New Hampshire Nutrient Lake TMDLs

Medium Scale Complexity Models

Sarah MacDougall & Don Kretchmer

ENSR | AECOM

NHDES

Total Maximum Daily Loads

- TMDLs
  - Required for Impaired Waters
  - Watershed Loading Study
  - Maximum Pollutant Load
    - TMDL= WLA + LA + MOS

Modeling for TMDLs

- Simulate complex watershed processes
- Scope problems
- Set targets
- Evaluate management options

Model Types

Simple

- Mass Balance
- Input/output Vollenweider Equation

Medium Scale

- AVGWLF- land use export only
- Sparrow – land use export only
- Reckhow's NE lakes model
- P8 - Bathtub, Flux, Profile
- WiLMS
- ENSR-LRM

Complex

- HSPF- BASINS
- SWAT
- WASP/EUTRO5
- WQRRS
- BIOLA
- SNL-EFDC

Part I:ENSR-LRM Watershed

Excel spreadsheet based export coefficient model

- What it does
  - Uses “local” nutrient export coefficients
  - Allows sub watershed analysis
  - Uses attenuation factors to calibrate results to tributary data

- What it does not do
  - Storm specific dynamics
  - Fate and Transport

Part II:ENSR-LRM In-Lake Model

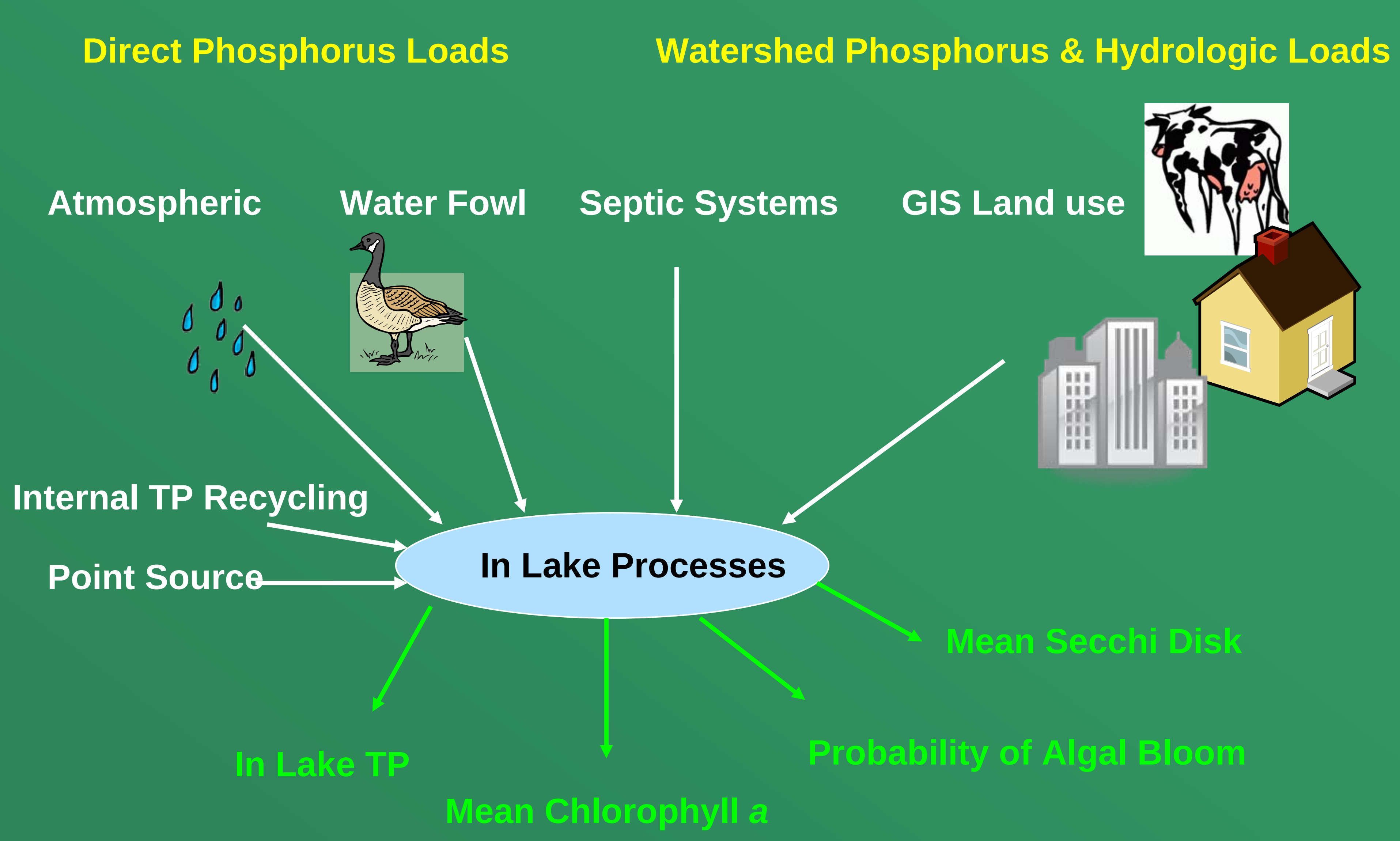
Combines export coefficient model with empirical in-lake models

- What it does
  - Calculates
    - Total Phosphorus
    - Chlorophyll *a*
    - Secchi Disk Transparency
    - Probability of algal bloom
  - Allows seasonal assessment
  - Calibrates results with in-lake data

- What it doesn't do
  - Multi-dimensional modeling
  - Mechanistic modeling
  - Stochastic probability modeling

Application of ENSR-LRM

- 30 NH nutrient impaired lakes
  - Chlorophyll *a*
  - Cyanobacteria
  - Dissolved Oxygen
- Modeled Total Phosphorus (TP)



Direct Phosphorus Loads
Watershed Phosphorus & Hydrologic Loads
Atmospheric
Water Fowl
Septic Systems
GIS Land use
Internal TP Recycling
Point Source
In Lake Processes
Mean Secchi Disk
Probability of Algal Bloom
In Lake TP
Mean Chlorophyll *a*

Hydrologic Loading Calculation

- Input average annual precipitation
- Determine runoff/base flow fractions for each land use
- Reality Check
  - Check load against standard water yield
- Calibrate using attenuation factors

TP Loading Calculations

- Point sources
- Nonpoint sources
    - Watershed loading
    - Septic system
    - Water fowl
    - Atmospheric
    - Internal

Watershed TP Loading

BASIN AREAS			
	BASIN 1	BASIN 2	BASIN 3
LAND USE	AREA (HA)	AREA (HA)	AREA (HA)
Urban 1 (Low Density)	15.5	17.9	4.6
Urban 2 (Medium Density)	5.2	21.2	
Urban 3 (Roads)	2.8	3.9	0.8

Add GIS land use data

Coefficient Look up Tables

P, N AND TSS EXPORT COEFFICIENTS FOR RUNOFF					
		PHOSPHORUS EXPORT (KG/HA/YR) N			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	6.2	1.9	1.1	0.2
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	6.2	1.9	1.1	0.2
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	6.2	1.9	1.1	0.2
Urban 4 (Ind)	Industrial	6.2	1.9	1.1	0.2
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	6.2	1.9	1.1	0.2
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	2.9	1.1	0.8	0.1
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	18.6	4.5	2.2	0.3
Agric 3 (Grazing)	Agricultural pasture with livestock	4.9	1.5	0.8	0.1
Agric 4 (Feedlot)	Concentrated livestock holding area	795.2	300.7	224.0	21.3
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.8	0.2	0.2	0.0
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.8	0.2	0.2	0.0
Open 1 (Wetland/Lak	Open wetland or lake area (no substantial canopy)	0.8	0.2	0.2	0.0
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.8	0.2	0.2	0.0
Open 3 (Barren)	Mining or construction areas, largely bare soils	4.9	1.5	0.8	0.1

	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1	6.2	1.9	1.1	0.2

Septic System TP Load

- Harvey Lake, Northwood
  - Counted # of dwellings in 125 ft lake buffer
  - Used reference export P coefficients & water use, attenuation factors
  - Calculated septic loads
    - Seasonal single family
    - Year-round single family
    - Coe Brown School

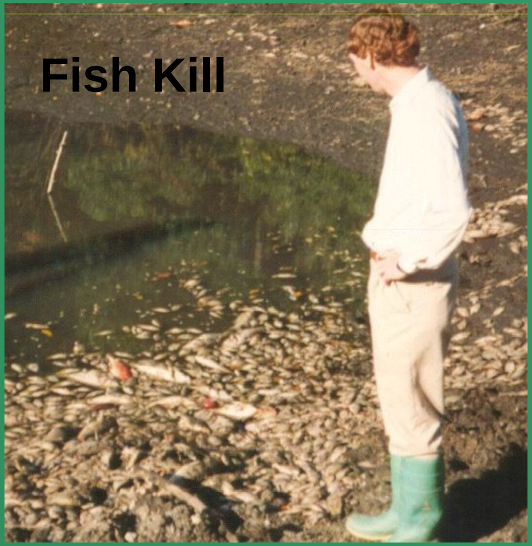
Water Fowl TP Load

- Greenwood Pond, Kingston
  - Input average annual bird population
  - Multiply by export coefficient for water fowl

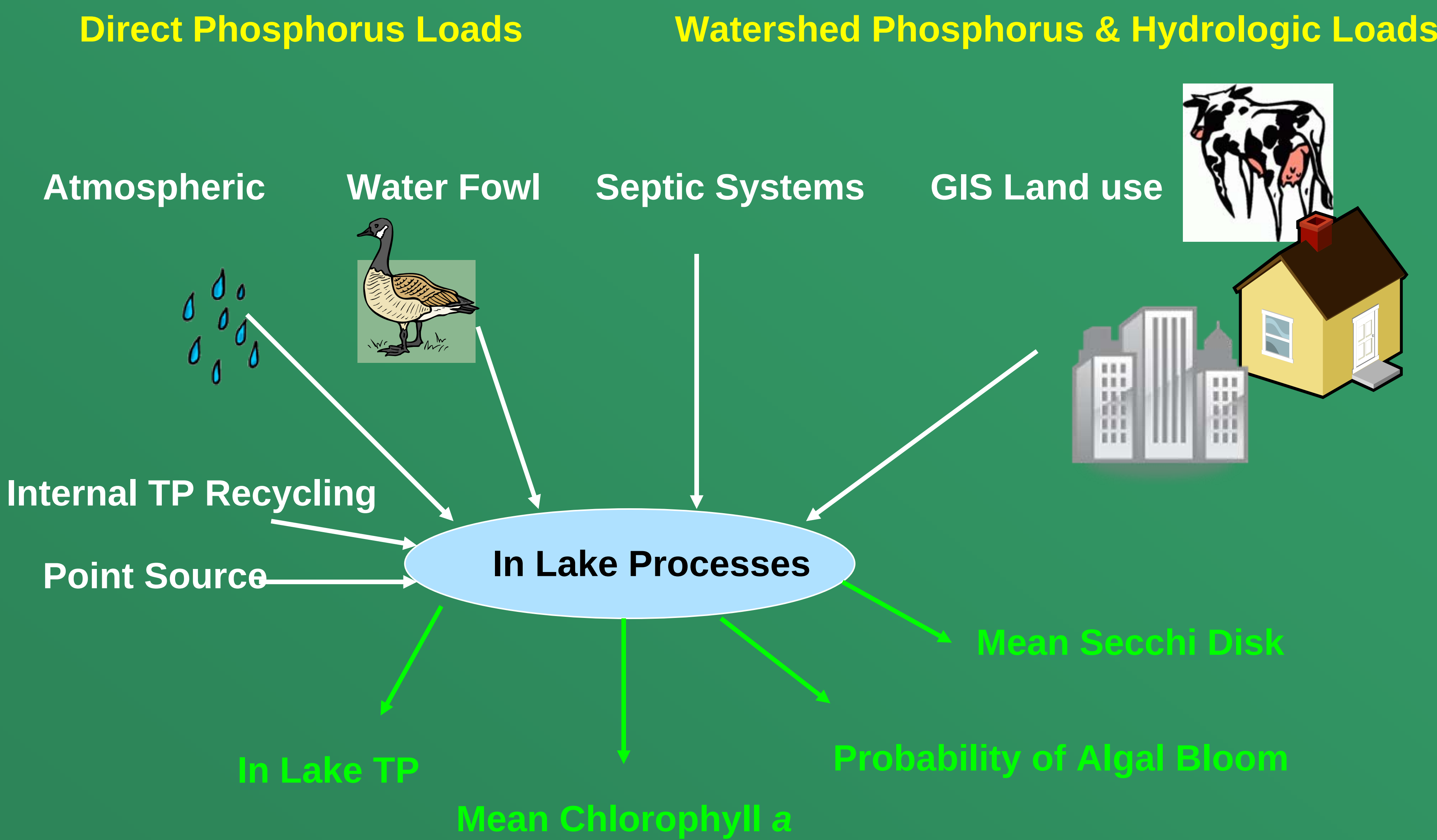
Atmospheric TP Load

- Showell Pond, Sandown
  - Input area of lake
  - Multiply by export coefficient
    - Precipitation
    - Dust from gravel operation

Internal TP Load



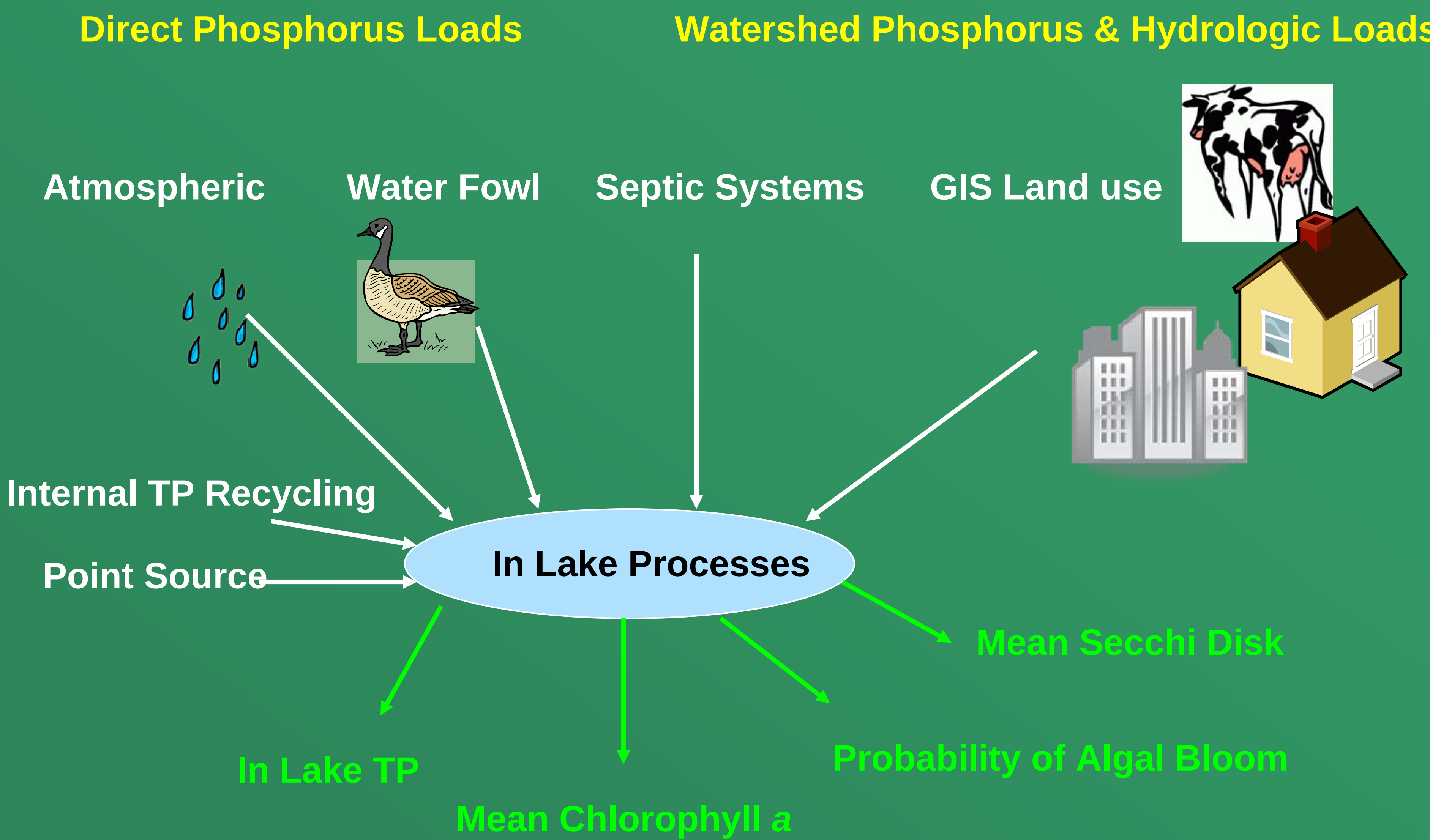
- Pawtuckaway Lake, Nottingham
  - Input volume of anoxic zone
  - Calculate P load using hypolimnetic P accumulation over summer


Direct Phosphorus Loads
Watershed Phosphorus & Hydrologic Loads
Atmospheric
Water Fowl
Septic Systems
GIS Land use
Internal TP Recycling
Point Source
In Lake Processes
Mean Secchi Disk
Probability of Algal Bloom
In Lake TP
Mean Chlorophyll a

In-Lake TP Predictions

	PHOSPHORUS	PRED.
		CONC.
NAME	FORMULA	(ppb)
Mass Balance	TP=L/(Z(F))*1000	37
(Maximum Conc.)		
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	19
(K-D)		
Vollenweider 1975	TP=L/(Z(S+F))*1000	31
(V)		
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	23
(L-M)		
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	25
(J-B)		
Reckhow General (1977)	TP=L/(11.6+1.2(Z(F)))*1000	14
(Rg)		
Average of Model Values		22
(without mass balance)		
	reality check-mean epi P ppb	19
	reality check-mean meta P ppb	27
	reality check-mean hyp P ppb	33

Reality check (monitoring data)


Direct Phosphorus Loads
Watershed Phosphorus & Hydrologic Loads
Atmospheric
Water Fowl
Septic Systems
GIS Land use
Internal TP Recycling
Point Source
In Lake Processes
Mean Secchi Disk
In Lake TP
Probability of Algal Bloom
Mean Chlorophyll *a*

TMDL Procedure with ENSR-LRM

- Model current scenario
  - Calibrate to available observed data
- Model background conditions
  - Set watershed back to forest & wetlands
- Model max practical reduction
- Model load required to meet TP target criteria
  - Determine Load Allocation (nonpoint source)
  - Determine Waste Load Allocation (point source)
  - Estimate percent reduction required

Advantages of Medium Scale Models

- Keeps calculations transparent
- Avoids “stranding” model-users
- Uses local export coefficients
- Adds in many reality checks
- Amenable to limited data means
- Can be easily updated to monitor progress during implementation

Conclusions

- Some lakes can be modeled on the back of an envelope, others require expensive, sophisticated models, but most need something in the middle.

- TMDLs can be viewed as another regulatory requirement, but should be viewed as a tool to help set the direction of a management strategy.

- Medium-scale models help provide this direction when you are miles away from the target. Precision is more crucial during implementation.

Questions?

A model is more than a pretty interface, look closely at what's inside