Annex 4 SAB Meeting
Chicago, IL 06/21/16

Annex 4 Load-Response Modeling for Lake Erie

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LimnoTech
Water Environment | Scientists Engineers

Modeling for Annex 4 Refinement

- Use an approach similar to the multiple model application used to establish and confirm target P loads in Annex 3 of 1978 GLWQA Amendment
  - Philosophy is to begin with biological response indicators of eutrophication and use **multiple models** to compute load-response relationships between metrics of indicators and load leading to a value of that metric
  - Set target/threshold measures of eutrophication response indicators and identify loads that correspond to the indicator thresholds
  - If necessary, can then use the models to extract appropriate tributary and *in-lake* phosphorus concentration objectives associated with those load-response values

Identify a suite of models that could produce ERI-P response curves

Model Selection Criteria:

- **Applicability to the ERI metrics**
- **Extent/quality of calibration and confirmation for Lake Erie**
- **Extent of model documentation**
- **Level of uncertainty analysis available**

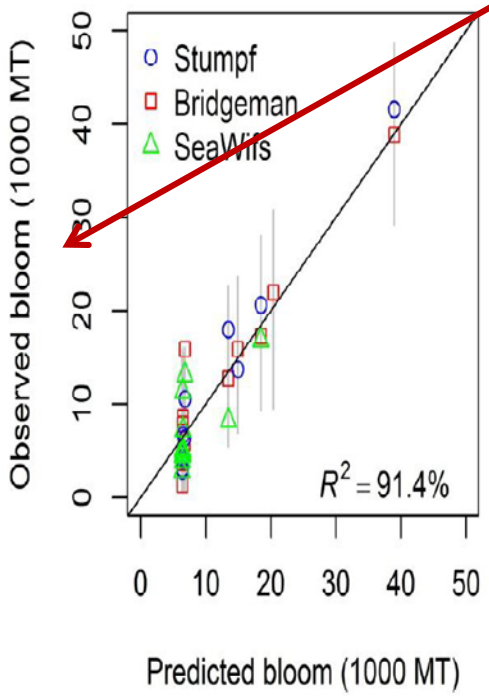
A Key Challenge:
Model inputs and outputs not always directly comparable

Model	Lead Author, Institution	Eutrophication Response Indicators			
		Western Basin phytoplankton biomass	Western Basin cyanobacteria biomass	Central Basin Hypoxia	Eastern Basin Cladophora
Statistical HAB model	Stumpf, NOAA		X		
Statistical HAB model	Obenour, U-M/NOAA		X		
3-D WB Ecosystem Model	DePinto, LimnoTech	X	X		
TP Mass Balance Model	Chapra, Tufts Univ.	X			
1-D CB Model	Rucinski, LimnoTech/U-M			X	
2-D WB/CB Model	Zhang, U-M	X		X	
9-Box CB Model	Lam, Environment Canada (EC)			X	
3-D ELCD model	Bocaniov, U-M/EC	X		X	
Cladophora Model	Auer, Michigan Tech.				X

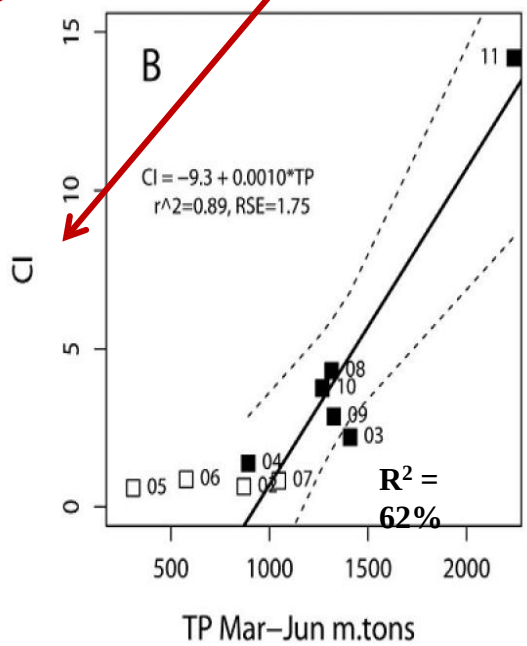
Western Basin HAB Model Calibrations

Three different ERI metrics

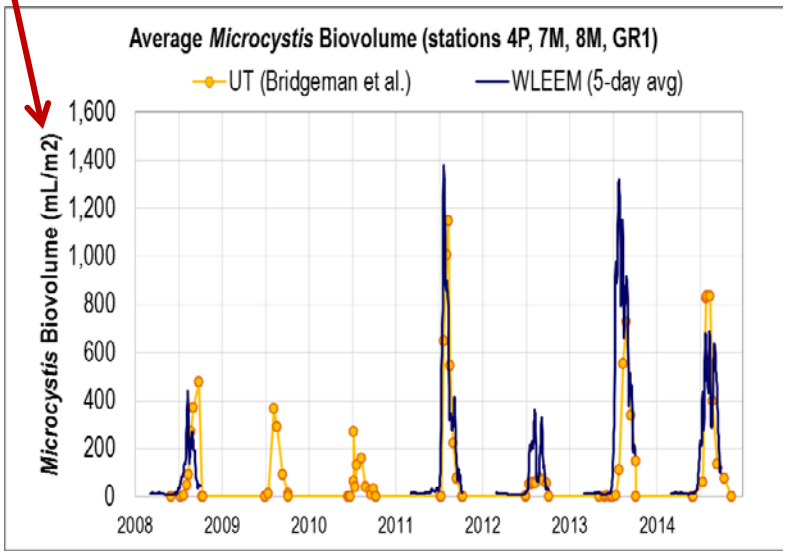
Obenour Model



Stumpf Model



LimnoTech Model



Includes temporal term

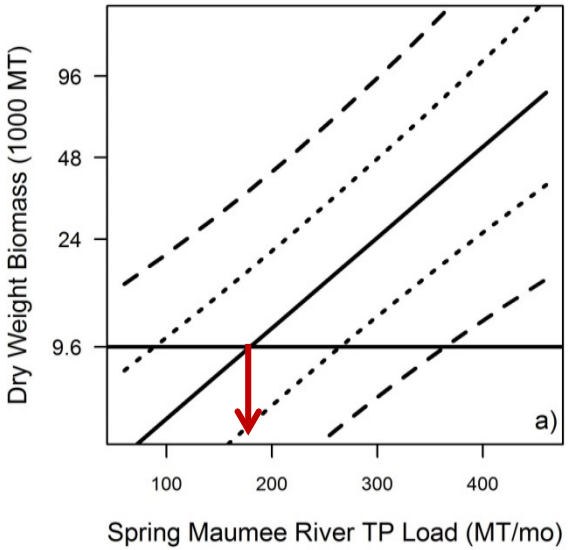
No temporal term

4 years of corroboration & confirmation for 2014/15

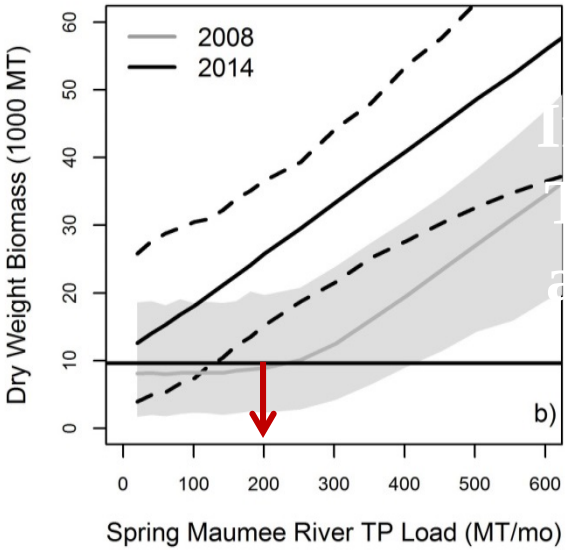
Western Basin HABs Load-Response Curves

(ERI Metric is Maximum 30-day Basinwide Biomass)

Stumpf Model

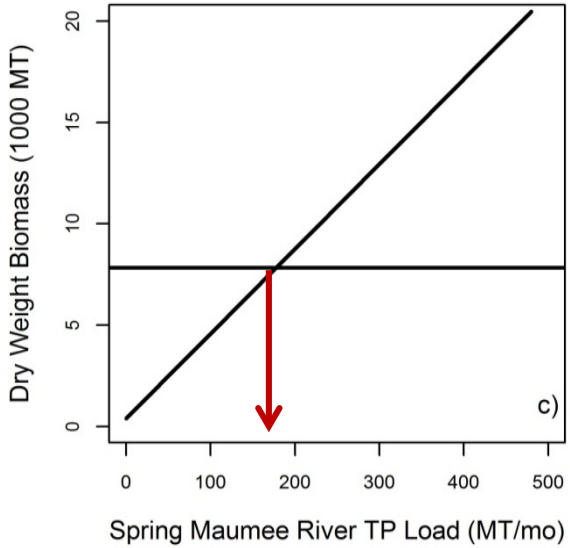


Obenour Model



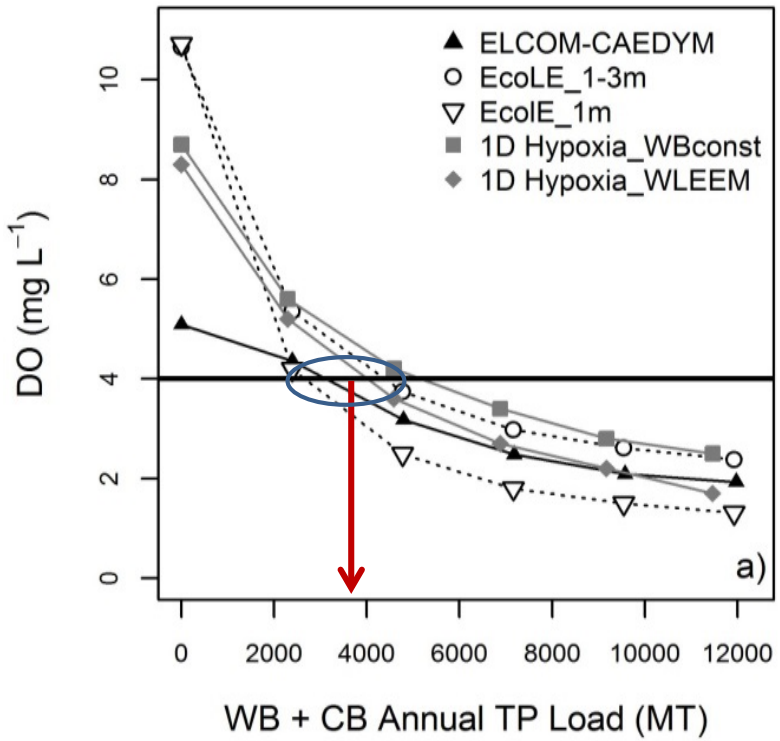
LimnoTech Model

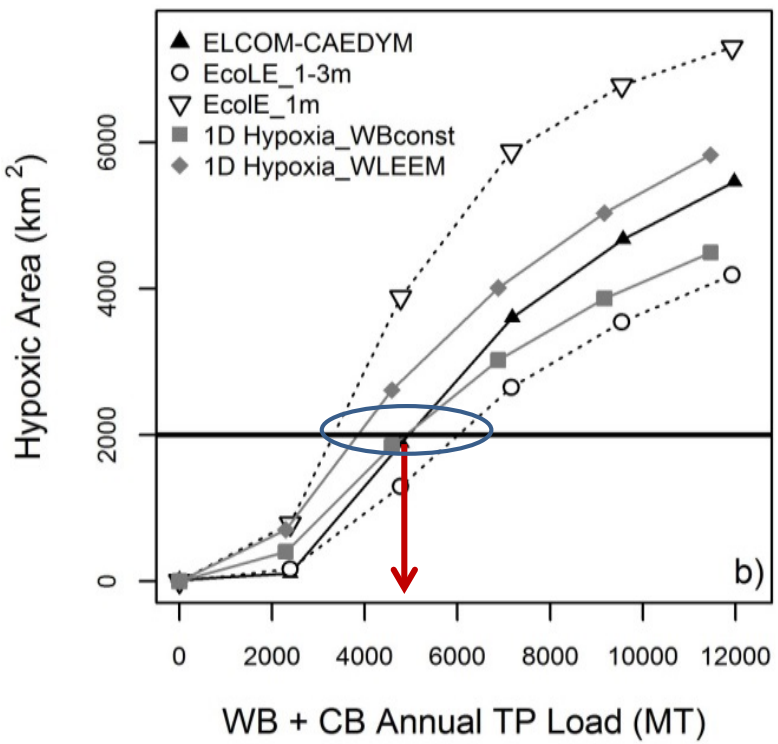
"Equivalent Threshold"



Recommended:
980 MT during Mar-July
(32% reduction from 2008)

Central Basin DO and Hypoxic Extent

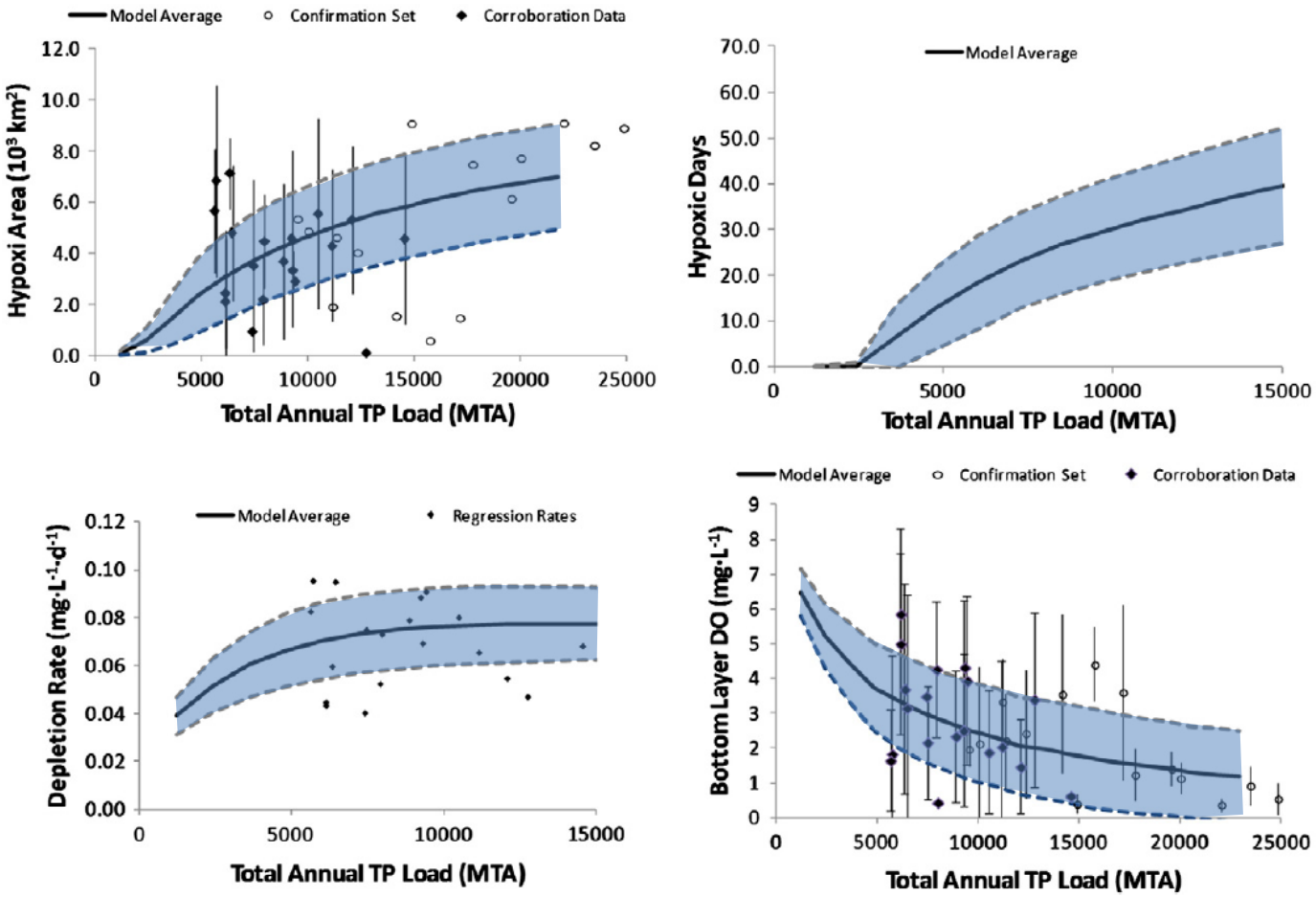




Recommended:
3840 MTA WB+CB
4364 MTA Whole Lake

Recommended:
4600 MTA WB+CB
5227 MTA Whole Lake

A note on hydro-meteorological variability



Exploring the effects of observed 1987-2005 meteorological forcing on scenarios

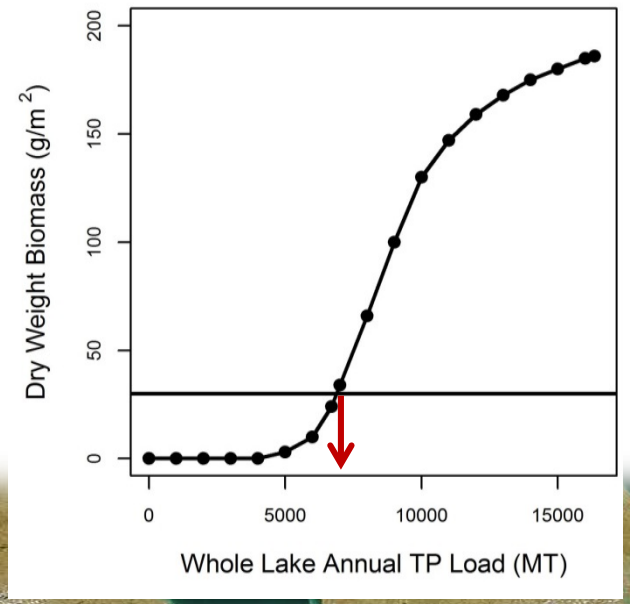
- Rucinski et al. 2014

Eastern Basin *Cladophora*

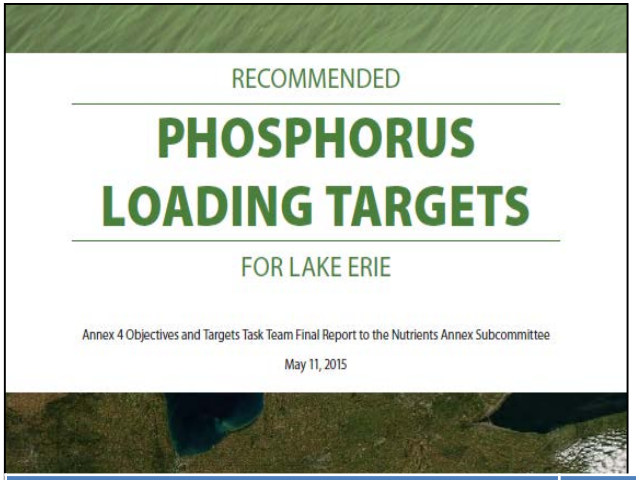
Process model relating EB TP as a function of TP load (Chapra)

Empirical relationship between TP and DRP in the Eastern Basin (Chapra)

Process model that Related *Cladophora* biomass to DRP concentration (Auer)



Recommended: 7000 MTA Whole Lake



Targets Adopted for Western + Central Basins

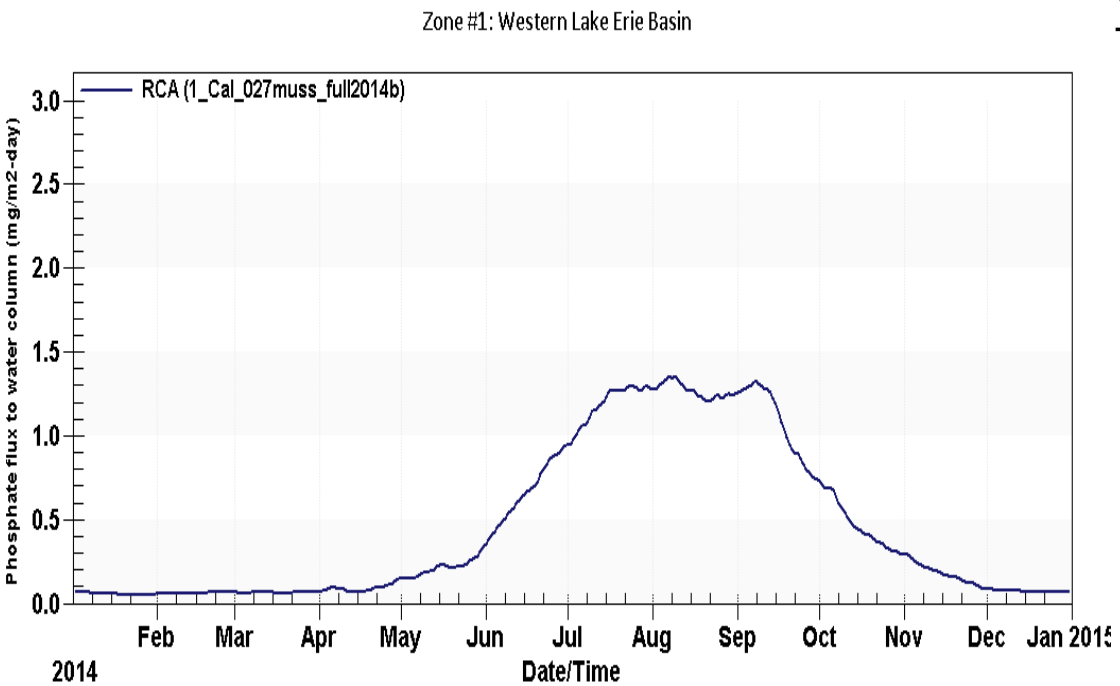
Eutrophication Response Indicator	Model-based Recommendation	Final Binational Targets
Western Basin HAB	Maumee Spring Load: 980 MT TP **32%** below 2008	Maumee Spring Load: 860 MT TP (186 MT DRP) **40%** below 2008: all tributaries
Central Basin Hypoxia	*DO:* 5227 MTA: **47%** below 2008 *Area:* 4364 MTA: **44%** below 2008	6000 MTA: **40%** below 2008
Eastern Basin Cladophora	7000 MTA: **30%** below 2008	**Defer**

Ongoing Work with Lake Erie Models

- Compiling model error analyses, sensitivity analyses, uncertainty analyses into final report
- Publishing model development and Annex 4 application results in a *Journal of Great Lakes Research* Special Topic Series – expected at end of 2016
- Ongoing model refinement and application
  - All three *Microcystis* models used for annual bloom forecast
  - Ongoing development of Cladophora modeling in Eastern Basin
  - Use of models in Adaptive Management process
  - Application of WLEEM in 2014 CSMI analysis of western basin sediment phosphorus diffusive flux analysis

WLEEM Sediment Phosphorus Diffusive Flux (Jan-Dec 2014)

Temporal Variability

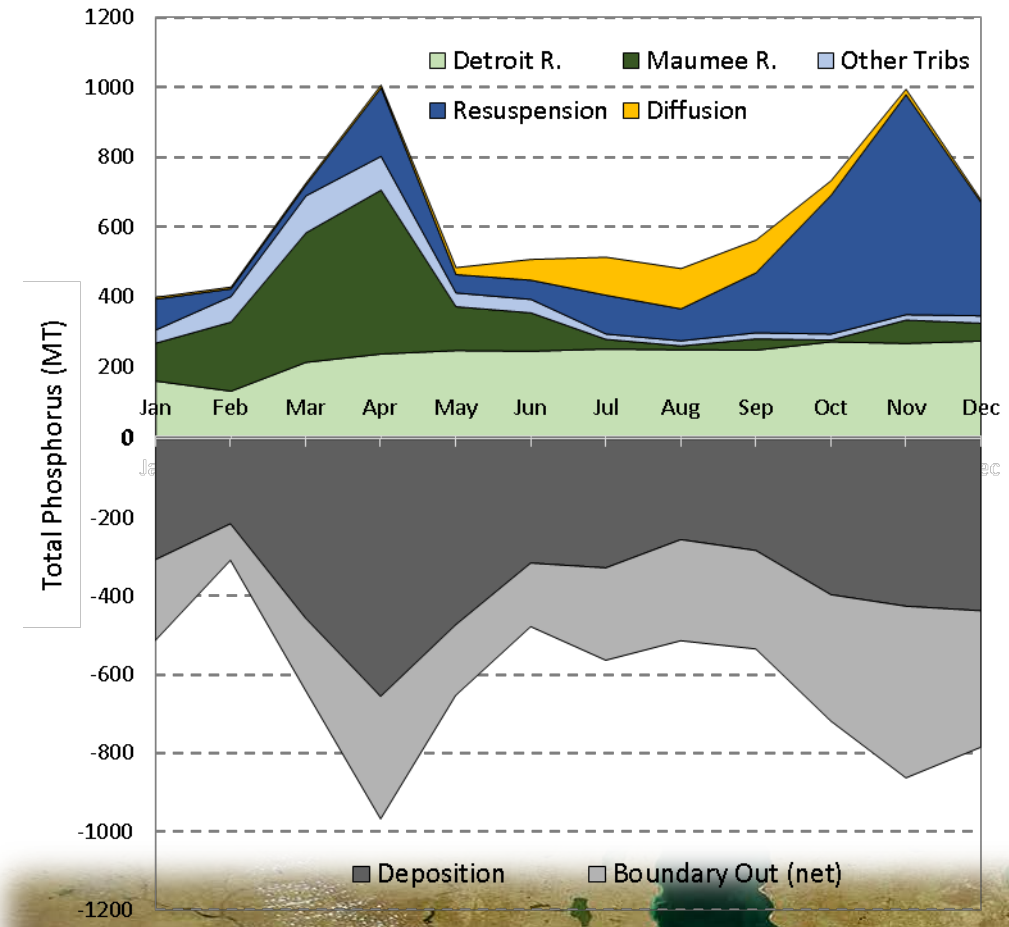


WLEEM

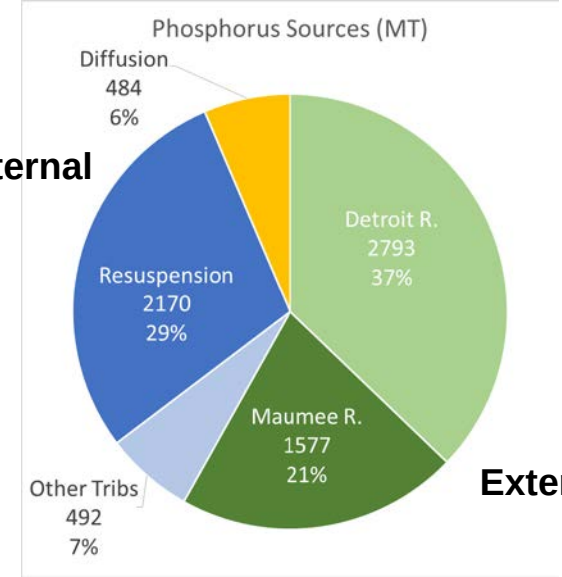
Month	Entire Basin Diffusion (MT)	Entire Basin Flux (mg/m^2-day)
Jan	5.18	0.06
Feb	4.98	0.06
Mar	5.77	0.06
Apr	8.05	0.09
May	19.82	0.21
Jun	**59.30**	**0.66**
Jul	**108.70**	**1.18**
Aug	**115.10**	**1.25**
Sep	**93.59**	**1.05**
Oct	41.44	0.45
Nov	15.22	0.17
Dec	6.48	0.07

484 MT	**0.44 mg/m^2-day**

WLEEM Western Basin Phosphorus Mass Balance (Jan-Dec 2014)



Internal



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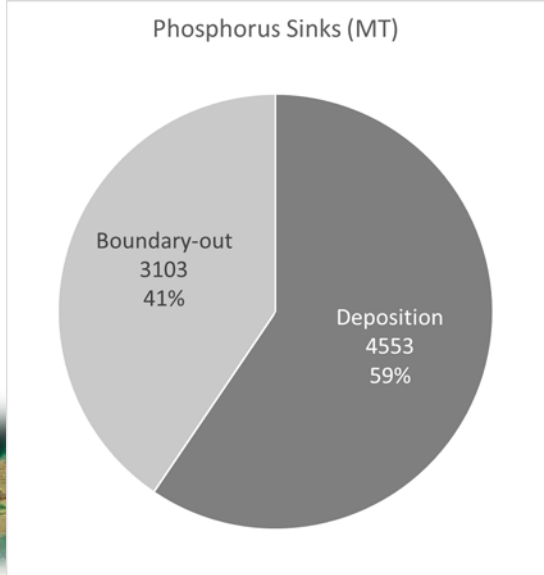

P Trapping Eff. = 39%

Questions?

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Extra Slides

Benefits of Multiple Modeling

- Range of complexities and approaches that all use the same basic input data afford a comparison of results that can often be very instructive
  - Reconcile differences among results in terms of the different assumptions
  - Provides insights about the most important sources and processes for a given system and management issue
- Benefits
  - Problems are viewed from different conceptual and operational perspectives;
  - The same datasets are mined in different ways;
  - Provides multiple lines of evidence;
  - Reduces the level of risk in environmental management decisions; and
  - Model diversity adds more value than model multiplicity.

Lake Erie Annex 4 Modeling Approach

<u>Workshop 1</u>:

- **Identify Eutrophication Response Indicators (ERIs) for Annex 4 Objectives**
- **Identify a suite of existing models that can produce ERI-P response curves**

Between Workshops:

- **Run models with a common range of P loads to develop response curves**
- **Prepare documentation (equations, driving variables, calibration, validation)**

<u>Workshop 2</u> :

- **Integrate results from different models to produce composite guidance**

Workshop 2

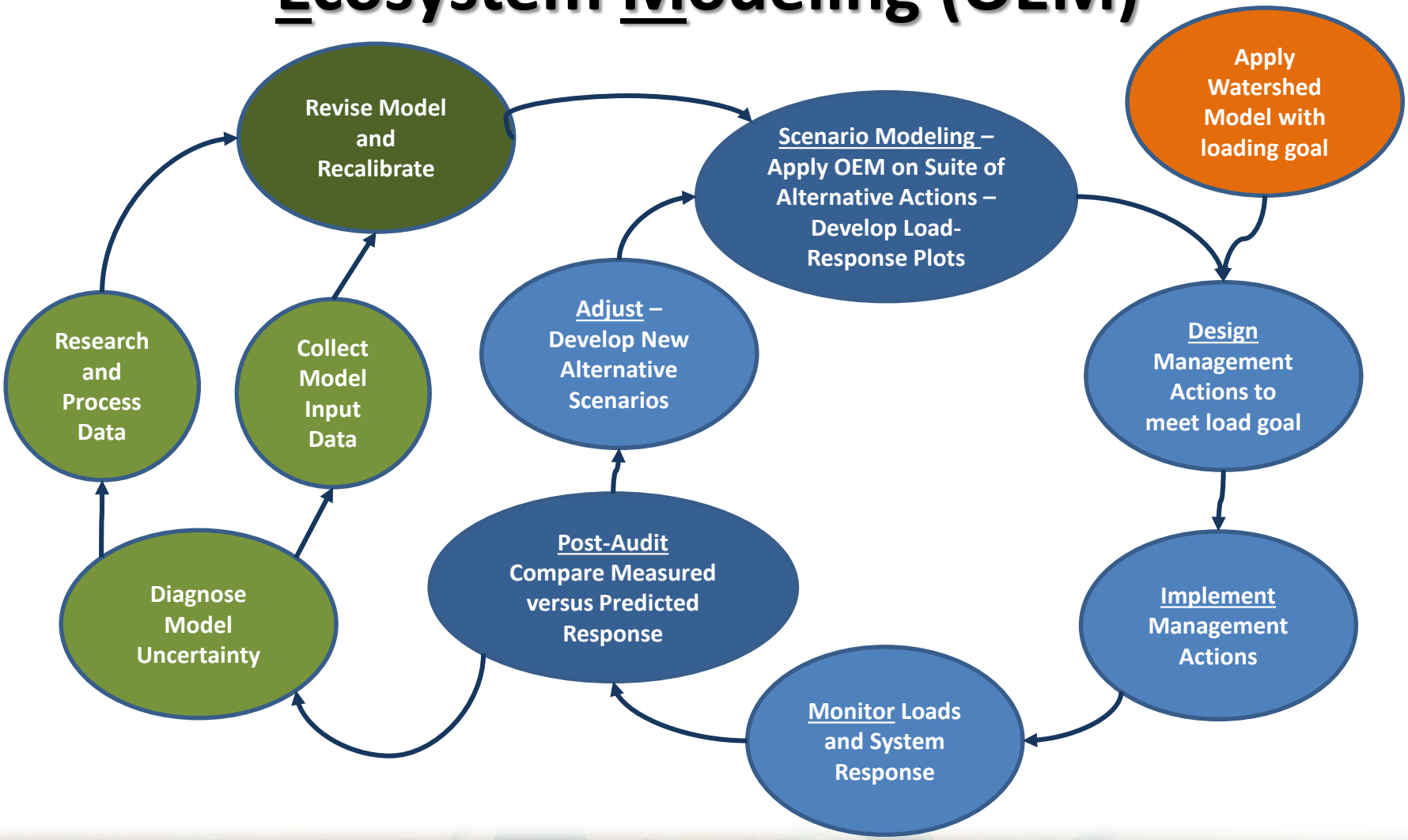
Integrate results from models to produce consolidated guidance

Each modeler presented:

- **calibration/confirmation results**
- **development of load-response curves**
- **level of uncertainty or sensitivity**

Team explored options/approaches for integration with agencies

Adaptive Management using Operational Ecosystem Modeling (OEM)



Common Steps to Develop an OEM

1. Select, formulate, and/or revise model to support:
   - User needs and management questions
   - System characteristics
   - Programmatic constraints
   - Desired level of model uncertainty – leads to adaptive improvement cycles
2. Collect calibration/confirmation data sets and perform the skill assessment/evaluation process
3. Develop model operation plan
   - Routine data needs and model application process
   - Output analysis and visualization
   - Delivery of model results to user and user support
   - Adaptive model refinement plan
   - Plan for data and model output storage and archiving
4. Develop institutional home for model and funding plan for model operation