Nutrient Removal in much of Utah-- an Avoidable Waste!

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For

LEGISLATIVE WATER DEVELOPMENT COMMISSION
UTAH LEGISLATURE
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First—A quick look at "eutrophication"

--Since this is the crux of the Utah nutrient debate

Eutrophication:

Increasing aquatic plant growth and overall biological productivity in a water body over time to a level where significant water quality problems result.

Natural eutrophication going from a pristine lake to a swamp often takes hundreds or thousands of years, or more—sometimes human activities accelerate this natural process.

The problems are associated with an over abundance of algae.

Trophic level classification for lakes:

- Oligotrophic (low bio-productivity, clear)
- Mesotrophic (moderate " ,slightly turbid)
- Eutrophic (high " , turbid)
- Hyper eutrophic (very high " , very turbid)

Turbidity as used here is --biological turbidity

- An oligotrophic lake

- A mesotrophic lake

- Eutrophic lakes

- Hyper-eutrophic lakes

- Most lakes eventually become marshland—then wet meadows—then “basin” land

Problems that might occur in lakes, more so in eutrophic lakes:

- *Turbidity: Turbid water from prolific algal and other biological growth*
- *Aesthetics: Significant floating algae and other bio-debris*
- *Debris Accumulation: Unsightly bio-debris along shorelines*
- *Oxygen Loss: "Normal" biota stressed or killed*
- *Mucky Bottom: "Mucky", often septic, conditions at the bottom*
- *Bad odors: Disagreeable odors from the lake*
- *Nuisance Insects: Increased swarms of insects and aquatic bugs*
- *Coarser Fish: Conditions that favor "coarser" fish and other aquatic life*
- *Toxics: Troublesome residual decay compounds in the water*

Important to Note—Most "problems" in eutrophic waters relate to on-site aesthetics and recreation—and generally not to the fundamental concerns with disease and filth.

That is, most eutrophic issues relate to

- **"How pristine and scenic is the lake (or river)?"**
- **"does it look good and smell okay?"**

Most lakes/reservoirs naturally have some of the problems associated with "eutrophic" conditions.

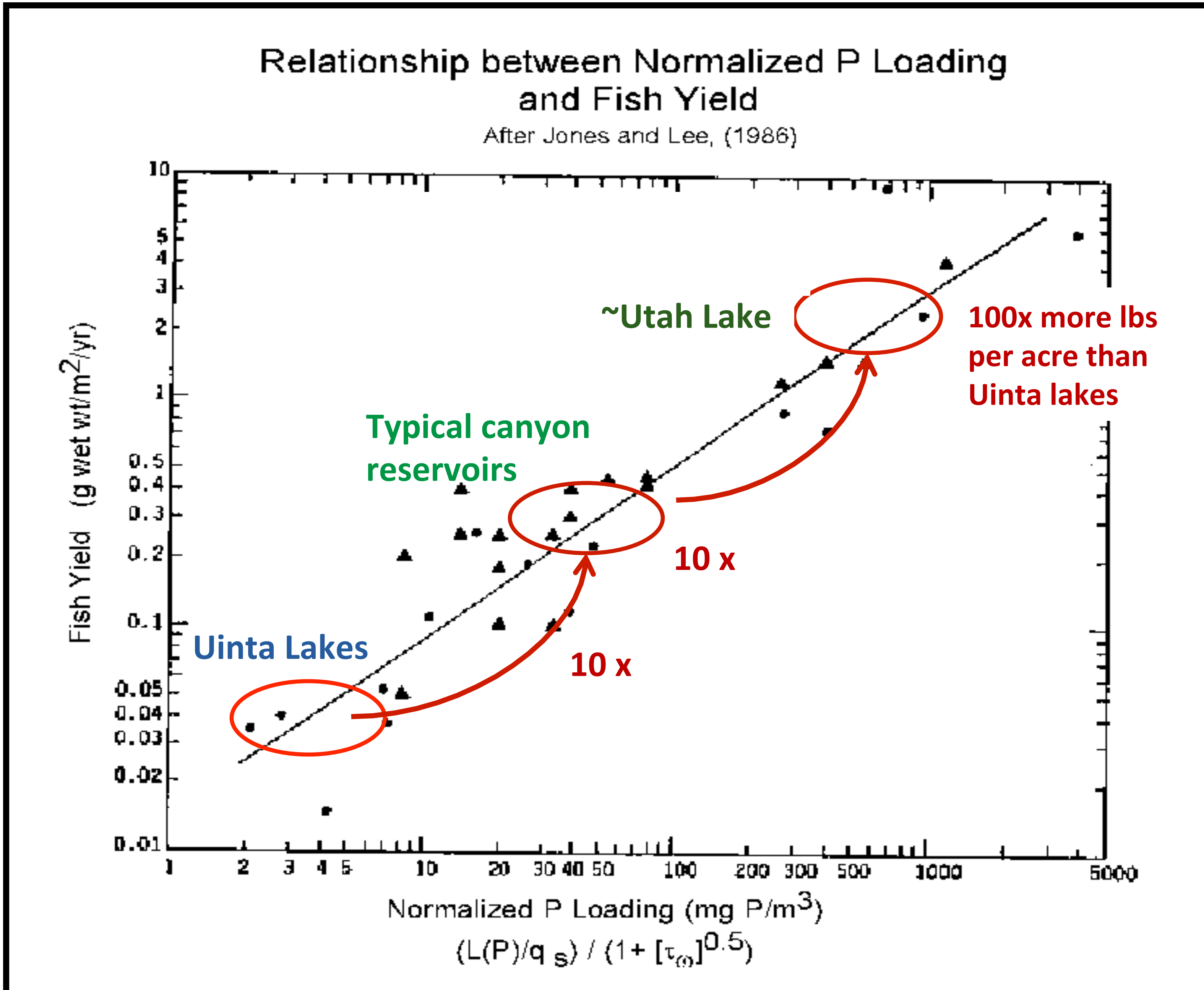
Rivers/steams can also have algae-caused water quality problems but usually to a lesser extent that lakes do.

So what's best?

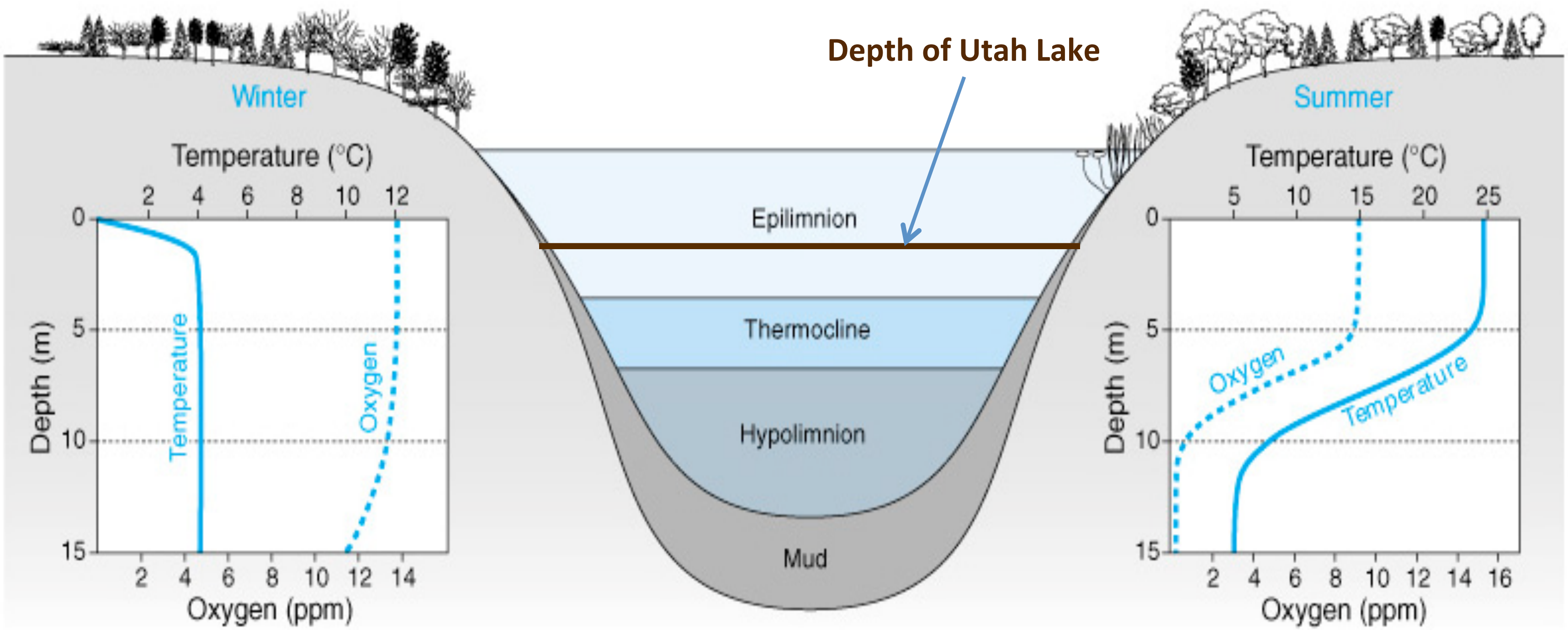
Lake Tahoe

or

Strawberry Reservoir


Relationship between Normalized P Loading and Fish Yield
After Jones and Lee, (1986)
Fish Yield (g wet wt/m2/yr)
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
0.05
0.04
0.03
0.02
0.01
1
2
3
4
5
10
20
30
40
50
100
200
300
500
1000
5000
Normalized P Loading (mg P/m3)
(L(P)/q s) / (1+ [τω]0.5)
~Utah Lake
100x more lbs per acre than Uinta lakes
Typical canyon reservoirs
10 x
Uinta Lakes
10 x

“Deep” Eutrophic Lake



Strawberry Reservoir--1975

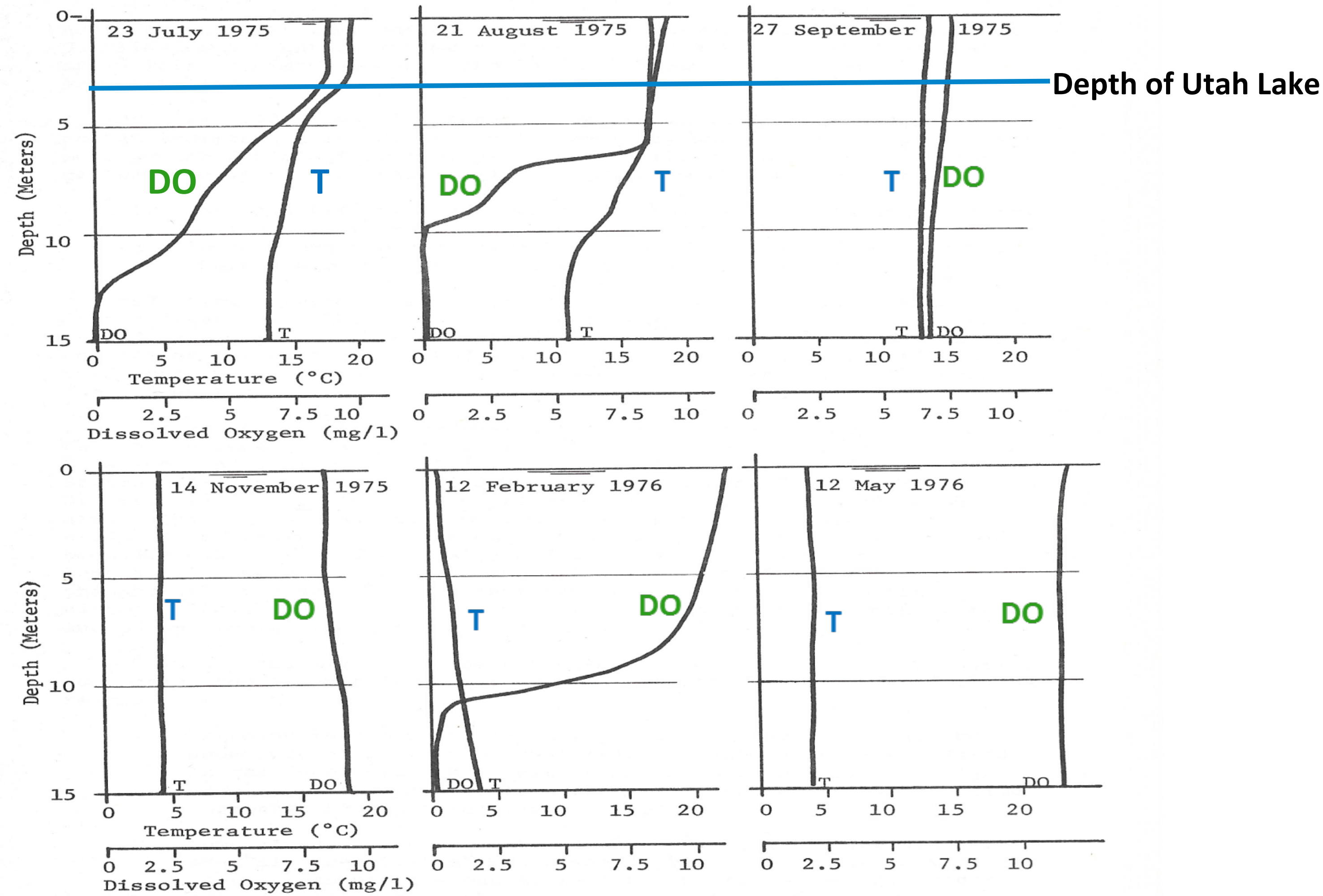


Figure 7.11. Strawberry Reservoir – Observed Temperature and Oxygen Profiles at Station SB-3, 23 July 1975 to 12 May 1976.

What about these eutrophic problems in Utah Lake?

- *Turbidity:* *mainly mineral turbidity—biological part moderate*
- *Aesthetics:* *moderate*
- *Debris Accum.* *moderate*
- *Oxygen Loss:* *rare*
- *Mucky Bottom:* *mainly mineral not organic*
- *Bad odors:* *moderate*
- *Insects:* *moderate*
- *Coarser Fish:* *yes but—largely not water quality related*
- *Toxics:* *low (low harmful algae growth)*

All in all:

Utah Lake has good water quality as compared to most eutrophic, basin-bottom lakes!

Most arid and semi-arid, basin-bottom lakes are strongly eutrophic to hyper eutrophic and rather undesirable for most recreation uses.

Now-

A quick look at growth factors involved in algae growth.

Main factors determining plant growth:

- Light (Amt. of sunshine reaching the algae)
- Nutrients (phosphorus, nitrogen, other trace minerals)
- Temperature
- Toxicants
- Time (length of little change in conditions)
- Variability in factors
- Competition
- Grazing/Harvesting

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- Grazing/Harvesting

Utah Lake's natural condition:

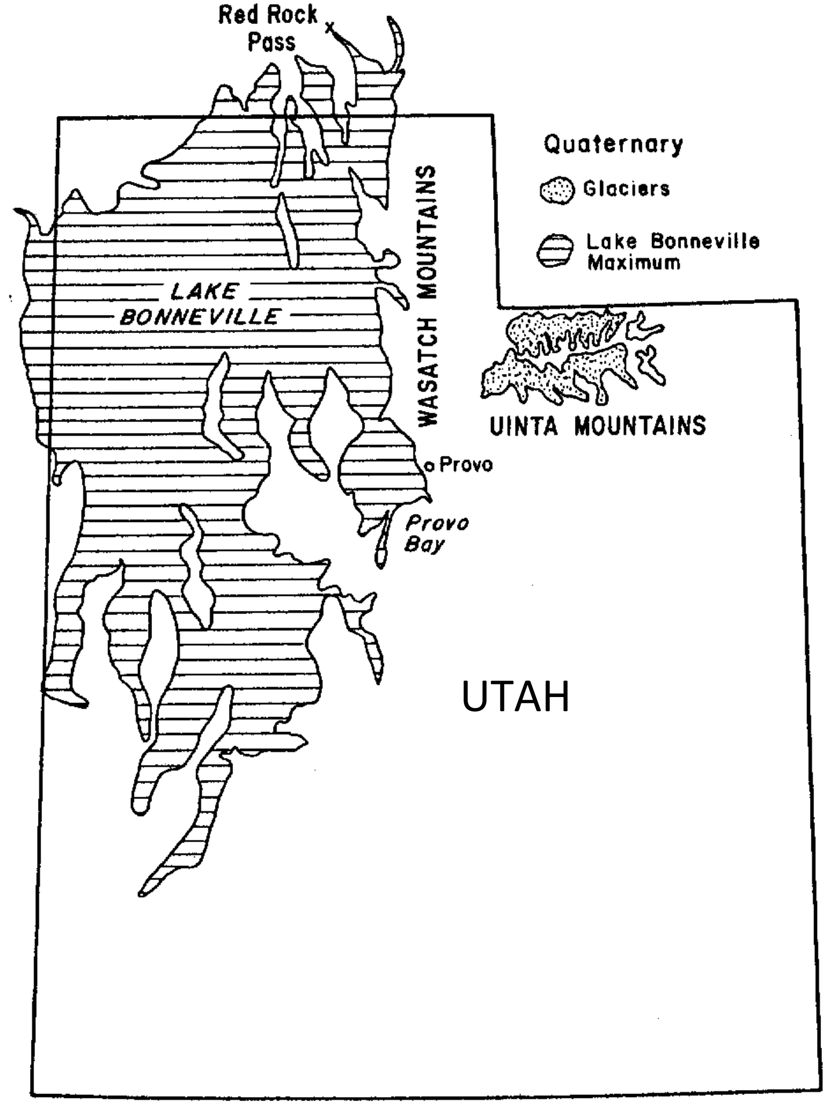
- shallow
- slightly saline
- turbid
- eutrophic
- in semi-arid region

Indications are that the lake has been essentially this way since it stabilized after Lake Bonneville last receded 8000 to10,000 yrs ago.

Utah Lake's Origins

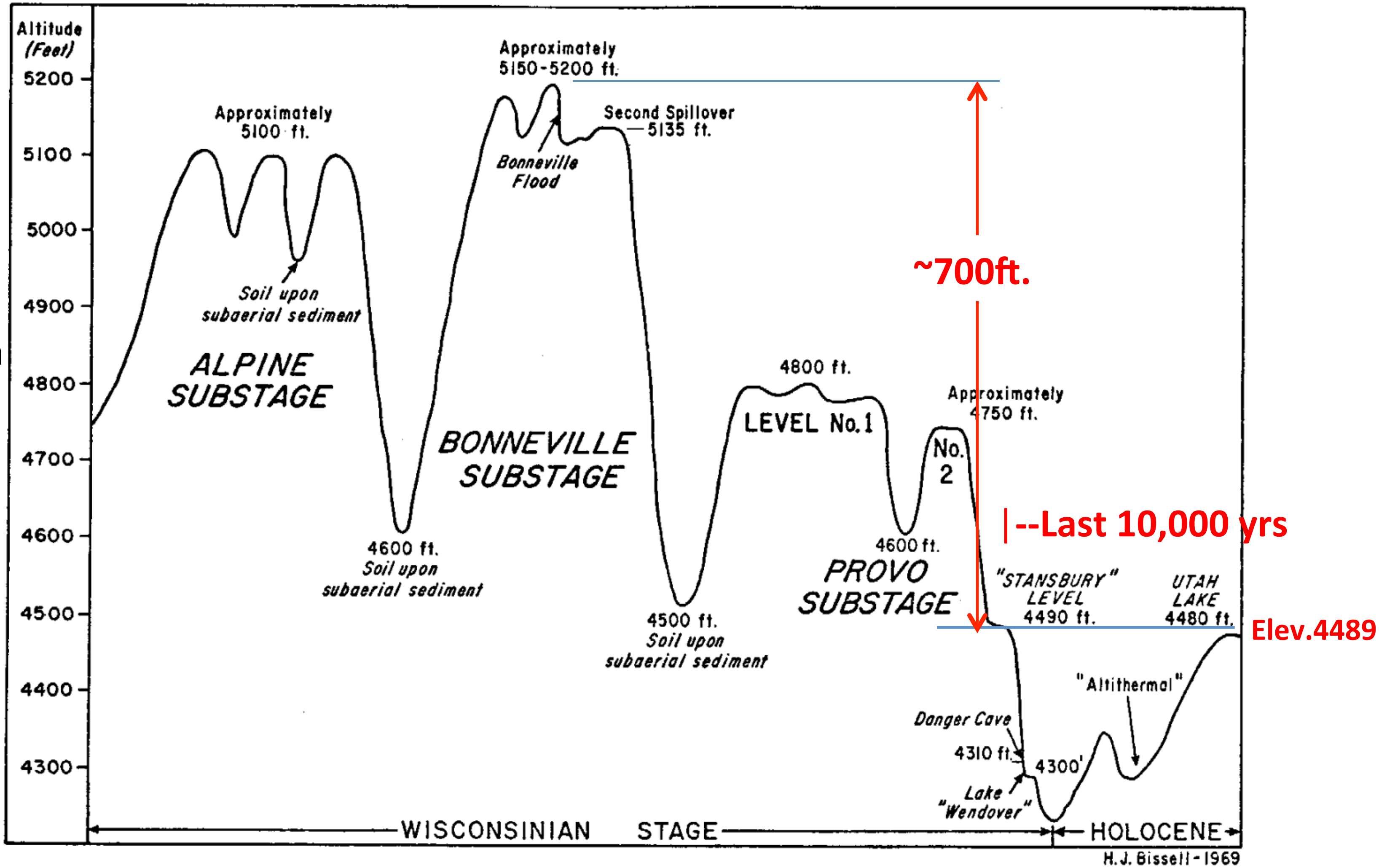
– Lake Bonneville

(A few hundred thousand years ago)



Utah Lake's Origin: --Remnant of Lake Bonneville.

Lake Elevation ft.



Geological Period

Utah Lake during a windy period

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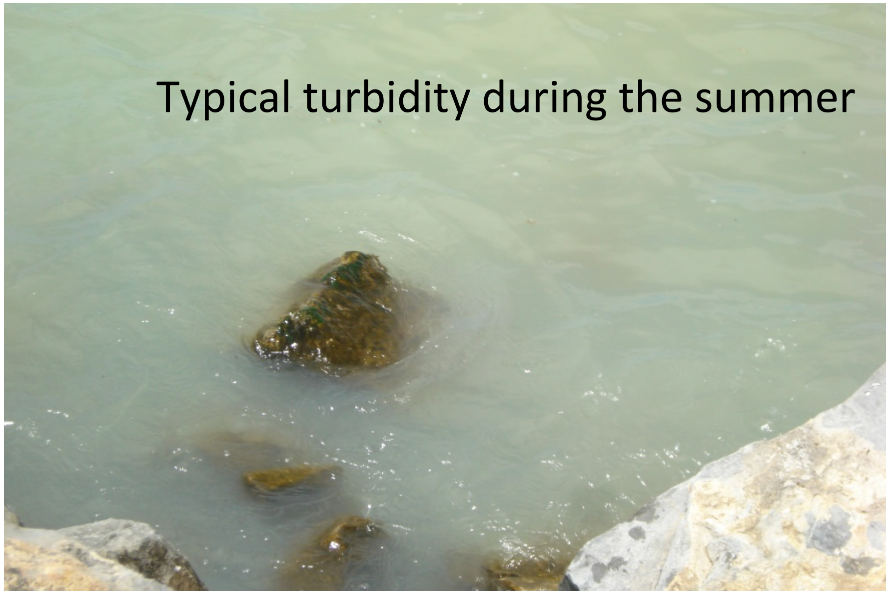
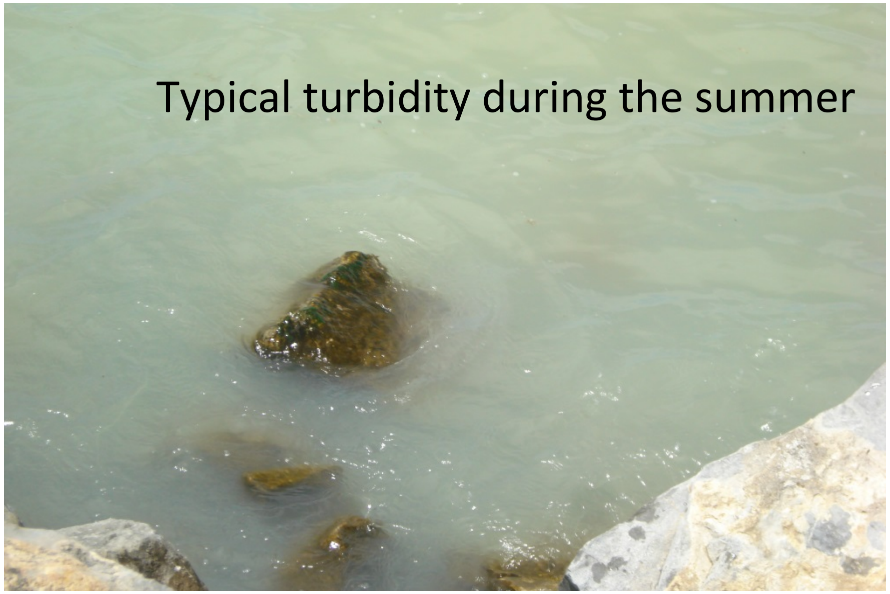
Turbidity in Utah Lake



Typical turbidity during the summer

Turbidity in Utah Lake

Why can't it be like this all of the time?



Typical turbidity during the summer

Table 1. Utah Lake Inflows: Avg Salt and Water Quantities for 2009-2013.

I. INFLOW	Flow		Percent of Inflowing S a l t s								% of Nutrients		
1. **Surface**	af/yr	%	TDS	Na	Ca	Mg	K	Cl	HCO3	SO4	TP	DN	DP
a. Mtn Strms	287862.	52.0	24.3	12.9	42.5	28.3	14.5	10.0	39.6	19.6	7.0	14.5	4.2
b. WWTP	53126.	9.6	11.0	12.9	8.9	9.0	14.2	14.3	10.4	6.3	**79.**	**54.7**	**85.5**
c. Main L-other	77799.	14.1	17.3	12.4	16.6	24.1	15.2	9.8	22.1	27.8	7.6	17.5	6.2
d. Provo B-other	53232.	9.6	9.8	4.8	13.0	11.8	7.6	4.6	12.1	11.4	1.6	5.5	1.3
e. Gosh. B-other	23073.	4.2	14.0	24.1	3.2	10.1	17.5	23.7	3.4	14.3	1.6	2.3	1.5
1. Subtotal:	495092.	89.5	76.4	67.1	84.2	83.3	69.0	62.5	87.6	79.4	**96.8**	**94.6**	**98.7**
2. **Fresh Grnd water**													
a. Main L-gw	31640.	5.7	3.3	1.9	3.9	5.2	3.4	1.7	5.2	2.7	0.4	1.8	0.3
b. Gosh. B-gw	11531.	2.1	3.0	3.4	2.1	3.9	4.7	3.8	2.3	2.9	0.1	0.7	0.1
2. Subtotal:	43171.	7.8	6.2	5.2	6.0	9.0	8.0	5.4	7.5	5.6	0.5	2.4	0.4
3. **Thermal/Mineral GW**													
a. Main-min sprs	13957.	2.5	16.7	26.8	9.5	7.0	22.6	31.1	4.6	14.5	0.3	0.1	0.3
b. Gosh. B-m sprs	787.	0.1	0.3	0.6	0.1	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0
3. Subtotal:	14744.	2.7	17.1	27.4	9.6	7.2	23.0	31.6	4.7	14.9	0.4	0.1	0.3
1,2& 3 subtot	553007.	100.0	99.7	99.8	99.8	99.5	100.0	99.5	99.9	99.9	97.7	97.0	99.4
4. **Precipitation**													
a. Main Lake	52884.	b. Provo Bay 8633. c. Goshen Bay 31649.											
4.Total Precip	93164.		0.3	0.2	0.2	0.5	0.1	0.5	0.1	0.1	2.3	3.0	0.6
			100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.

INFLOW TOTAL 646,171.

II. **Outflow.**

1. **Jordan River 336,045.**

2. **Evaporation**

a. Main Lake 218073. b. Provo Bay 32133. c. Goshen Bay 92602.

2. Subtotal **332,808.**

About 50% of the water evaporates

II. Outflow tot 668853.

Lake Storage -22682.

Net 646171.

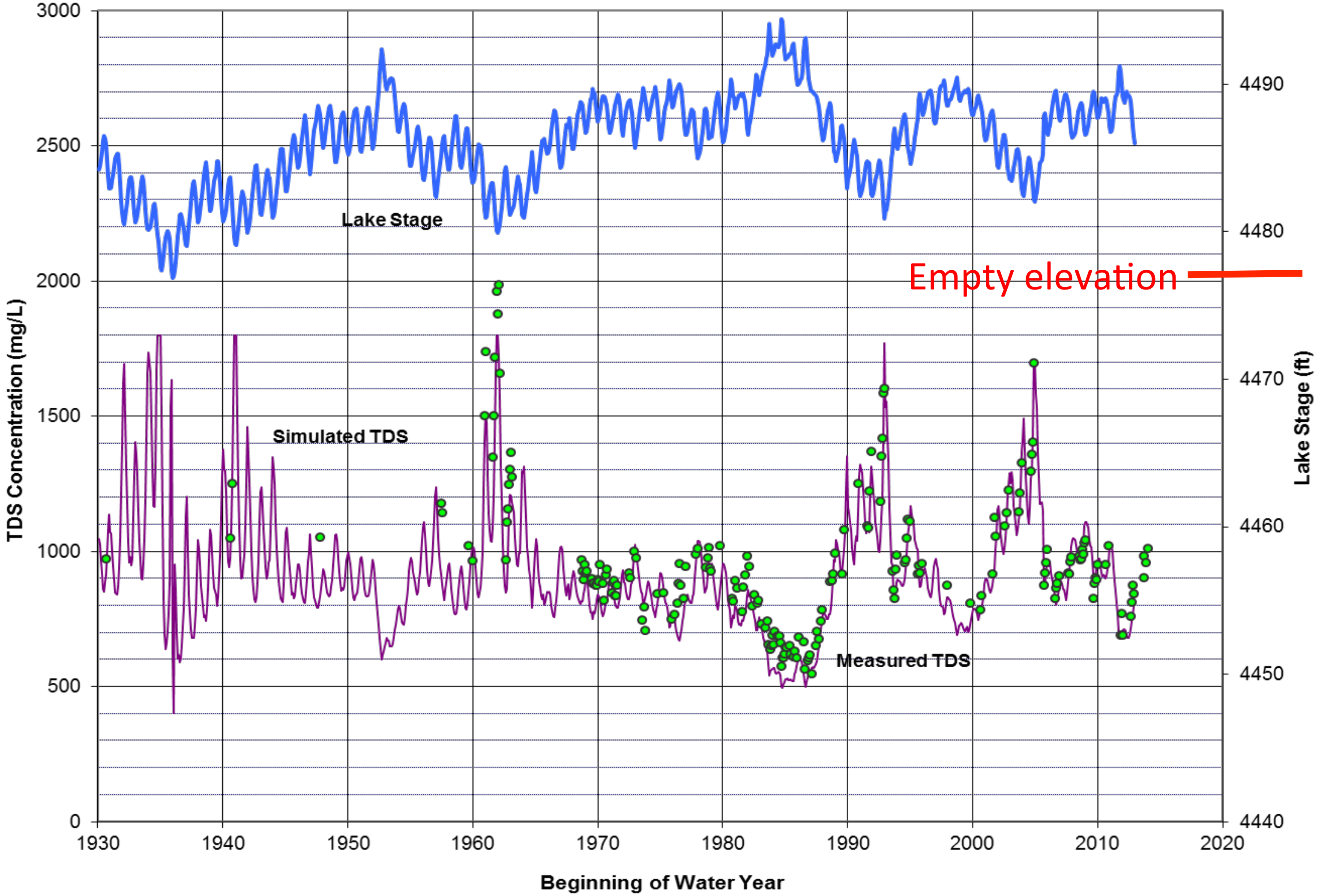
	TDS	Na	Ca	Mg	K	Cl	HCO3	SO4	TP	DN	DP
Ratio: salts out/salts in:	85.	108.	39.	107.	109.	110.	54.	110.	**9.4**	**17.1**	**9.4**

Approx. corrected

Table 1. Utah Lake Inflows: Avg Salt and Water Quantities for 2009-2013.

	TDS	Na	Ca	Mg	K	Cl	HCO3	SO4	TP	DN	DP
Percentage: **(salts out/salts in)**	**79**	100	**36**	100	100	100	**50**	100	**9**	**16**	9

The Ca and HCO3 precipitated averages about 100,000 tons /yr
--this is about 2”/100 yr over the full-lake area!
--or about 200” (18 ft) in 10,000 yrs.



Historical Total Dissolved Solids and Water Levels in Utah Lake

Table 2 . Utah Lake nutrient inflows and outflow—2009-2013. (w/o atmos. deposition)

			Nutrient LoadIngs -- ton/Yr			
			TP		DN	DP
1. **Surface Inflow**	af/yr	%		%		
a. Mtn Strms	287862.	52.0	19	**7**	311	10
b. POTW	53126.	9.6	215	**79**	1174	196
c. Main L-other	77799.	14.1	21	**8**	375	14
d. Provo B-other	53232.	9.	4	**1**	118	3
e. Gosh. B-other	23073.	4.2	4	**1**	50	3
1. Subtotal:	495092.	89.5	264	**97**	2028	226
2. **Fresh Grnd water**						
Subtotal:	43171.	7.8	1		51	1
3. **Thermal/Mineral GW**						
Subtotal:	14744.	2.7	1		2	2
1,2& 3 subtot	553007.	100.0				
4. **Precipitation (rain and snow)**						
Total Precip	93164.		6	**2.2**	64	1
INFLOW TOTAL	646171.		**272**		**2145**	**229**
II. **Outflow.**						
1. **Jordan River**	33604.		**26**	**9.6**	**367**	**22**
2. **Evaporation**	332808.					
II. Outflow tot	668853.					
Change in Storage	-22682.		TP	%	DN	DP
Net	646171.		**26**	**9.6**	**367**	**22**
Lost--precipitated in the Lake			**246**	**90.4**	**1778**	**207**

these values are under final review and may change slightly

Utah Lake has high natural high turbidity, Why?

1. In-lake chemical precipitation of calcium-carbonate-silica-phosphorus (largely clayey Marls) adds a natural, cloudy, mineral turbidity. (removes some 100,000 tons/yr--this is an avg. of about 2 in. of bottom sediments per 100 yrs.—3” or 4” in deeper areas)

Secchi Disk readings indexes light penetration.

(Typically at 2x to 3x the Secchi depth there isn’t enough light for rapid algae growth—During the summer, Secchi depths in Utah Lake are usually less than 1 ft. --indicating very high turbidity and limited algae growth occurring below 1 to 2 ft deep.)

Light limitation Cont.

Avg. depth of Lake is only 9 ft. Frequent waves tend to also stir up and re-suspend previously precipitated sediments giving turbid, light-limiting, algae-growth conditions most of the time.

Ans:

Overall, Utah Lake algae growth is light-limited.

This being the case then **nutrients are of no concern** and removing or adding more causes little change in algae growth.

The Current Issue!

The State Div. of Water Quality has assumed that nutrients are always a problem and we must remove them—period!

WWTP effluents contain high levels of nutrients (phosphorus and nitrogen).

But what is the impact of WWTP nutrients? –Are they always an actual problem?

That is—

Are P & N possibly limiting or be made limiting to algae growth?

In other words—will removal do any good?

To answer this question, consider:

1. What are the actual in-lake conditions?
2. What do predictive Trophic Level models indicate?

1. What is the actual in-lake trophic condition?

Carlson Trophic State Index (Utah Lake in red)

Trophic Index	Chl a (ug/l)	P (ug/l)	Secchi Disk (m)	Trophic Class
<30—40	0—2.6	0—12	>8—4	Oligotrophic
40—50	2.6—20	12—24	4—2	Mesotrophic
50—70	**20—60**	**25—100**	2—0.5	**Eutrophic**
70—100+	56—155+	96—384+	**0.5—<0.25**	**Hyper-eutrophic**

The hyper-eutrophic level from Secchi Disk readings is a false indicator here since it's mainly due to mineral turbidity—not biological turbidity.

Conclusion:

- Based on in-lake observations/samples:

The actual biological status of Utah Lake is moderately eutrophic

2. What do the trophic state models predict?

Larsen-Mercier Trophic State Model

(developed by EPA scientists—improvement on the original Vollenweider Model.)

Model data:

- annual average concentration of phosphorus in inflowing waters.
- lake water residence time and depth in the lake.

Predicts the expected lake trophic level

--but only if phosphorus is the controlling/limiting factor in the lake!

Table 3. Nutrient Loadings to Utah Lake by water year, 2009 – 2013 (w/o Atmos. D.)

Water Year	Phos. tons/yr	SRP tons/yr	Nitrogen tons/yr
2009	277	232	2235
2010	257	219	1813
2011	327	267	2872
2012	247	211	1812
2013	252	216	1816
Average	**272**	**229**	**2145**

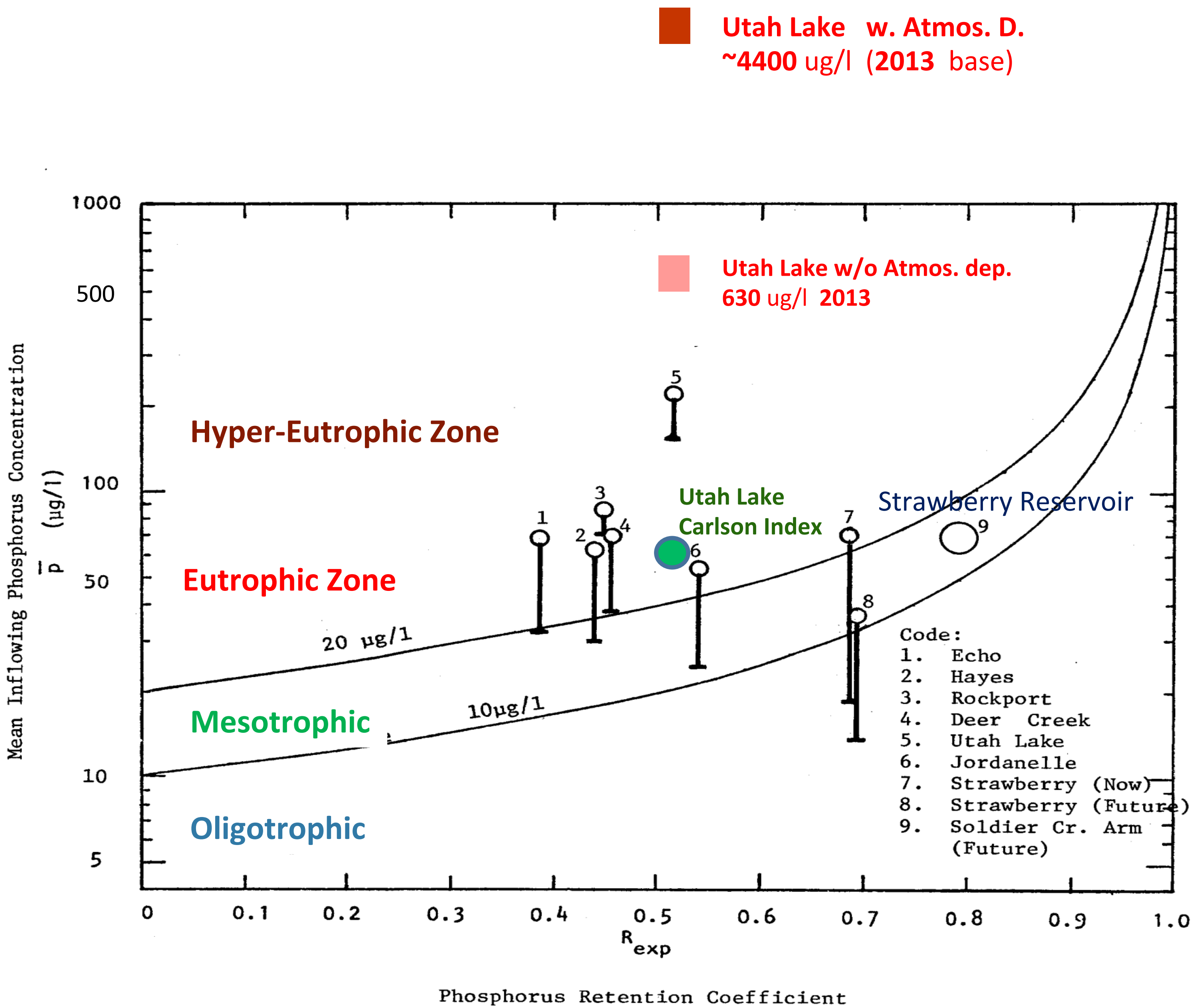
Momentous current information—

Atmospheric Deposition Research (Ongoing research study at BYU)

Findings:

Atmospheric Deposition (rain, snow, "dust" particles) is huge in this area!
It appears that it completely dominates phosphorus sources for shallow ponds and lakes!

Initial estimates of Atmos. phosphorus added to Utah Lake is **1600** ton/yr!
Which is about 6 times more than all other sources, incl. the WWTPs!



Predicted Trophic State based on the Larsen-Mercier Model

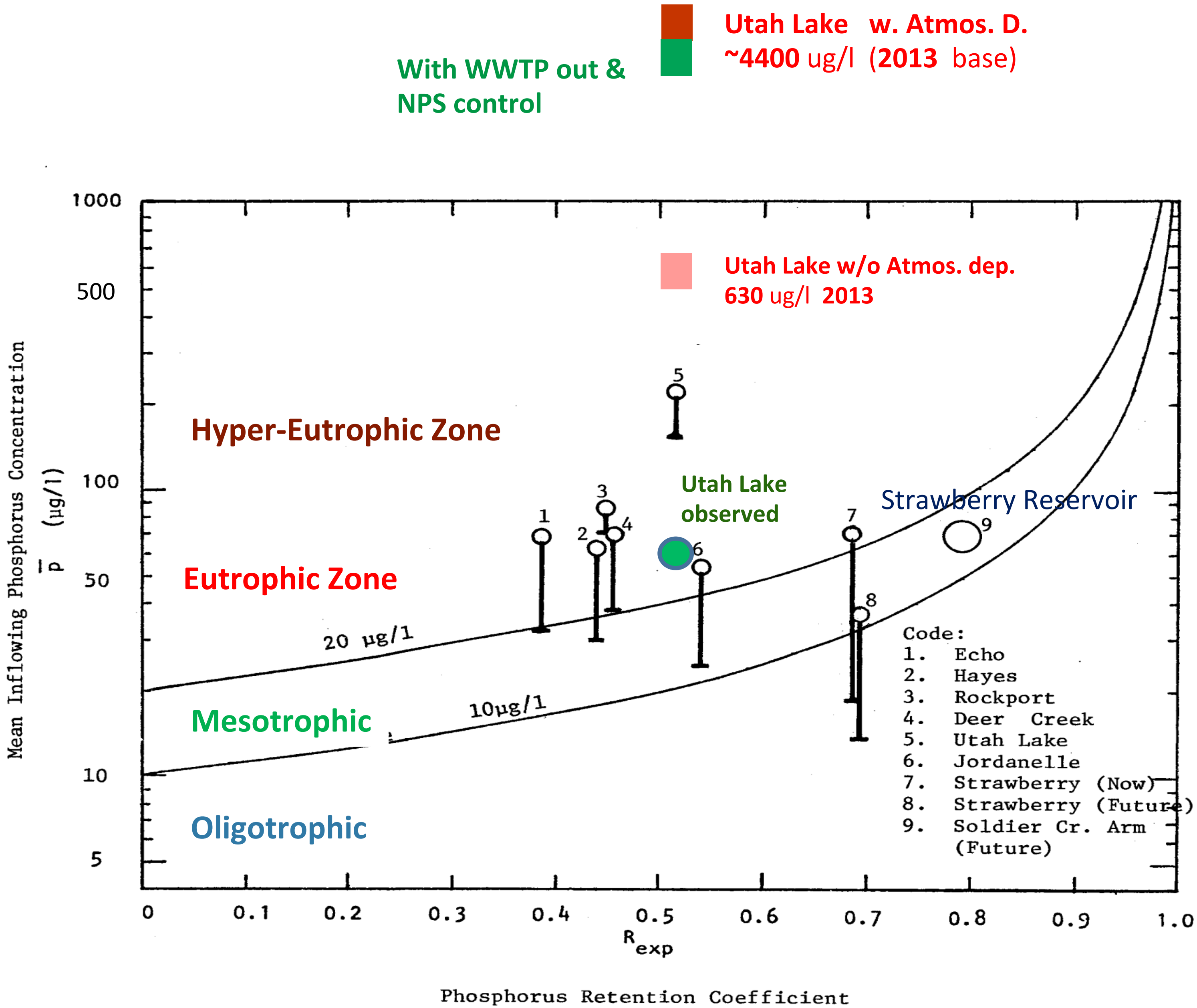
Is P limiting?

Ans: The L-M model predicts ultra,ultra, ultra. . .-hyper eutrophic level but the actual level is just eutrophic.

Therefore: Phos. Is <u>not controlling (not limiting)</u>!

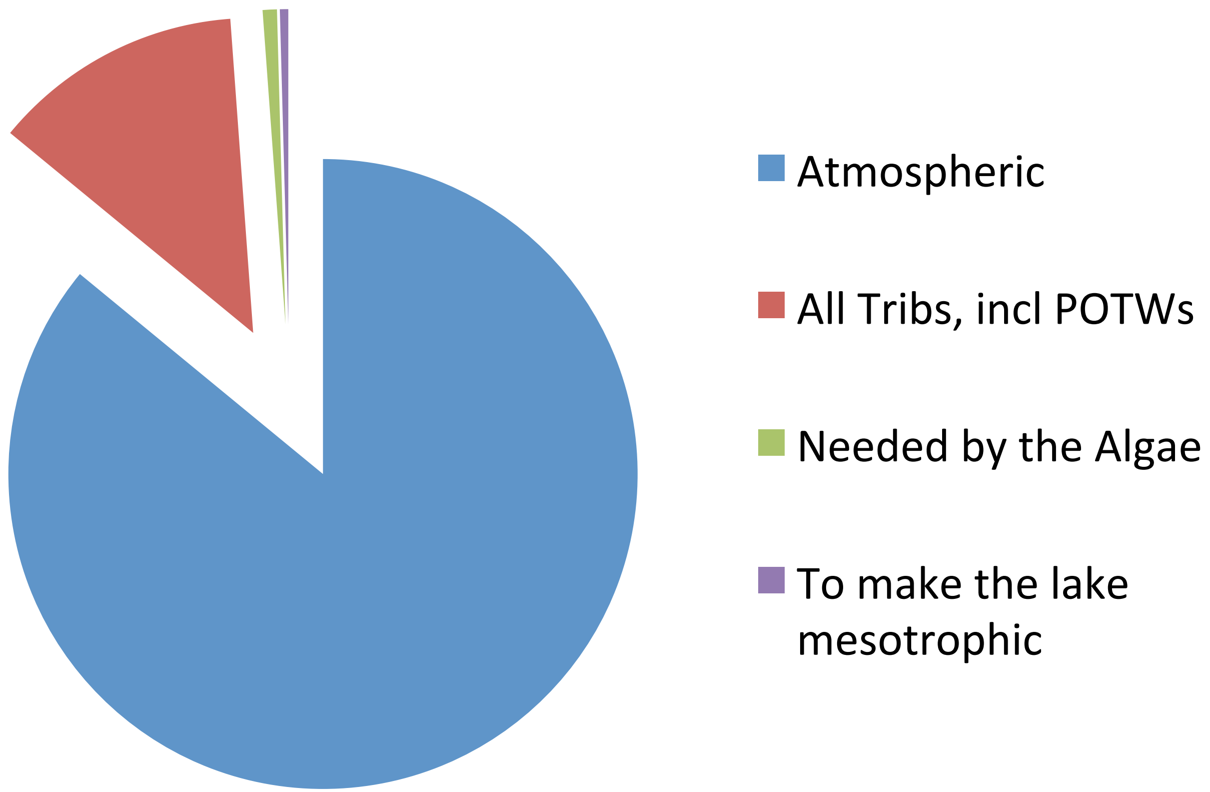
Might P be made limiting? (The DWQ has assumed it can.)
But what is possible?

- WWTPs: About 12% of the Lakes P loading from WWTPs (2013 conditions including atmos. deposition).
  - 90-95% removal at POTWs would cost perhaps $400-$600 million in construction costs and tens of millions in annual O&M costs and would likely more than double sewer fees.
- Nonpoint sources (NPS)—
  - Maybe 25% of the remaining Phos. <u>might</u> be removed with rigorous NPS controls.
  - Costs would be staggering—likely $10s of millions to get to a 25% reduction in all other phosphorus loadings to the lake.
- 4360 ug/l would go to 3850 ug/l (Approx. 12% decrease—99% is needed)



Predicted Trophic State based on the Larsen-Mercier Model

Phosphorus Loads to Utah Lake



- Obviously, It’s impossible to reduce Phos.enough to make P limiting!

Looking at the actual nutrient balance information (where is all the P going?)—

The actual phosphorus retention in the Lake is 99%.

If the Lake were a "normal" phosphorus-limited lake then P retention would be about 50%-and the Jordan River would have ~2200 ug/l rather than the ~50 ug/l found there.

But its actual retention is about 99%--this means there are some rather dramatic, extraordinary, removal mechanisms occurring in the lake:

There are: The main one is mineral precipitation (largely Marl clays) to the bottom sediments.

The "take- away": *Utah Lake is not a normal lake as to phosphorus—it has "unlimited" capacity to trap P into the bottom sediments; balance (equilibrium) with the precipitated particles (sediments) gives about 50 ug/l of P in the water--which is a moderately eutrophic level.*

(About 4400 ug/l are coming in)

The lake is doing a better job of P removal than any advanced treatment plant could ever do—and it's natural, organic and Free!

And! This also naturally helps hold the algae growth down during short term blooms—when the lake is calm for more than a day or two, Phos. is low enough that it does become temporally limiting.

Again—where is 99% of the inflowing Phos. going?

Since the Lake has:

- High pH
- High oxygen levels
- Abundant Calcium, Carbonate, Silica and Phosphorus.

Ans—To the sediments via mineral precipitation.

and

Precipitation of Marl & other minerals reduces available soluble phosphorus to relatively low levels—typically 40 to 60 ug/l—regardless of how much is entering the lake!

But even then Phos. is not limiting algae growth most of the time,

that is, even these values would make the lake more eutrophic most of the time than it actually is—if it weren't for Light limitation due to the lakes natural mineral turbidity!

Summary:

1. Light-limitation limits algae in Utah Lake to an overall natural, moderately eutrophic condition.

2. Phos. loading to the lake is about100 times larger than needed to support its natural eutrophic level and can never be made limiting to overall algae growth.

3. Nitrogen loading is also many 10's of times larger than a eutrophic level and can not be made limiting to overall algae growth.

4. It is essentially certain that removal of even all of the phosphorus coming from WWTPs plus 25% of remaining 'surface" loads would not significantly lower the lakes natural eutrophic algal-growth level. I.e., Each year enough P for about 100 years is going to the bottom sediments

5. Phos. in the Jordan River is quite low (about 50-60 ug/l) and largely the result of chemical equilibria in the Lake. It can not feasibility be lowered and is not determined by the amount of phosphorus coming into the lake.

Conclusion:

It is essentially certain that Utah Lake would be the same quality as now, even if every nutrient source were reduced to the highest degree possible—costing many hundreds of millions of dollars.

We would simply be paying a gigantic price to remove only a very small part of the phosphorus that is now removed free by mother nature!

Postscript:

Similar scenarios exist for most of the valley-basin waters of Utah.

It's very unlikely that a significant improvement in receiving water quality would result from nutrient removal at most of Utah's Wastewater Treatment Plants.

Since:

The receiving waters are naturally nutrient-rich and overall algae growth is largely determined by factors other than nutrients!

Do we want to spend well over a billion dollars in an experiment to see if nutrient removal at WWTPs will change the amount of algae that grows in the receiving waters? My research and long experience say it would be a gigantic waste!


Thank You for the opportunity!