Development of Nutrient Criteria for Lakes and Reservoirs in Northern Plains States

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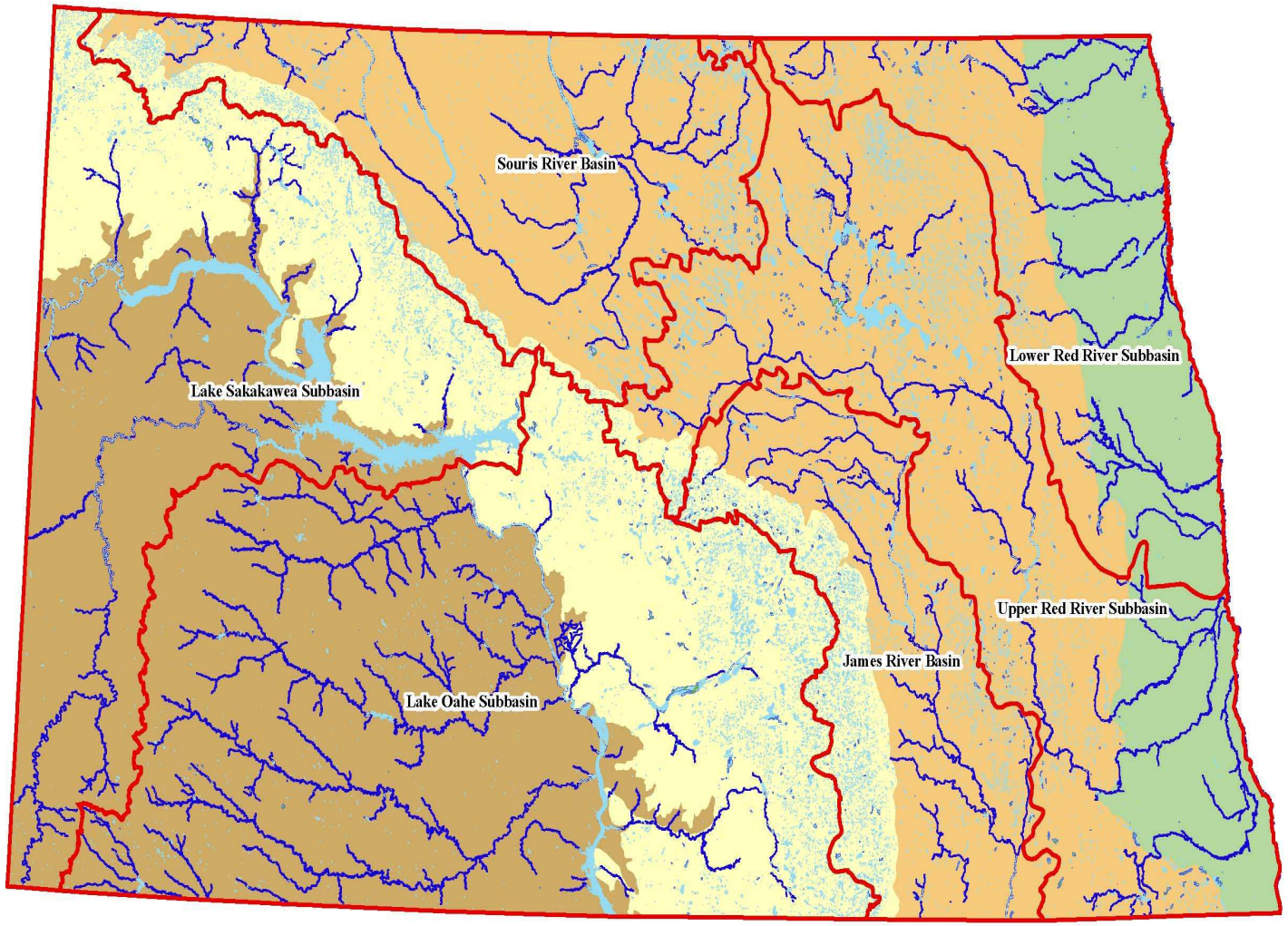
Topics for Today's Presentation

- ND work as technical basis for plains states
- Approach and results for ND work
- Early results for plains state reservoirs
- Hurdles to Overcome

North Dakota's Road Map for Criteria Development

- Prepared *Implementation Plan* (2007)
- Lacking information for "reference" conditions
  - Existing data lacks in abundance and distribution
  - Consider regional modeling
- Recommended
  - First lentic (non-flowing), then lotic (flowing), systems; address wetlands separately
  - Stratify criteria development by hydrologic planning regions before using ecoregions



Major Drainage Basins

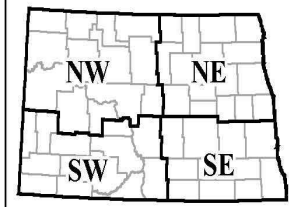
Ecoregions

- 42
- 43
- 46
- 48

Water Features

- Lake or Pond
- Reservoir
- Stream or River
- Swamp or Marsh
- Perennial Streams

Location Map



N
W E
S

0 10 20 40 60 80 Miles

Data Source: ND Department of Health and ND GIS Hub.

Ecoregions & Major Drainage Basins

Scale: As Shown	Drawn by: CLS	Checked by:	Project No.: 4965-000	Date: 09/11/06	Sheet: 1 of

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State-wide Classification of Lentic Systems was Critical First Step

- Must determine which water bodies are lakes? reservoirs? wetlands?
- Lake and reservoir classes must be further divided into sub-classes
  - Must reflect how system will respond to environmental conditions and ultimately stressors (excess nutrients)
- Considered 11 metrics for classification but lack of data limited use (e.g., hydraulic residence time)
- Established four sub-classes for lakes and reservoirs

Lake and Reservoir Classification

Assigned Class	Average Surface Area (acres)	Average Volume (ac-ft)	Average Drainage Area (sq.mi.)
LAKES			
I	74.1	575.9	13.8
II	156.8	1,770.8	12.9
III	364.3	4,444.3	16.6
IV	1,203.5	68,204.0	80.2
RESERVOIRS			
I	86.2	637.8	70.0
II	279.6	2,760.1	144.8
III	1,613.0	19,741.5	1,167.9
IV	1,542.7	28,570.0	472.2

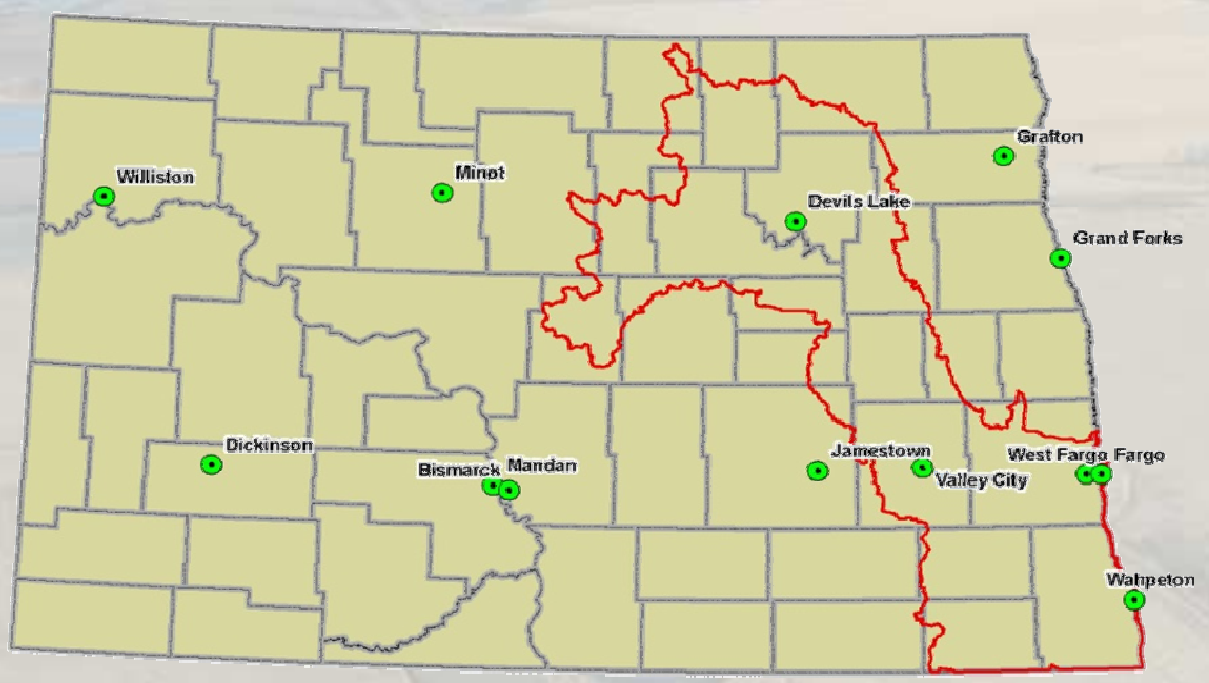
(Water body SA / Contributing DA) * Water body VOL

General Approach to Setting Lake and Reservoir Nutrient Criteria

- Use a “regional model” to:
  - Calibrate “current” conditions mean nutrient concentrations tied to land use index (% cultivated)
  - Adjust land use parameters (% cultivated, % urban) to establish “reference” condition
  - Use reference condition to establish nutrient criteria
- Regional model uses Monte Carlo approach
- Modeling approach incorporates uncertainty (e.g., model inputs, range of lake physical characteristics across geographic area)
- Upper Red River Basin selected as pilot area

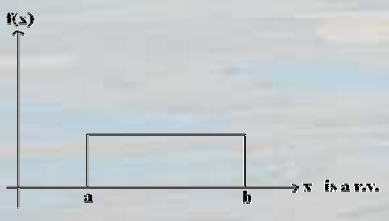
North Dakota Nutrient Criteria Pilot Area
Upper Red River Basin

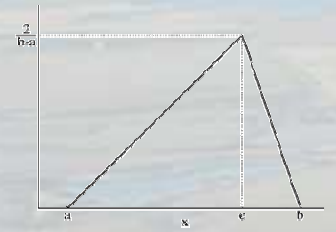
- URRB statistics
  - 13,420 Square Miles
  - 309 12-digit HUC basins
  - 2,085 Lakes, 184 sq mi (excludes Devils Lake)
  - 46 Reservoirs, 33.7 sq mi



Range in watershed condition (e.g., % cultivated) and resource characteristics (lake size, depth, volume)

Monte Carlo Modeling

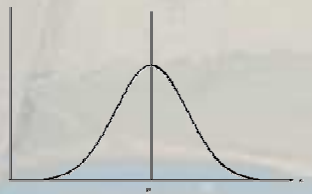




Model Inputs

Compute Many Trials

Daily Runoff Volume

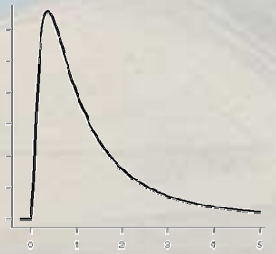


X

TP Event Mean Concentration

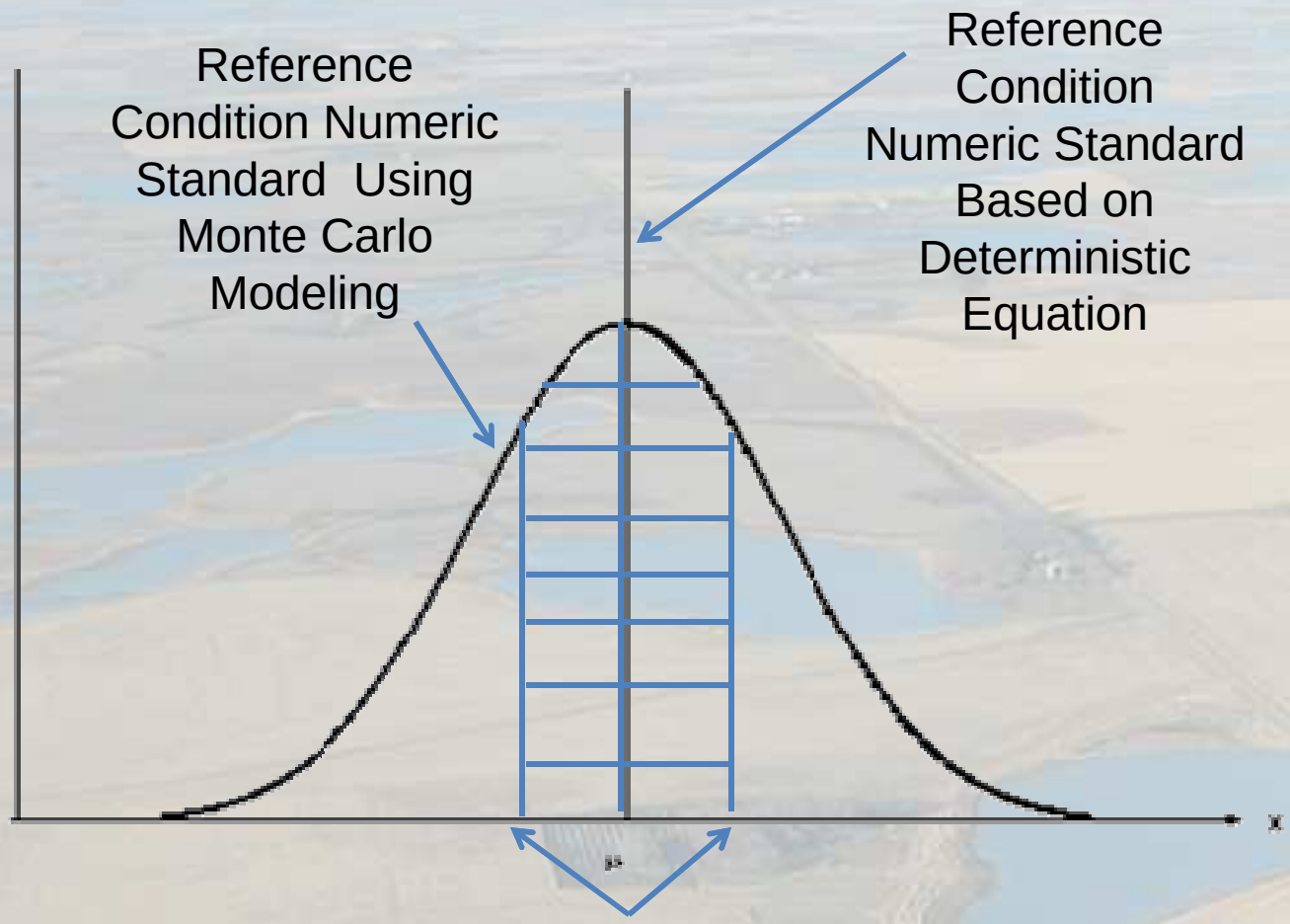
Compute Many Trials

Daily Watershed Load



Distribution of inputs from Upper Red River Basin region.

Using Monte Carlo Simulation to Establish Reference Condition



Distribution of lake mean annual TP concentrations reflects reference land use and range characteristics within lake class

Implementation of Monte Carlo Modeling Approach

- Integrated into CNET model (W.W. Walker)
  - BATHTUB model
  - Spreadsheet (EXCEL) based
  - Quickly evaluate multiple scenarios with same inputs across classes
- Define model inputs with probability distributions
  - Receiving water: Surface areas, drainage areas, volumes
  - Landscape: Curve numbers by land use, total phosphorus land-use event mean concentrations, precipitation depths

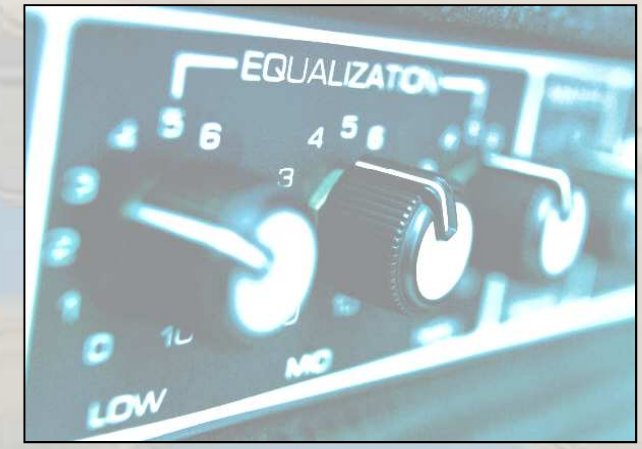
Used Crystal Ball software as Monte Carlo engine

Modeling “Tweaks”

- Altered “annual” time-step for runoff input
- Computed daily runoff volumes and loads
- Ensure spatial consistency
- Adjust eutrophication response (Secchi and Chl-a) based on regional data

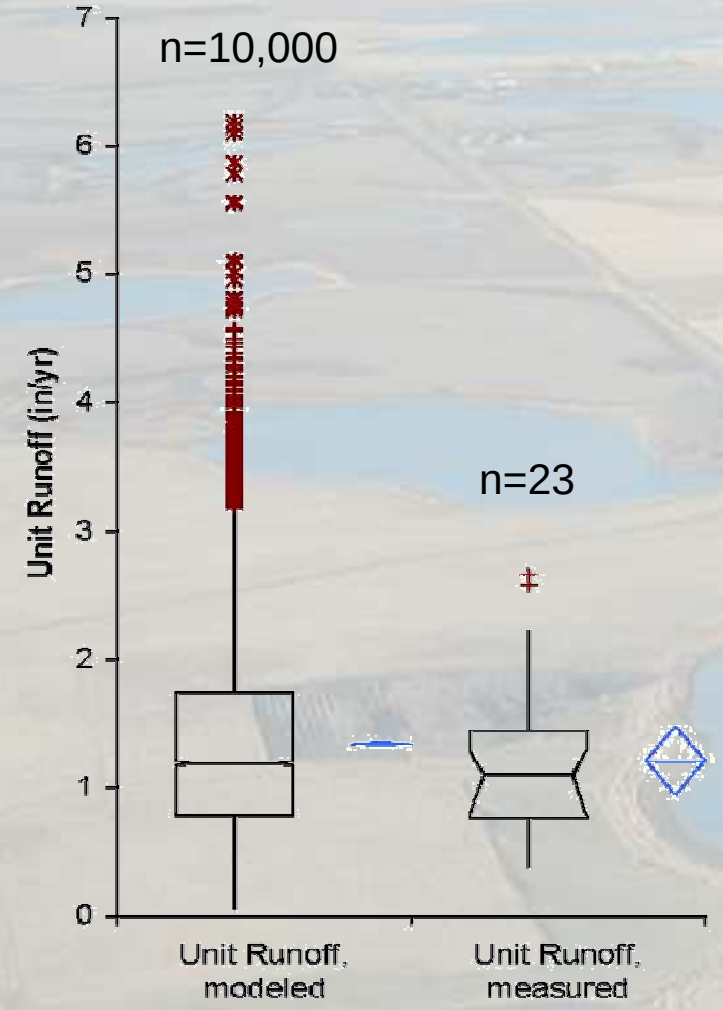
Assessing Outputs and Model Credibility

- How do we fine-tune the model?
  - Are regional annual runoff volumes in the ball-park?
  - Are regional water-column concentrations in the ball-park?



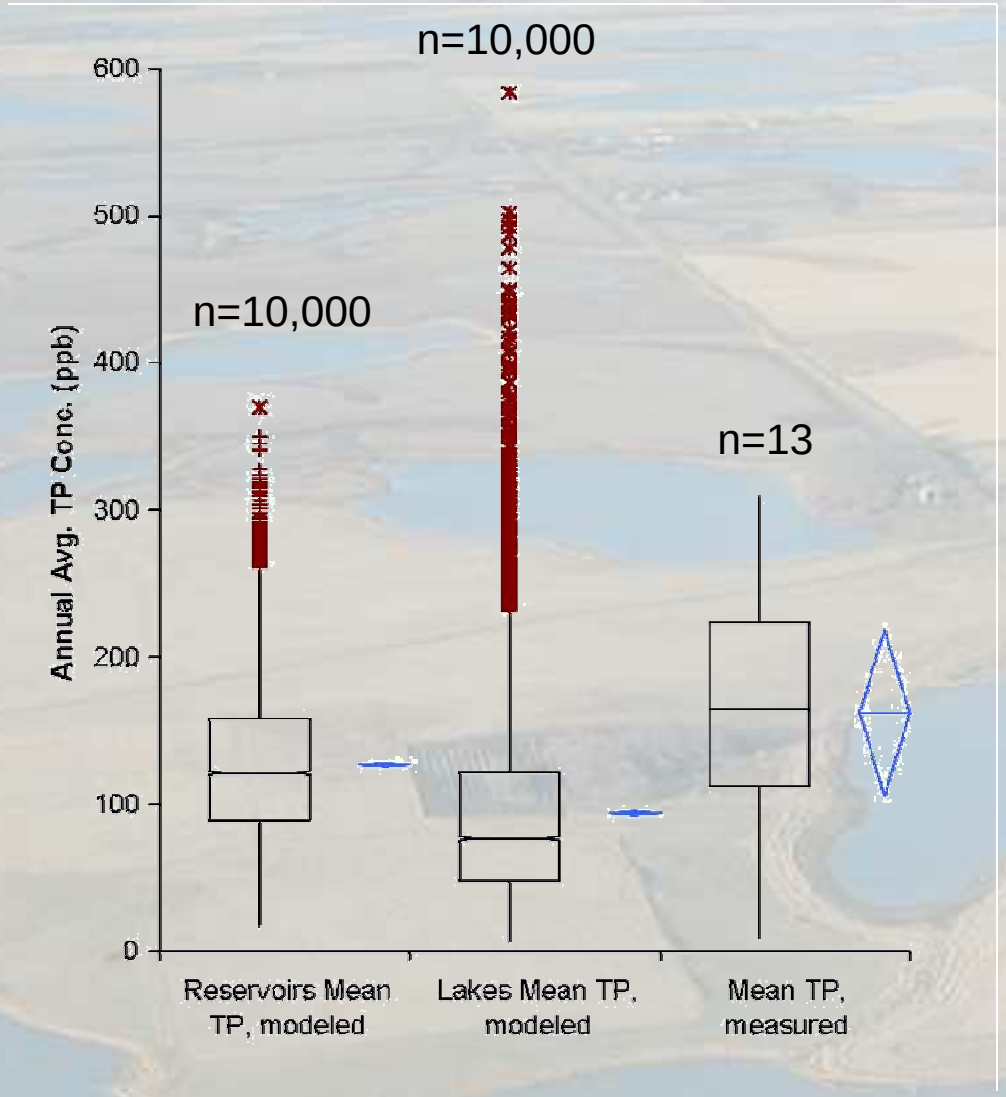
Annual Runoff Volumes

USGS gage stations



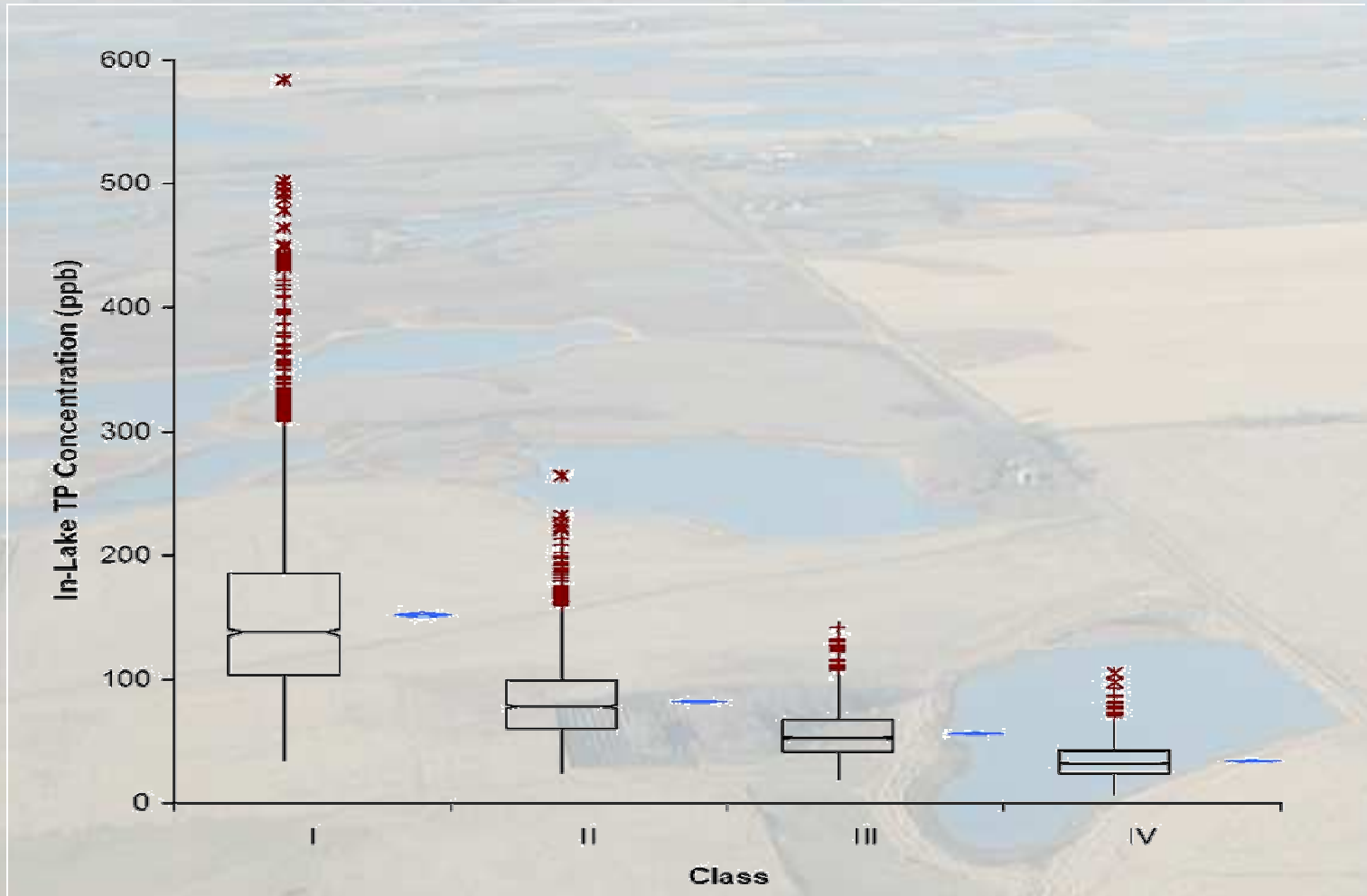
Represents current land use conditions in the URRB (82% cultivated land)

Estimated Mean TP Concentrations (all lake and reservoir classes)



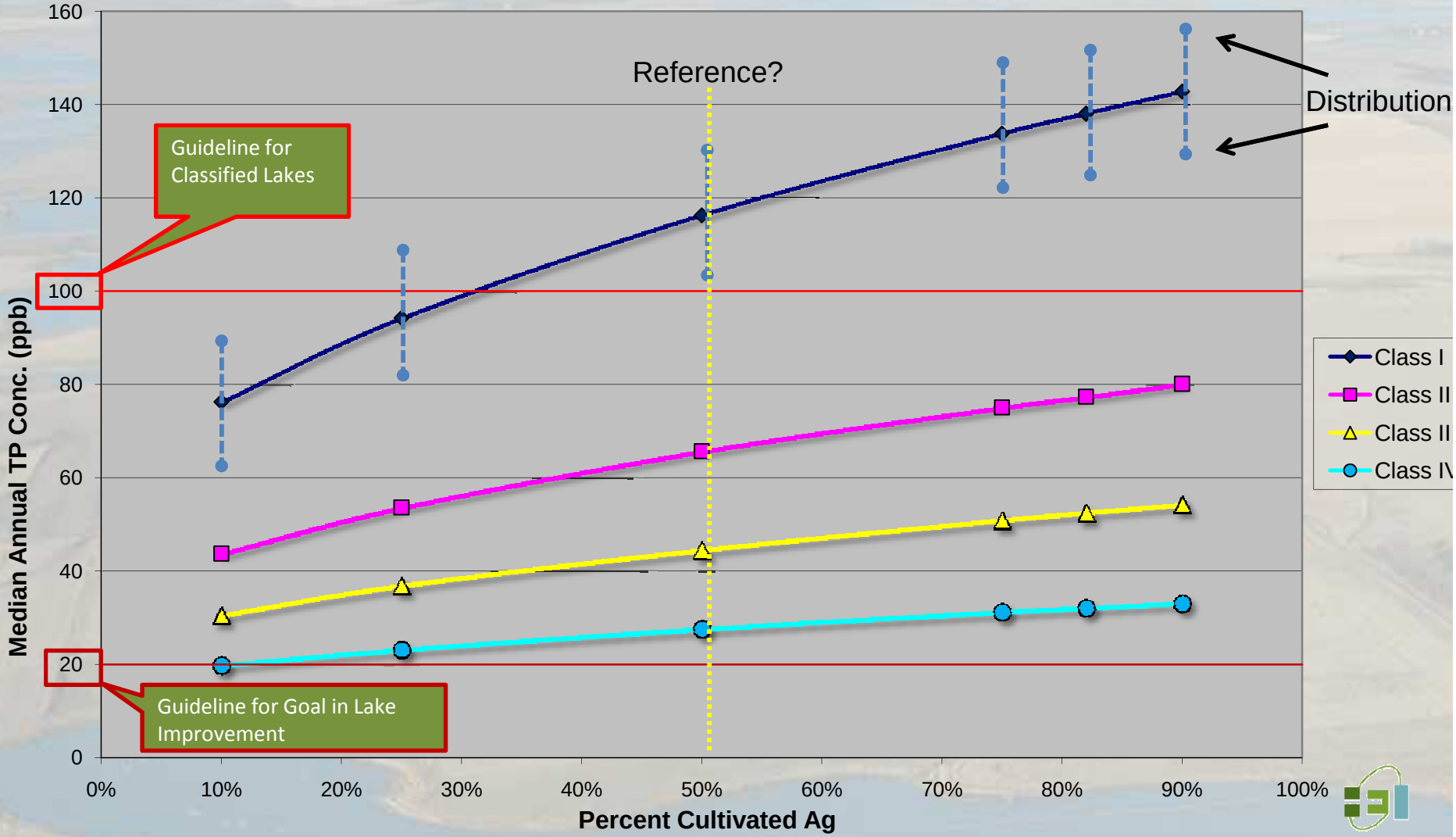
Represents current land use conditions in the URRB (82% cultivated land)

Lake Classes & Annual TP Concentrations



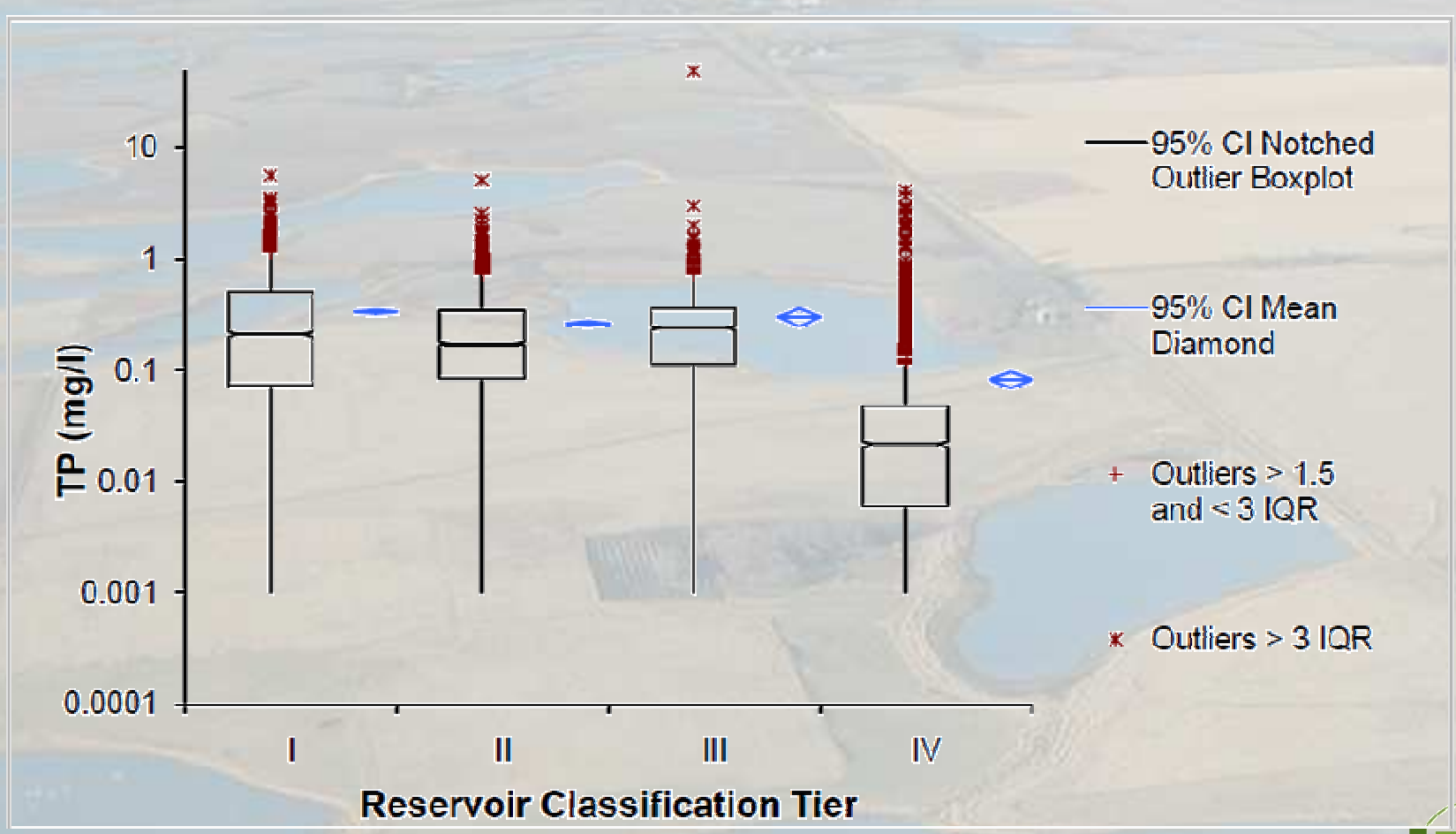
Represents current land use conditions in the URRB (82% cultivated land)

Using Results to Establish Reference Condition (Lakes)



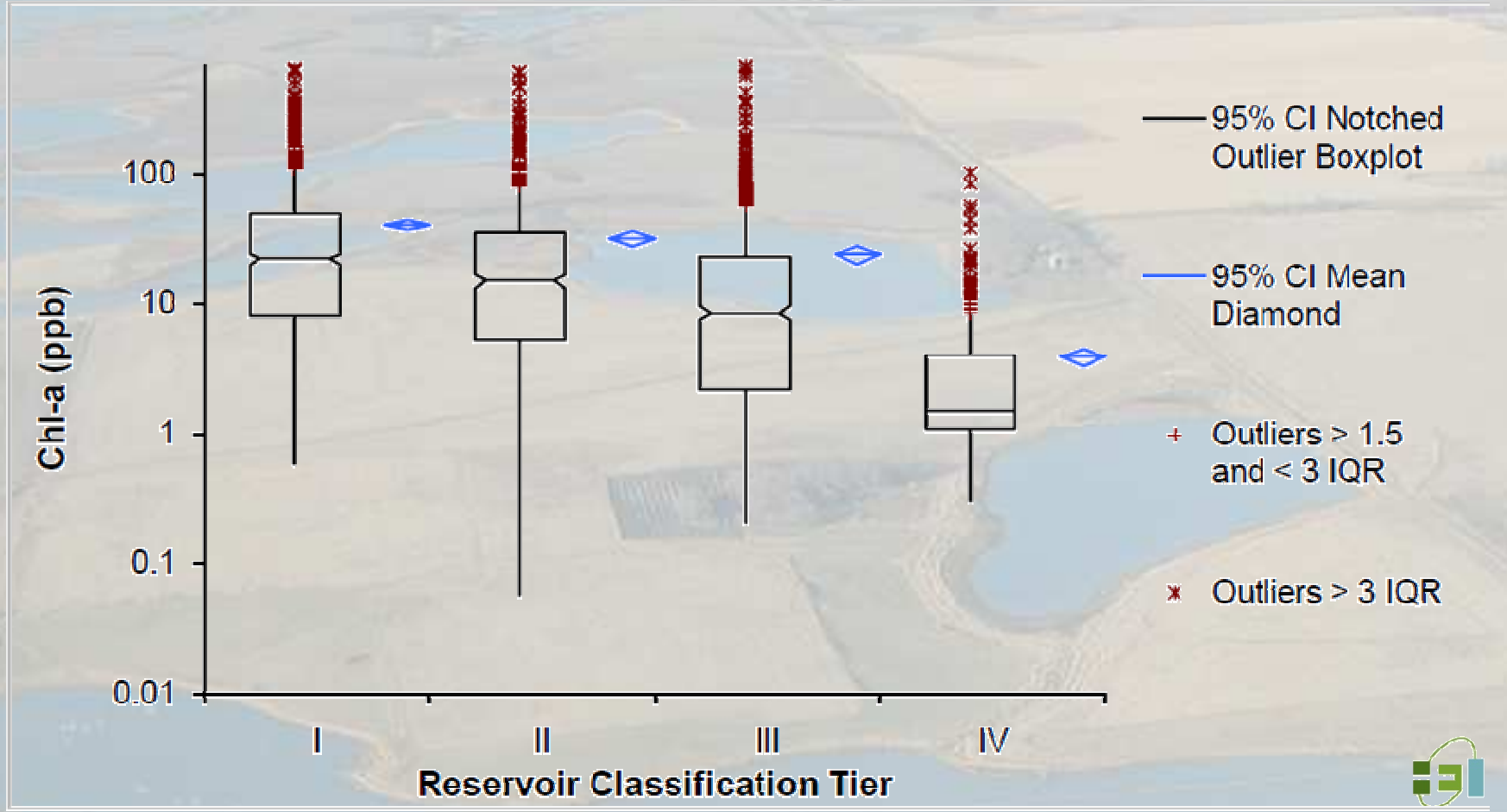
Application to Plains States (ND, SD, WY, MT)

Figure 4: Distribution of Total Phosphorus Values by Reservoir Classification Tier



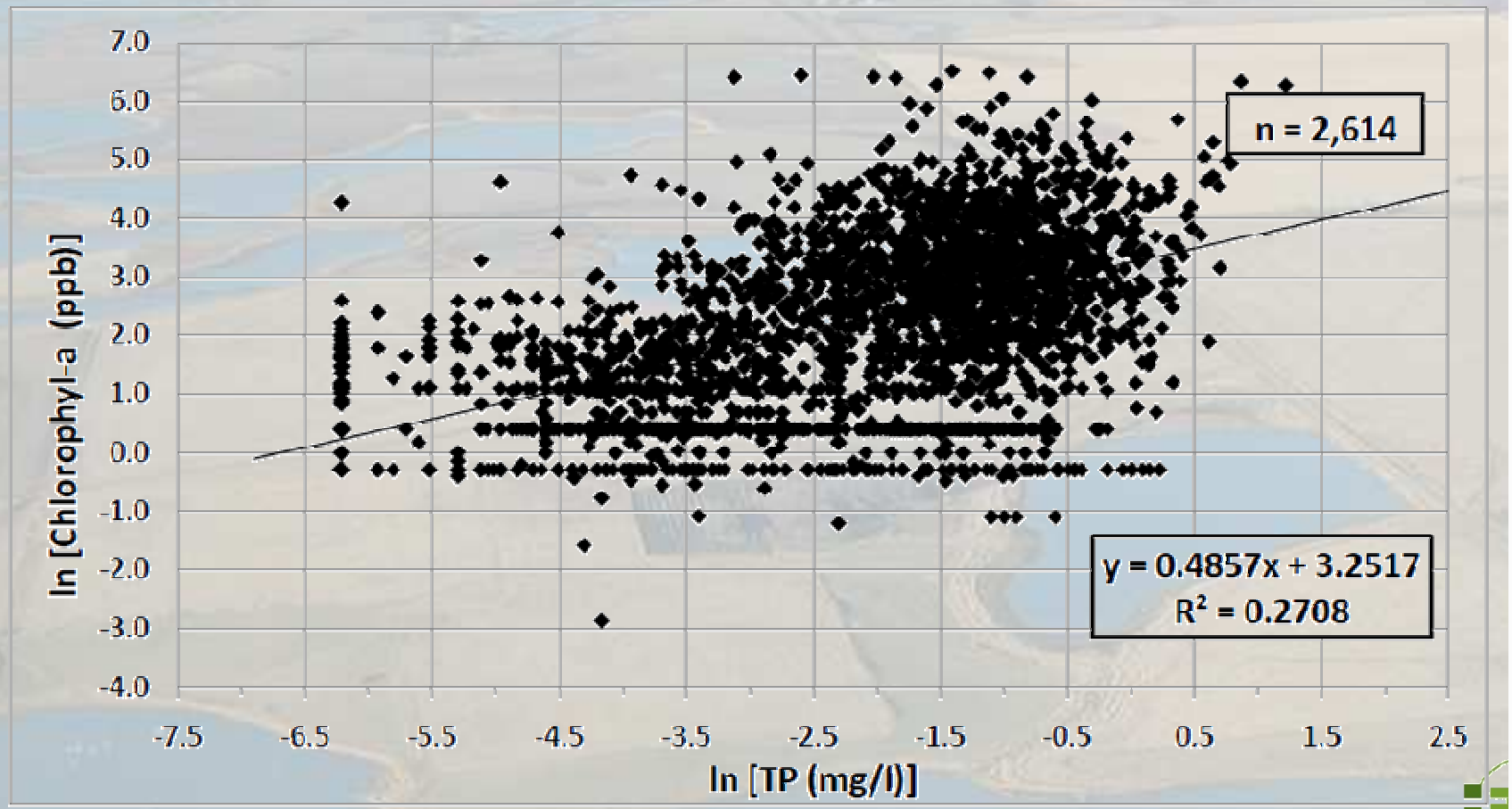
Application to Plains States (ND, SD, WY, MT)

Figure 7: Distribution of Chl-a Values by Reservoir Classification Tier



Stressor – Response Relationship for Plains States

Figure 1: Total Phosphorus vs. Chl-a (ln transformed)



Lessons Learned

- How to define lake, reservoir, wetland?
- Consistent naming conventions for lakes / reservoirs is badly needed
- Must do basic data collection
  - Lake and reservoir morphometry (need volumes)
  - Watershed (need drainage areas)
  - Need calibration / validation data
  - Need data for stressor – response relationship
- Common database structure would be great
- What land use condition is reference?

Conclusions

- Monte Carlo modeling showed distinct differences between classes
- Monte Carlo approach works
  - Addressed gaps in data
    - Physical lake / reservoir characteristics
    - Water column concentrations
  - Multiple scenarios and trials evaluated – can be used to establish reference and load allocations???
  - Incorporated uncertainty across range of landscape / environmental conditions
- Model showed potential regional targets for TP criteria, bounded by ranges
- Need <u>data</u>

Next Steps

- Application of Monte Carlo model regionally to Plains States (reservoirs only)
- Calibrate using reservoir data and adjust stressor – response relationships
- Use the modeling to recommend numeric criteria by ecoregion and reservoir class

Thank you.

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