Appendix L

Comfort Lake Investigations

- Mass Balance Model of Comfort Lake
- Review of MPCA 1995 Lake Assessment Report
- Review of McComas 2004 Comfort Lake Report

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TECHNICAL MEMORANDUM

TO: John R. Thene, P.E., Project Manager
Wenck Associates, Inc.

FROM: Andy Erickson

DATE: October 16, 2007

SUBJECT: Comfort Lake Forest Lake Watershed District
Mass Balance Model of Comfort Lake

INTRODUCTION

The purpose of this memo is to document and present findings from a model developed to predict the total phosphorus concentration in Comfort Lake based on a daily mass balance of phosphorus load and water volume. The model was constructed around simple phosphorus transport processes in order to describe in-lake phosphorus concentration on a time-variable basis. Once the processes are adjusted such that in-lake phosphorus concentration is accurately predicted, the results can be used to develop conclusions about the significant transport processes.

Most lake management programs are tasked with estimating an annual phosphorus load reduction that is developed from an annual in-lake phosphorus model. The time scale for phosphorus transport processes, however, is often much shorter than one year and therefore the need for a more detailed phosphorus model is evident.

Comfort Lake has been modeled here due to its importance as a local resource, but also due to its unique inflow loading and discharge characteristics. It receives large volumes and loading from its main tributaries, making it susceptible to short-term variations in water quality. Some of this detail is lost in the annual time-step models such as the Canfield-Bachmann model commonly used in Minnesota. Therefore, this model is to make fuller use of the time-varying loading and lake data to gain a greater understanding of the phosphorus processes in Comfort Lake.

MODEL CONSTRUCTION

The model is built on the theory of phosphorus mass balance within the epilimnion of Comfort Lake as given by equation (1).

$$[TP]_{i+1} = \left[\frac{M_{LAKE(i)} + \sum L_{INFLOW(i+1)} - \sum L_{OUTFLOW(i+1)}}{V_{i+1}}\right] \times C \qquad (1)$$

where: [TP] = epilimnetic average total phosphorus concentration [μg/L]
M_{LAKE} = total in-lake epilimnetic phosphorus mass as given by equation (2)
i = time step [days]
V = volume of the epilimnion [ac-ft]
C = conversion factor from pounds per acre-foot (lb/ac-ft) to micrograms per liter (μg/L)
L_{INFLOW} = Inflow phosphorus load [lb]
$L_{OUTFLOW}$ = Outflow phosphorus load [lb]

$$M_{LAKE(i)} = \frac{TP_i \times V_i}{C} \qquad (2)$$

where: M_{LAKE} = total in-lake epilimnetic phosphorus mass
i = time step [days]
TP = In-lake total phosphorus concentration [μg/L]
V = volume of the epilimnion [ac-ft]
C = conversion factor from pounds per acre-foot (lb/ac-ft) to micrograms per liter (mg/L)

Inflow phosphorus load for Comfort Lake is calculated from available monitoring data. Inflow loads are composed of Little Comfort Lake outflow, Sunrise River outflow, septic discharge, wet and dry atmospheric deposition, and internal phosphorus load. Outflow includes sedimentation (from the epilimnion to the thermocline) and discharge to the Sunrise River downstream of Comfort Lake. Groundwater interactions are assumed to be negligible for Comfort Lake and therefore were not included in this model.

Septic Discharge

Daily phosphorus loads from septic systems along Comfort Lake's perimeter are estimated as described in section 2.2.4.6.2, Shoreline Septic System Load.

Wet and Dry Deposition

Wet and dry deposition of phosphorus onto Comfort Lake is estimated from published values (14.91 kg/km^2-yr) for average precipitation years (Barr Engineering 2004). Wet and dry deposition is applied in the model with a daily loading rate applied to the surface area of Comfort Lake.

Internal Phosphorus Load

Internal load represents the physical and chemical process of phosphorus release and transport from bottom sediments to the epilimnion of Comfort Lake. Internal load is modeled as a linear function of time such that start date, initial internal load (lb/day), end date, and final internal load rate (lb/day) can be modified to adjust the total internal load. The start date roughly corresponds to the date when stratification in Comfort Lake leads to sediment anoxia, which typically corresponds with the release of phosphorus from bottom sediments. The end date represents the date when stratification ends (i.e., turnover) and the lake becomes completely mixed. Initial and final release rates determine the rate at which phosphorus is delivered from bottom sediments to the epilimnion and are expressed in pounds per day (lb/day). The total internal load can be calculated by summing the pounds of phosphorus released in a specific year.

Sedimentation

Phosphorus sedimentation within Comfort Lake represents the physical settling of particulate phosphorus (e.g., in the form of dead algae and detritus) from the epilimnion to the thermocline and hypolimnion. Sedimentation is modeled as a linear exponential function of the in-lake total phosphorus mass as given in equation (3). Sedimentation is expressed in pounds of phosphorus per day and is greater than or equal to zero.

$$S_{i+1} = c \times \left(TP_i \times V_i\right)^b \qquad (3)$$

where: S = Phosphorus sedimentation rate [lb/day]
c = sedimentation coefficient [1/day]
i = time step [days]
TP = In-lake total phosphorus concentration [μg/L]
V = volume of the epilimnion [ac-ft]
b = constant where b = 1.0

Discharge to Downstream Lakes or Tributaries

Discharge to downstream lakes or tributaries is calculated from the model-predicted Comfort Lake total phosphorus concentration and inflow water volume, as given in (4). Inflow water volume is used because discrepancies exist between the measured inflow and outflow volume as described below in Data Sources.

$$L_{OUTFLOW(i+1)} = \frac{TP_i \times V_{i+1}}{C} \qquad (4)$$

where: $L_{OUTFLOW}$ = Outflow phosphorus load [lb]
i = time step [days]
TP = In-lake total phosphorus concentration [μg/L]
V = volume of the epilimnion [ac-ft]
C = conversion factor from pounds per acre-foot (lb/ac-ft) to micrograms per liter (mg/L)

DATA SOURCES

Available monitoring data from the Washington Conservation District is used as input into the model for inflow volume and phosphorus load. In-lake phosphorus concentration is used to estimate Little Comfort Lake outflow load and for comparison to model-predicted in-lake phosphorus concentration.

Inflow

Inflow tributary water volume for Comfort Lake was calculated from stream measurement data upstream of Little Comfort Lake (SM #4) and in the Sunrise River (SM #7) upstream of Comfort Lake. Inflow phosphorus load from Little Comfort Lake was calculated as the product of measured phosphorus concentration within Little Comfort Lake and the inflow tributary water volume measured upstream of Little Comfort Lake (SM #4). Inflow phosphorus load from the Sunrise River was calculated as the product of measured phosphorus concentration within the river and the inflow tributary water volume measured upstream of Comfort Lake (SM #7). Because phosphorus concentration was measured at irregular intervals and discharge was measured continuously, phosphorus concentration between measurements was estimated. It was assumed that phosphorus concentration is a linear function between measured data.

Outflow

Outflow from Comfort Lake is measured downstream of the Lake outlet (SM #8). The measured stream data, however, does not correspond with the measured inflow data as described above. A comparison of lake surface elevation, inflow water volume, and outflow water volume illustrates the discrepancy as shown in Figures 1 and 2.

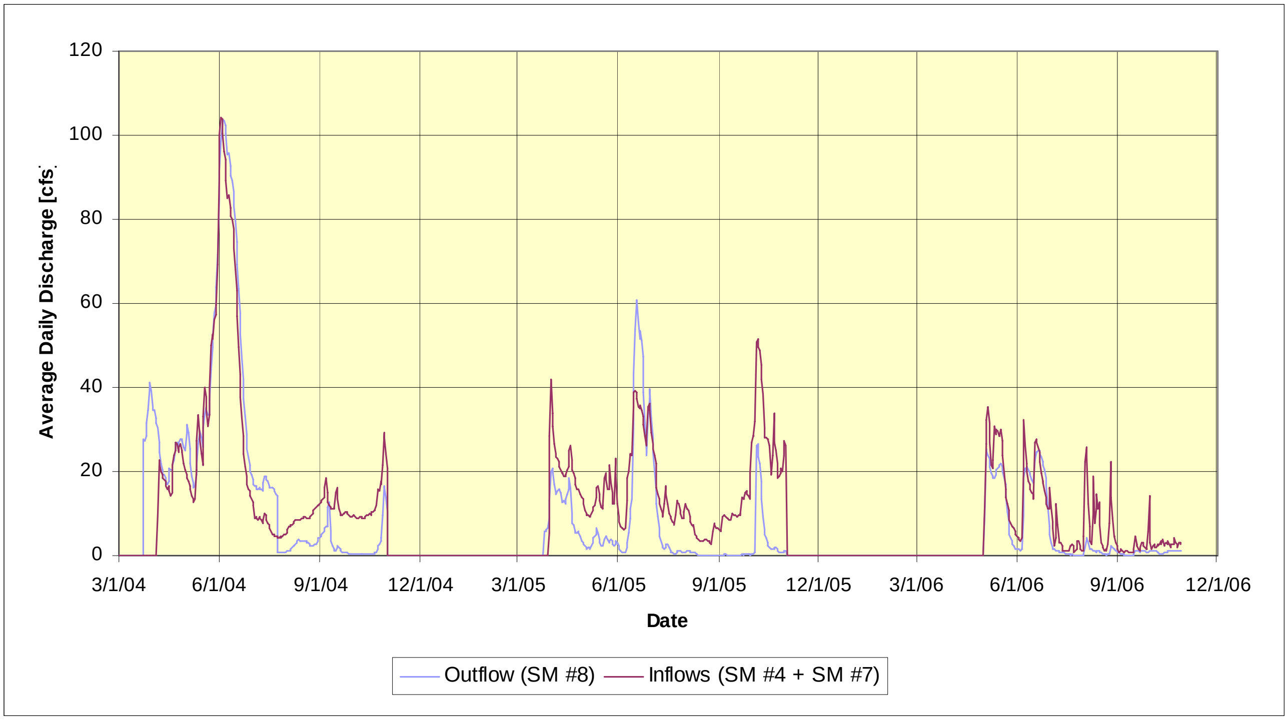


Figure 1: Measured daily inflow and outflow volume for Comfort Lake.

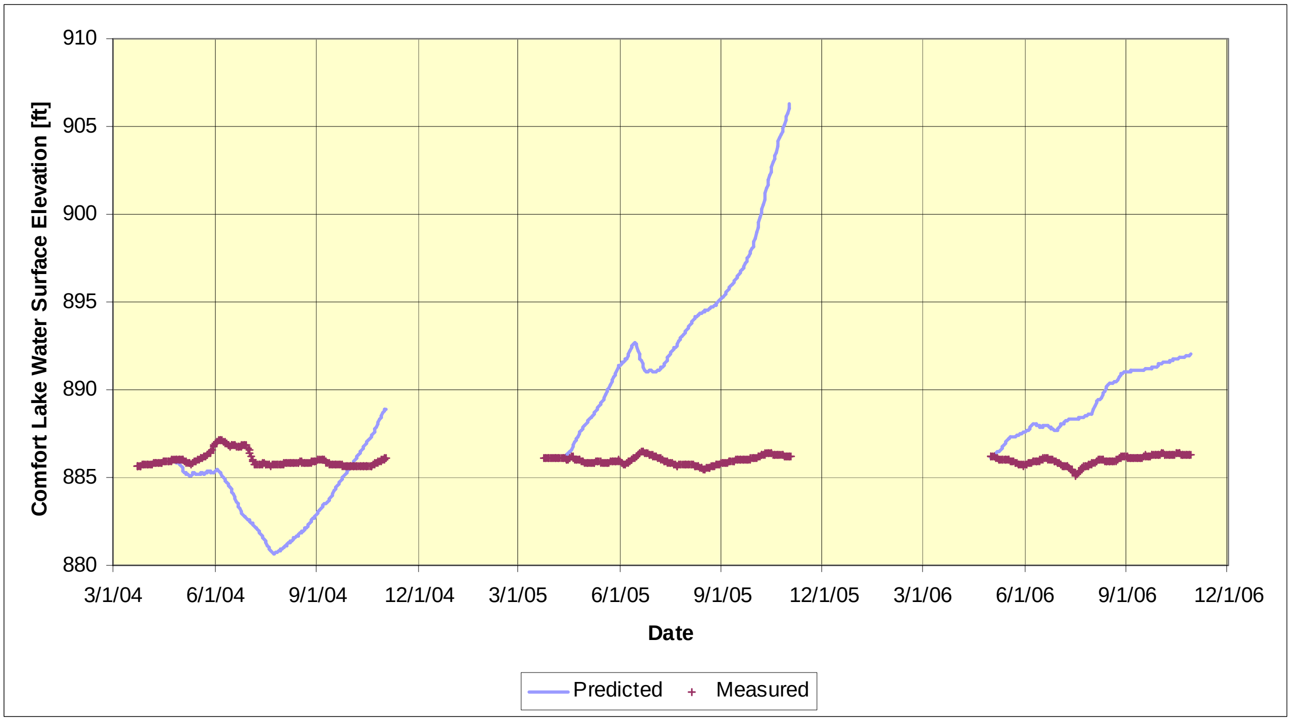


Figure 2: Measured and predicted Comfort Lake water surface elevation. Predicted changes in water surface elevations determined from difference in inflows and outflows.

The record includes periods of remarkable agreement, but with periods where outflow appears to be under-represented. Due to the discrepancy illustrated in Figures 1 and 2, the outflow tributary discharge was assumed to equal the summation of inflow tributary discharge.

Little Comfort and Comfort Lake Data

Little Comfort and Comfort Lake surface water quality data was acquired from the Minnesota Pollution Control Agency website (http://www.pca.state.mn.us/data/edaWater/index.cfm). The available data for 2004, 2005, and 2006 total phosphorus surface measurements are shown in Figure 3. Some data in Figure 3 (circled in red) for 2006 in both lakes appears erratic and inconsistent with historical data. For example, the Comfort Lake data showed five values that were about two times as high as the predecessor and its following sample. For the purposes of this model, the data circled in red is excluded from calculation of phosphorus load, predicted in-lake total phosphorus concentration, and comparison to model predictions.

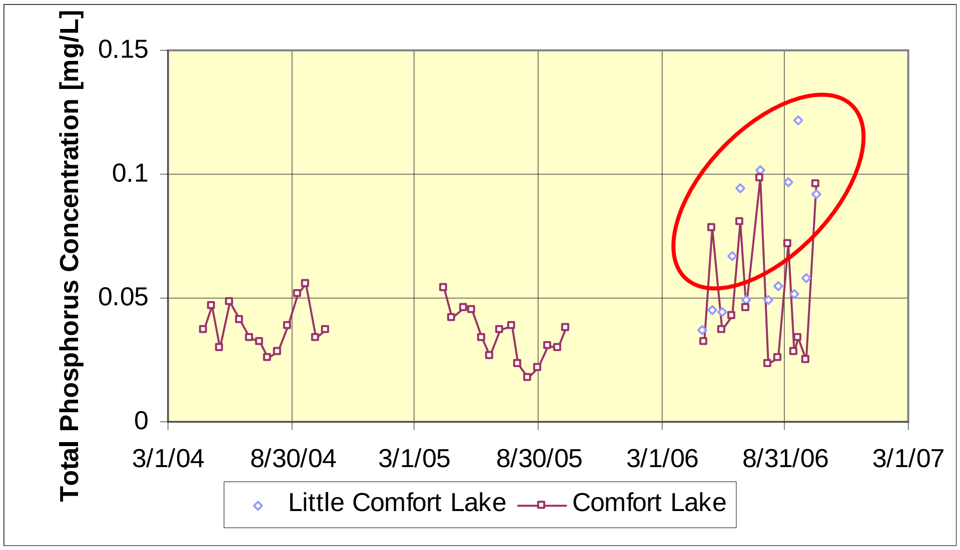


Figure 3: In-lake total phosphorus data for Little Comfort and Comfort Lake.

SYNTHESIS OF LITTLE COMFORT OUTFLOW LOADS

Little Comfort Lake outflow into Comfort Lake is calculated using Little Comfort Lake total phosphorus concentration and stream discharge into Little Comfort Lake (SM #4). In-lake total phosphorus measurements for Little Comfort Lake are not available for 2004 and 2005. To estimate total phosphorus concentration in Little Comfort Lake in 2004 and 2005, a linear regression between in-lake total phosphorus and in-stream (SM #4) total phosphorus was developed, as shown in Figure 4. This linear regression was used to estimate in-lake total phosphorus concentration for Little Comfort Lake in 2004 and 2005, as shown in Figure 5. As discussed in the previous section, some in-lake total phosphorus measurements from Little Comfort and Comfort Lake are excluded from the linear regression shown in Figure 4.

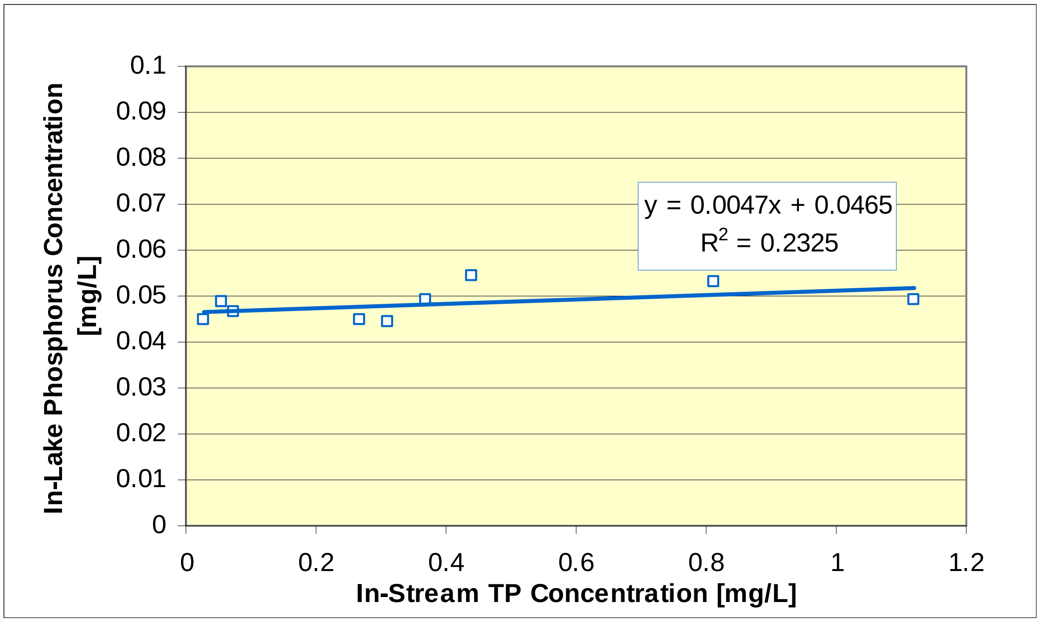


Figure 4: Linear Regression between in-lake total phosphorus for Little Comfort Lake and total phosphorus in the main inflow to Comfort Lake.

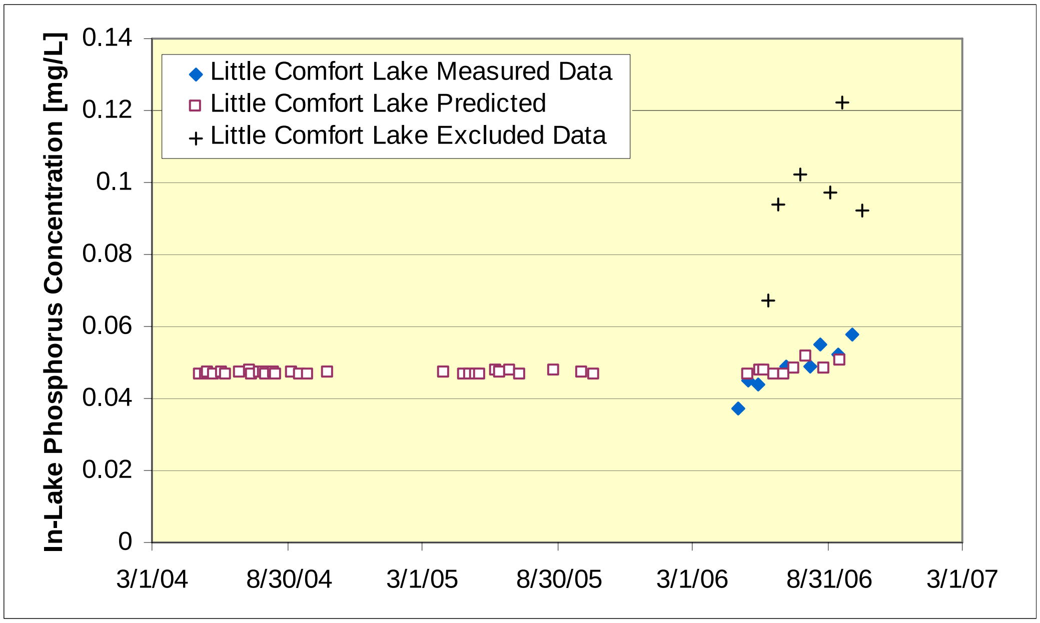


Figure 5: Model-predicted in-lake total phosphorus concentration for Little Comfort Lake.

MODEL PARAMETERS AND CALIBRATION

Model calibration involved modification of the following model parameters: initial settling for Sunrise River discharge, short-circuiting of Sunrise River discharge, phosphorus sedimentation within Comfort Lake, and internal loading within Comfort Lake. Sedimentation and internal load were discussed in Model Construction.

Initial settling of the Sunrise River represents the physical process of large particulate phosphorus settling out of the Sunrise River discharge as it enters Comfort Lake and before the phosphorus mixes with the epilimnion. Initial settling is expressed as a percent of the total Sunrise River phosphorus load and could vary from 0% to 100%, although it is likely to be less than 25%.

Short-circuiting of the Sunrise River represents the physical process by which discharge of the Sunrise River does not mix with the epilimnion of Comfort Lake and is delivered directly out of the lake. This process can be caused or exacerbated by the temperature of the Sunrise River being larger than the lake temperature which would allow the Sunrise River discharge to ‘float’ over the top of the lake and never mix throughout the epilimnion water column. Short-circuiting is expressed as a percent of the total Sunrise River phosphorus load and discharge volume which could vary from 0% to 100%, although it is likely to be less than 50%.

RESULTS & DISCUSSION

After model construction and calibration, two scenarios appear to predict measured in-lake phosphorus concentration for Comfort Lake in 2004 and 2005. The model does not predict measured in-lake phosphorus concentration for 2006 in any scenario. I conclude both models equally represent measured data in 2004 and 2005. The model inputs are tabulated in table 1.

Table 1: Model inputs for Scenario 1 and Scenario 2.

Year	2004		2005		2006	
Scenario	1	2	1	2	1	2
Settling model coefficient [1/day]	0.0426	0.079	0.0426	0.079	0.0426	0.079
Initial Settling [%]	0%	0%	0%	0%	0%	0%
Short-Circuiting [%]	50%	0%	25%	0%	0%	0%
Internal Load Start Date	6/15	6/1	6/15	6/1	6/1	6/1
Internal Load End Date	9/22	9/30	10/1	9/30	9/15	915
Internal Load Initial Rate [lb/day]	0	0	0	0	7	15
Internal Load Final Rate [lb/day]	14	23	6	11	7	15

The period for analysis was limited for each year so that temperature, stratification, and sunlight were approximately constant and by the availability of stream data. The period of analysis and associated in-lake mass, inflow loads, and outflow loads are listed in Table 2.

Table 2: In-lake total phosphorus mass, inflow, and outflow loads for Comfort Lake.

Year	2004		2005		2006	
Scenario	1	2	1	2	1	2
Start Date	May 4	May 4	May 24	May 24	May 30	May 30
End Date	Oct 6	Oct 6	Oct 11	Oct 11	Aug 22	Aug 22
Initial in-lake mass [lb]	221	221	212	212	174	174
Atmospheric & septic load [lb]	42	42	38	38	23	23
Sunrise River load [lb]	542	1,084	502	669	309	309
Little Comfort load [lb]	250	250	160	160	118	118
Initial settling [lb]	0	0	0	0	0	0
Short-circuited load [lb]	542	0	167	0	0	0
Internal load [lb]	700	1,400	327	670	609	1,300
Sedimentation load [lb]	1,151	2,138	773	1,290	818	1,524
Final in-lake mass [lb]	155	168	182	158	237	231

Model Scenario 1

The model output results of Scenario 1 are shown in Figure 7. It is important to note the magnitude of internal load for Scenario 1; 700 pounds and 300 pounds for 2004 and 2005, respectively. Based on the 2004 data, it is only possible to model the increase in measured phosphorus concentration from August through October with a significant internal load. It is also only possible to accurately predict the measured in-lake phosphorus concentration with significant short-circuiting of Sunrise River discharge. It is also important to note that the initial in-lake phosphorus mass as given by equation (2) ranges from approximately 95 to 270 pounds per day as compared to the total cumulative inflow phosphorus load of approximately 1,500 pounds.

Model Scenario 2

The model output results of Scenario 2 are shown in Figure 8. Compared to Scenario 1, Scenario 2 has a larger internal load; 1,400 pounds and 670 pounds for 2004 and 2005, respectively. Sedimentation is also greater as shown in Figure 6 and by $c = 0.079$ day^{-1} compared to $c = 0.0426$ day^{-1} for Scenario 1. Similar to Scenario 1, it is only possible to model the increase in measured phosphorus concentration from August through October 2004 with a significant internal load. It is also only possible to capture the decrease in phosphorus concentration during June and July for both 2004 and 2005 with a significant sedimentation component.

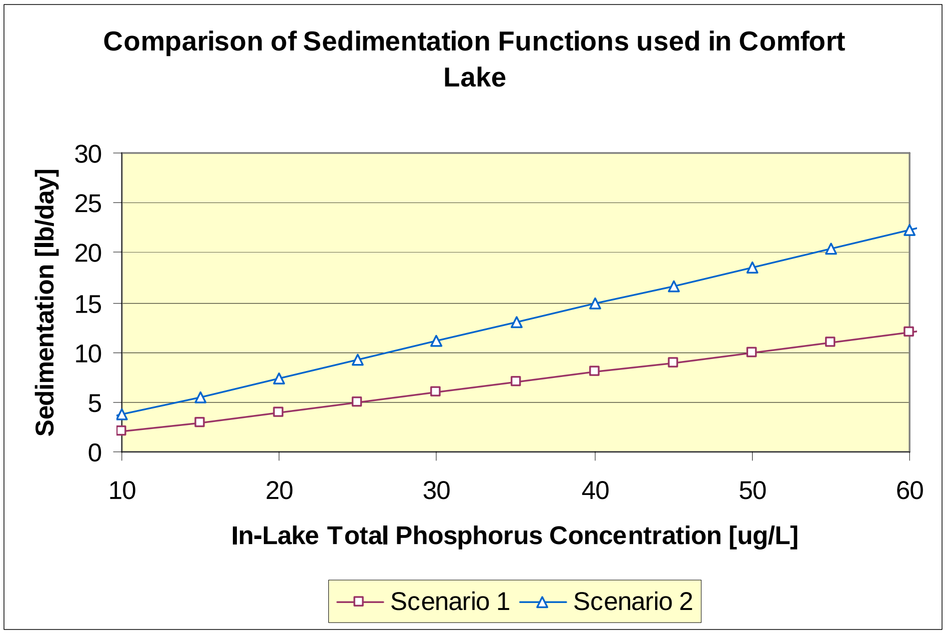


Figure 6: Comparison of sedimentation function for Scenario 1, 2, and 3.

CONCLUSIONS

This analysis and comparisons between Scenarios 1 and 2 lead to two possible conclusions: 1) per Scenario 1, internal load in Comfort Lake is significantly more important than determined in the basic analysis and that short-circuiting occurs up to about 50 percent of the total inflow, particularly for high flows, and 2) per Scenario 2, internal load is still significantly higher but no short-circuiting is necessary. Therefore, because both models fit the Comfort Lake data equally, this analysis is inconclusive regarding the short-circuiting. This analysis does, however, indicate that treatment of internal loading will be necessary to achieve substantial improvement of Comfort Lake water quality.

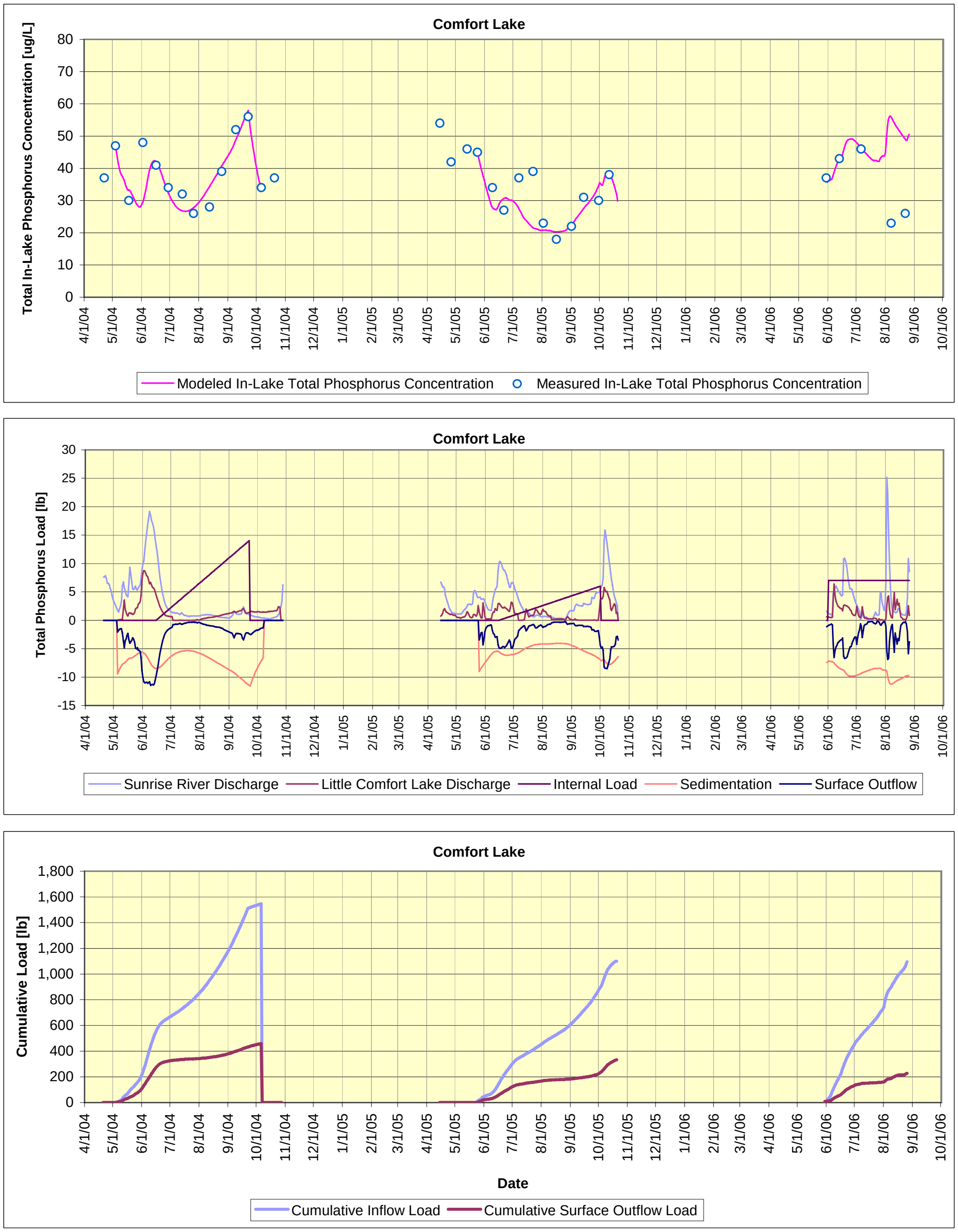
Because measured data is used as input and to fit the model, the accuracy of measured data is vital to the ability of the model to predict in-lake phosphorus concentration. As described in Data Sources, measured discharge and phosphorus concentration has apparent inaccuracies. Future data collection should be expanded to include measurement of Little Comfort outflow, spatial in-lake temperature variation in Comfort Lake, and temperature of the Sunrise River. Alternative to temperature measurements, tracers (such as salt which is measured by conductivity) could be used to track the movement of inflow from the Sunrise River through Comfort Lake. Measurements of temperature or tracer could be used to verify or discard any conclusions about short-circuiting.

REFERENCES

Barr Engineering. (2004). "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds." Prepared for the Minnesota Pollution Control Agency, St. Paul, MN.

Canfield, D. E., Jr., and Bachmann, R. W. (1981). "Prediction of total phosphorus concentrations, chlorophyll *a*, and Sec8chi depths in natural and artificial lakes." *Canadian Journal of Fisheries and Aquatic Science*, 38, 414-423.

Wilson, C. B., and Walker, W. W., Jr. (1989). "Development of lake assessment methods based upon the aquatic ecoregion concept." *Lake and Reservoir Management*, 5(2), 11-22.



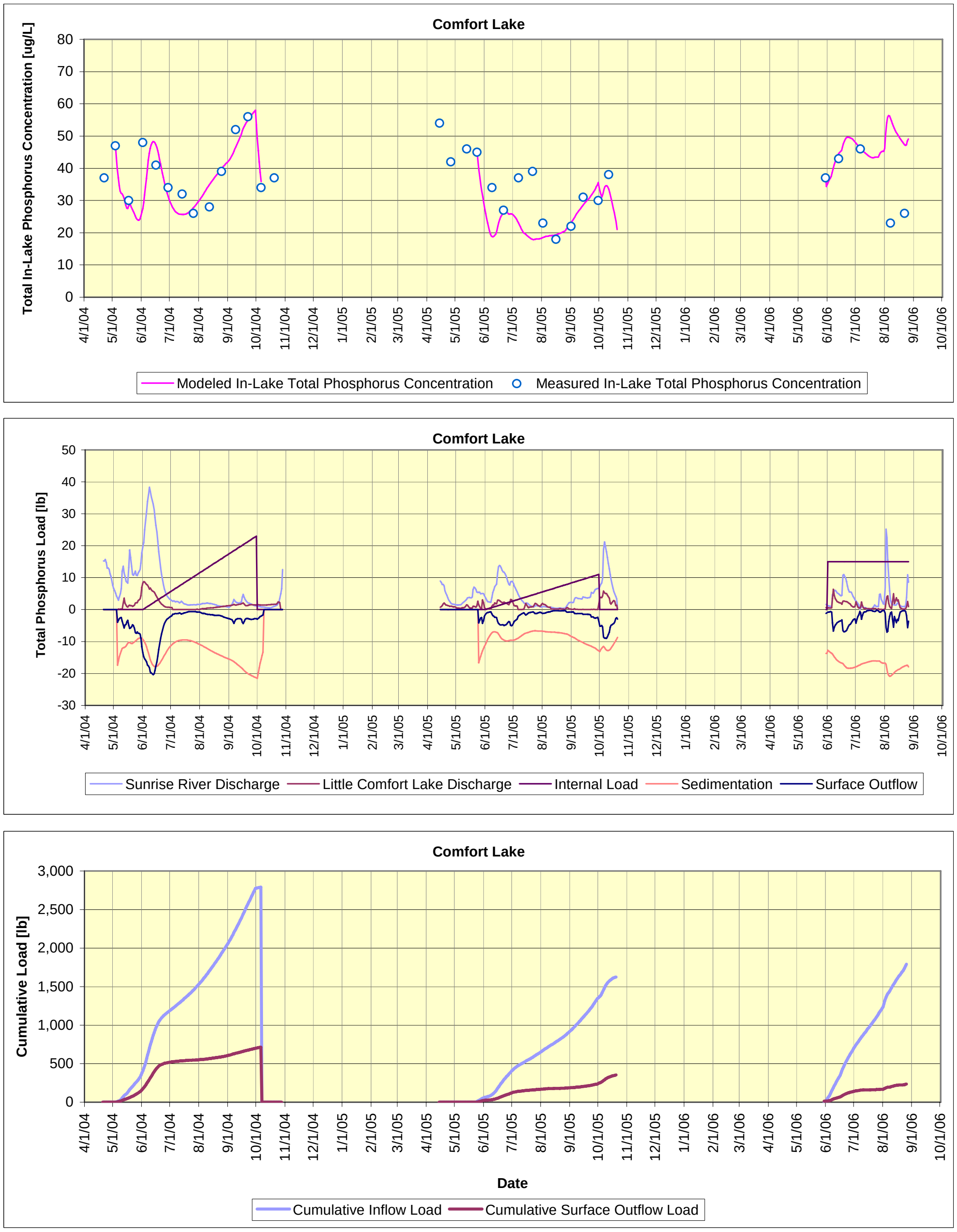
Sedimentation and Short Circuiting Paramters

	2004	2005	2006
c [1/day] =	0.0426	0.0426	0.0426
b =	1	1	1
Sunrise River Initial Settling =	0%	0%	0%
Sunrise River Short Circuiting =	50%	25%	0%

Internal Load Parameters

	2004	2005	2006
Start Date	6/15/04	6/15/05	6/1/06
Start Rate [lb/day]	0	0	7
End Date	9/22/04	10/1/05	9/15/06
End Rate [lb/day]	14	6	7
Internal Load Slope [lb/day^2]=	0.141	0.056	0.000
Internal Load Mass [lb]=	700.0	327.0	609.0

Figure 7: Model Output Scenario 1



Sedimentation and Short Circuiting Paramters

	2004	2005	2006
c [1/day] =	0.079	0.079	0.079
b =	1	1	1
Sunrise River Initial Settling =	0%	0%	0%
Sunrise River Short Circuiting =	0%	0%	0%

Internal Load Parameters

	2004	2005	2006
Start Date	6/1/04	6/1/05	6/1/06
Start Rate [lb/day]	0	0	15
End Date	9/30/04	9/30/05	9/15/06
End Rate [lb/day]	23	11	15
Internal Load Slope [lb/day^2]=	0.190	0.091	0.000
Internal Load Mass [lb]=	1403.0	671.0	1305.0

Figure 8: Model Output Scenario 2

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TECHNICAL MEMORANDUM

TO: John R. Thene, P.E., Project Manager
Wenck Associates, Inc.

FROM: John Erdmann, P.E., PhD

DATE: June 13, 2007

SUBJECT: Comfort Lake Forest Lake Watershed District
Review of MPCA's April 1995 report, "Lake Assessment Program 1994 Big and Little Comfort Lakes"

The MPCA's LAP report includes the following data:

- Lake areas:
    - Big Comfort – 219 ac
    - Little Comfort – 37 ac
- Watershed area – 21.2 square miles [Wenck study use 39.0 square miles]
- Sunrise River outflow from Big Comfort Lake:
    - 18 cfs for monitoring period (May-Sep)
    - 23 cfs for water year 1994
    - Compared with 2003, 2004, 2006 data:

Mean Sunrise River Outflow from Big Comfort Lake		
Year	**Monitoring Period [cfs]**	**Water Year [cfs]**
MPCA 1994 LAP report:		
1994	18	23
Wenck results from Washington CD data (SM8):		
2003	12.8	23.4
2004	13.9	16.8
2006	5.4	7.8

Remark: Big Comfort outflow data for 1994 and 2004 are comparable.

- Mean summer surface water quality, Big Comfort:
    - TP – 35 ug/L
    - Chloro-a – 16 ug/L
    - Secchi depth – 6.5 ft
    - Compared with 2003 – 2006 data:

Big Comfort Lake Mean Summer Surface Water Quality				
Lake	**Year**	**TP (ug/L)**	**Chloro-a (ug/L)**	**Secchi Depth (ft)**
MPCA 1994 LAP report:				
Big Comfort	1994	35	16	6.5
Washington CD:				
Big Comfort	2003	48	25	4.2
Big Comfort	2004	40	17	6.0
Big Comfort	2005	29	16	6.3
Big Comfort	2006	50	12	6.6

Remark: Big Comfort data for 1994 and 2004 are comparable.

- Mean summer surface water quality, Little Comfort:
    - TP – 51 ug/L
    - Chloro-a – 32 ug/L
    - Secchi depth – 5.8 ft
    - Compared with 2005 -2006 data:

Little Comfort Lake Mean Summer Surface Water Quality				
MPCA 1994 LAP report:				
Little Comfort	1994	51	32	5.8
Washington CD:				
Little Comfort	2005	51	--	5.9
Little Comfort	2006	76	25	4.4

Remark: Little Comfort data for 1994 are comparable to 2005 data but not 2006; was not sampled in 2003 – 2004.

- Plankton data:
    - Diatoms dominant in May in Big Comfort (no Little Comfort data in May)
    - Blue-greens dominant throughout summer in both lakes, incl. *Aphanizomenon* in August –September
    - Small zooplankton abundant in both lakes, probably grazing down small algae

- Sunrise River inflow to Big Comfort:
    - FWMC TP – 67 ug/L
    - P load – 2,367 lb [1,073 kg, 82% of 1,309 kg]
    - Comparison with 2004 and 2006 data:

Sunrise River P Load to Big Comfort Lake		
Year	**Mean TP (ug/L)**	**P load (lb)**
MPCA 1994 LAP report:		
1994	67	2,367
Washington CD (SM7):		
2004	74	1,621
2006	118	813

Remark: P load was higher in 1994 than in 2004 and 2006 owing to higher runoff in 1994.

- Water quality goals suggested by MPCA – mean surface summer TP:
    - Big Comfort: TP – 35 ug/L
    - Little Comfort – 40 ug/L

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TECHNICAL MEMORANDUM

TO: John R. Thene, P.E., Project Manager
Wenck Associates, Inc.

FROM: John Erdmann, P.E., PhD

DATE: June 13, 2007

SUBJECT: Comfort Lake Forest Lake Watershed District
Review of McComas' 2002-2004 report, "Comfort Lake, Chisago County Phase I Resource Investigation" [report published 4/02; revised 2/01 and 9/04]

McComas conducted monitoring in 1998. Key results:

- Watershed area – 33.7 square miles [Wenck study has 39.0, MPCA 21.2 square miles]
- Sunrise River inflow to Big Comfort Lake:
  - 17.4 cfs for monitoring period (Feb 27 – Oct 12)
  - Close to MPCA's monitoring period *outflow* of 18 cfs, suggesting 1998 runoff somewhat higher than 1994
  - Compared with 2004, 2005, 2006 data:

Mean Sunrise River Inflow to Big Comfort Lake	
Year	**Monitoring Period [cfs]**
McComas 2002-04 report:	
1998	17.4
Wenck results from Washington CD data (SM7):	
2004	15.6
2005	10.6
2006	4.8

Remark: Runoff data for 1998 and 2004 are comparable; 2003 data also are comparable in general (though unmonitored at this site in 2003).

- Sunrise River inflow to Big Comfort:
  - FWMC TP – 263 ug/L
  - P load – 3,269 lb
  - Comparison with 2004 and 2006 data:

Sunrise River P Load to Big Comfort Lake		
Year	**Mean TP (ug/L)**	**P load (lb)**
McComas 2002-04 report:		
1998	263	3,269
MPCA 1994 LAP report:		
1994	67	2,367
Washington CD (SM7):		
2004	74	1,621
2006	118	813

Remark: P load was highest in 1998 because of very high mean TP concentration and high runoff (less than 1994 but higher than 2004 and 2006).

- Mean summer surface water quality, Big Comfort:
    - TP – 40 ug/L
    - Chloro-a – 11 ug/L
    - Secchi depth – 4.3 ft
    - Compared with 1994 and 2003 – 2006 data:

Big Comfort lake Mean Summer Surface Water Quality				
Lake	**Year**	**TP (ug/L)**	**Chloro-a (ug/L)**	**Secchi Depth (ft)**
McComas 2002-04 report:				
Big Comfort	1998	40	11	4.3
MPCA 1994 LAP report:				
Big Comfort	1994	35	16	6.5
Washington CD:				
Big Comfort	2004	40	17	6.0
Big Comfort	2005	29	16	6.3
Big Comfort	2006	50	12	6.6

Remark: Big Comfort data for 1994, 1998 and 2003-06 are in general accord.

- Mean summer surface water quality, Little Comfort:
    - TP – 58 ug/L
    - Chloro-a – 15 ug/L
    - Secchi depth – 3.9 ft
    - Compared with 1994 and 2005 -2006 data:

Little Comfort Lake Mean Summer Surface Water Quality				
Lake	**Year**	**TP (ug/L)**	**Chloro-a (ug/L)**	**Secchi Depth (ft)**
McComas 2002-04 report:				
Little Comfort	1998	58	15	3.9
MPCA 1994 LAP report:				
Little Comfort	1994	51	32	5.8
Washington CD:				
Little Comfort	2005	51	--	5.9
Little Comfort	2006	76	25	4.4

Remark: Little Comfort data for 1994, 1998, and 2005-06 are generally comparable.

- Effect of Shallow Pond on P load in Sunrise River (Judicial Ditch 1):
    - The timeline presented in Table 27 (page 61) includes the following item for the 1970s, which suggests a historic reason why Shallow Pond could be a phosphorus source:

> "Sod farming occurring in 'Shallow Pond'. Fertilization rates are unknown."

- TP data for 1998 include stations 6 (upstream of pond) and 5 (downstream) [per map on page 33]:

1998 Stream TP Data Upstream and Downstream from Shallow Pond				
Date	**Weather Condition**	**Station 6 Upstream (ug/L)**	**Station 5 Downstream (ug/L)**	**Ratio Up/Down (--)**
1/21/98	dry	75	83	0.90
5/7/98	dry	75	100	0.75
6/18/98	dry	392	97	4.0
6/26/98	storm	85	186	0.46
7/15-16/98	storm	126	159	0.79
8/3/98	storm	155	112	1.4
8/17/98	storm	226	140	1.6
8/20/98	storm	216	66	3.3
8/23/98	dry	154	90	1.7
	Mean (all data)	**167**	**115**	**1.7**
	Count (all data)	**9**	**9**	**9**
	Mean (Jan-Jul)	**151**	**125**	**1.4**
	Count (Jan-Jul)	**5**	**5**	**5**
	Mean (Aug-Nov)	**188**	**102**	**2.0**
	Count (Aug-Nov)	**4**	**4**	**4**
	Mean (dry)	**174**	**93**	**1.9**
	Count (dry)	**4**	**4**	**4**
	Mean (storm)	**162**	**133**	**1.5**
	Count (storm)	**5**	**5**	**5**

- TP data for July 12, 1999 include stations 7 (upstream of pond) and 3 and 1 (downstream and further downstream, resp.) [per map on page 37]:

7/12/99 Stream TP Up- and Downstream from Shallow Pond			
	TP Concentration		
Station	**Station 7 Upstream (ug/L)**	**Station 3 Downstream (ug/L)**	**Station 1 Downstream (ug/L)**
Sample 1	109	81	81
Sample 2	112	78	87
Average	**111**	**80**	**84**

  - The above data give very little support to the notion that Shallow Pond acts as a phosphorus source, which is a key element of one of the report's important findings, listed in the summary (page ix) as follows:

    > "In recent years, in Big Comfort Lake watershed, the increase in impervious surfaces has increased the quantity of stormwater runoff, while not greatly increasing the amount of phosphorus. However, the increased volume of stormwater coupled with problem culverts that hold back flow, apparently has increased saturation in a large wetland area in what is called Shallow Pond. The increase in saturation results in additional phosphorus leaching from the wetland peat. This wetland area then exports elevated amounts of phosphorus that are carried into Big Comfort Lake."

- Effects of commercial development in upper reaches of Judicial Ditch 1:
  - Other data from the July 12, 1999 sampling show extremely high TP upstream from station 7:
    - TP = 694 ug/L, station 8 (tributary from Heims Lake)
    - TP = 212 ug/L, station 10 (Judicial Ditch 1 at highway 61, above confluence with Heims Lake tributary) [per map on page 37]
  - The report gives no flow data for July 12, 1999, but the decrease from these TP concentrations to the concentration at station 7 (111 ug/L) requires an intervening clean water inflow with much larger flow rate than at stations 8 and 10 (or, alternatively, some efficient process of TP removal between stations 8/10 and 7) – or else reflects nonrepresentative data from one or more of the stations
  - The above and previously cited data seem to be at variance with the timeline entry for 1998 in Table 27 (page 61), which reads as follows:

    > "Monitoring results show phosphorus levels are moderate in subwatersheds that feed into Shallow Pond. However, phosphorus levels and nutrient loads are high at the outlet of Shallow Pond."

- Water quality goals suggested by McComas – both lakes:
  - TP – 35 ug/L
  - Secchi depth – 6 to 7 ft
  - TP goal is the same as MPCA's earlier goal for Big Comfort; Secchi depth goal here is new

The report proposes 12 specific watershed and lake projects (pages x, 77 and 101), including lowering the culvert at the downstream end of Shallow Pond.