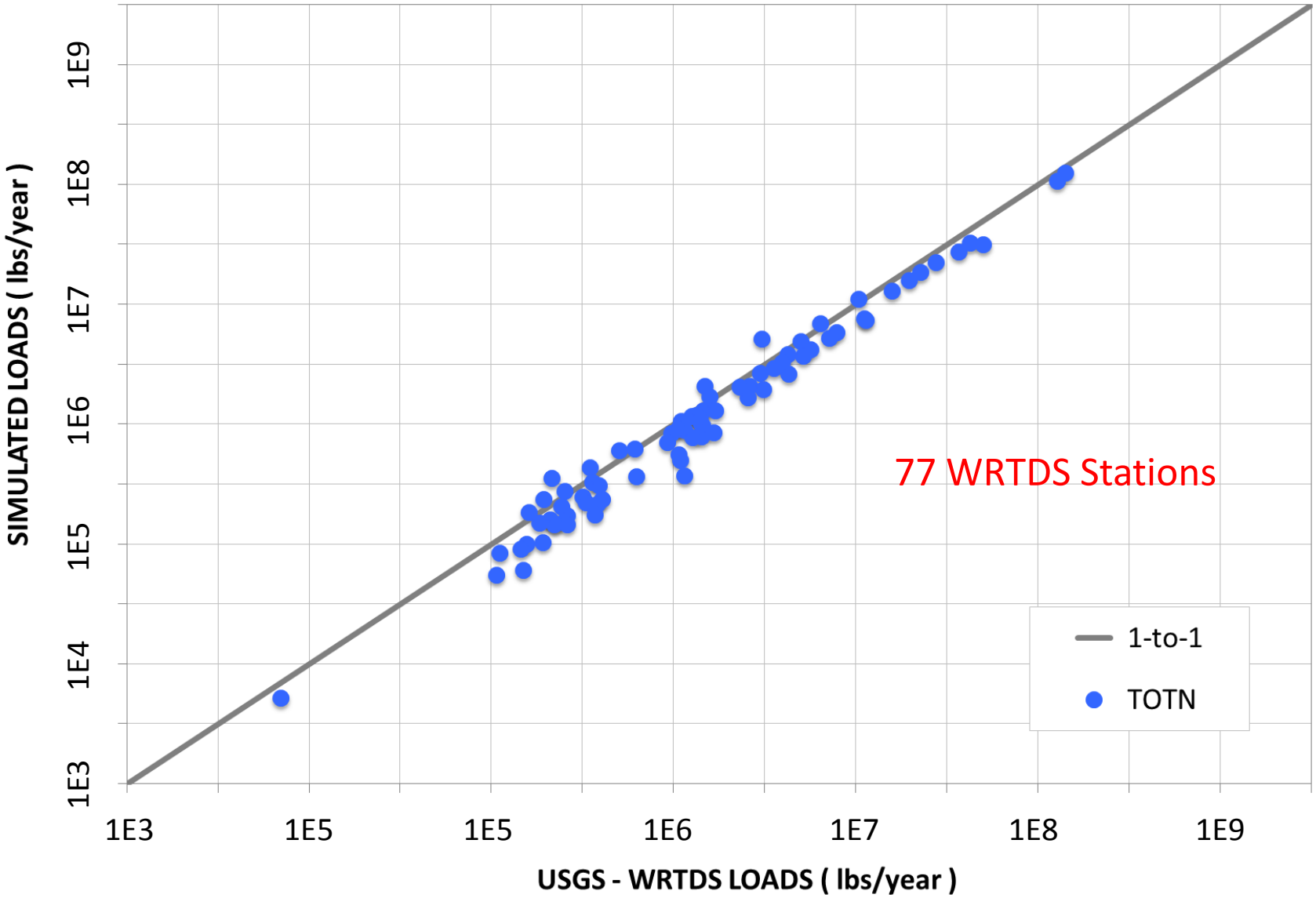
PHASE 6
BETA 2

NITROGEN



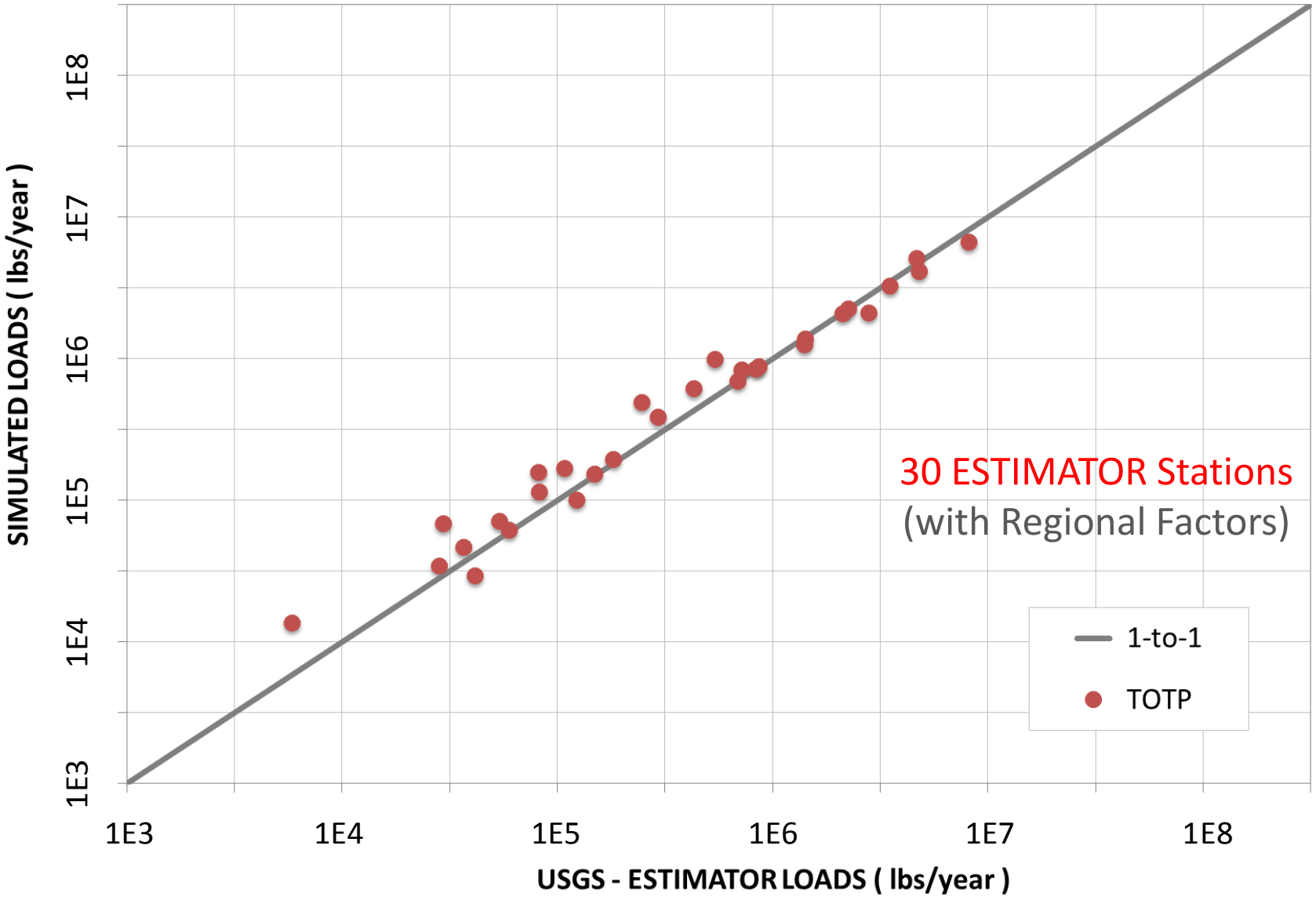
PHASE 6
BETA 3

NITROGEN



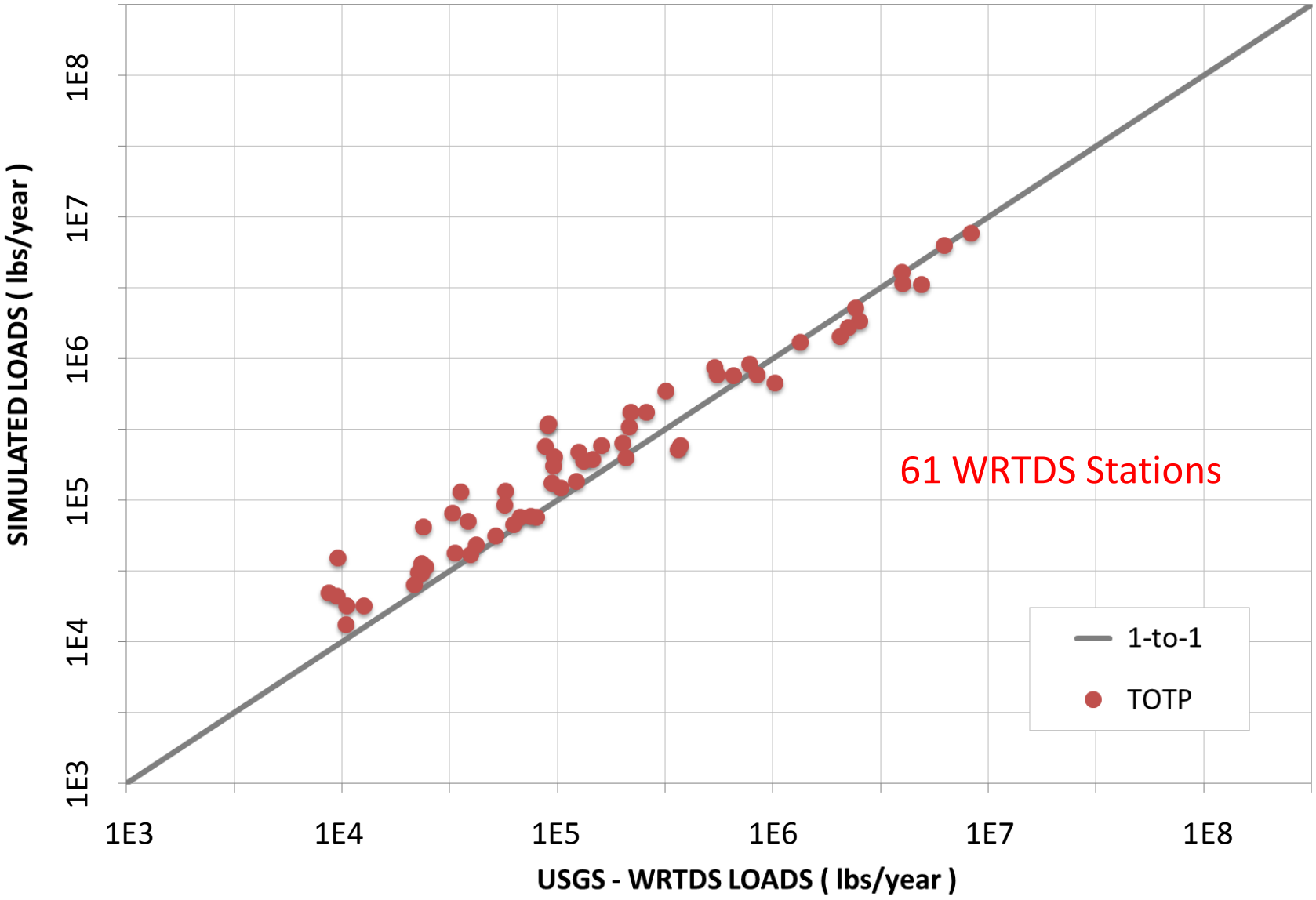
PHASE 5

PHOSPHORUS



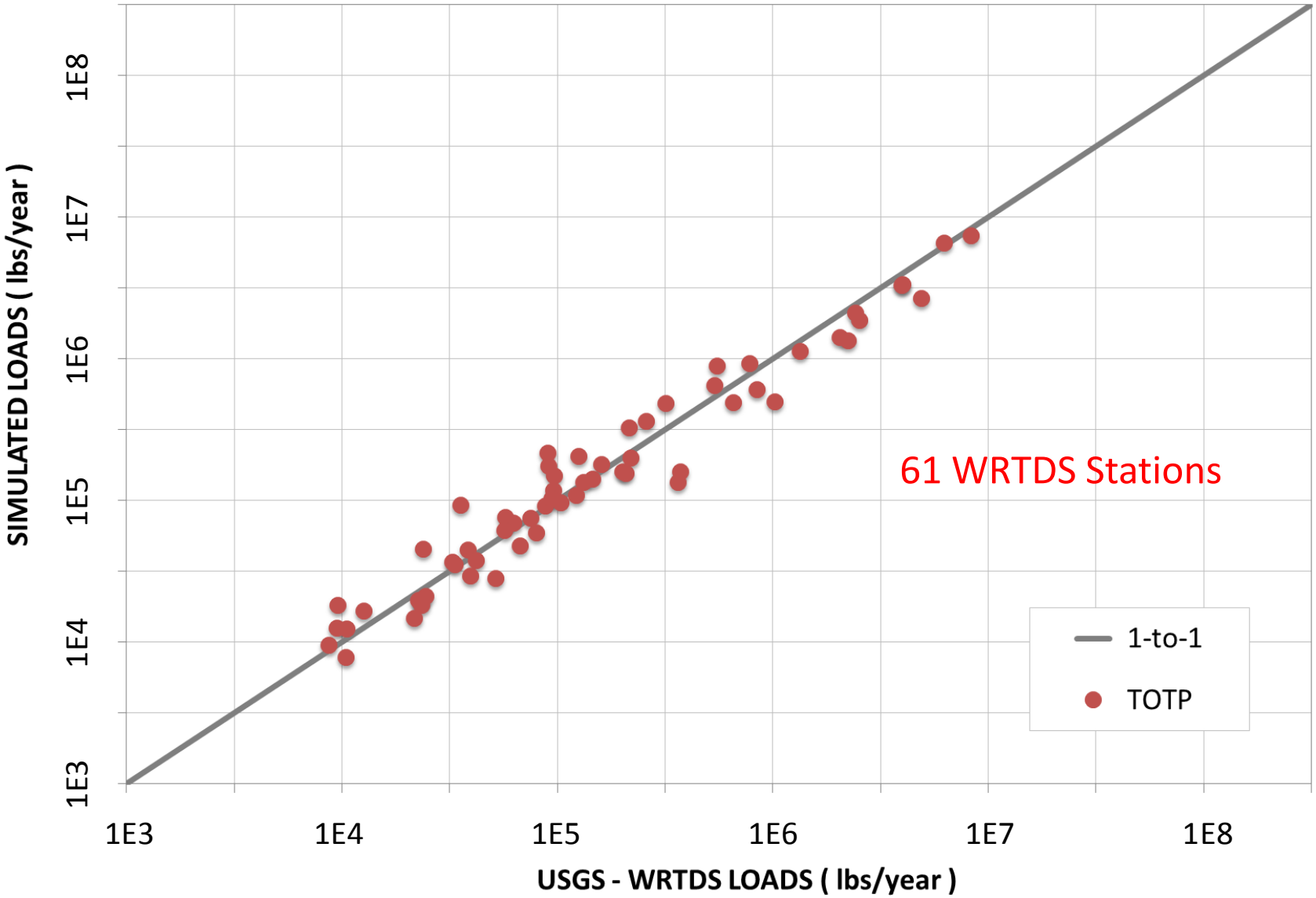
PHASE 6
BETA 2

PHOSPHORUS



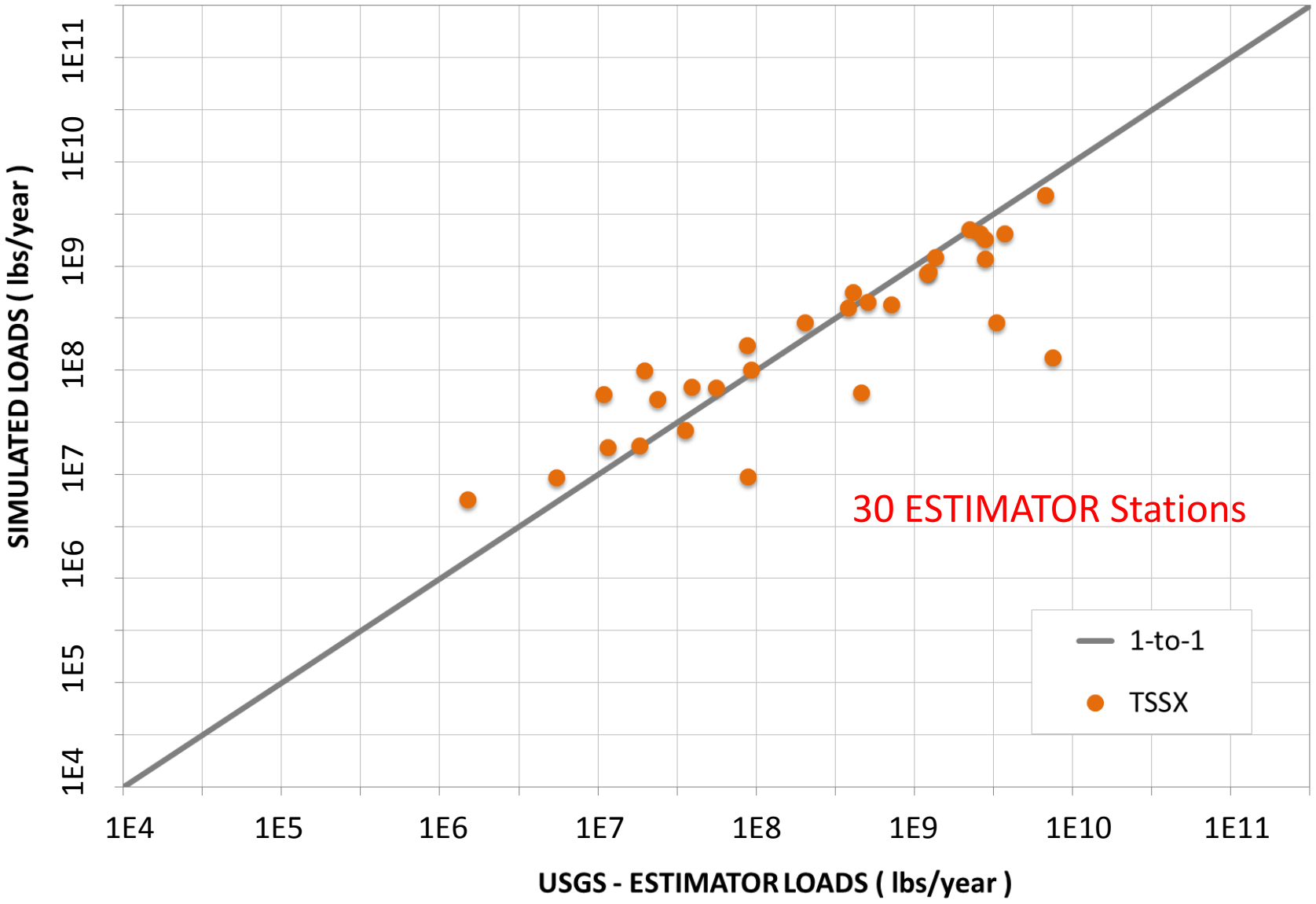
PHASE 6
BETA 3

PHOSPHORUS



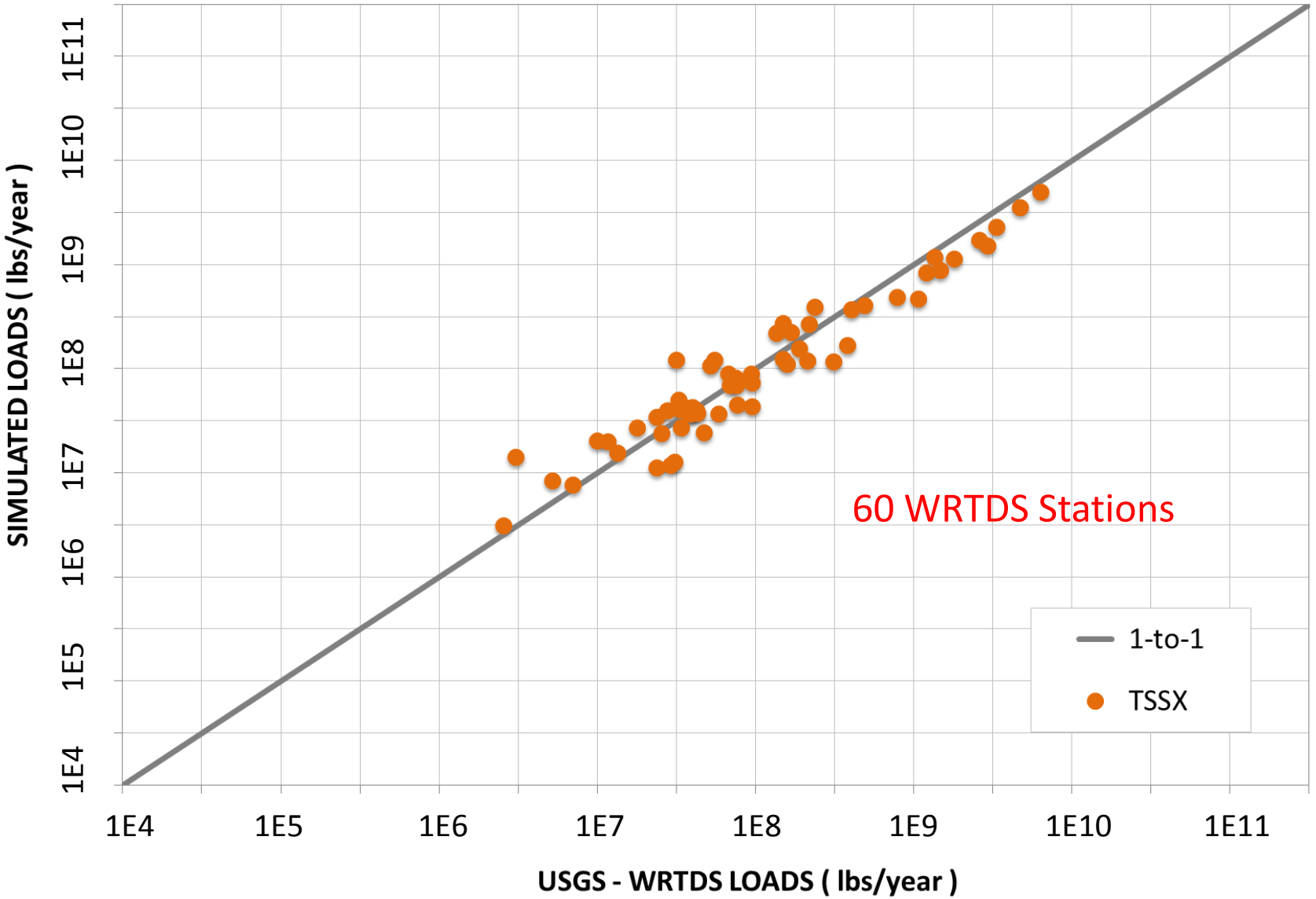
PHASE 5

SEDIMENT



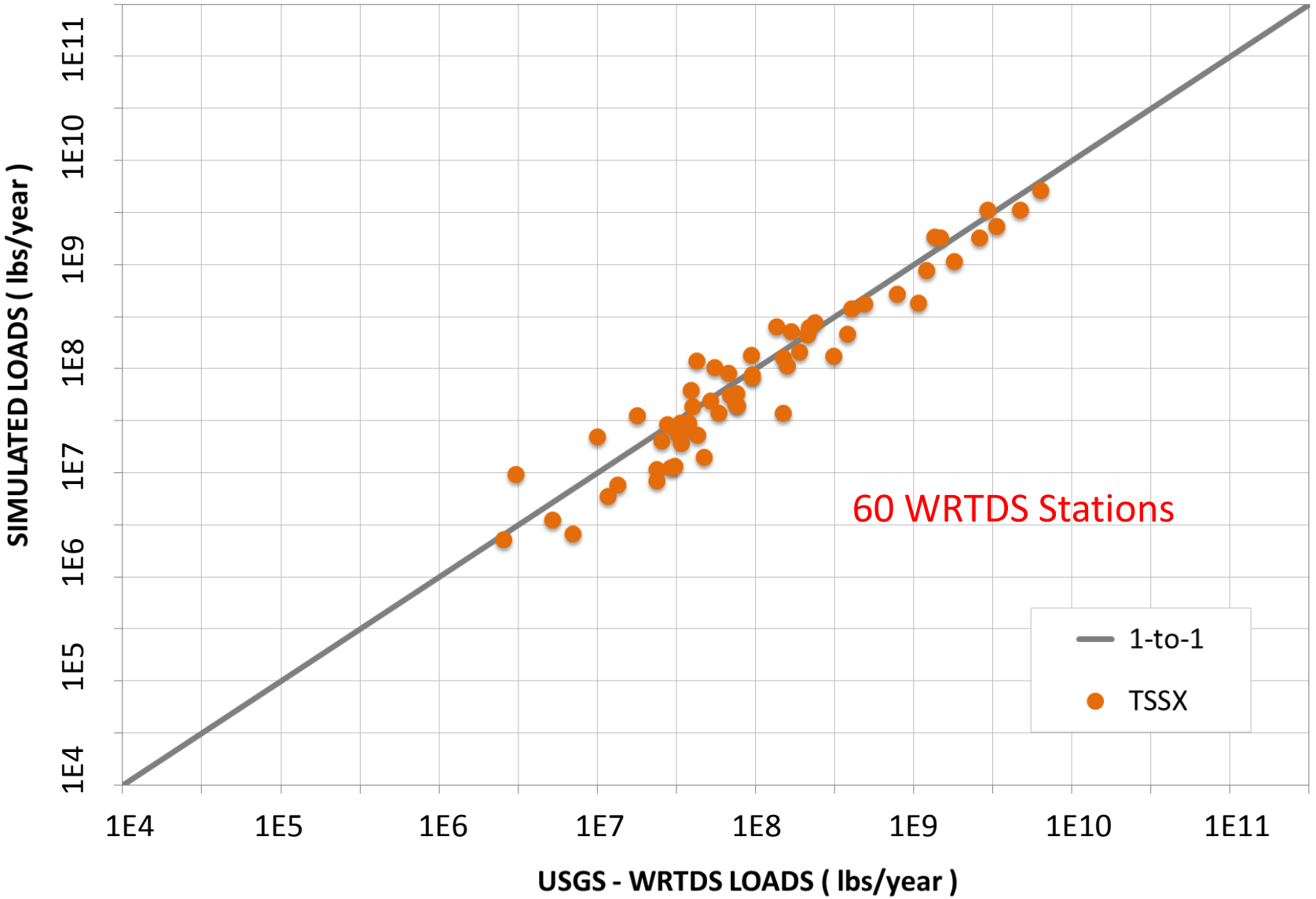
PHASE 6
BETA 2

SEDIMENT

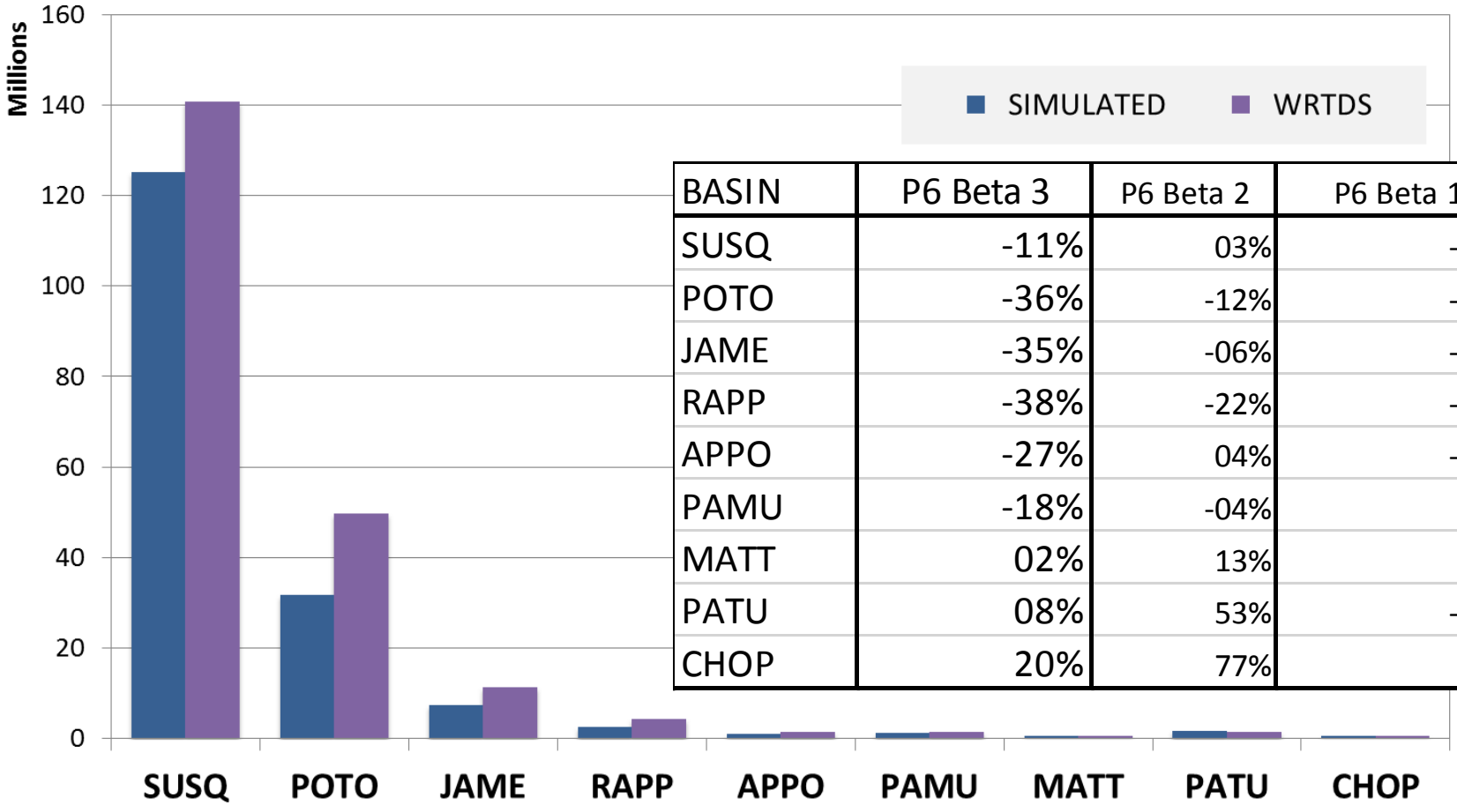


PHASE 6
BETA 3

SEDIMENT



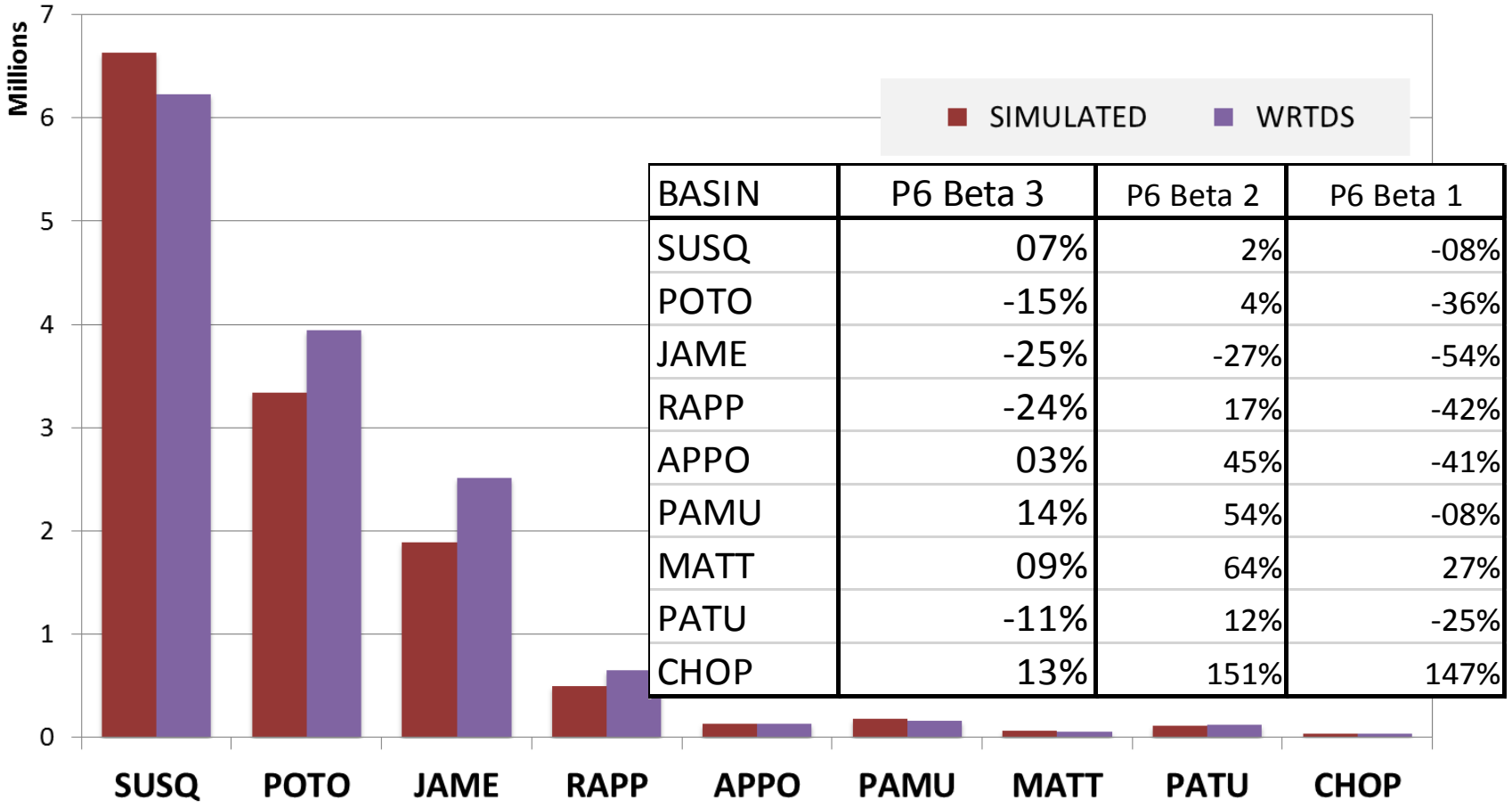
RIM loads: total nitrogen



BASIN	P6 Beta 3	P6 Beta 2	P6 Beta 1
SUSQ	-11%	03%	-05%
POTO	-36%	-12%	-18%
JAME	-35%	-06%	-33%
RAPP	-38%	-22%	-25%
APPO	-27%	04%	-44%
PAMU	-18%	-04%	07%
MATT	02%	13%	57%
PATU	08%	53%	-03%
CHOP	20%	77%	17%

+/- 10% difference

RIM loads: total phosphorus

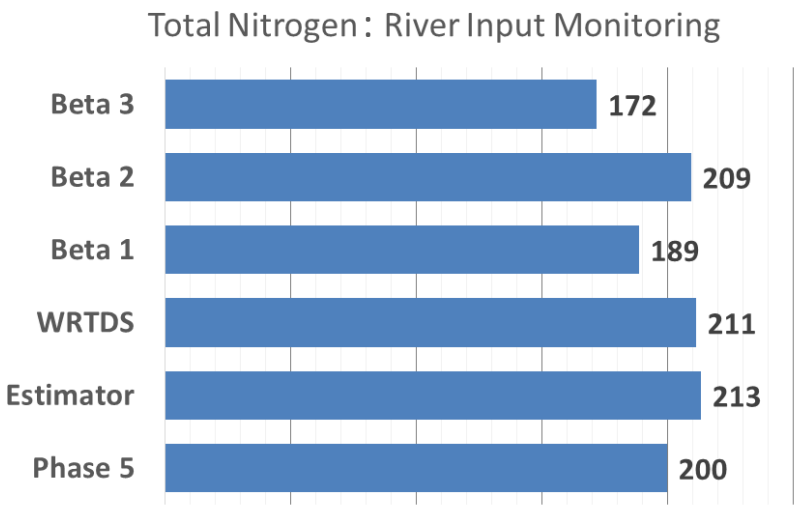


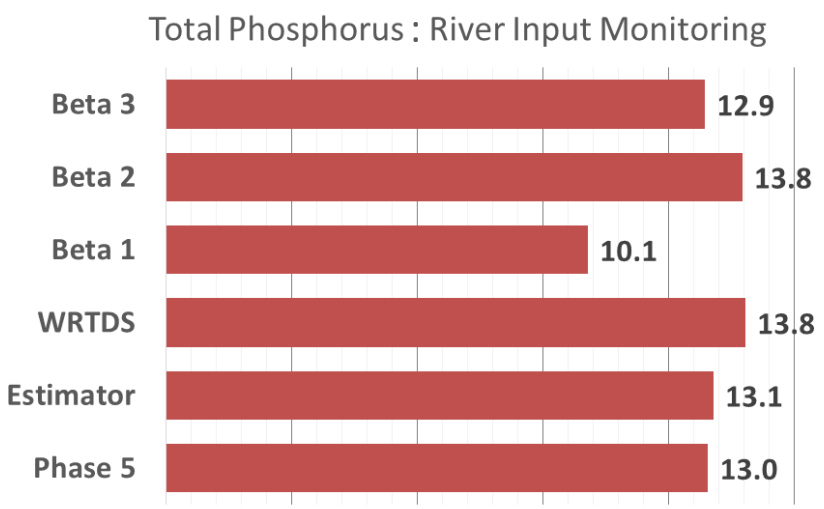
BASIN	P6 Beta 3	P6 Beta 2	P6 Beta 1
SUSQ	07%	2%	-08%
POTO	-15%	4%	-36%
JAME	-25%	-27%	-54%
RAPP	-24%	17%	-42%
APPO	03%	45%	-41%
PAMU	14%	54%	-08%
MATT	09%	64%	27%
PATU	-11%	12%	-25%
CHOP	13%	151%	147%

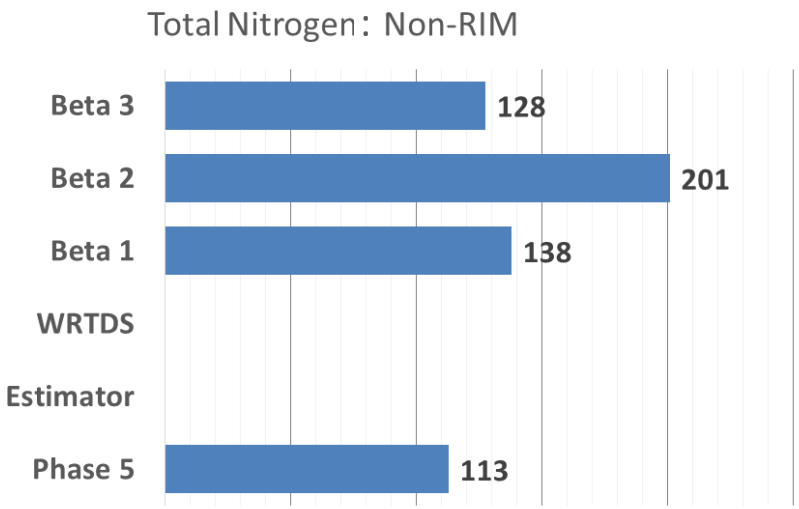
+/- 15% difference

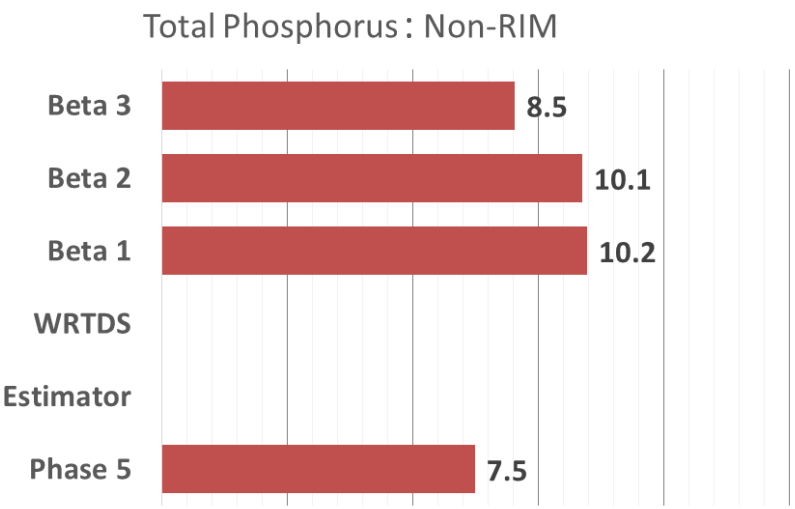
RIM and Non-RIM Loads

(in millions of pounds / year)



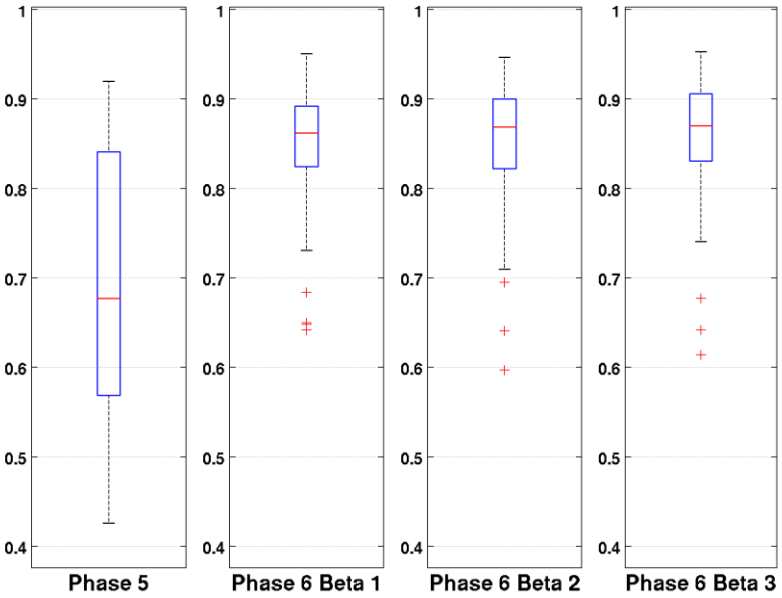




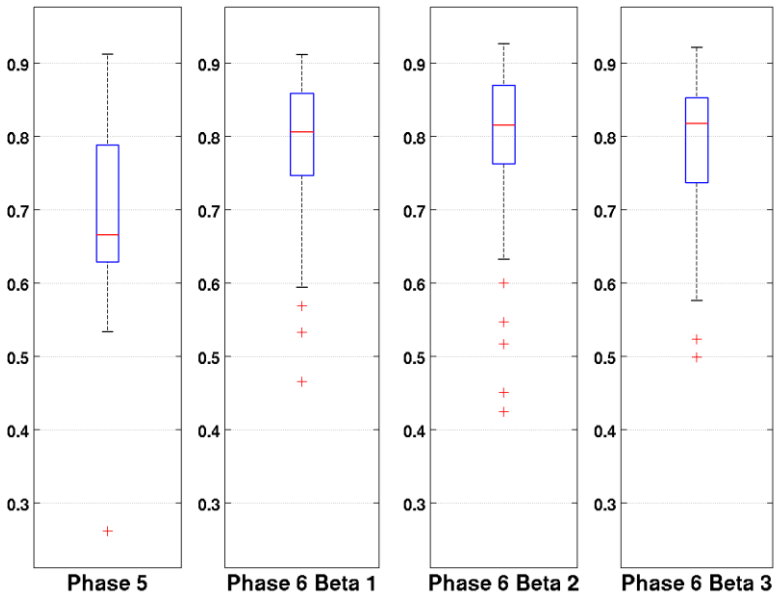


Seasonality of simulated monthly loads

Total Nitrogen Correlation



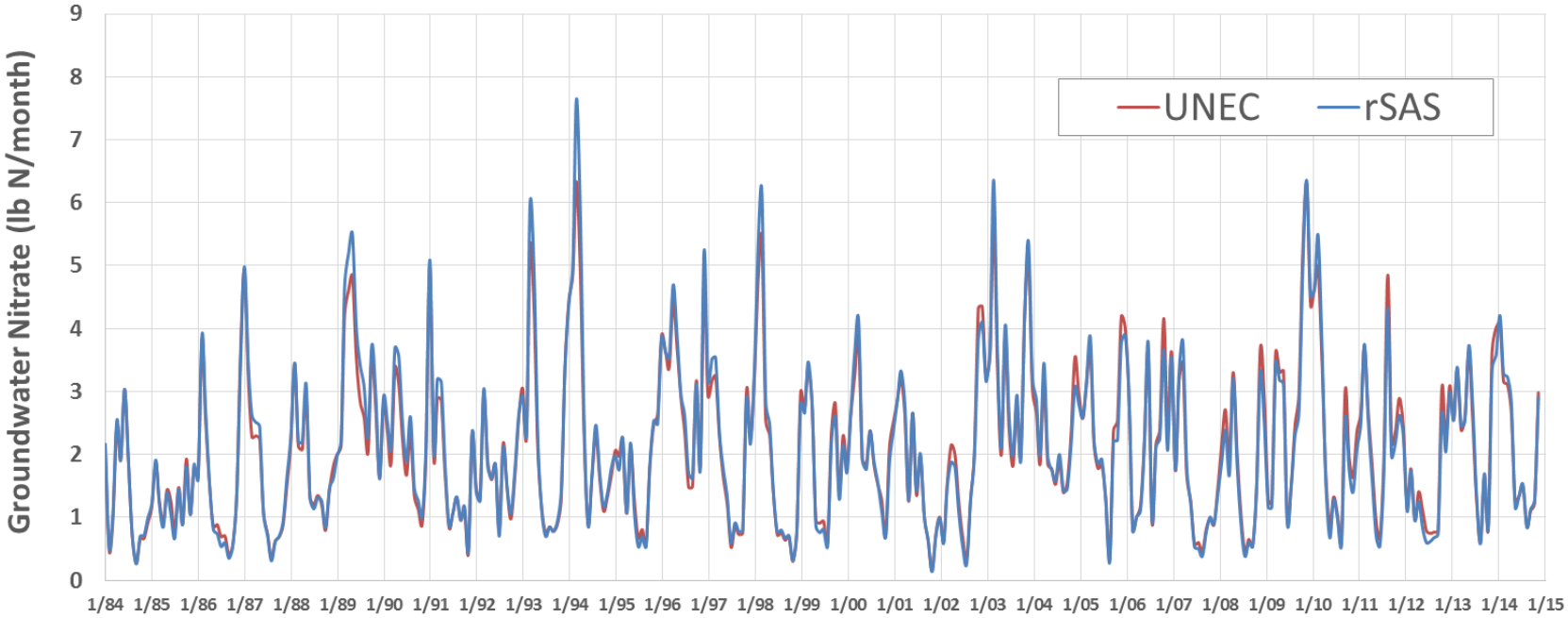
Total Phosphorus Correlation



There is a good agreement in the seasonality of simulated loads with WRTDS.

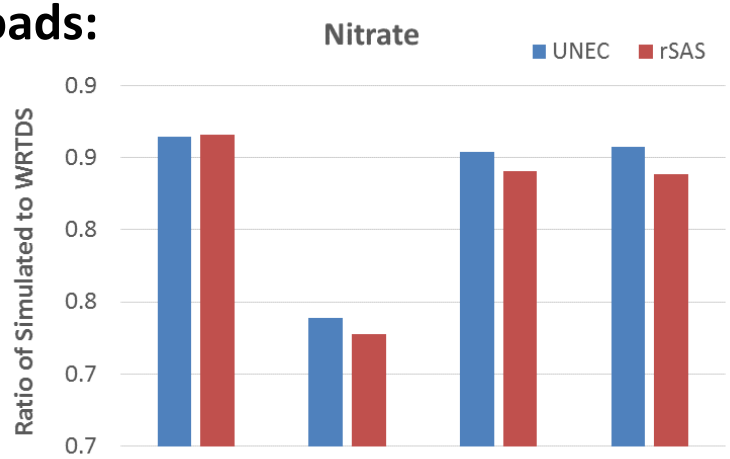
5. rSAS prototype

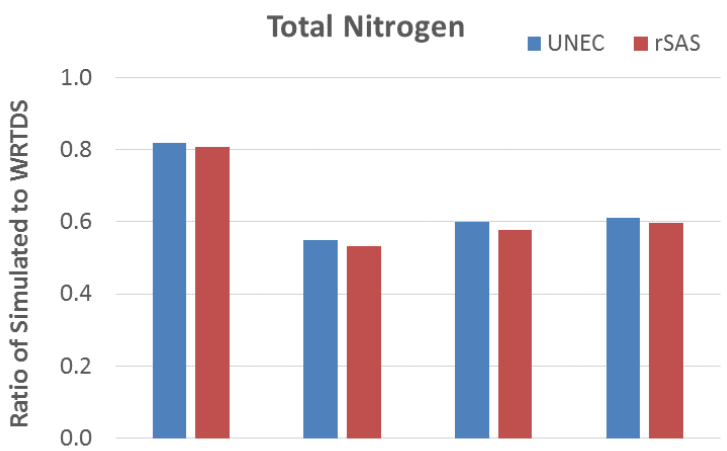
- A few issues in CBP-rSAS were fixed.
- For validation, land use export rates simulated by rSAS were compared with UNEC. Groundwater nitrate loads for *grain without manure* in Kent, DE is shown below.



- Rappahannock river water quality was calibrated using rSAS simulated loads.

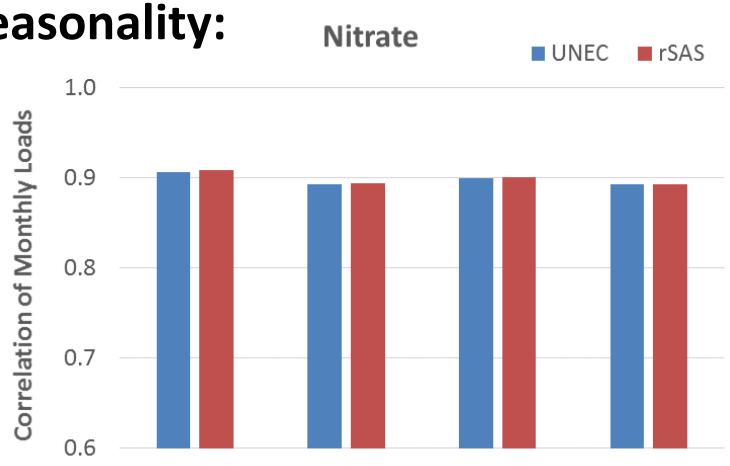
(a) Loads:

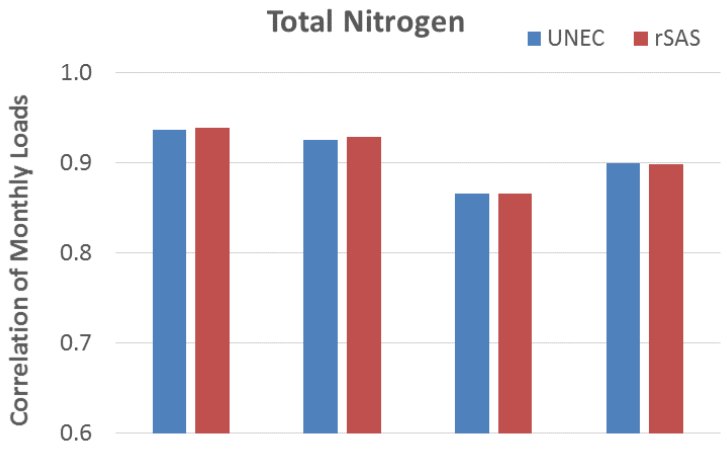




Simulated loads are same between the two model.

(b) Seasonality:





Seasonality of simulated loads matched quite well.

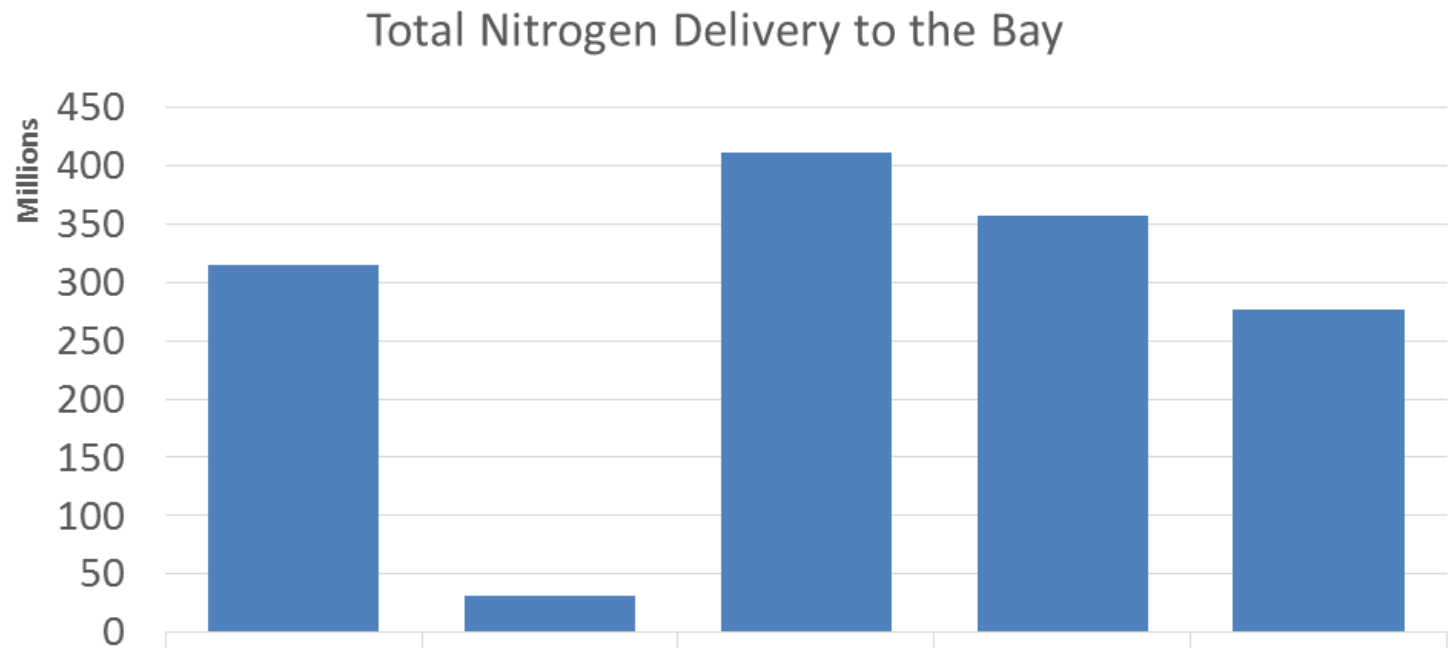
6. Key scenarios using Beta 3 model

- Land use export rates for the key scenarios were calculated using the Phase 6 Steady State Model.
- The steady state model uses Phase 6 sensitives for calculating export rates for a scenario as –

$$Scenario = Calibration_{(1991-2000)} + Change\ in\ Input \times Sensitivity$$

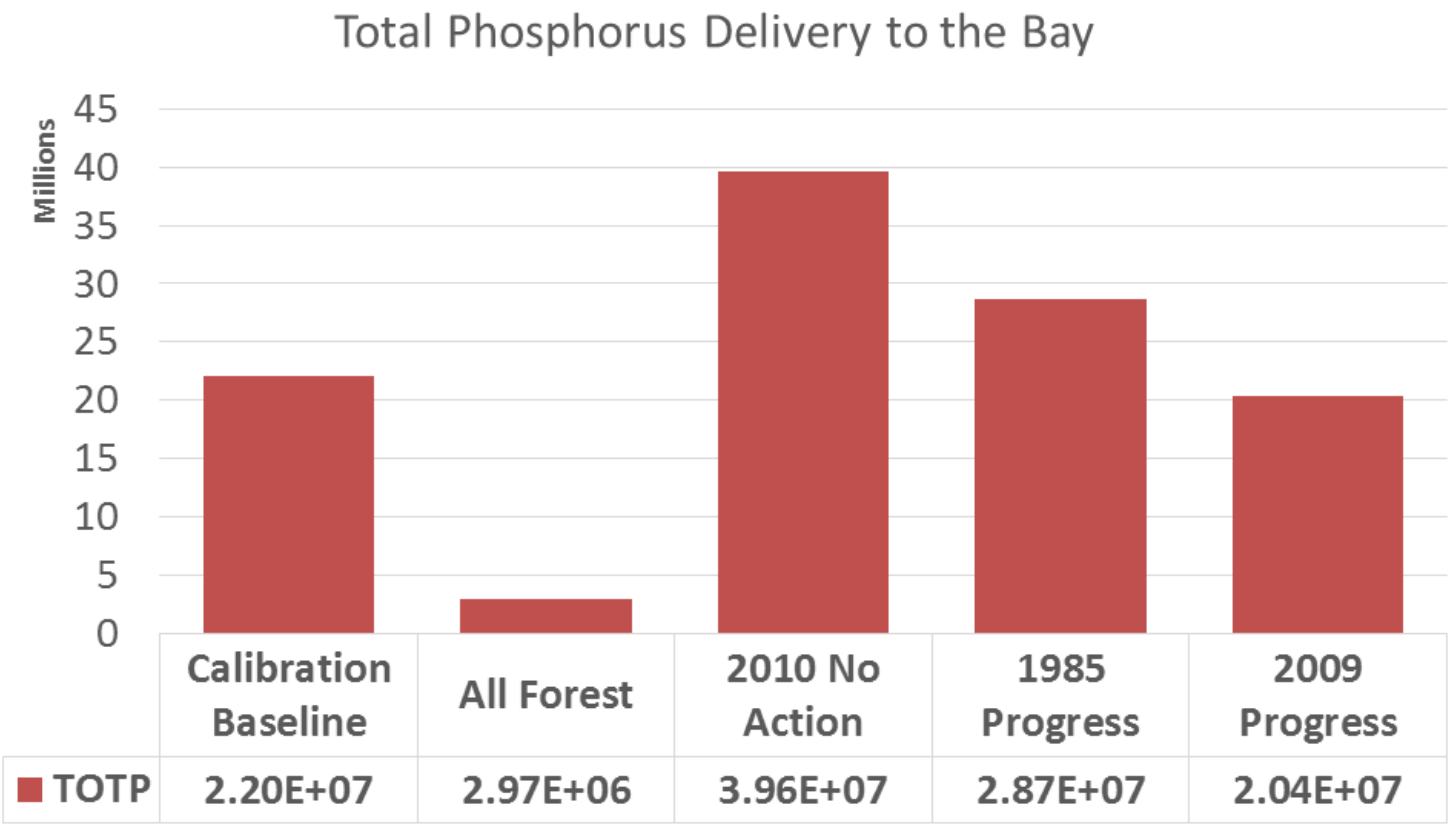
Key Scenarios	Atmospheric Deposition
Baseline calibration (1991-2000)	1991-2000
1985 Progress	1985 deposition
2009 Progress	2009 deposition
2010 No Action	2010 deposition
All Forest	10% of 2020 CAIR

Total nitrogen delivery to the Bay

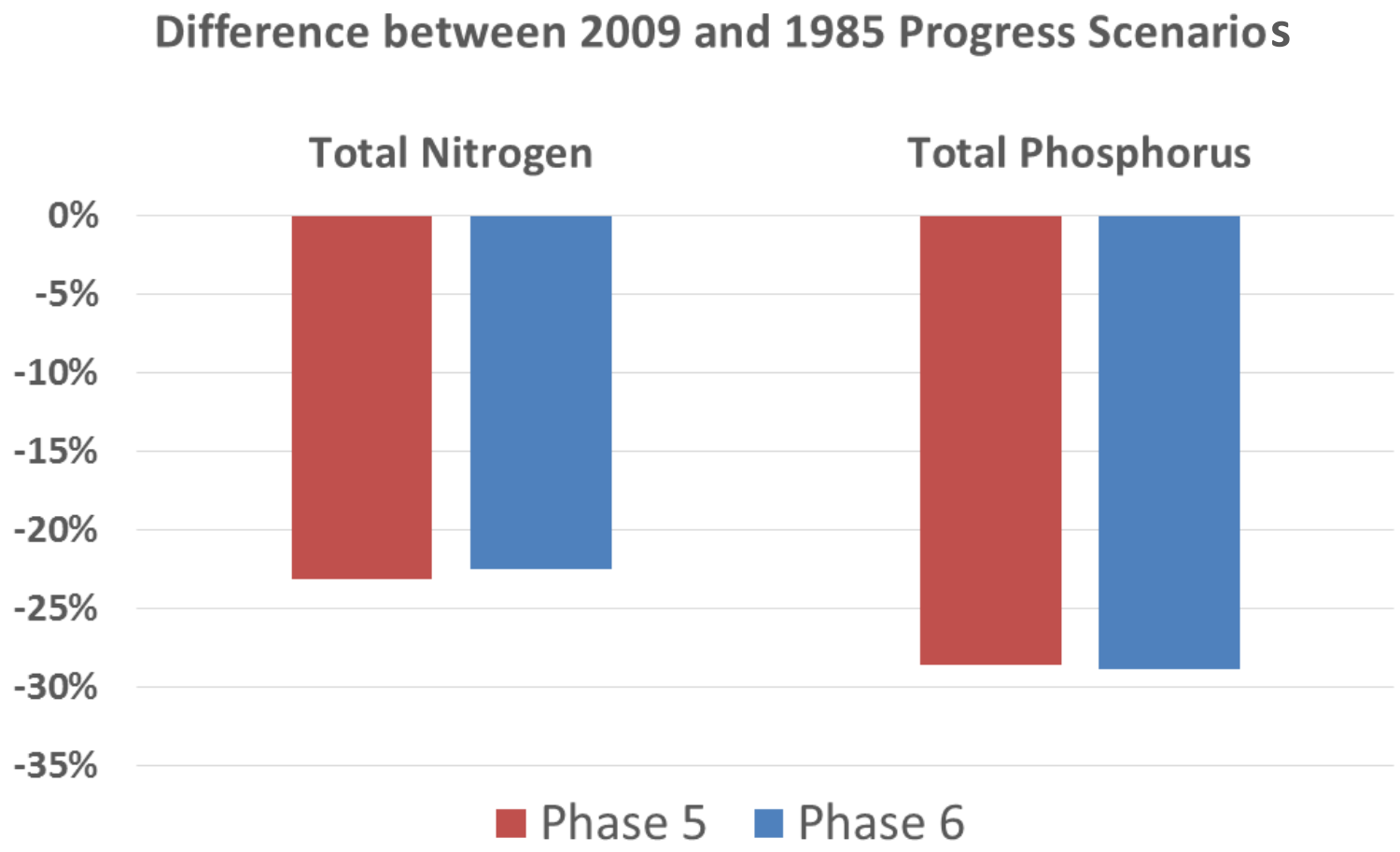


	Calibration Baseline	All Forest	2010 No Action	1985 Progress	2009 Progress
TOTN	3.15E+08	3.13E+07	4.11E+08	3.57E+08	2.77E+08

Total phosphorus delivery to the Bay



Tracking progress: Phase 5 vs. Phase 6

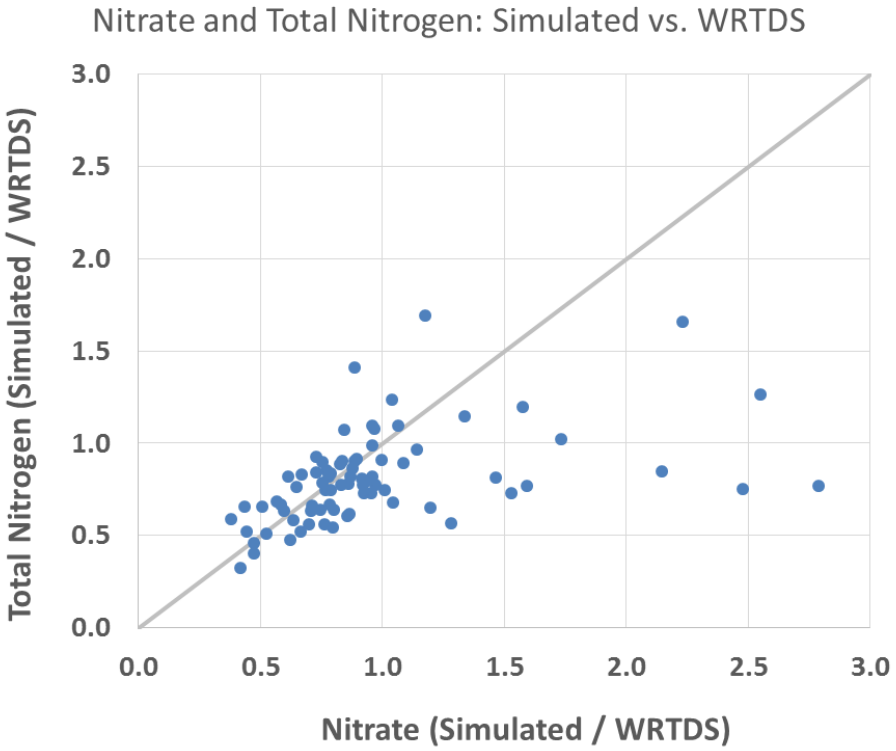


7. Next steps

- Nitrogen calibration
  - Investigate proportion of nitrate
- Phosphorus calibration
  - Investigate mass balance
  - Investigate sediment loads
  - Partitioning of phosphorus (dissolved/sorbed)

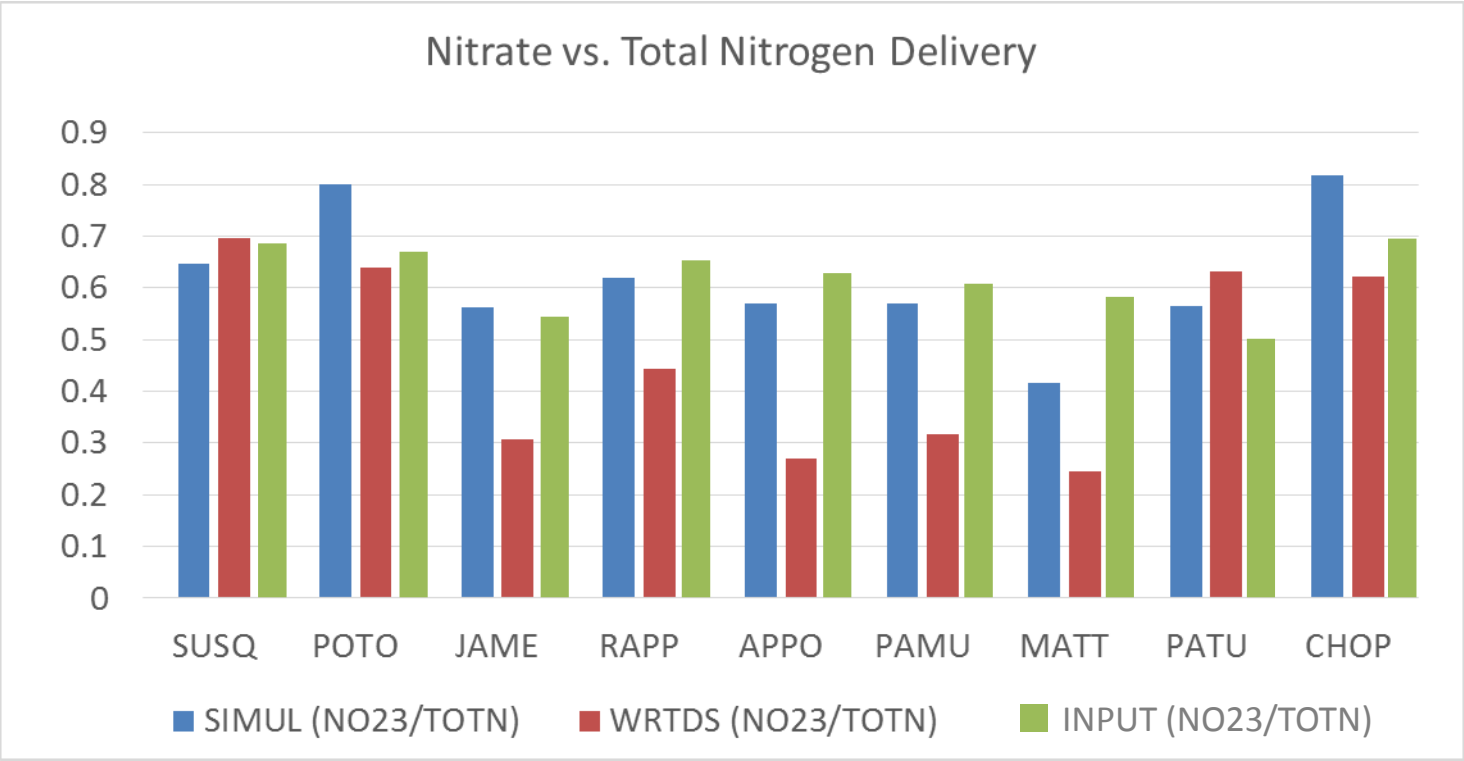
Investigate proportion of nitrate

- Under simulation of total nitrogen is related to under simulation of nitrate.

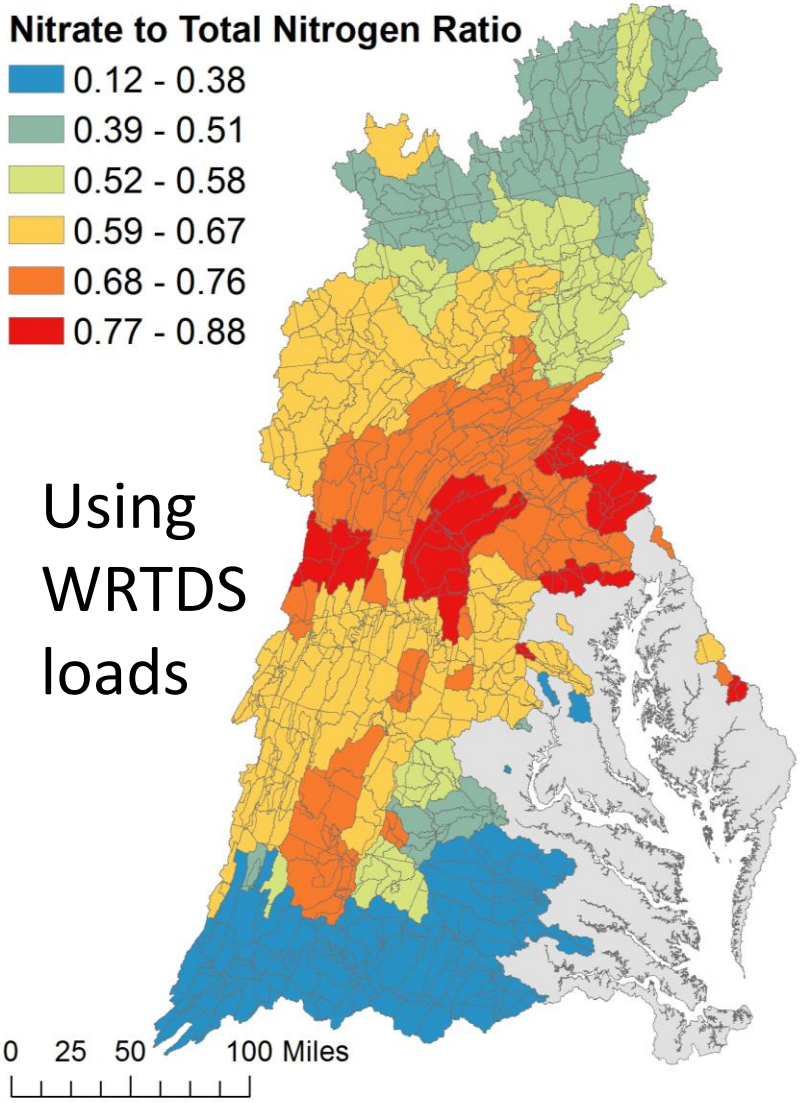


Likely to have 70 lb output (i.e. an under simulation)

Investigate proportion of nitrate

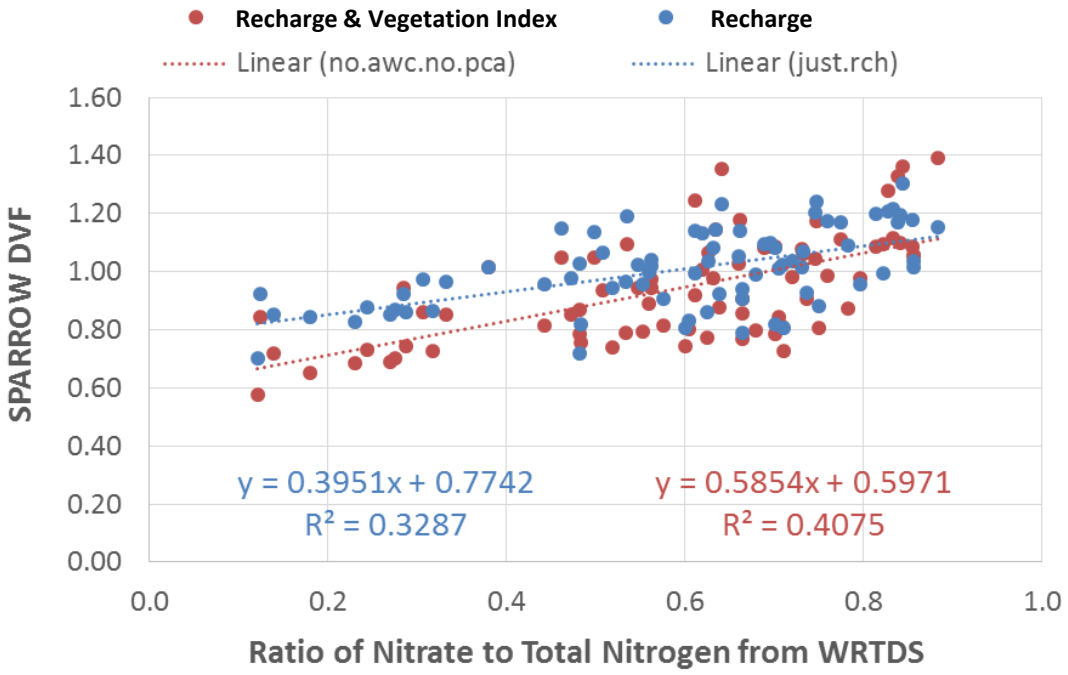


Investigate proportion of nitrate

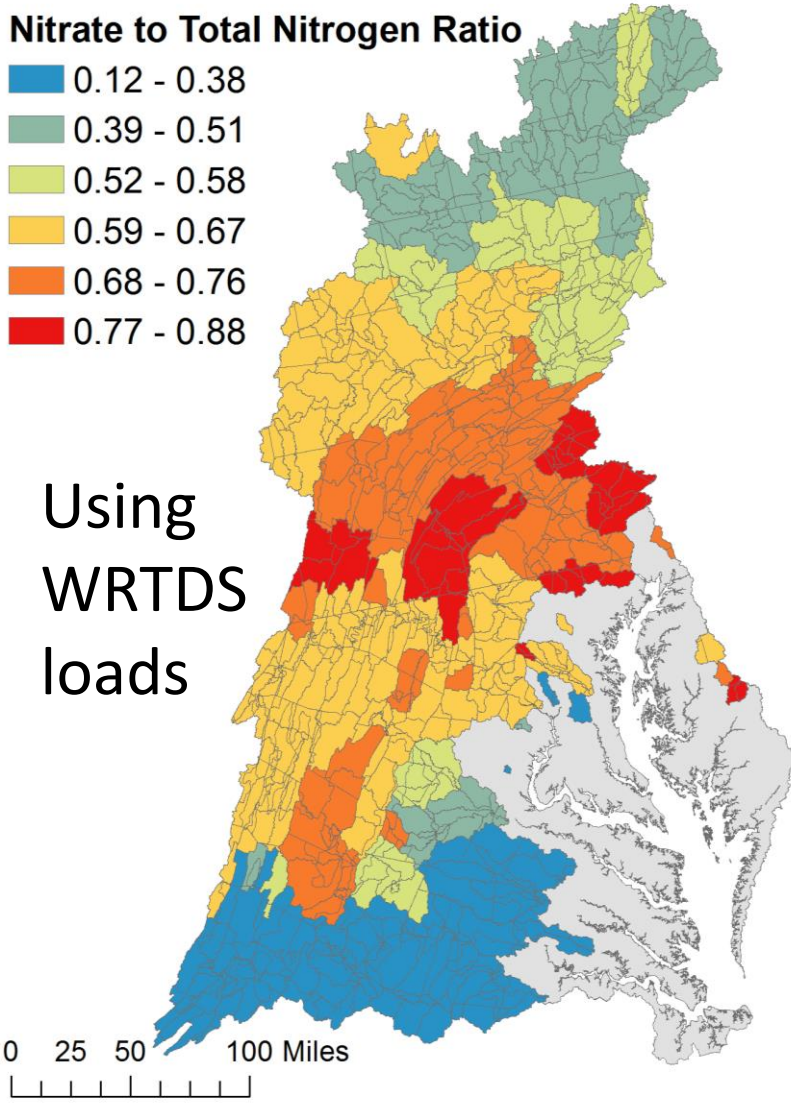


Using WRTDS loads

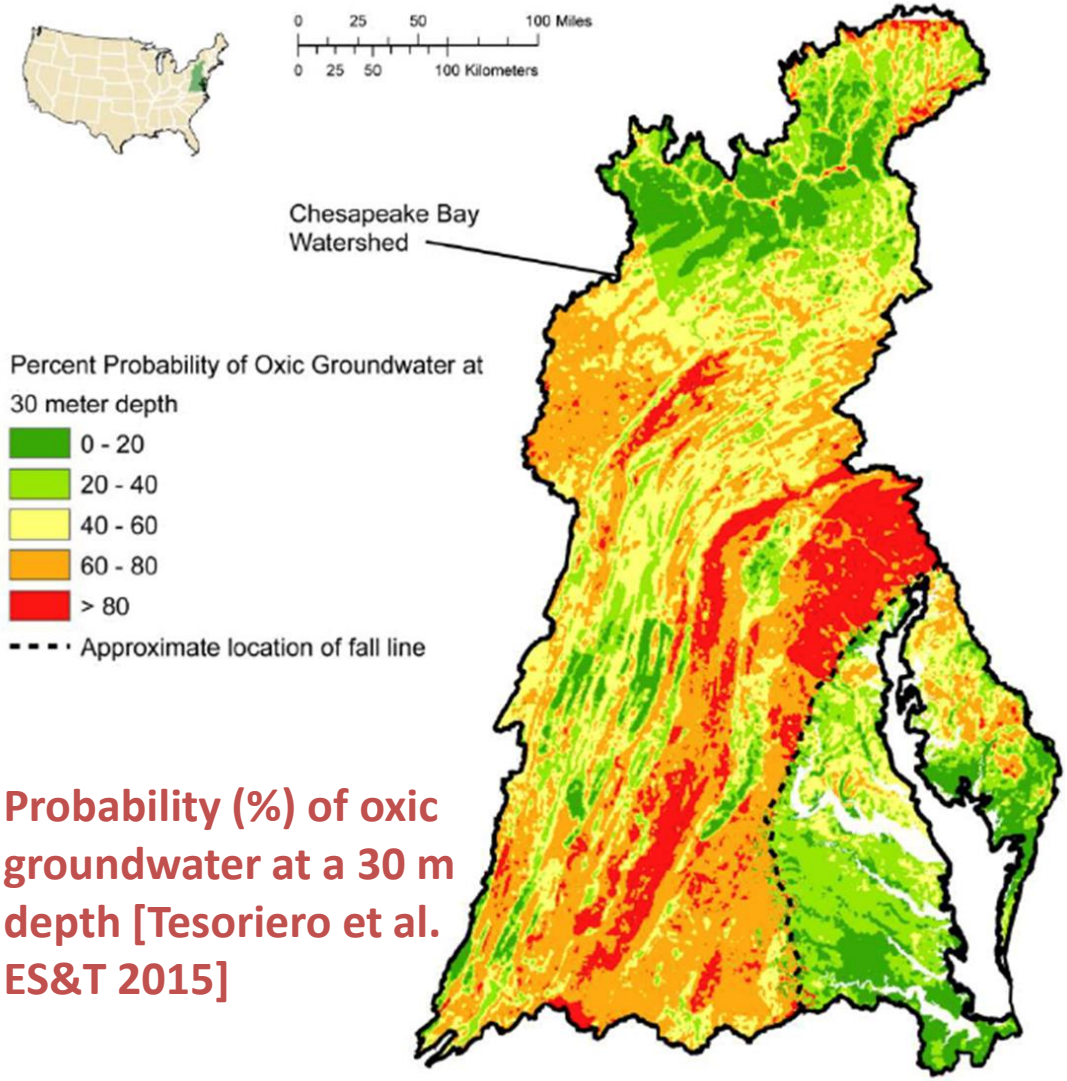
A regression analysis was done against several SPARROW nitrogen land-to-water factors.



- Redox reactions in groundwater markedly affect the transport of nutrients.



Using WRTDS loads



Probability (%) of oxic groundwater at a 30 m depth [Tesoriero et al. ES&T 2015]

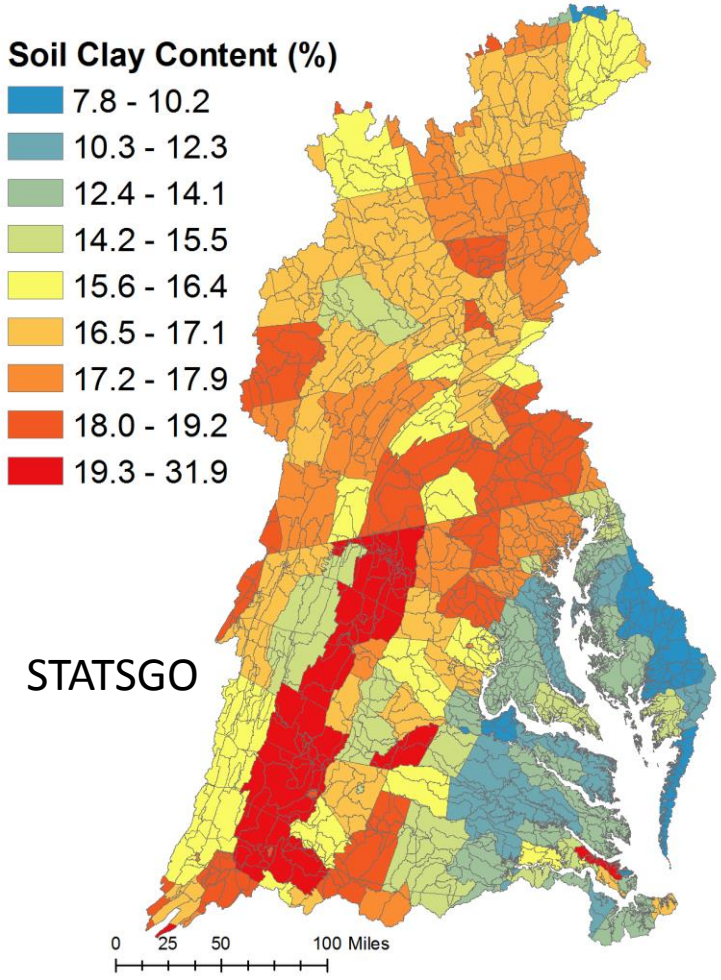
Investigate sediment loads

- Sediment has implications on phosphorus in terms of both the calibration targets and its delivery.

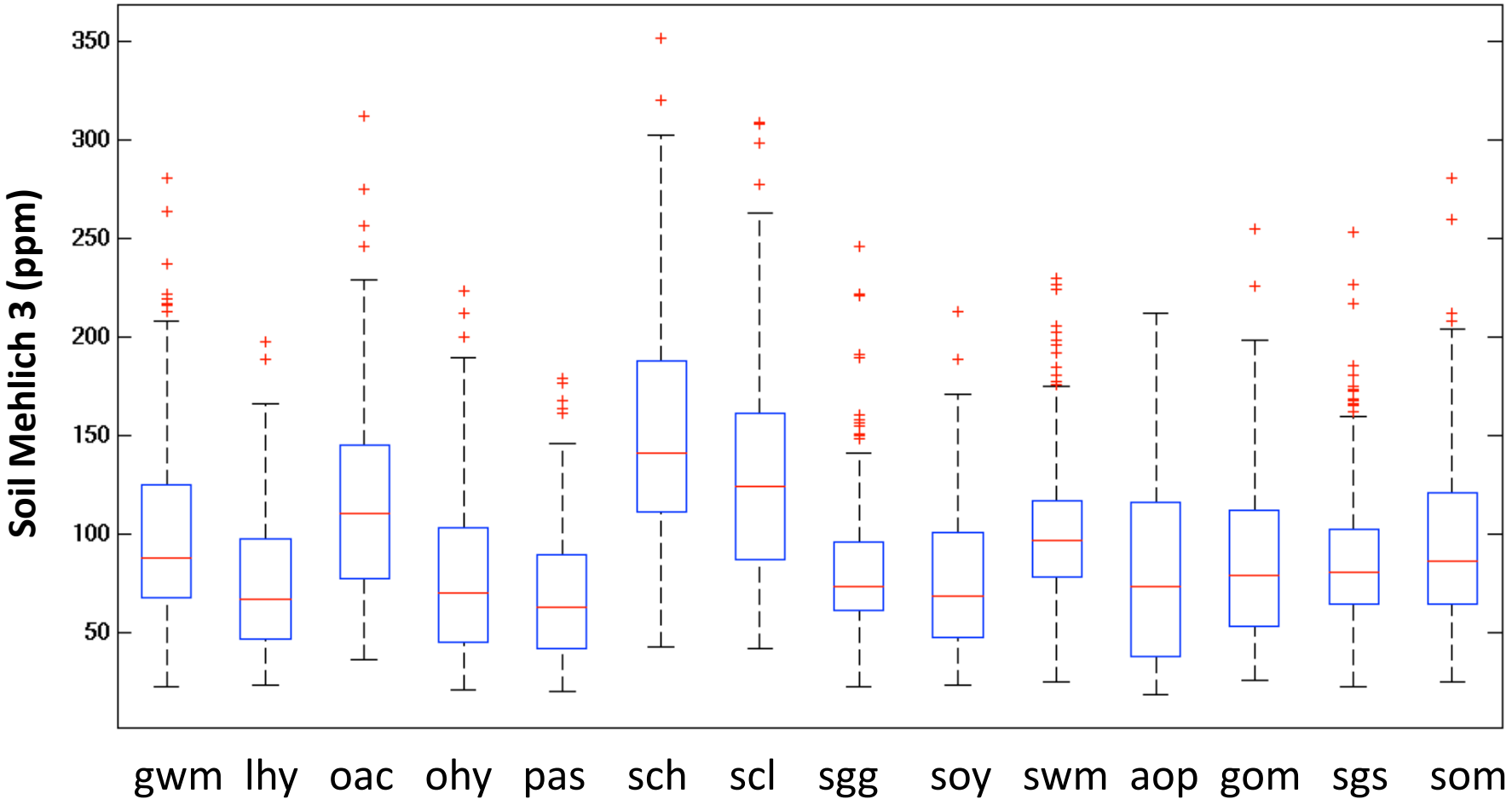
Partitioning of phosphorus (dissolved / sorbed)

- The soil P sorption indices are correlated to soil clay content. They are also related to Al, Fe, total/active $CaCO_3$, and organic carbon contents. (Ryan et al., 1985; Borrero et al., 1988, Pena and Torrent, 1990; Samadi, 2006)

- APLE uses soil clay content in a log linear relationship between sorbed and dissolved P.



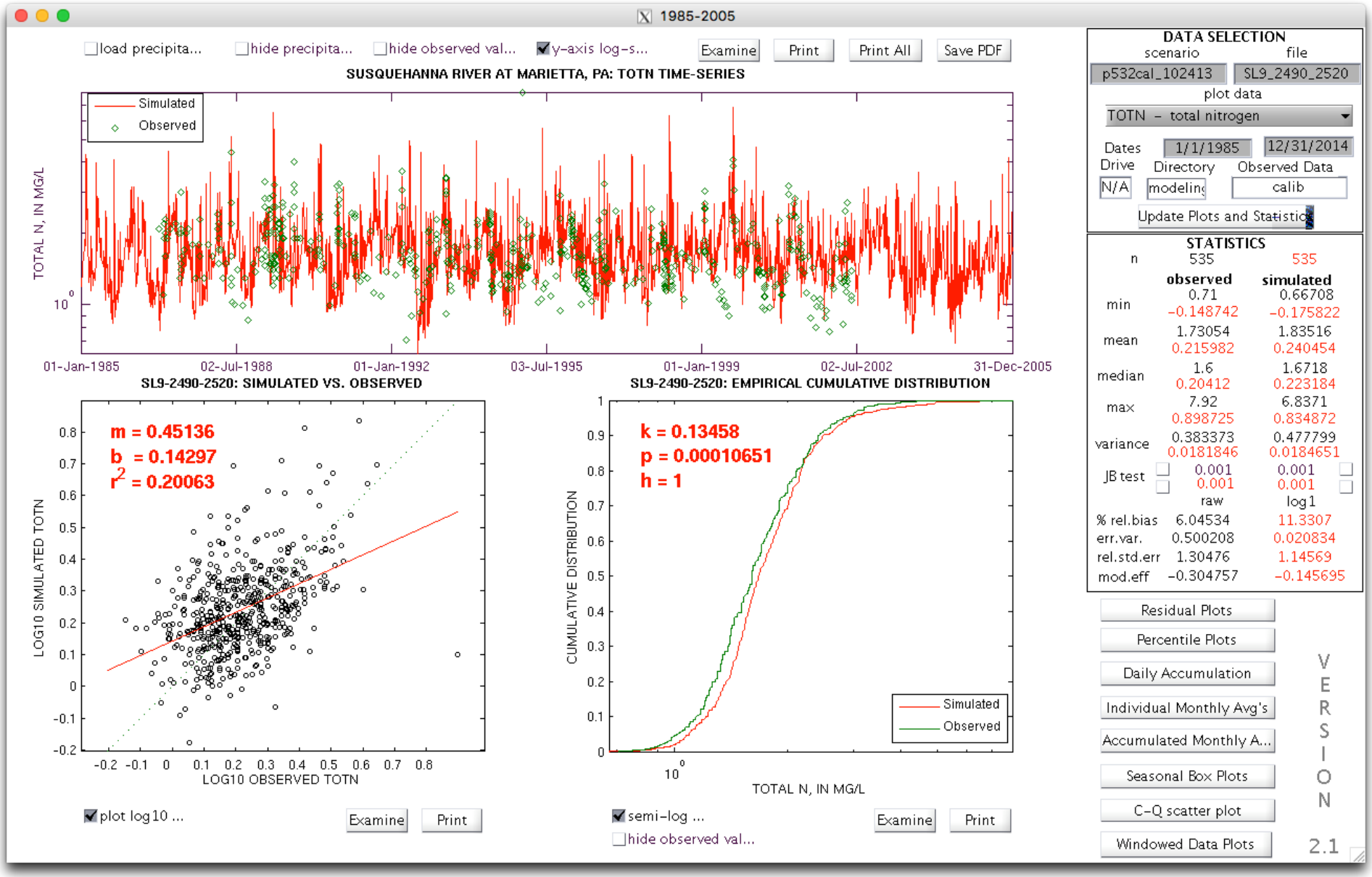
Variability in Soil Mehlich 3 for Ag land uses, and across P6 land segments



SUSQUEHANNA AT MARIETTA

PHASE 5

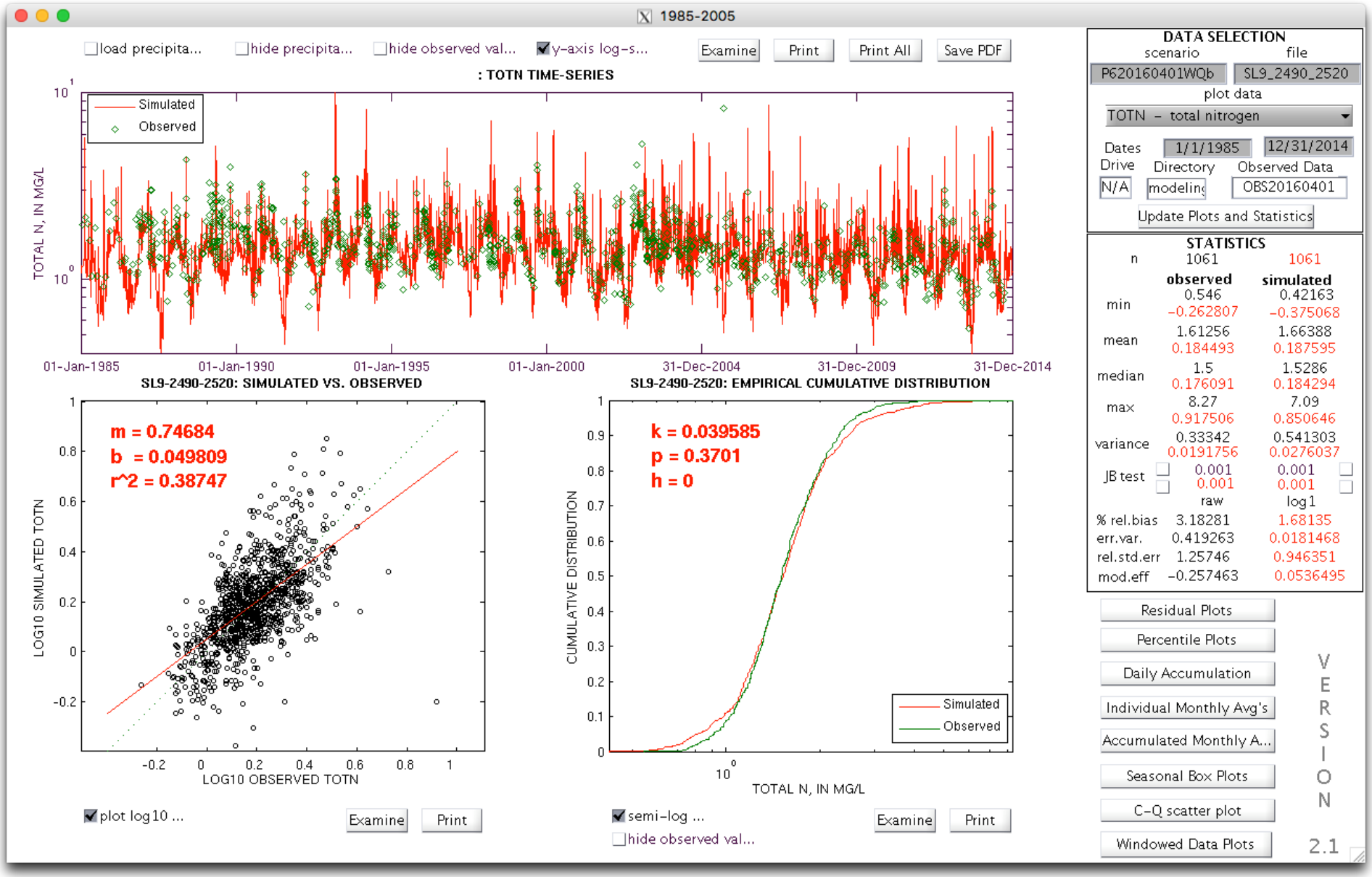
NITROGEN



SUSQUEHANNA AT MARIETTA

PHASE 6 BETA 2

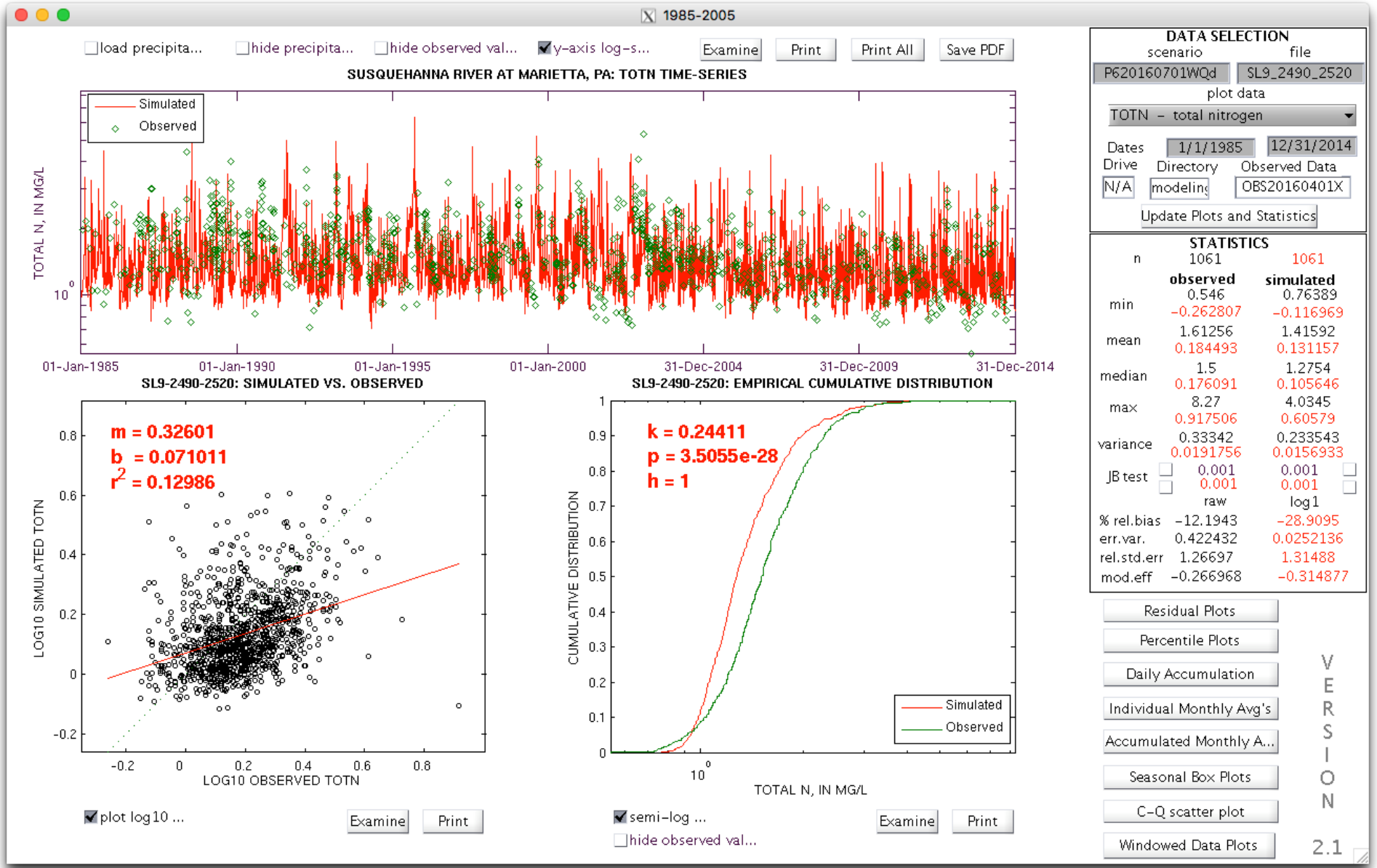
NITROGEN



SUSQUEHANNA AT MARIETTA

PHASE 6 BETA 3

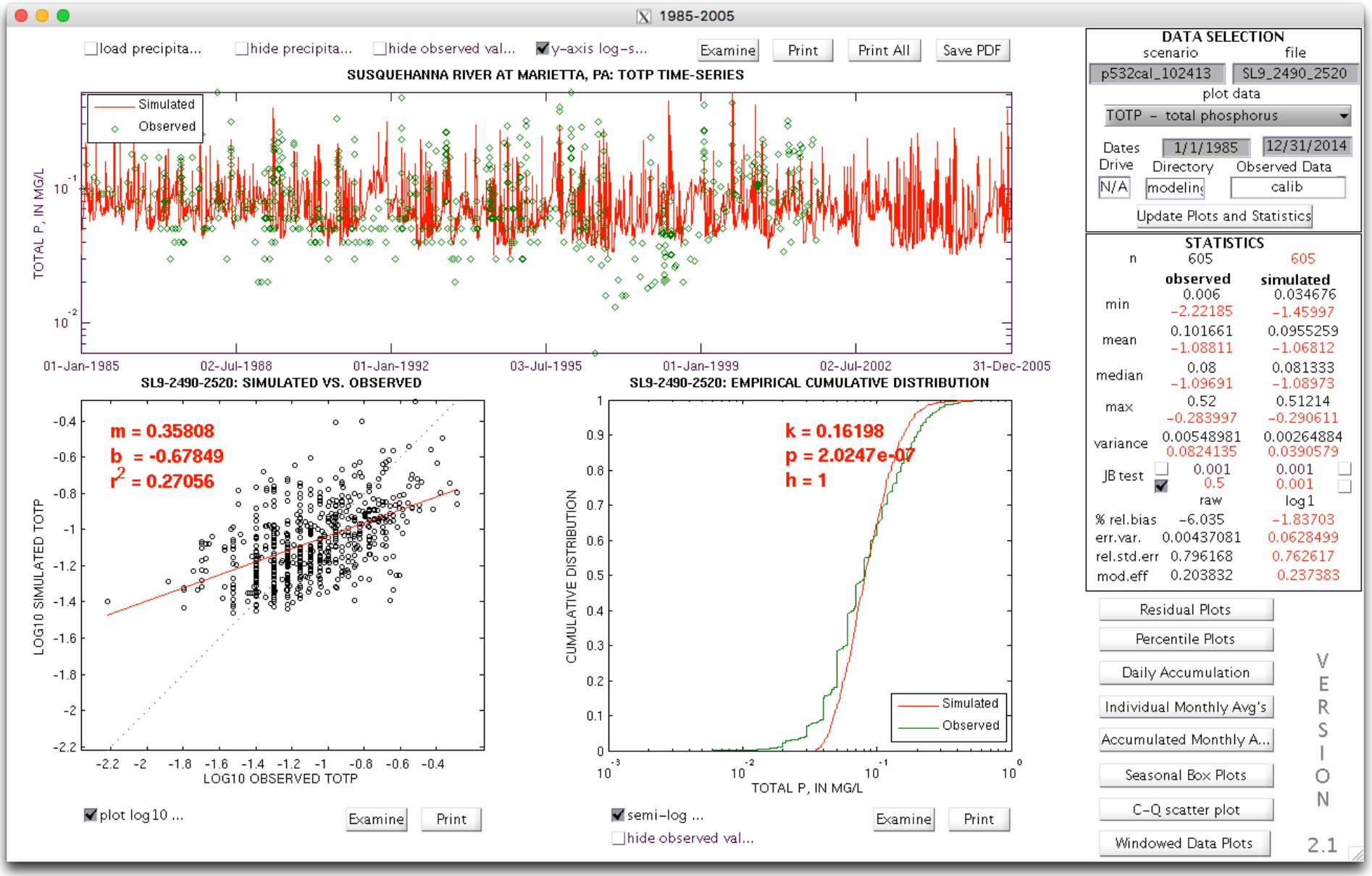
NITROGEN



SUSQUEHANNA AT MARIETTA

PHASE 5

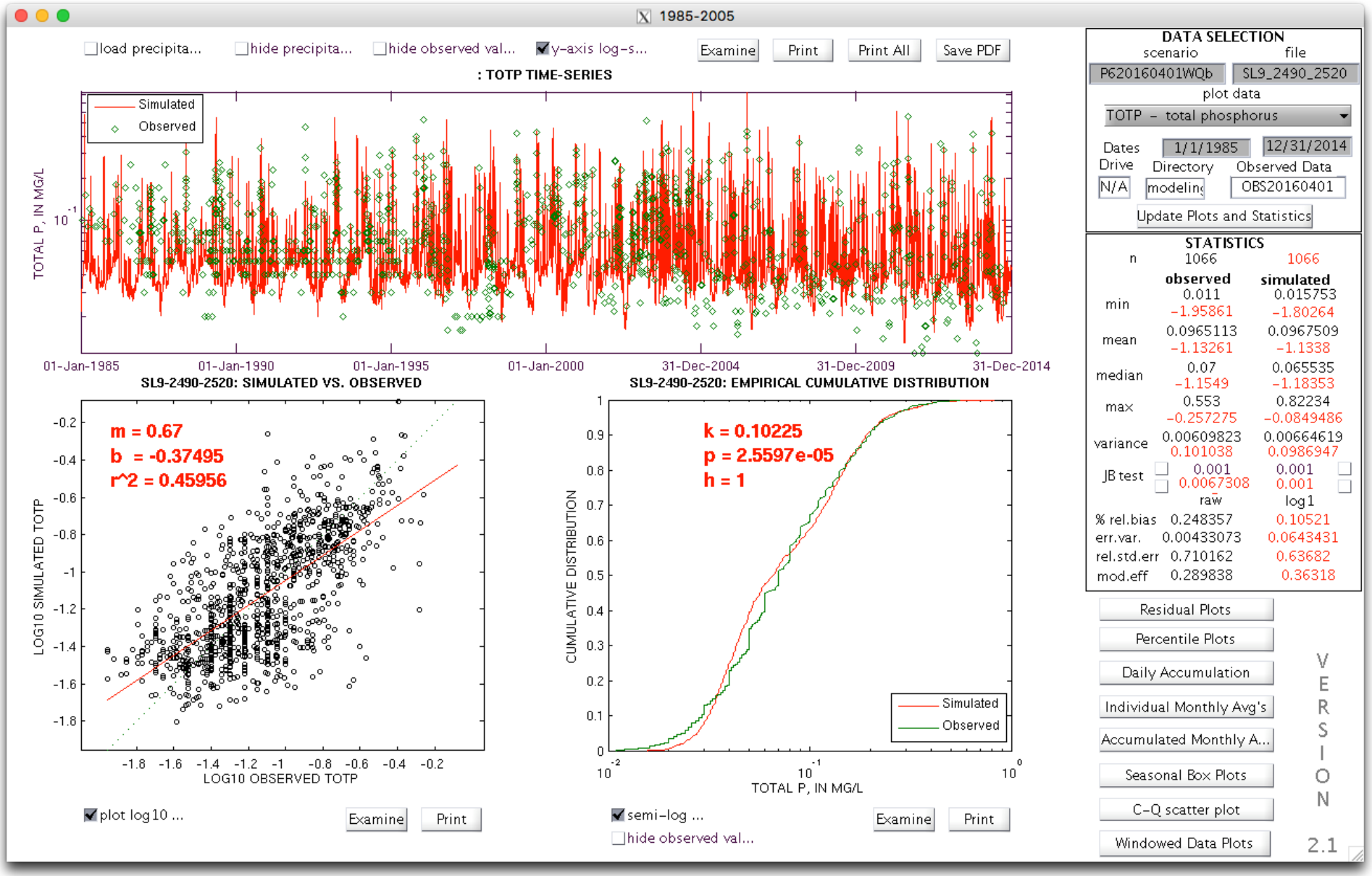
PHOSPHORUS



SUSQUEHANNA AT MARIETTA

PHASE 6 BETA 2

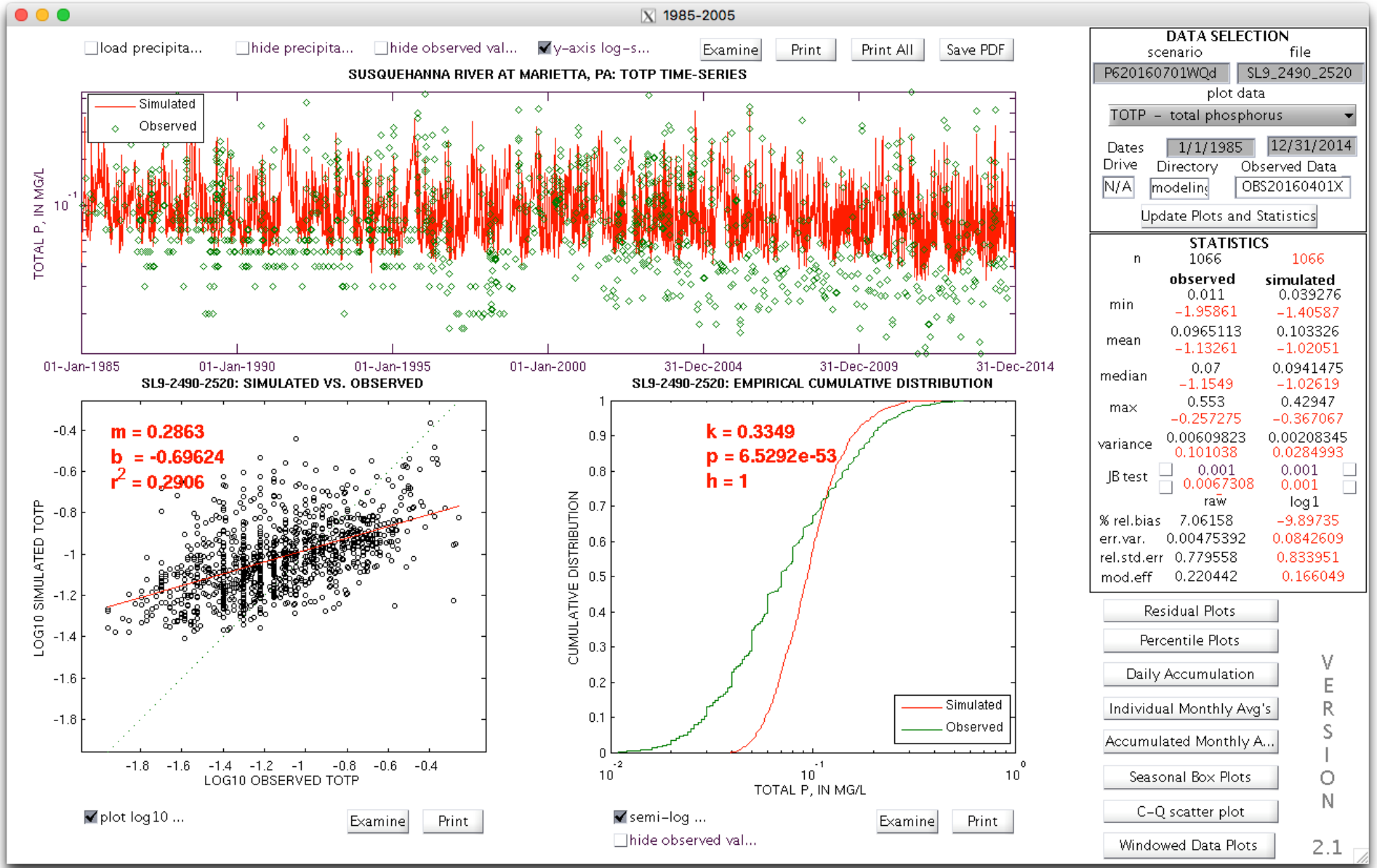
PHOSPHORUS



SUSQUEHANNA AT MARIETTA

PHASE 6 BETA 3

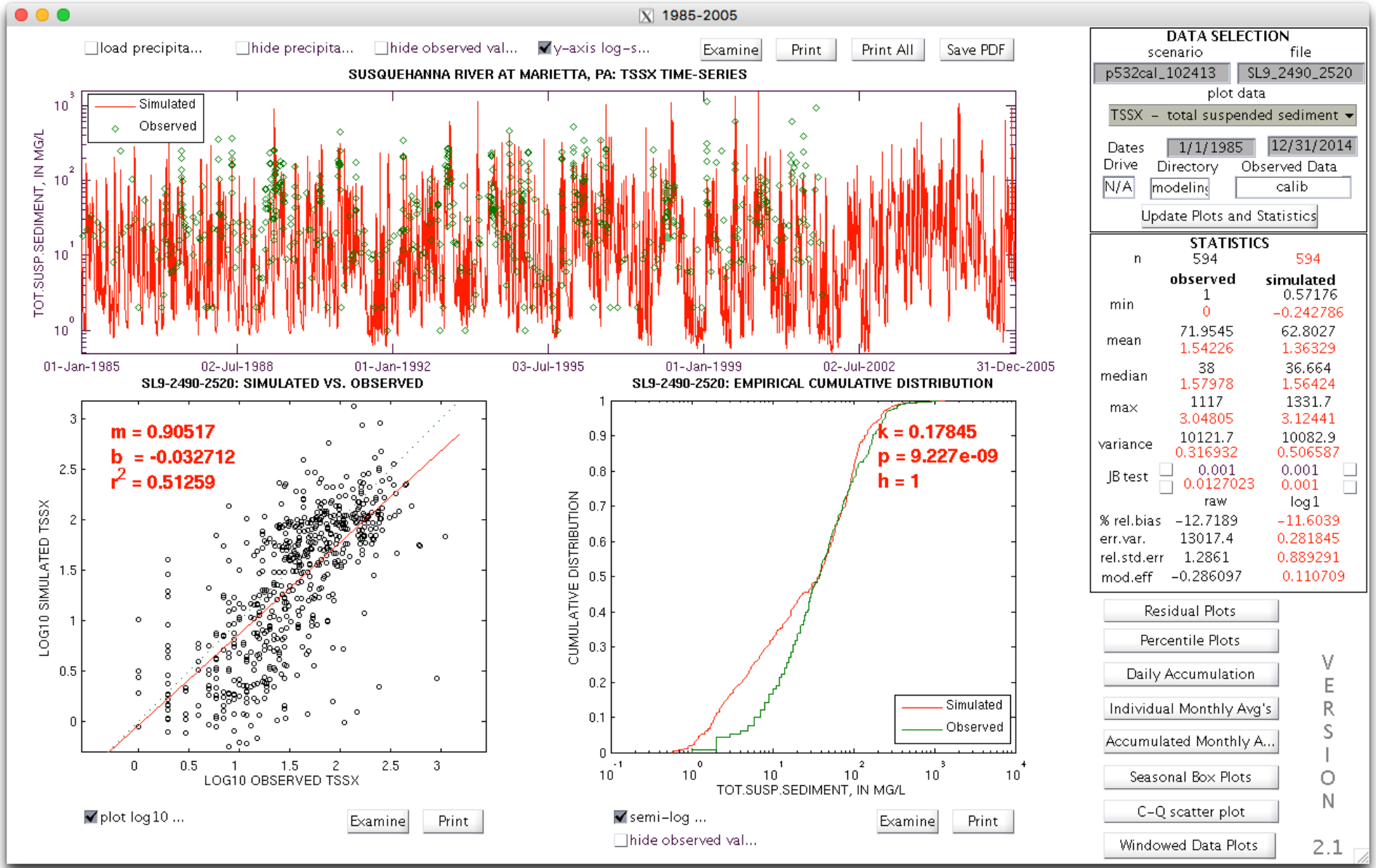
PHOSPHORUS



SUSQUEHANNA AT MARIETTA

PHASE 5

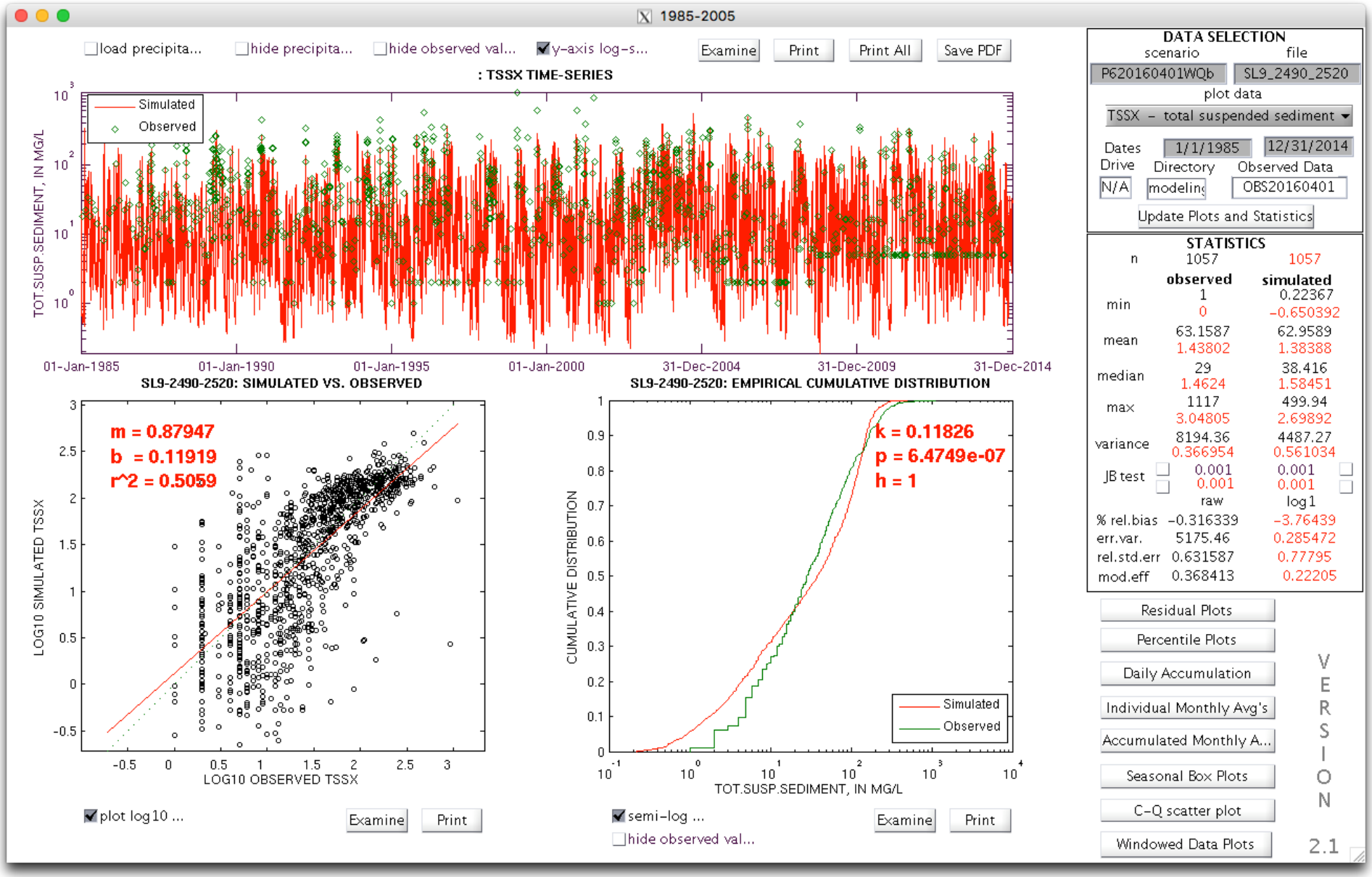
SEDIMENT



SUSQUEHANNA AT MARIETTA

PHASE 6 BETA 2

SEDIMENT



SUSQUEHANNA AT MARIETTA

PHASE 6 BETA 3

SEDIMENT