

Does Comfort Lake receive and accumulate a large load of sediment?

- **(1) What is sediment?**
 - *Which component are we concerned with?*
 - **(2) How much sediment does Comfort Lake accumulate?**
 - **(3) Is this large?**
 - *Relative to reference conditions and other sites*
-
- *None of these questions is particularly simple or easy to answer.*
 - *All calculations can have considerable error.*
 - *Best approach is to try multiple independent calculations.*

(1) What is sediment?

Lake sediment = particles that have settled, *or could settle*, to the bottom.

Driven mostly
by landscape
erosion

- ❖ **Particles delivered to the lake by streams, overland runoff, and dustfall**
 - Sand
 - TSS = Total Suspended Sediment
 - Organics: plant matter, eroded peat, algae from streams and upstream lakes
 - VSS = volatile suspended solids (~50%)
 - Inorganics: silts & clays from eroded soils
 - NVSS = non-volatile suspended solids (~50%)

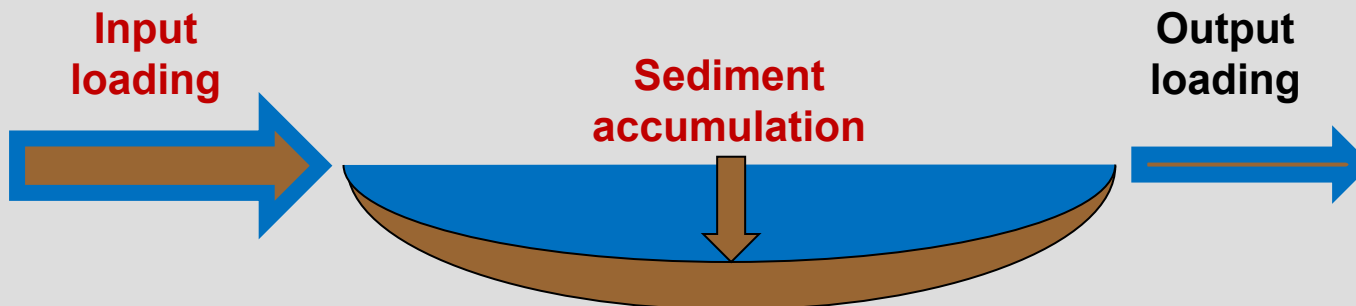
Driven mostly
by nutrient
delivery to lake

- ❖ **Particles created in the lake**
 - Organics = algae, macrophyte bits
 - Inorganics =
 - CaCO₃ (calcium carbonate)
 - Diatom frustules (cell walls; “biogenic silica”)
 - Metal oxides and salts

Comfort Lake sediment components

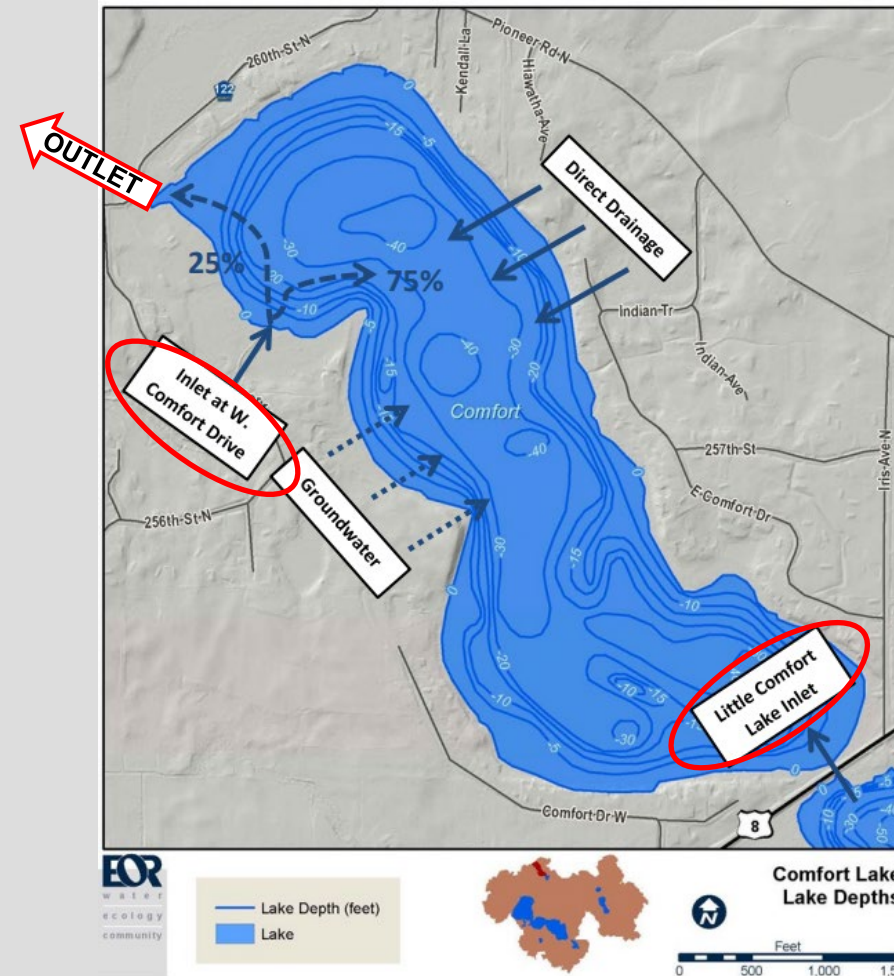
- ❖ Organics = 20-55%
 - Some washed in from stream inlet
 - Some (most?) from in-lake algal productivity
- ❖ Calcium carbonate = 20-30%
- ❖ Diatom frustules = 5-15%
 - Some from streams?
- ❖ Inorganics = 20-40%
 - Silts & clays from eroded soil

*How much **input loading** and **accumulation** of this component does Comfort Lake receive?*



(2) How much sediment does Comfort Lake receive?

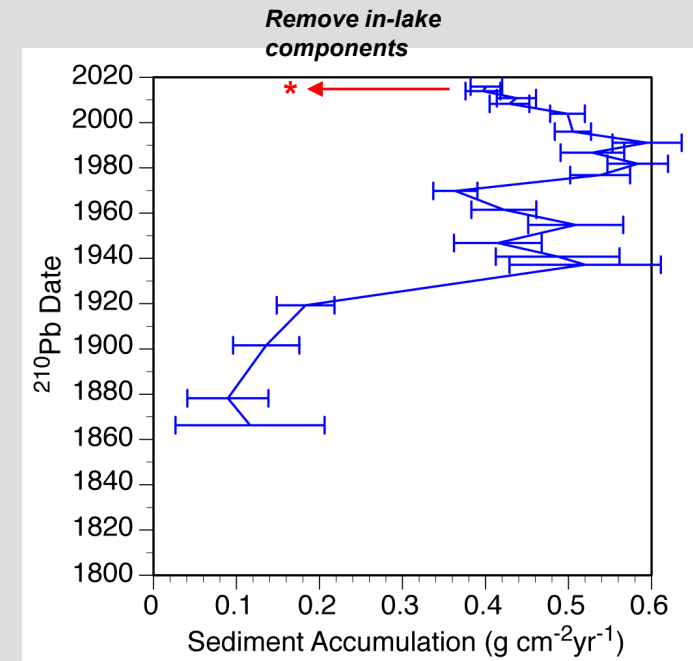
- ❖ **What have we measured?**
 - (2a) Sediment accumulation by Pb-210
 - (2b) Sediment budget from stream monitoring
 - $\text{Input} - \text{Output} = \text{Accumulation}$



(2) How much sediment does Comfort Lake receive:

(2a) Sediment accumulation as measured by Pb-210

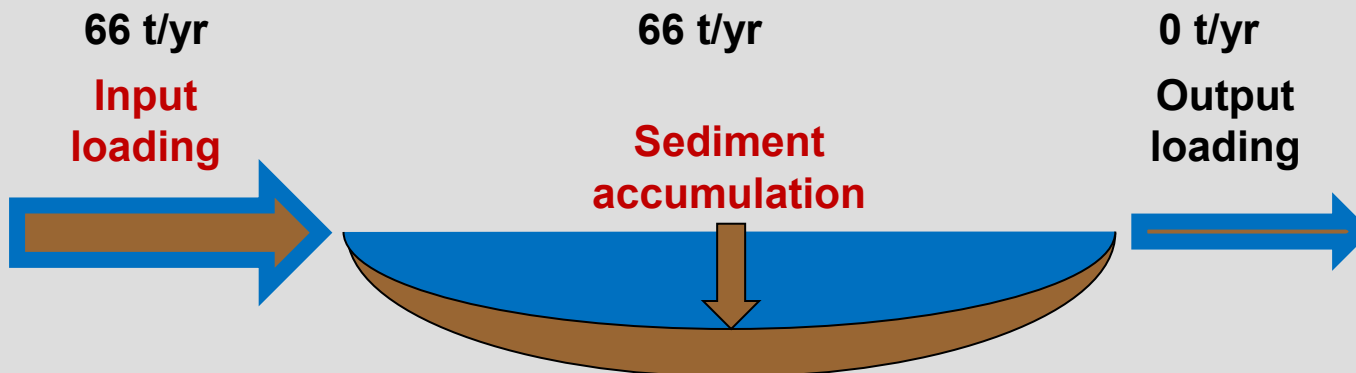
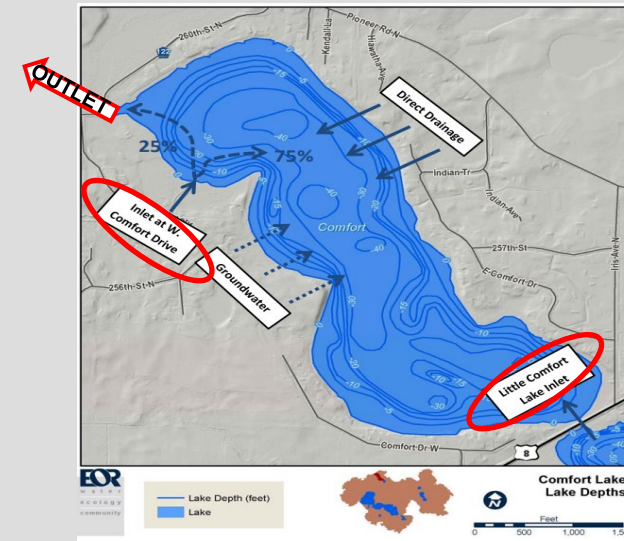
- Sediment core collected from deep part of lake
 - Pb-210 concentration and sediment content measured in sediment core
 - Gives sediment accumulation rate ($\text{g}/\text{cm}^2/\text{yr}$) & focusing factor at core site
- Results for Comfort Lake
 - Current (top of core) accumulation of silts & clays = $0.16 \text{ g}/\text{cm}^2/\text{yr}$ at core site
 - Organics, CaCO_3 , and *bSi* (diatoms) subtracted out from total
 - Divide by focusing factor (2.89) to get $0.055 \text{ g}/\text{cm}^2/\text{yr}$ over whole lake area
 - Times lake area (218 acres)
 - = **489 t/yr**
- Limitations
 - Not tested with multiple cores
 - Not compared to other methods...
 - ...which we'll test now



(2) How much sediment does Comfort Lake receive:

(2b) Sediment accumulation as measured by stream monitoring

- **Load = suspended sediment concentration X stream flow**
 - Average of 2004-2020 values
 - Assumes NVSS = 50% of TSS
- **Input loads of NVSS = 66 t/yr**
 - From Little Comfort Lake = 27 t/yr
 - From Forest Lake via Sunrise River = 39 t/yr
- **Output loads of NVSS = 0**
 - It's all algae – no silts and clays
- **Sediment accumulation = 66 t/yr**
 - Much lower than the Pb-210 value of 489 t/yr



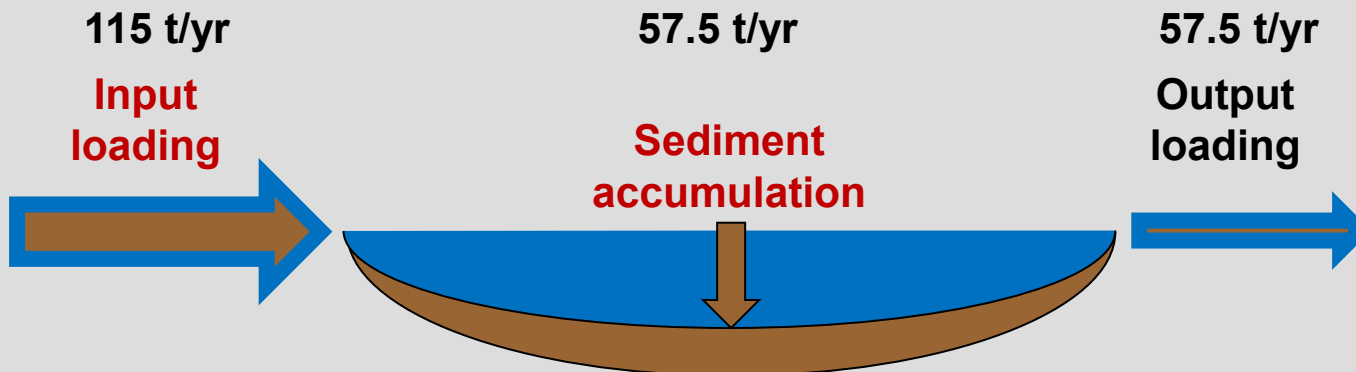
(3) Is the sediment input and accumulation in Comfort Lake large?

- ❖ **How does sediment in inlet streams and Comfort Lake compare to standards and other sites?**
 - *We tried to answer this question in (at least) four different ways.*

(3) Is the sediment accumulation in Comfort Lake large:

(3a) Input loading under reference (natural, pre-settlement) conditions

- Estimated reference NVSS from Robertson et al. 2006 statistical study of Great Lakes region
 - 7.1 mg/L NVSS in streams for our area
 - 0.05 t/ha/yr
- Input loads of NVSS = 115 t/yr
 - From direct basin around lake = 22 t/yr
 - From Little Comfort Lake = 30 t/yr
 - From Forest Lake via Sunrise River = 63 t/yr
- Output loads of NVSS = 57.5 t/yr (guessed 50% trapping)
- Sediment accumulation = **57.5 t/yr**



2022 Comfort Lake Sediment

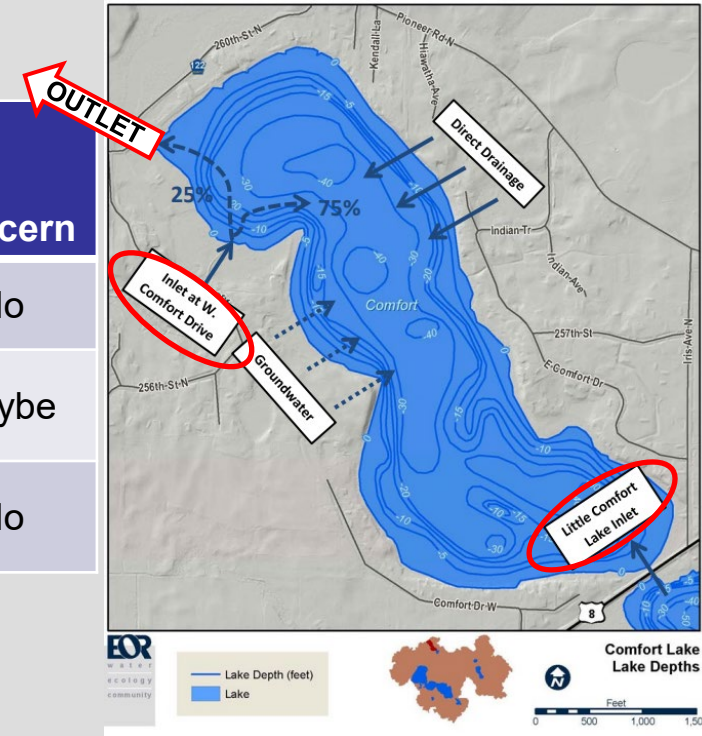


(3) Is the sediment accumulation in Comfort Lake large:

(3b) Are TSS concentrations in inlet streams large?

Stream Concentrations (2011-2020)

Site	Number of NVSS Samples	Number of Exceedances	Percentage of Exceedances	Concern
Sunrise River	21	2	9.5%	No
Little Comfort Lake Inlet	21	5	24%	Maybe
Comfort Lake Outlet	17	0	0%	No

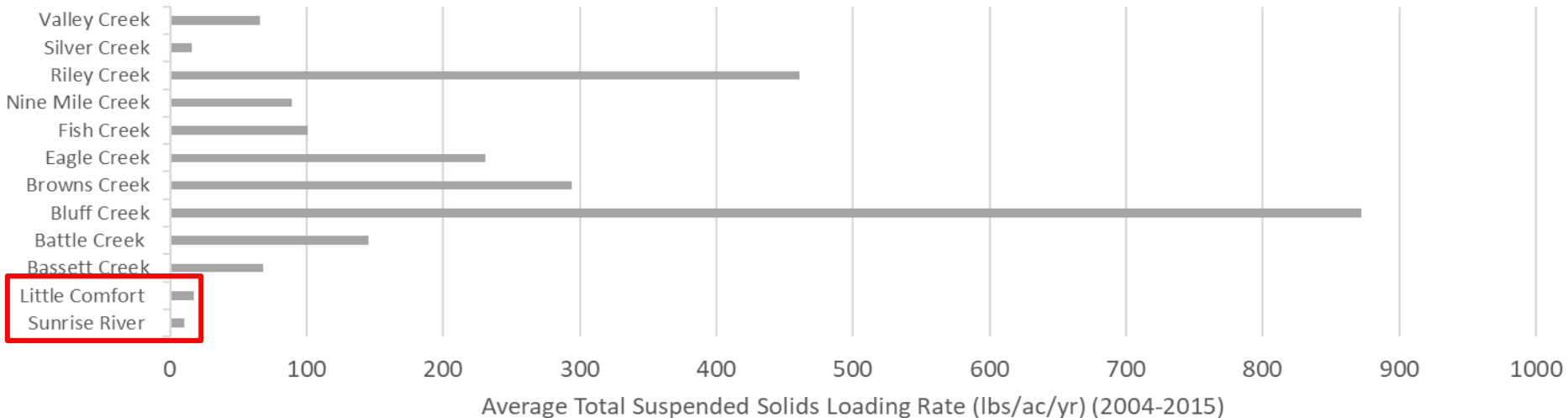
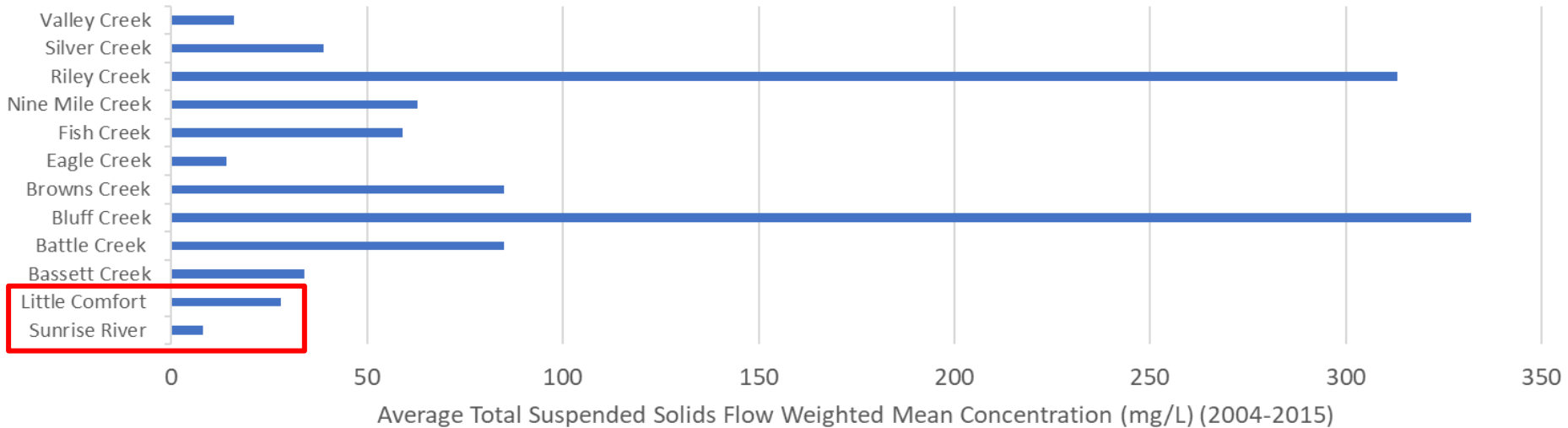


- TSS standard concentration: 30 mg/L
- Sampling Protocol

2022 Comfort Lake Sediment



(3c) How do TSS concentrations and loading rates compare to other metro-area streams?

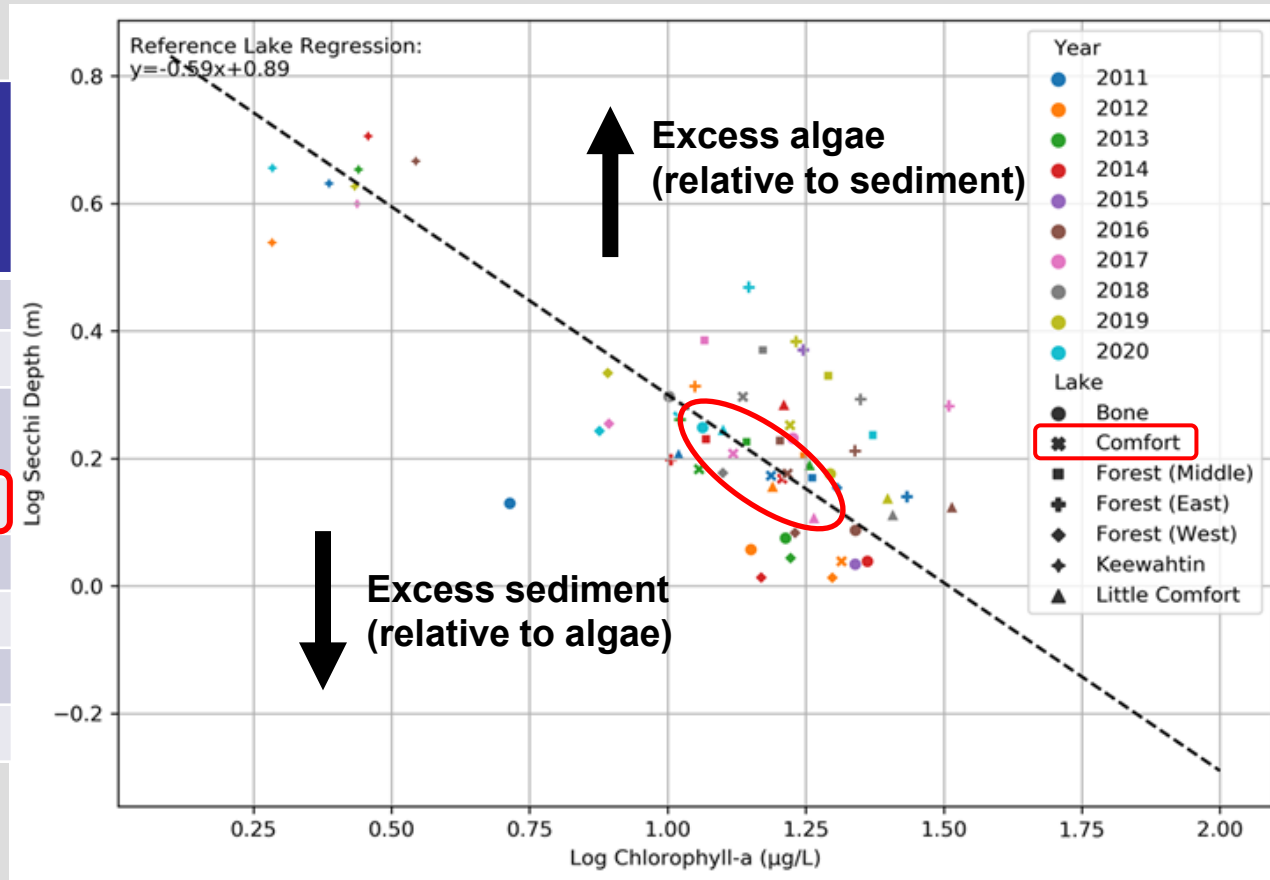


2022 Comfort Lake Sediment



(3d) How does turbidity in Comfort Lake compare to other WD lakes?

Lake	Secchi Depth (ft) (2011-2020)	Distance to Reference Chl-a~Secchi Line
Keewahtin	15	0.08
Forest (East)	6.3	0.18
Forest (Middle)	6.1	0.11
Comfort	5	0.05
Little Comfort	4.8	0.07
Forest (West)	4.6	0.11
Bone	4.4	0.13
Moody	2.5	0.07



Comfort Lake plots close to the regression line – so it does not have disproportionately more NVSS (silts and clays) relative to algae (or vice versa)

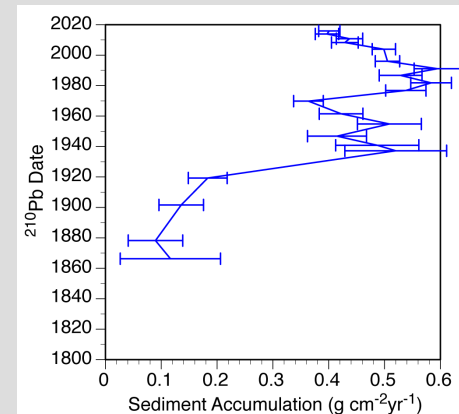
Summary

- ❖ (1) What sediment component are we interested in?
 - NVSS = non-volatile suspended solids = eroded soil silt & clay
- ❖ (2) What is NVSS accumulation in Comfort Lake?
 - (a) 489 t/yr from lake-sediment Pb-210 calculations
 - (b) 66 t/yr from stream monitoring calculations
- ❖ (3) Is this accumulation rate large?
 - (a) 57.5 t/yr under reference (natural) conditions
 - (b) TSS concentrations in inlet streams are not large. They mostly meet the standard (30 mg/L).
 - (c) TSS concentrations and loading rates are low compared to other metro-area streams.
 - (d) Turbidity in Comfort Lake is not driven by NVSS (silts and clays).

Conclusions

- ❖ **The input loads and accumulation rates of NVSS in Comfort Lake do not appear to be large.**
 - *Monitored values are larger than the reference value, but overall near or better than current water-quality standards.*
- ❖ **The accumulation rate from the sediment Pb-210 study appears to be anomalously large.**
 - *However, the trends in the lake-sediment core samples are self-consistent and thus reliable.*
- ❖ **Reductions in TSS may be possible for Little Comfort Lake inlet**
 - *Additional monitoring between School Lake and Little Comfort Lake*
 - *Preliminary stream condition walk through during Little Comfort Lake model survey*

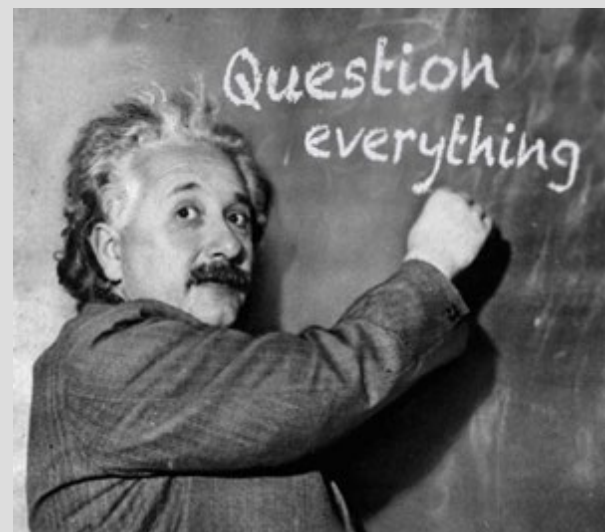
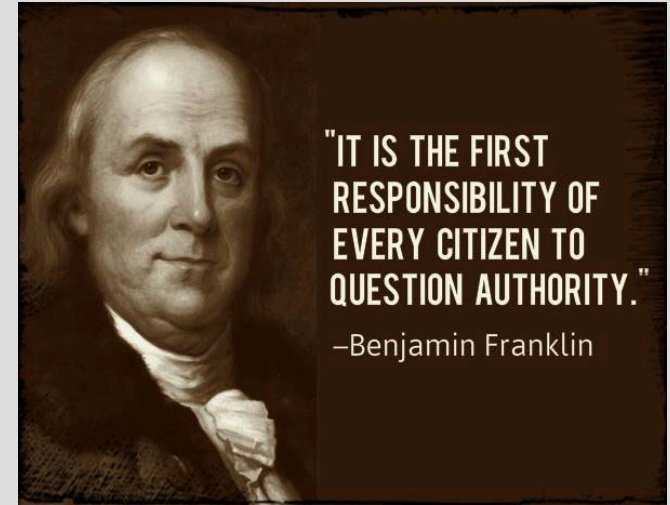
Minnesota
designations:



2022 Comfort Lake Sediment



Protecting Your Water Resources



2022 Comfort Lake Sediment



Protecting Your Water Resources

Monitoring Review Summary

Site	Concentrations Concern	Load Concern	Lake Condition
Sunrise River	No	No	No
Little Comfort Lake Inlet	Maybe	No	No

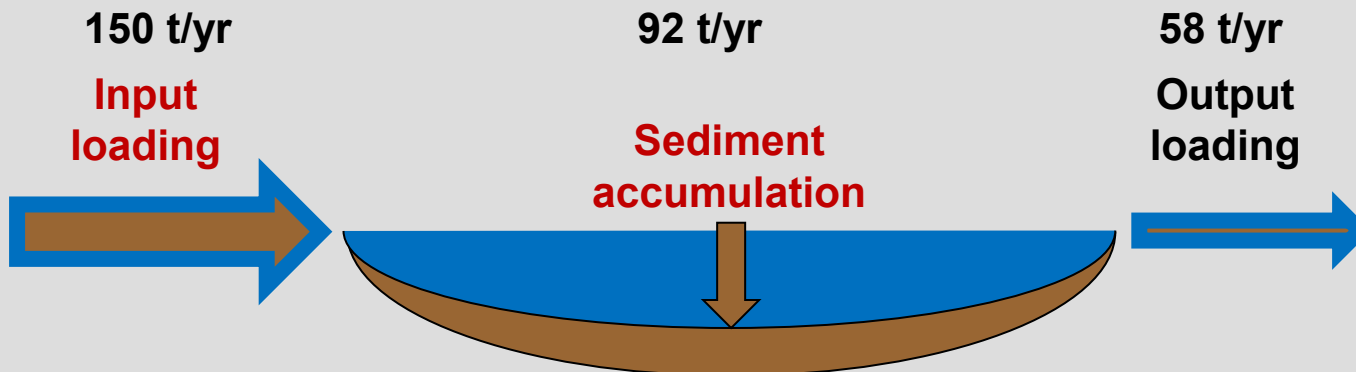
Recommendations

- **Additional monitoring between School Lake and Little Comfort Lake**
- **Preliminary stream condition walk through during Little Comfort Lake model survey**

(2) How much sediment does Comfort Lake receive:

(2c) Sediment accumulation as modeled by SWAT

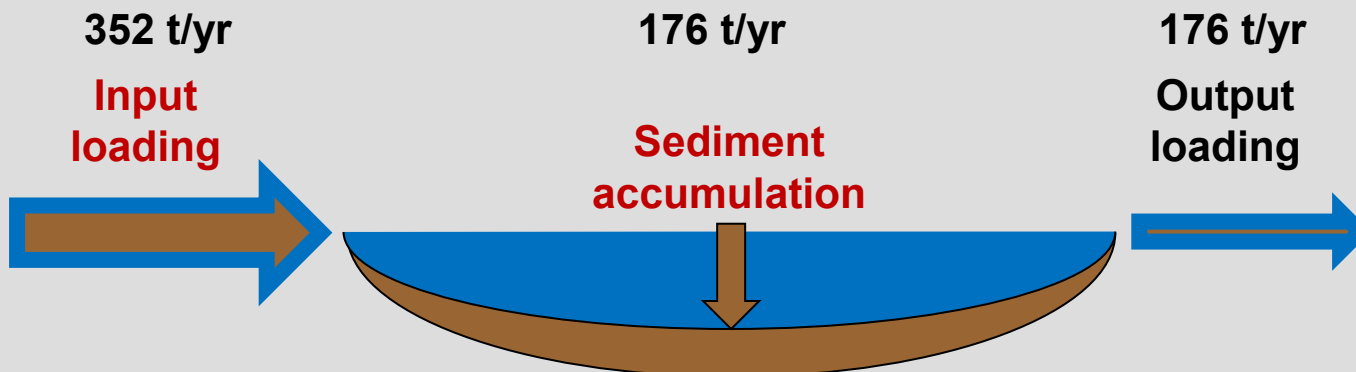
- **Load = suspended sediment concentration X stream flow**
 - Average of 1990-2009 values
- **Input loads of NVSS = 150 t/yr**
 - From direct basin around lake = 8 t/yr
 - From Little Comfort Lake = 79 t/yr
 - From Forest Lake via Sunrise River = 63 t/yr
- **Output loads of NVSS = 58**
- **Sediment accumulation = 92 t/yr**
 - Much lower than the Pb-210 value of 489 t/yr
 - Larger than stream-measured 66 t/yr



(3) *Is the sediment accumulation in Comfort Lake large:*

(3b) Input loading under WQ standard conditions

- **WQ standard = 30 mg/L TSS**
 - *Assuming TSS is entirely NVSS*
- **Input loads of NVSS = 352 t/yr**
 - From Little Comfort Lake = 84 t/yr
 - From Forest Lake via Sunrise River = 268 t/yr
 - *Value from stream monitoring is much less than this (39 t/yr)*
- **Output loads of NVSS = 176 t/yr (guessed 50% trapping)**
- **Sediment accumulation = 176 t/yr**



2022 Comfort Lake Sediment

(3) Is the sediment accumulation in Comfort Lake large:

(3b) Comparison to standards, other streams, and other lakes

- ❖ Stream Concentrations compared to Minnesota Rules
- ❖ Stream Loading Rates compared to Metro Streams
- ❖ Lake water quality compared to District Lakes

