

Development of TMDL's for two Eutrophic Lakes in Vermont

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March 28, 2008

Some acknowledgements

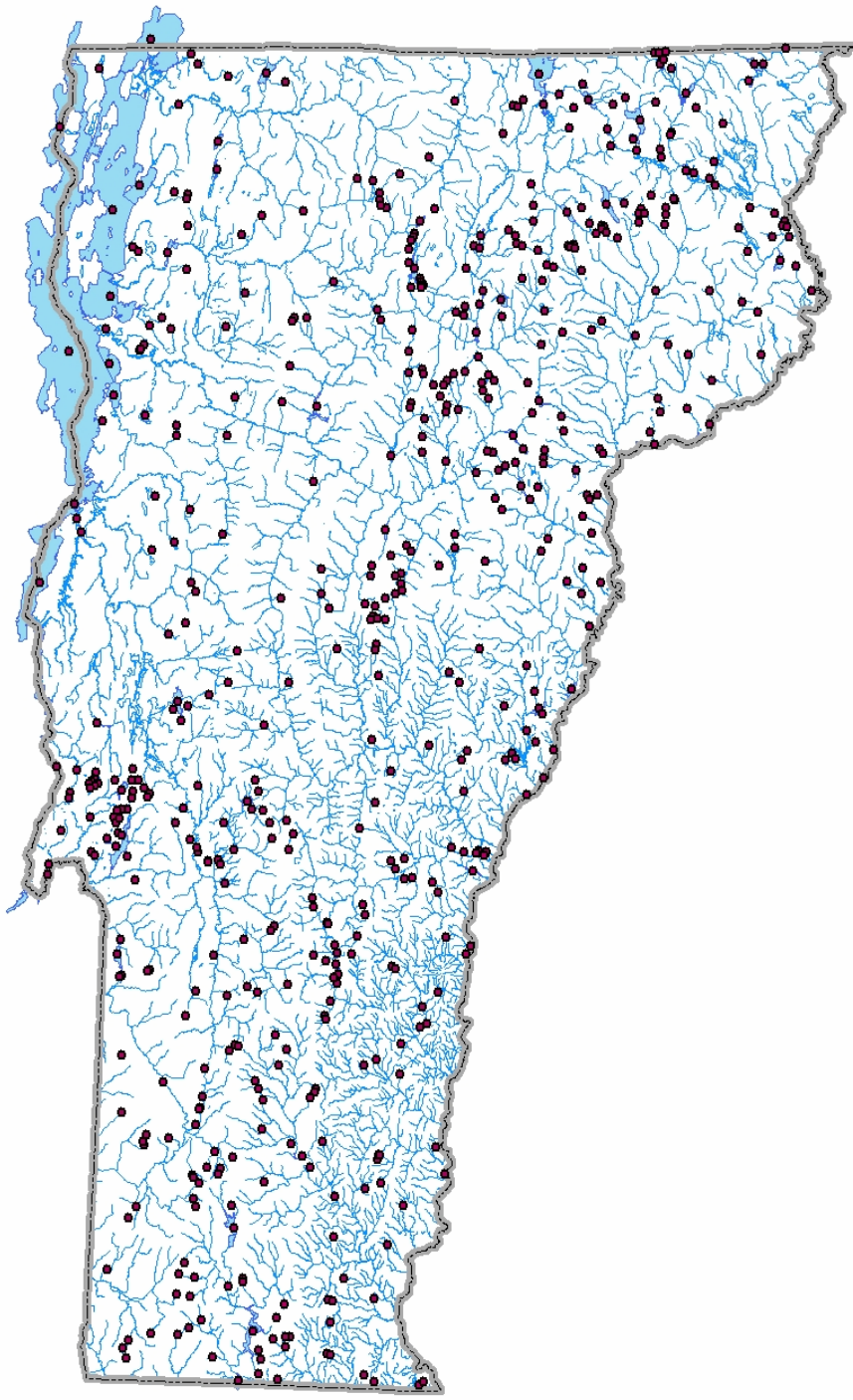
- Individuals

- Eric Perkins EPA R1
- Lindsay Harris and Sarah Wheeler, VTANR
- Brent Frankland, VT Technical College and UVM
- Ticklenaked Pond Watershed Association
- Franklin Watersheds Council

- Funding

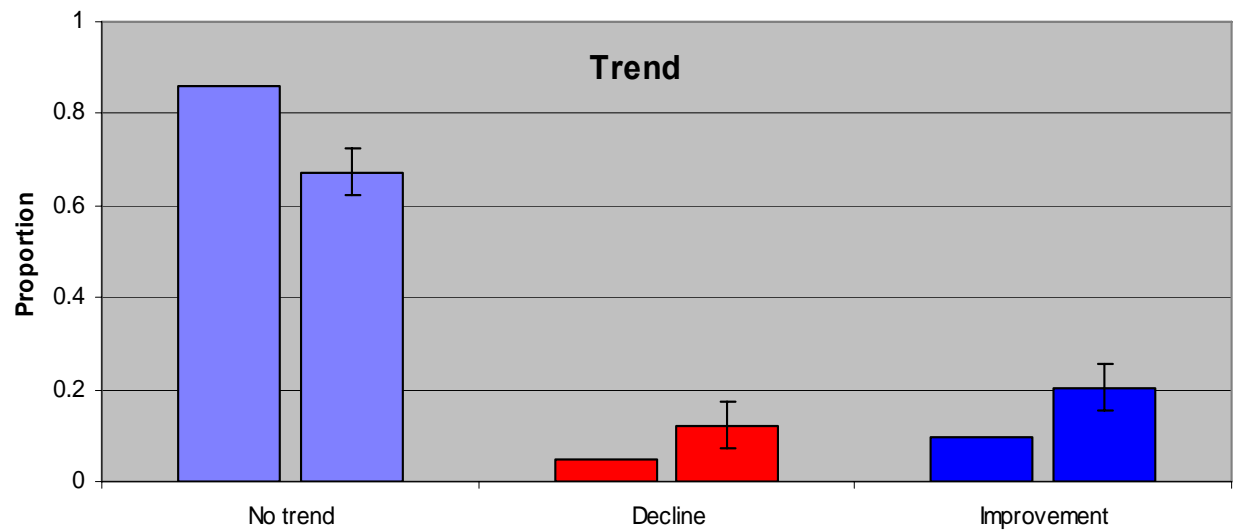
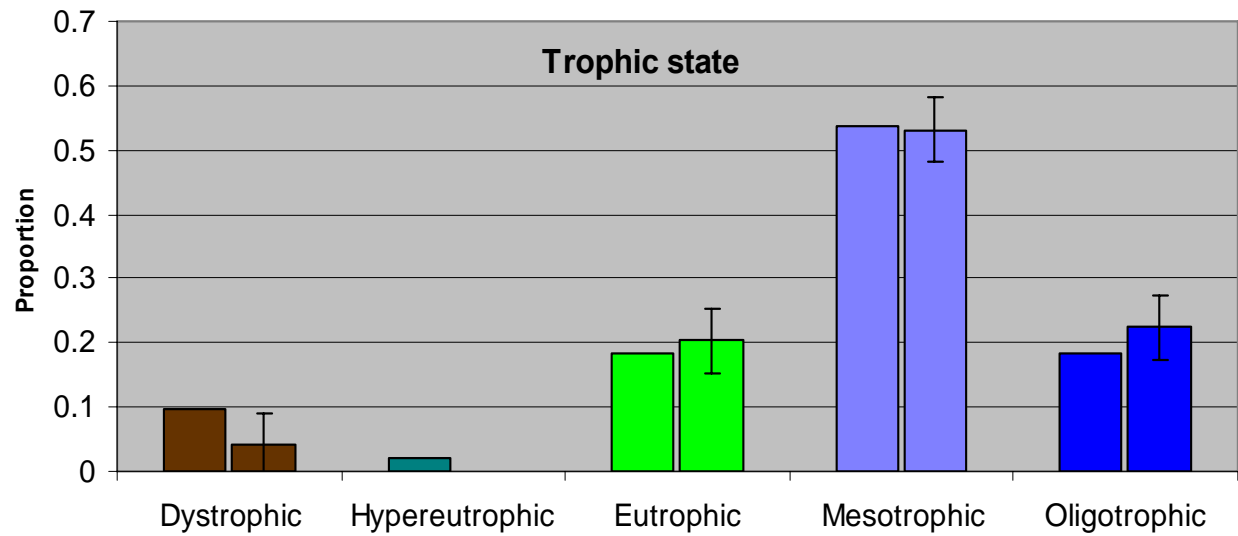
- USEPA C.W.A. 104(b)(3) X-97124401
- VTANR

Vermont's lakes



- 560 assessed lakes in 1,436 assessment units
- 229,767 assessed acres
- 174,175 within 11 Lake Champlain segments
- Focus of inland lake program is protection from impairment.
- We are presently working on several lakes that do support uses, but where trends suggest declines in quality

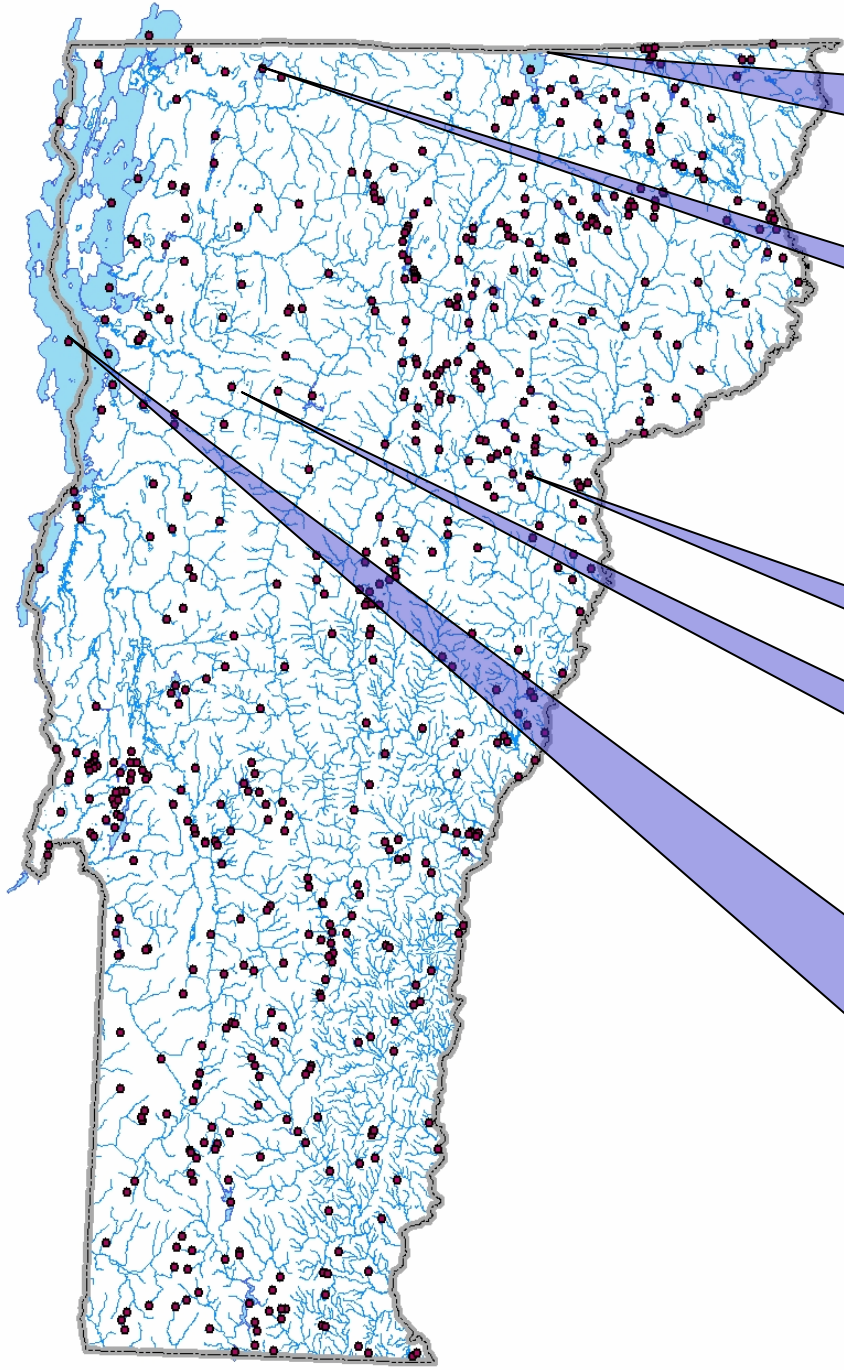
Trophic state and trends in VT lakes



Left bar = targeted lakes (n=232); right bar = probability lakes (n=49)

VT's lake-nutrient TMDL world

| Lake | Complexity of TMDL | Jurisdictions involved | TMDL done? |
|---------------------------------|---|------------------------|----------------------------------|
| Lake Champlain | Very high, 18 major tribs, dozens of WWTF's | VT, NY, Quebec | Yes, major cleanup plan underway |
| Lake Memphremagog | Moderate, 4 major tribs, several WWTF | VT, Quebec | Monitoring studies in progress |
| Shelburne Pond | Low | VT | Possible UAA candidate |
| Ticklenaked Pond and Lake Carmi | | | Subject of this presentation |



Lake Memphremagog
(5,966 ac). Monitoring
studies in progress

Lake Carmi (1402
ac), listed and TMDL
in development

Ticklenaked Pond (52 ac),
listed and TMDL in
development

Shelburne Pond
(452 ac), listed and
we wonder what to
do??

Champlain
174,175 (ac) TMDL approved
2002

Format of this presentation

- Follow flow of a TMDL
- Articulate commonalities and differences in approaches for these TMDL's
- Highlight the use of some simple tools to facilitate development of lake nutrient TMDL's
- Cast of characters:
 - Lake Carmi, Franklin, VT
 - Ticklenaked Pond, Ryegate, VT

Lake Carmi




- 1,402 ac lake
- 6,308 ac basin
- $Z_{max} = 33\text{ft}$
- $Vol = 17,554\text{ acft}$
- TP 28 ppb (spring)
- TP 28-38 ppb (summer)



- One small gaugable tributary, several smaller intermittent tribs
- Outlet is headwater of Pike River
- Land use primarily agricultural
- Several MFO farms active in watershed
- Some (very) recalcitrant landowners

Lake Carmi Watershed

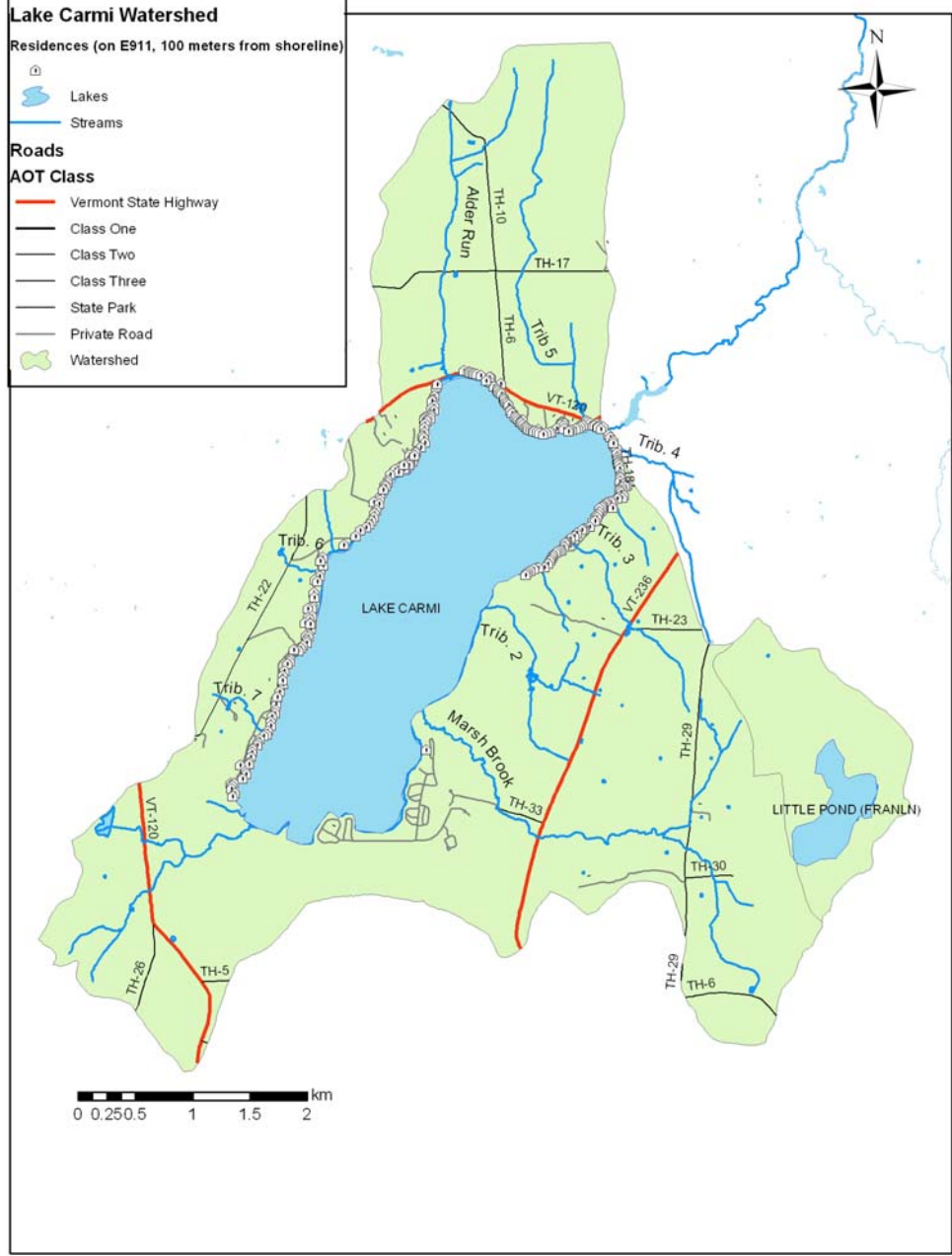
Residences (on E911, 100 meters from shoreline)

-  Residences
-  Lakes
-  Streams

Roads

AOT Class

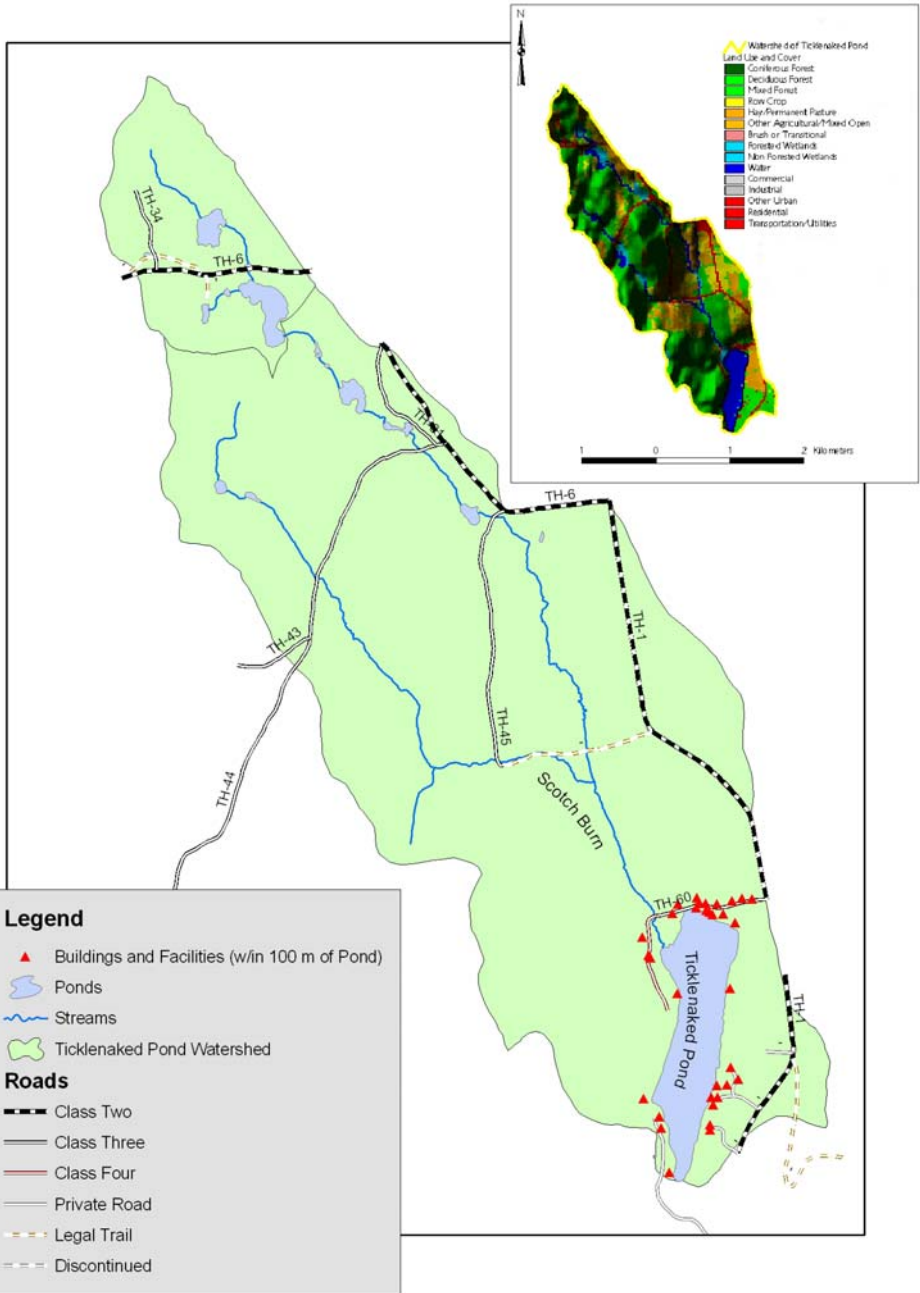
-  Vermont State Highway
-  Class One
-  Class Two
-  Class Three
-  State Park
-  Private Road
-  Watershed



Ticklenaked Pond

- 54 ac lake
- 1,444 ac basin
- $Z_{max} = 46\text{ft}$
- $\text{Vol} = 864\text{ acft}$
- TP 41 ppb (spring)
- TP 45 ppb (summer)
- Outlet to CT River
- One small gauged tributary
- Land use forested with some agriculture
- Two MFO farms active in watershed





TMDL Section: Background

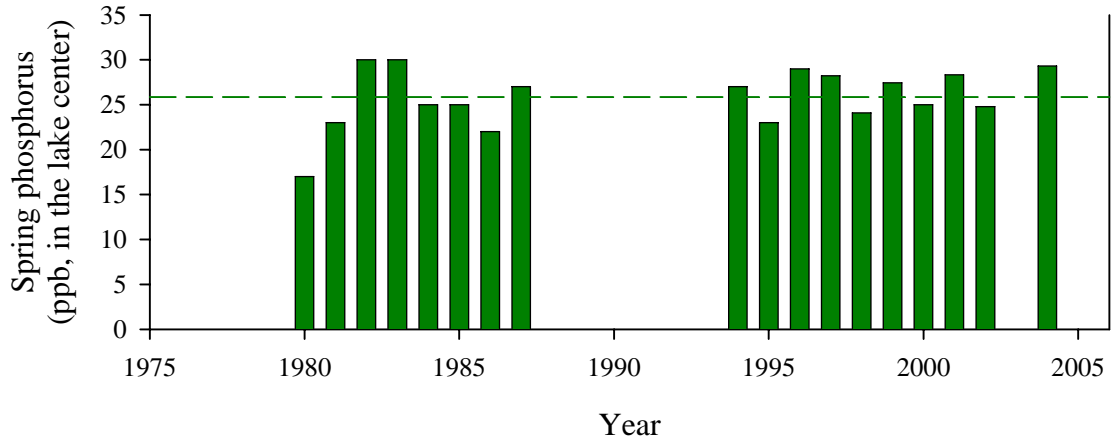
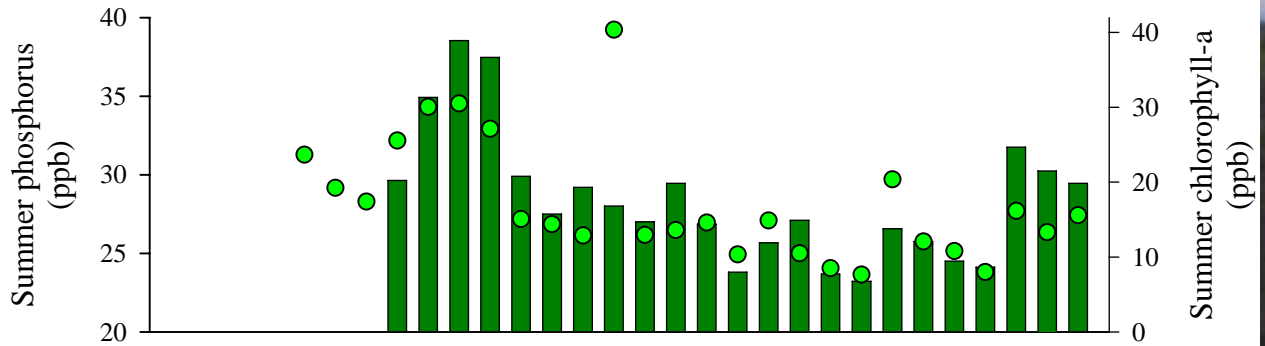
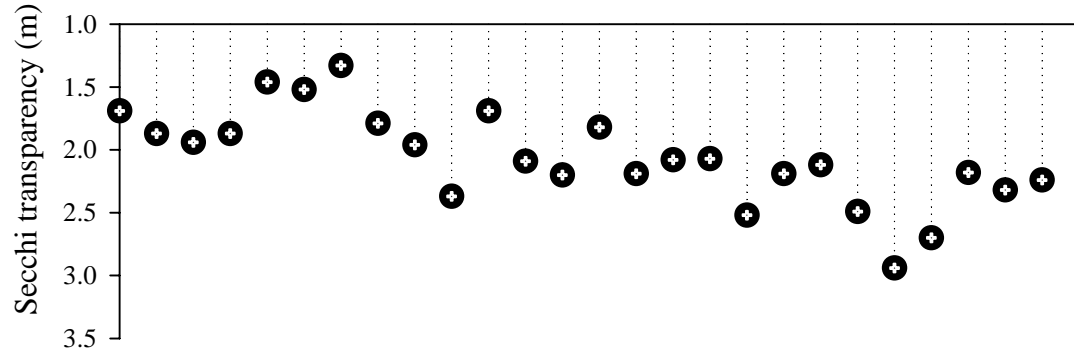
Lake Carmi

- Recurring, severe cyanobacteria blooms
- Long history of impairment
- Long history of farming use in watershed
- Mean chl_a of 17 ppb is in top 5% of inland VT lakes
- Stratified polymictic, little evidence of internal P loads
- Uses impaired: aesthetics, contact recreation

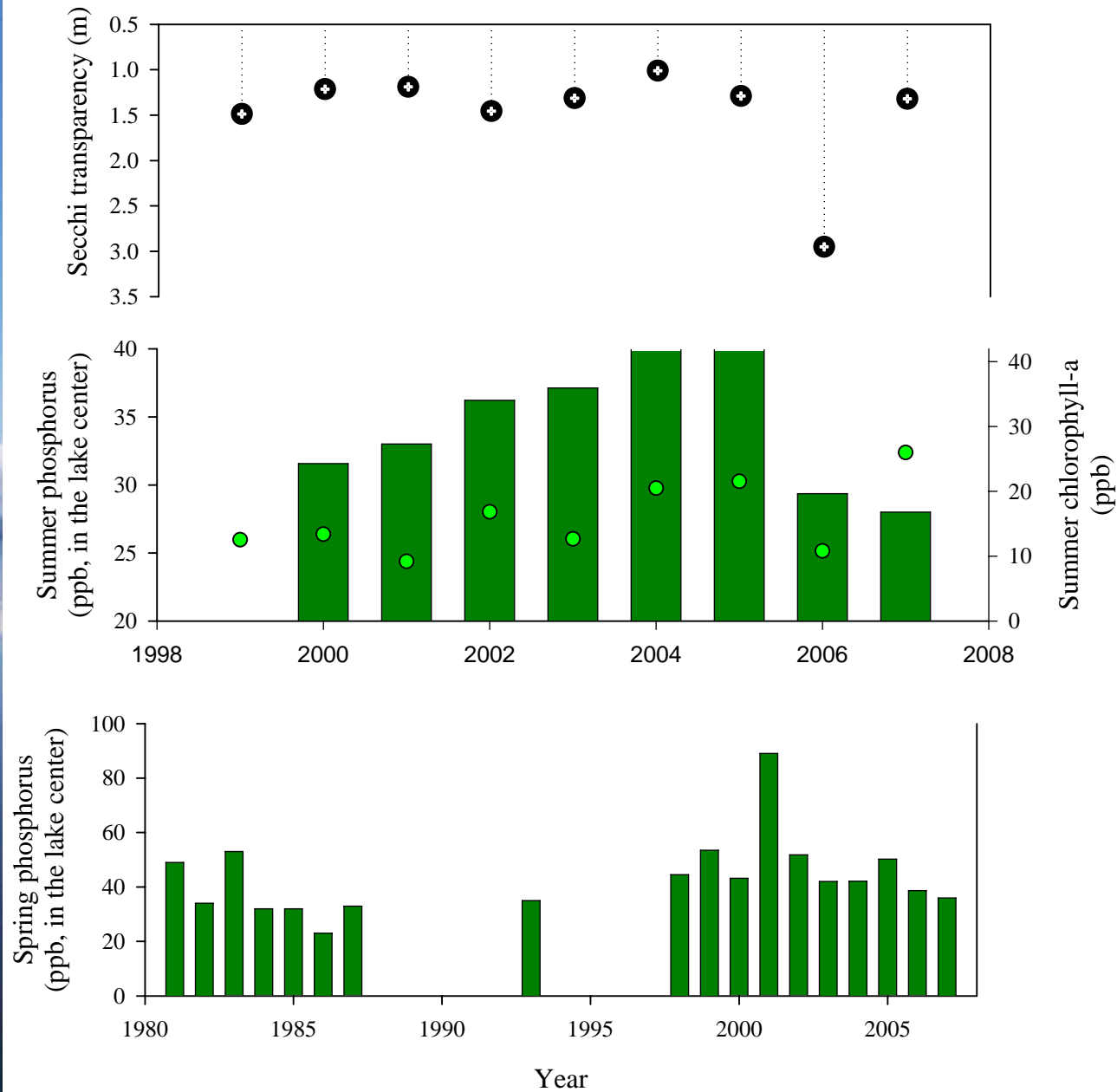
Ticklenaked Pond

- Thin monitoring data until 1999
- Rapidly deteriorating WQ from 1999 to 2004
- Moderate cyano blooms beginning 1999
- TP and chl_a (15 ppb) in top 5% of inland VT lakes
- Stratified dimictic, evidence of internal P loads
- Uses impaired: aesthetics, contact recreation, AQL

Lake Carmi WQ Trends



Ticklenaked Pond WQ Trends



TMDL Category: Applicable WQS

10 V.S.A. Chapter 47,

All waters - general policy

In all waters, total phosphorous loadings shall be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses. (...)

- In Class B waters, this means:
 - Consistently good aesthetic value
 - Supports swimming
 - No change from reference conditions that would have an undue adverse effect on the composition of the aquatic biota, the physical or chemical nature of the substrate or the species composition or propagation of fishes.

TMDL Target Concentration

Lake Carmi

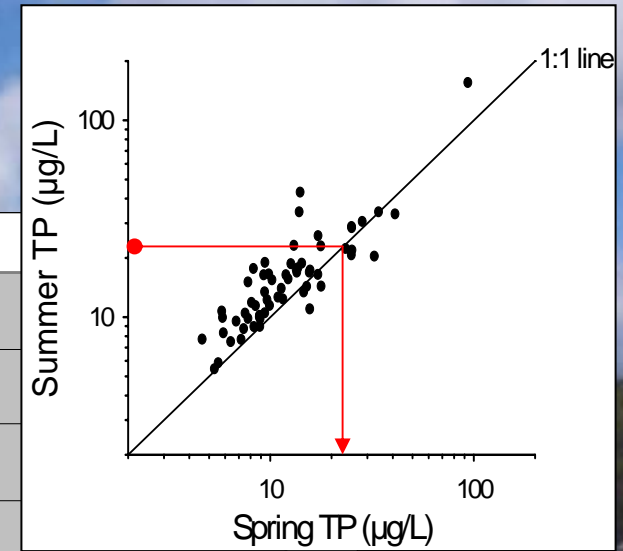
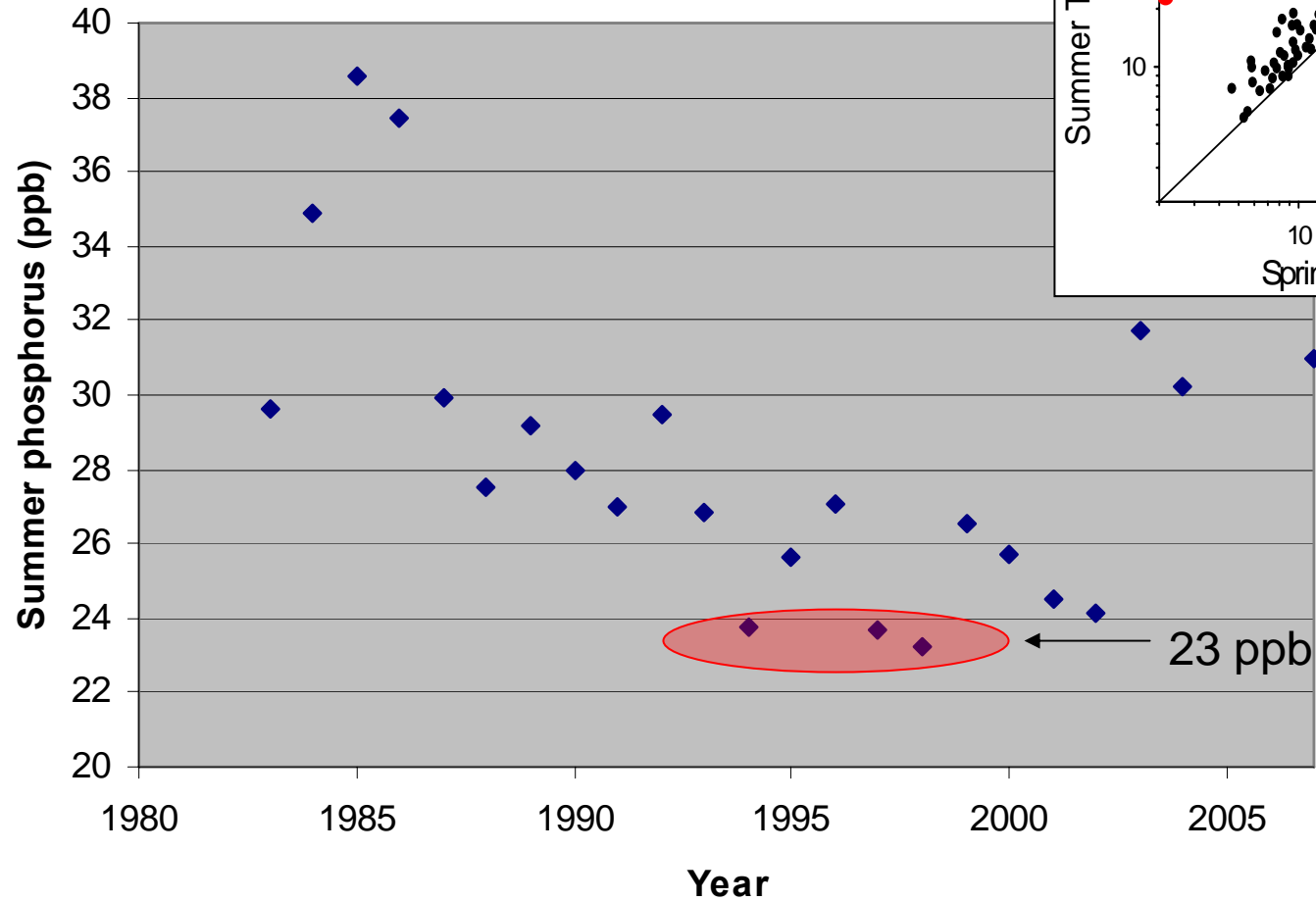
- Lake has experienced good WQ in occasional years
- Identify measured concentration for the best (lowest P) three years
- Yields target of 23 ppb

Ticklenaked Pond

- Leverage analyses from nutrient criteria project to guide selection of criterion
- Perceived nuisance → summer chla → summer TP → spring TP
- Yields target of 22 ppb

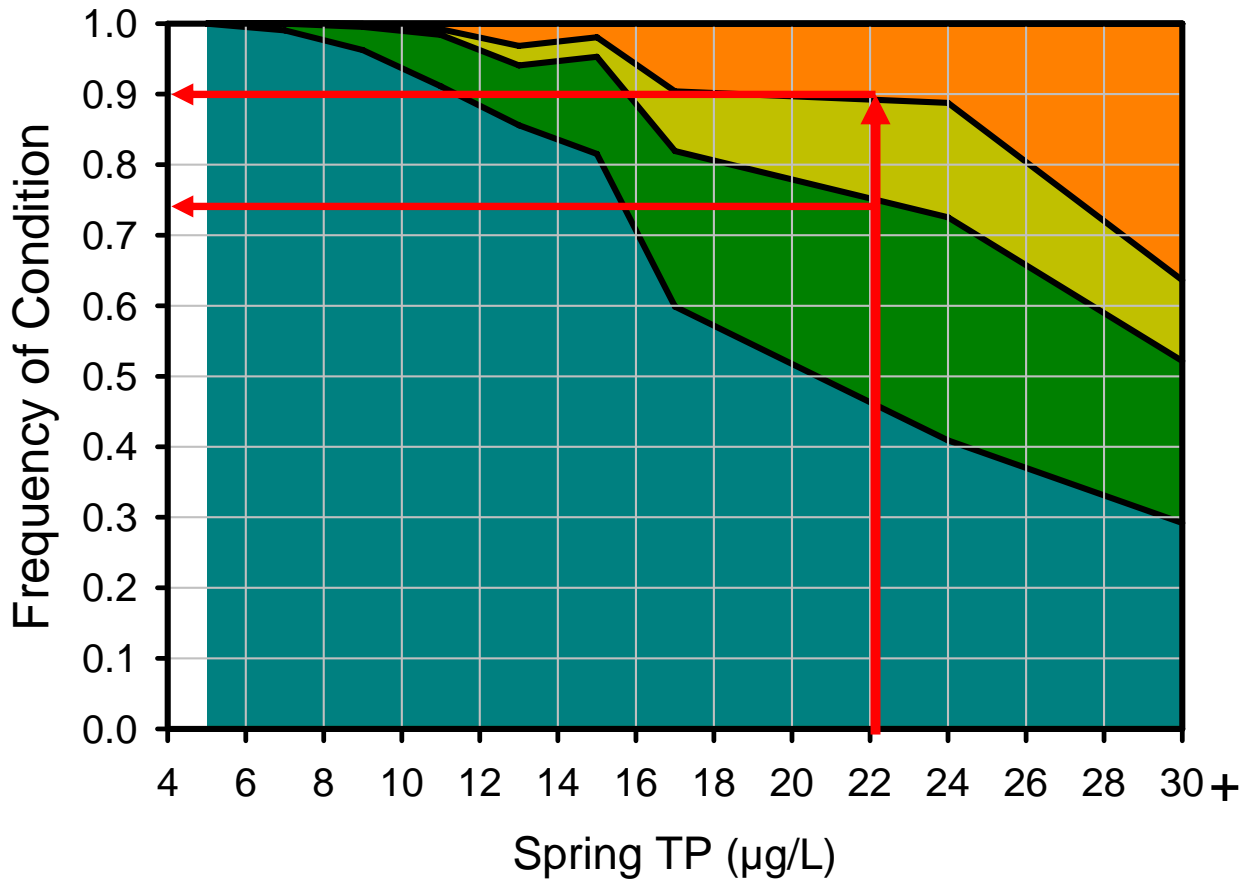
For consistency, both TMDL's were calculated using a target criterion of 22 ppb

TMDL Target Concentration (Carmi)



23 ppb

TMDL Target Concentration (Tick-N)



Aesthetic Condition

- Less than good
- Good
- Very good
- Excellent

Less than good: Chl-a $>24 \mu\text{g/L}$
Good: Chl-a $>16 \mu\text{g/L}$ and $\leq 24 \mu\text{g/L}$
Very Good: Chl-a $>9 \mu\text{g/L}$ and $\leq 16 \mu\text{g/L}$
Excellent: Chl-a $\leq 9 \mu\text{g/L}$



Estimating Total Loads

Lake Carmi

- Modeled nutrient export from land use to estimate TP loads to lake
- Export coeff's from Troy et al., 2007
- Use WILMS model to bound export estimates against measurements and estimate internal load
- Use WILMS to predict load reductions needed

Ticklenaked Pond

- Conducted mass P balance study during 2005-2006
- Calculated mass P balance for WY2006
- Adjusted annual P load to long-term mean WY
- Use WILMS to predict load reductions needed at mean WY

Wisconsin Inland Lakes Modeling Suite (WILMS)

Phosphorus Loading Data Setup

General | Hydrologic & Morphometric Module | Phosphorus Module (NPS) | **Phosphorus Module (PS)** | Total Loading

Reset Defaults

Land Use

- Row Crop AG
- Mixed AG
- Pasture/Grass
- HD Urban (1/8 Ac)
- MD Urban (1/4 Ac)
- Rural Res (>1 Ac)
- Wetlands
- Forest
- Other Water
- Lake Surface
- User Defined 3
- User Defined 4
- User Defined 5
- User Defined 6
- Lake Surface

% NPS Change:

Set User Defin

Phosphorus Loading Data Setup

General | Hydrologic & Morphometric Module | Phosphorus Module (NPS) | **Phosphorus Module (PS)** | Total Loading

----- Phosphorus (kg/year) -----

| Point Sources | Water Load (m ³ /year) | Low | Most Likely | High | Loading % |
|---------------------------|-----------------------------------|-----|-------------|------|-----------|
| Internal Load | 0.0 | 0.0 | 94.0 | 0.0 | 3.7 |
| Septic | 0.0 | 0.0 | 15.4 | 0.0 | 0.6 |
| Carmi State Park Indirect | 0.0 | 0.0 | 1.5 | 0.0 | 0.1 |
| User Defined 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| User Defined 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| User Defined 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

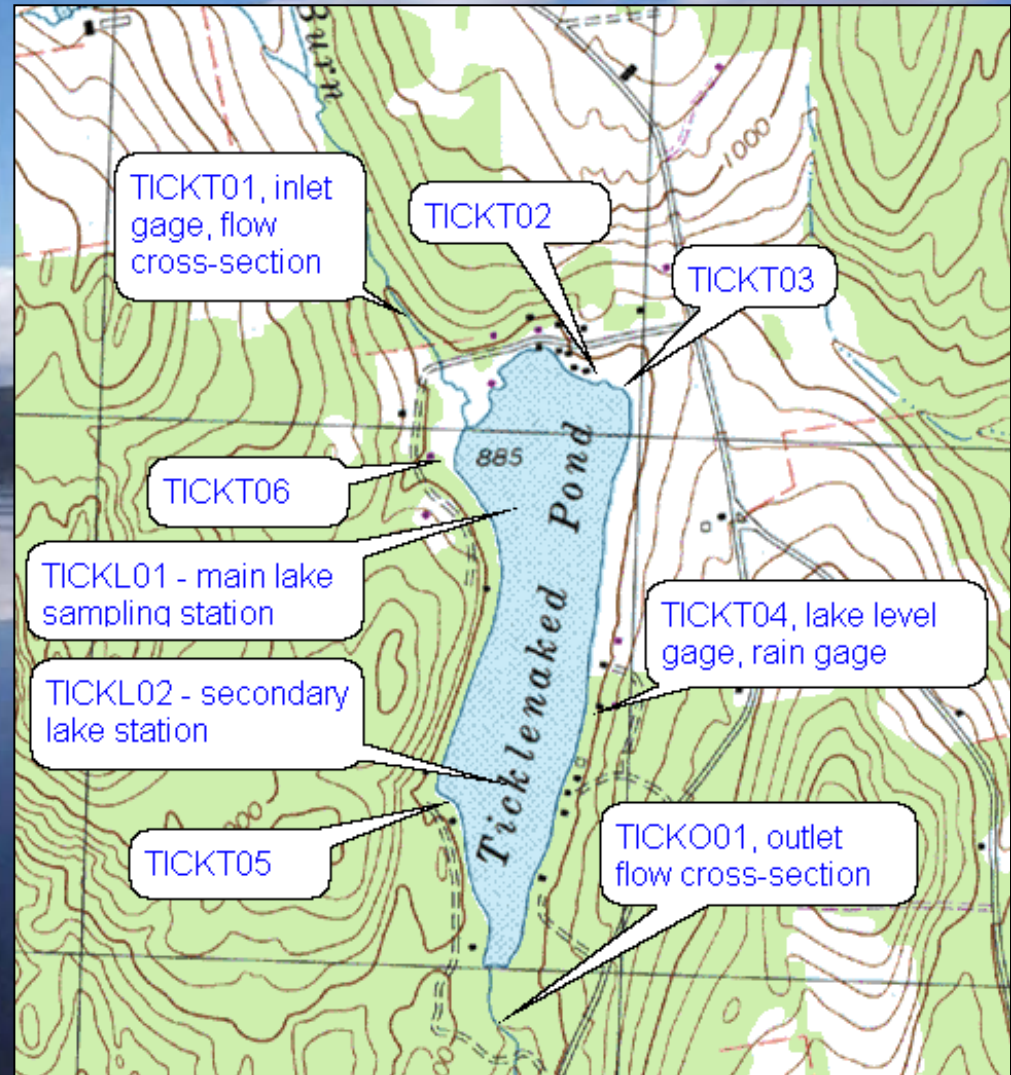
| Description | Low | Most Likely | High | Loading % |
|-------------------------------------|-------|-------------|-------|-----------|
| Septic Tank Output (kg/capita-year) | 0.30 | 0.50 | 0.80 | |
| # capita-years | 309.0 | | | |
| % Phosphorus Retained by Soil | 98.0 | 90.0 | 80.0 | |
| Septic Tank Loading (kg/year) | 1.85 | 15.45 | 49.44 | 0.6 |

% PS Change: 0%

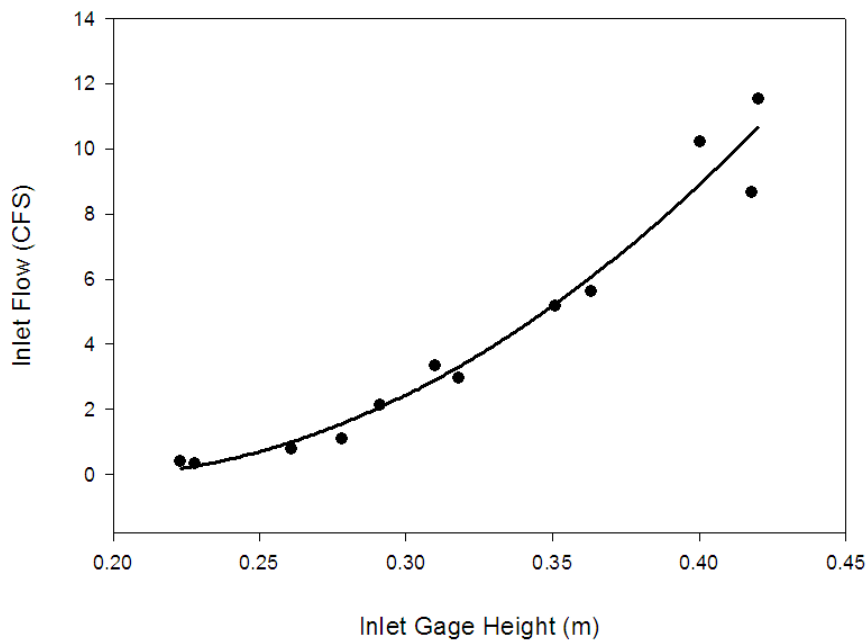
Set User Defined Leave Write Results ? Help Select A Graph

Ticklenaked Pond Mass P Balance -Field study

- Five inlet tributaries
- One inlet gauge
- One lake-level gauge
- One rain gauge
- One ISCO autosampler

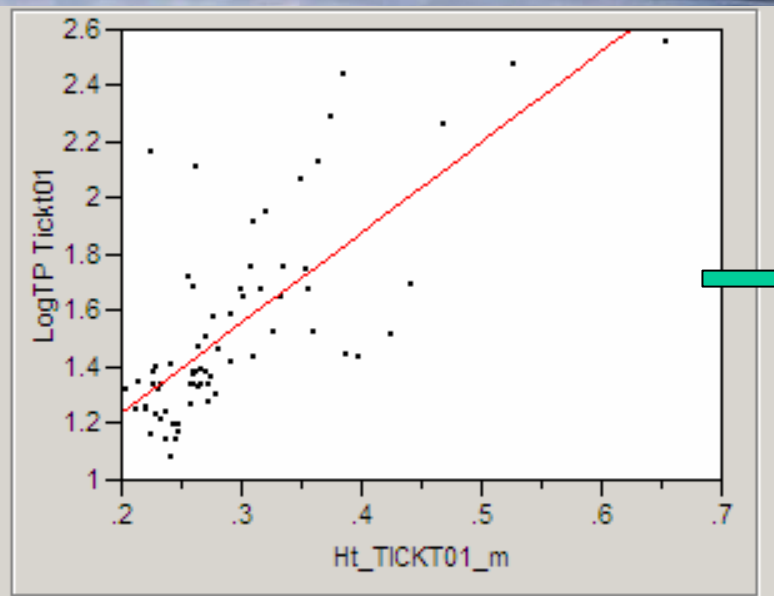


- *Stage-discharge relationship:*
- Measure water heights and water flows, use this to construct flow history, for inlet and outlet



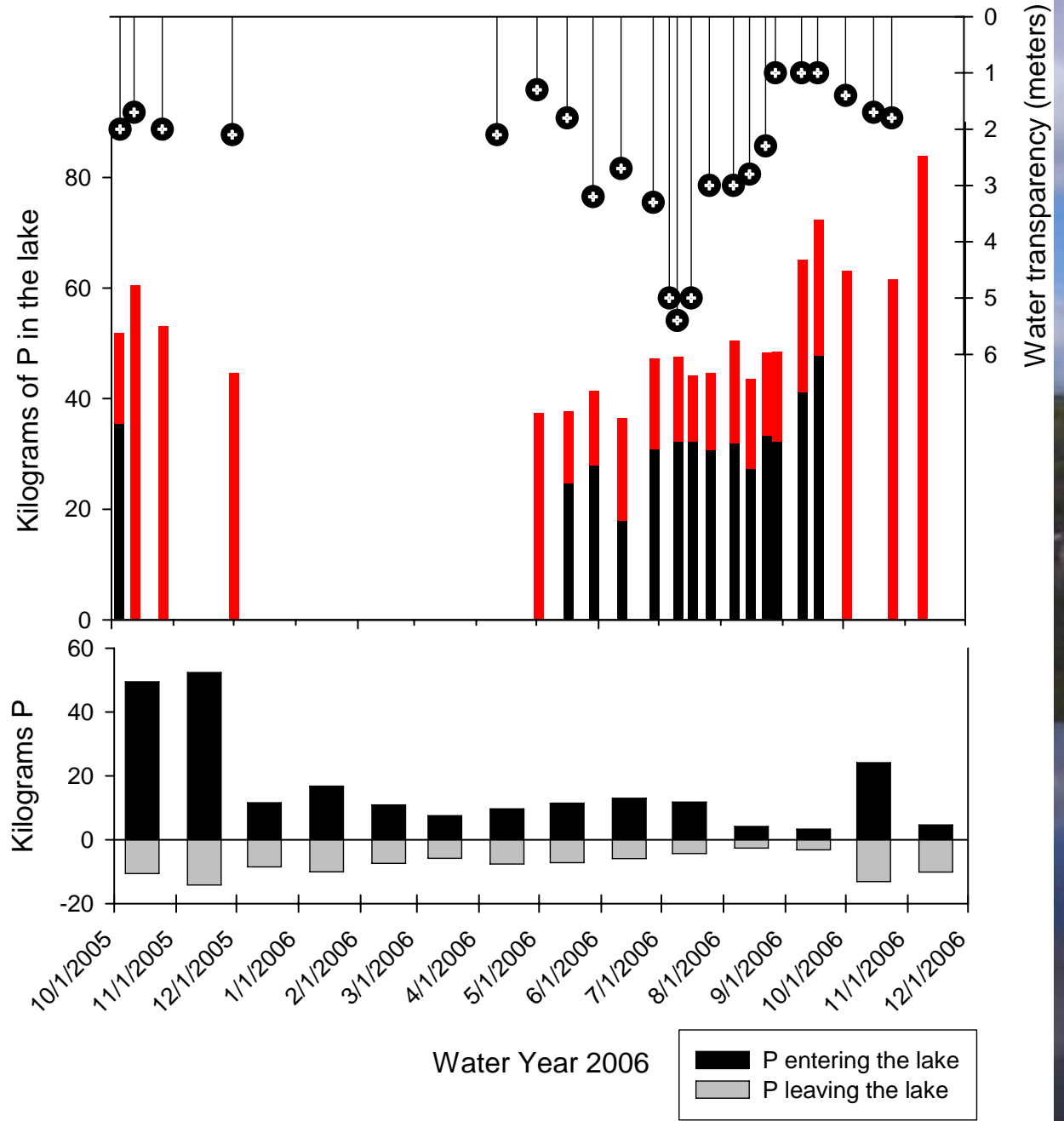
| Date | Hour | Q_Tick01_L/H (daily for infilled data) | Q_Tick001_L/H (daily for infilled data) | HourlyPLoad_g (daily for infilled data) |
|-----------|------|---|--|--|
| 22-Jul-05 | 13 | 155742 | 127954 | 3.25 |
| 22-Jul-05 | 14 | 124806 | 124782 | 2.34 |
| 22-Jul-05 | 15 | 145235 | 138670 | 2.93 |
| 22-Jul-05 | 16 | 202719 | 161876 | 4.92 |
| 22-Jul-05 | 17 | 237268 | 162440 | 6.38 |
| 22-Jul-05 | 18 | 223493 | 164136 | 5.77 |
| 22-Jul-05 | 19 | 216704 | 164702 | 5.48 |
| 22-Jul-05 | 20 | 207551 | 165836 | 5.11 |
| 22-Jul-05 | 21 | 199118 | 165836 | 4.77 |
| 22-Jul-05 | 22 | 189610 | 165836 | 4.41 |
| 22-Jul-05 | 23 | 185493 | 164136 | 4.26 |
| 23-Jul-05 | 0 | 182569 | 166404 | 4.16 |
| 23-Jul-05 | 1 | 176761 | 164702 | 3.95 |
| 23-Jul-05 | 2 | 172154 | 163570 | 3.79 |

- *Stage-concentration relationship*
- Relate water heights to total nutrient concentrations
- Use this to construct nutrient accumulation history for gauging record
- Calculated hourly to account for flashiness of stream
- Calculated loads from minor tribs, then sediments, by mass balance



| Date | Hour | Q_Tick01_L/H (daily for infilled data) | Q_Tick001_L/H (daily for infilled data) | HourlyPLoad_g (daily for infilled data) |
|-----------|------|---|--|--|
| 22-Jul-05 | 13 | 155742 | 127954 | 3.25 |
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Phosphorus in and out of the lake



Loading summary for both ponds

Ticklenaked Pond

| Source of phosphorus load | Measured load in kg (\pm range), water year 2006 | Estimated load, mean water year ³ | Value used to calculate TMDL (kg) |
|------------------------------------|--|--|-----------------------------------|
| Watershed tributaries ¹ | 206 (141-264) ² | 116 | 116 |
| Septic loads | 2.5 (<1 – 8) | 2.5 | 3 |
| Internal load | 42 | 86 | 86 |
| Total annual load | 251 (184 – 314) | 205 | 205 |

Lake Carmi

| Source of phosphorus load | Annual range (kg) | Value used to calculate TMDL |
|---|-------------------|------------------------------|
| Watershed tributaries ¹ | 510 – 2,227 | 1,731 |
| Septic loads | 16 - 50 | 33 |
| Internal loads | -154 - 245 | 94 |
| Load from Lake Carmi State Park WWTF ⁴ | 1.5 | 2 |
| Total annual load | | 1,860 |

1) Includes direct P to lake; 2) expressed as std. err; 3) 57% of 2006 flows

Using WILMS to estimate TLC

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 40.0 mg/m³
 Observed growing season mean phosphorus (GSM): 45.0 mg/m³
 Back calculation for SPO total phosphorus: mg/m³
 Back calculation GSM phosphorus: mg/m³

Nurnberg Model Input -
 Est. Gross Int. Loading: kg
 % Confidence Range:

| Lake Phosphorus Model | Low Total P (mg/m ³) | Most Likely Total P (mg/m ³) | High Total P (mg/m ³) | Predicted -Observed (mg/m ³) | % Dif. | Confidence Lower Bound | Confidence Upper Bound | Parameter Fit? | Back Calculation (kg/year) | Model Type |
|---|----------------------------------|--|-----------------------------------|--|--------|------------------------|------------------------|----------------|----------------------------|------------|
| Walker, 1987 Reservoir | 16 | 35 | 52 | -10 | -22 | 20 | 51 | FIT | 156 | GSM |
| Canfield-Bachmann, 1981 Natural Lake | 23 | 44 | 61 | -1 | -2 | 14 | 127 | FIT | 107 | GSM |
| Canfield-Bachmann, 1981 Artificial Lake | 21 | 37 | 50 | -8 | -18 | 11 | 107 | FIT | 118 | GSM |
| Rechow, 1979 General | 17 | 36 | 54 | -9 | -20 | 20 | 55 | FIT | 151 | GSM |
| Rechow, 1977 Anoxic | 27 | 58 | 87 | 13 | 29 | 34 | 84 | FIT | 94 | GSM |
| Rechow, 1977 water load<50m/year | 20 | 42 | 63 | -3 | -7 | 24 | 63 | FIT | 130 | GSM |
| Rechow, 1977 water load>50m/year | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Walker, 1977 General | 22 | 47 | 70 | 7 | 18 | 23 | 78 | FIT | 117 | SPO |
| Vollenweider, 1982 Combined OECD | 19 | 35 | 48 | -8 | -19 | 17 | 60 | FIT | 142 | ANN |
| Dillon-Rigler-Kirchner | 16 | 35 | 52 | -5 | -13 | 20 | 51 | P | 157 | SPO |
| Vollenweider, 1982 Shallow Lake/Res. | 15 | 29 | 41 | -14 | -33 | 14 | 49 | FIT | 185 | ANN |
| Larsen-Mercier, 1976 | 21 | 45 | 67 | 5 | 13 | 27 | 64 | P Pin | 122 | SPO |
| Nurnberg, 1984 Oxidic | 18 | 39 | 58 | -6 | -13 | 20 | 62 | FIT | 140 | ANN |

Finished
 Write Results
 Display Parameter Values
 ? Help

TMDL: Total Loading Capacity (initial)

| Lake Phosphorus Model - Lake Carmi | Predicted current TP | LCL - UCL | Model Fit | Total Loading capacity (kg) for TP = 22 ppb |
|---|----------------------|-----------|-----------|---|
| Rechow, 1979 General | 24 | 11-34 | FIT | 1825 |
| Nurnberg, 1984 Oxidic | 38 | 16-58 | FIT | 1168 |
| Vollenweider, 1982 | 39 | 16-64 | FIT | 1056 |
| Rechow, 1977 | 46 | 21-65 | FIT | 960 |
| Average of four models | | | | 1252 |
| Ticklenaked Pond | | | | |
| Rechow, 1977 Anoxic | 49 | 24 - 66 | FIT | 94 |
| Walker, 1977 General | 39 | 16 - 62 | FIT | 117 |
| Canfield-Bachmann, 1981 | 37 | 11 - 107 | FIT | 107 |
| Rechow, 1977 | 35 | 16 - 49 | FIT | 130 |
| Average of four models | | | | 112 |

TMDL Element: Margin of Safety

- A-priori added 5% margin of safety to both lakes to ensure attainment after watershed implementation
- Lake Carmi
 - 63 kg
- Ticklenaked Pond
 - 7 kg

TMDL: Load and wasteload allocation

- All documented sources in these watersheds presently fall within the Load Allocation
- New point sources...part of the Wasteload Allocation?
- For the purposes of these TMDL's, we are not articulating a defined WLA. However we acknowledge that stormwater permitted discharge falls within WLA.
- New development will have to undergo permitting through stormwater construction general permit, which contains provisions for TMDL watersheds.
- Other NPDES permitting would require reopening TMDL

TMDL Summary

$$\text{TMDL} = \text{LA} + \text{WLA} = \text{MOS}$$

| TMDL Category | Lake Carmi | Ticklenaked Pond |
|-------------------------|------------|------------------|
| Existing Load | 1,860 | 205 |
| Wasteload Allocation | - | - |
| Load Allocation | 1,189 | 105 |
| Margin of Safety | 63 | 7 |
| Total Loading Capacity | 1,252 | 112 |
| Load Reduction Required | 608 | 93 |
| % | 33% | 45% |

TMDL

- Expressed as an annual load, with allowable daily and seasonal variation
- Permissible per *NRDC v. Muszynski*, 286 F 3d.91 (2nd Cir. 2001)

Reasonable Assurance

- Where WLA is predicated on anticipated non-point controls, reasonable assurances on NPS implementation are necessary
- No WLA, so not relevant.

Implementation Plans

Lake Carmi

- 18-point plan
- Tasks articulated within in-lake, lakeshore, and watershed categories
- Plan written as a menu of items from which to choose, with priorities

Ticklenaked Pond

- 3-phase plan, 18 items
 1. Watershed + lake- shore project planning
 2. Watershed+ lakeshore implementation, plan for in-lake treatment
 3. In-lake treatment
- Plan written as a sequence of events designed to facilitate in-lake treatment by controlling watershed sources

Both plans envision multiple-stakeholder involvement!!

Questions?

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