Atmospheric Nutrient Deposition to Utah Lake:

Technical Support Evaluation

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The initial information brochure: *Atmospheric Nutrient Deposition to Utah Lake: What is it and is it Significant?* briefly discussed the importance of atmospheric deposition (AD) to the nutrient budget of Utah Lake. The impetus behind this program lies in the growing public awareness of the occasional harmful algal blooms which has led to frequent closing of beaches, marinas, and occasionally open water of the lake to recreational use. Typical EPA and Utah Division of Water Quality (DWQ) response to such blooms is to mandate nutrient reduction in permitted wastewater discharges and most early nutrient budgets developed during the Total Maxim Daily Load (TMDL) process were so simplified that they focused on identifying and regulating these measurable inputs through the NPDES process. Secondarily, nonpoint source runoff such as stormwater runoff from urban landscapes and irrigation return flows and overland runoff from agricultural lands were often identified and estimated, although there is currently no regulatory mechanism to force municipalities and farmers to reduce nutrients in these uncontrolled releases.

Origin of the Program

Observations of the immense dust storms that often accompany thunderstorms prompted the hypothesis that these nutrient-rich playa dusts could add substantial amounts of nutrients to Utah Lake and Great Salt Lake as they passed over these waterbodies. The scientific literature describes how arid regions receive much more dry deposition than wet (rain/snowstorm) deposition.

We designed samplers to capture and isolate each type of deposition, dry and wet. Furthermore, scientific literature described how wet surfaces are “stickier” to airborne particles than dry surfaces – where falling dust could simply become re-mobilized with ensuing winds. We constructed AD samplers following the National Atmospheric Deposition Program (NADP) schematic drawings of AD wet/dry measuring devices. The “dry side” sampling buckets were supplied with 3 liters of distilled water to emulate the lake surface. Samples from the first year (2016) resulted in an estimated 350 tons of total phosphorus and 950 tons of total nitrogen fell on Utah Lake in 2016. These values were about three times the current estimates of nutrient loading from all the POTWs discharging to Utah Lake combined. Moreover, based on measurements presented in units of grams per square meter, these estimates were several times higher than estimates made from NADP samplers placed throughout the intermountain west.

Utah DWQ asked Dr. Janice Brahney, a USU assistant professor to provide an estimate of AD using data from regional NADP sampling stations. Unfortunately, the nearest NADP samplers were 100 to 200 miles to the east and northeast of Utah Lake, near the Colorado border and the eastern end of the Uinta Mountains, surrounded by forests and at elevations higher than 6000 ft. Selecting these remote and elevated sites was by design by the NADP as their goal is to measure regional distribution and deposition of long-range airborne particles. Nevertheless, the Utah Lake Science Panel chose the NADP regional data to make estimates of what was falling on Utah Lake with no regard to the more local sources of thousands of square miles of playa and agriculture immediately south and southwest of UL. AD numbers provided by Brahney are in the table below. The estimates by Brahney have been disputed in each of our four peer-reviewed scientific journal articles based on local deposition sampling.

Another point of debate was the method to estimate the attenuation of dust as it is blown across the lake. The closest lake which has received substantial AD studies is Lake Tahoe, a lake about 1.5 times larger than Utah Lake and more than 2000 feet higher in elevation. Nevertheless, these studies warrant a comparison. The first study measured dust mobilized by passing traffic on a gravel road adjacent to the southern shoreline. Using an air sampler carried in a boat, the authors reported that 90% of these large dust particles settled on the lake within 200 meters from the shoreline and so the SP extrapolated this value to represent urban dust. The second study performed over several years established sites on the western and southern shores as well as a sampler mounted on a buoy anchored 20 kilometers (12 miles) from the western shore and in the middle of Lake Tahoe. Notably, even after being transported 12 miles, the nutrients in buoy samples only declined by about 10% of values sampled on the western shoreline. While we certainly acknowledge that the buoy samples were dominated by lighter particles than road dust, there is no doubt that significant amounts of medium to small-sized airborne particles can travel much farther than 200 meters. Notably, the continued slow march to eutrophication of Lake Tahoe has been attributed to atmospheric nutrient deposition sourced from California's central valley and the Mohave Desert to the south. Yet, the majority of the science panel members voted to use the data from the road dust assuming that 90 percent of urban dust settled within 200 meters – leaving about 95% of the Utah Lake surface estimated to receive only regional dust as measured from locations 100 to 200 miles away and 2000 feet higher in elevation than UL. Moreover, the SP chose to ignore the surface water contact of particles contained in the frequent winter inversions. The SP decision was highly disputed by Council researchers and BYU professors verbally and in written rebuttal, to no avail.

Subsequently, Council and BYU researchers installed a sampler near the middle of Utah Lake at Bird Island (see map below). It was located about 5 miles from the western shore and 3.5 miles from the mouth of Provo Bay. With about 40 samples collected at Bird Island, measurement values at BI were not statistically different from the shoreline sites (See map and figure below). We concluded that such similar values were explained by the majority of particle sizes were moderate to small (between 2.5- and 10-microns diameter) and thus experienced negligible attenuation or settling as they were transported across the lake (See Review comments" below).

This is similar to the results obtained in the second Lake Tahoe study. As with the second Lake Tahoe study, a sampler was installed at Bird Island near the center of the lake with the goal of measuring attenuation of particles carried over the lake by wind as well as the deposition of aerosols that hover over the lake during inversions (see photo in Informational Brochure). This

Map showing sample locations used to measure AD for Utah Lake.

direct contact of dust on the lake surface is retained because of the natural “stickiness” of water. The table below identifies and compares each type of deposition as well as reporting total annual deposition.

A number of sweat bees (Family Halictidae) were found in our sampler located at Mosida. Although these were removed prior to analysis, members of the SP complained that significant amounts of nutrients leach from the bodies or other debris into the sample. While it was debated by the non-entomologists whether this was true, these bees reach the lake and may be a natural contribution to the nutrient budget.

Nevertheless, Council researchers agreed to install nylon-meshed screens above the water in the dry-side buckets to prevent bees and other debris from entering the sample. However, this introduced an additional large problem. As noted in the scientific literature, the electrostatic attraction between the nylon screens and the negatively charged dust particles attracted dust particles to the screen. To quantify this, side by side comparisons with samplers built using the latest NADP design (without screens) demonstrated that the nylon screens removed an average of 50% of all dust/nutrient particles even without the presence of any insects or debris.

All 2020 data reported in the figure below is from screened samplers – and hence is the reason 2020 data is generally much lower than for earlier years.

When asked about this deviation from NADP protocol, the director of NADP, Dr. David Gay said this is not standard NADP protocol. Rather, any debris in NADP samples is removed before analysis and the presence of such debris is simply noted in the metadata. This leaves the decision whether to include that particular sample datum up to the end user of the data.

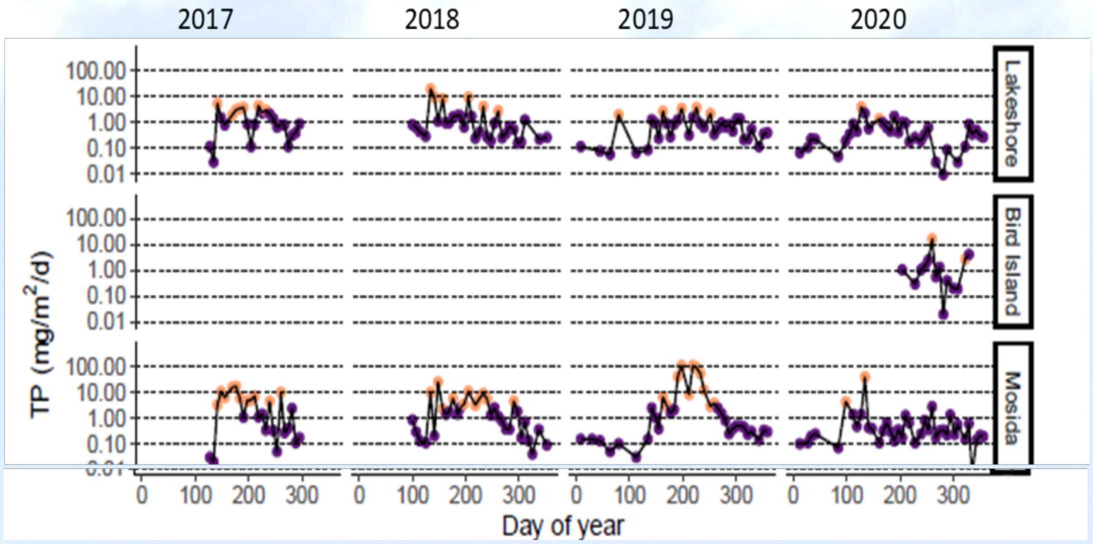

Figure showing individual data points from four years and from three sampling locations developed by Division of Water Quality's consultant to the Science Panel. Orange dots represent outliers, designated as exceeding the 75th quartile. This resulted in removal of 5 to 35% of data values before median values were calculated. Note that similar removal of low-end outliers was not performed – biasing the results to the low side. This is further discussed below.

After culling out the high – end outliers, the SP also chose to ignore (exclude) the Bird Island data and with no scientific explanation. It was simply that they had expected a strong attenuation signal that would corroborate the road dust attenuation in Lake Tahoe and subsequent use of the NADP regional data to apply to the entire interior of Utah Lake. This is the process used by the SP to reach the 32 tons of P and 153 tons of N deposition to Utah Lake in the table of estimates below.

Table of estimates between methods or types of deposition measurements for phosphorus and nitrogen deposition on Utah Lake. Table entries that include a range of data are the result of analyzing numerous data sets over several years. In addition to seasonal or annual variability, the low range reported by Barrus includes data from screened samples (See text above).

Study	Process	Amount		Notes	No. of Samples
		(TP tons/yr)	(TIN tons/yr)		
Brahney	Dry dust	2 – 9	40 - 75	Includes some minimal contact	Varies
Brahney	Precipitation	5	113 - 213	Includes some minimal contact	Varies
Carling	Dry dust	55		Include some minimal contact	4
Miller	Precipitation	88 – 142	163 - 481	Includes some minimal dust and contact	850
Barrus	contact, dry dust, precipitation	133 - 262	482 - 1052	The lower value is from screened samples	306
Science Panel	Removing high end outliers and invoke 90% attenuation within 200 m from shoreline	32	153	Excludes all data from Bird Island	

The similarity of results between Bird Island and the shoreline sites was yet questioned by the Science Panel and they proposed a hypothesis that the BI sample must be contaminated in some way by the birds. We explained that observations of potential contamination by fecal material were made during each sampling, visit with no such evidence ever documented. Yet the SP voted to eliminate the entire BI data set from the analysis. By omitting the BI data, the SP continued to calculate that 90% of local AD settles within 200 m of the Utah Lake shoreline.

In an effort to resolve these disagreements, the Council sought review and comments by Dr. David Gay, Director of the NADP, of the Science Panel's "Utah Lake Water quality Study: Atmospheric Deposition Decision Document" direct quotes from Dr. Gay's review of this and other important issues follow.

1. Dr. Gay's comment on <u>attenuation:</u> I generally agree that attenuation would be expected, particularly for large particulates (and mostly TP). But small particulates could move very far from the original source and easily across the lake. Again, this is probably more important for N. However, gases and small particles can easily move out into a lake with minimal attenuation. I realize that some of these graphs have logarithmic axis, but it seems clear to me that the Bird Island data is going up and down relatively consistently with the other sites, reflecting a real depositional signal.

2. <u>Bird Island observations</u>: "I agree that contamination of samples is a possibility, as the committee notes. However, I am not sure if I would remove all these samples, since we don't know what caused the high values. I don't know if I have a better explanation, but I don't think I would dismiss them out of hand. Looking at the distribution of Bird Island data, they don't look out of line to me, at least in the earlier years. They are high for the individual year, but middle of the road versus other years. Was there evidence of bird feces in the samples, and on the sampler? Council scientists responded: *During each weekly sampling event, the sampling tabletop, buckets and screens were carefully examined for*

potential contamination by birds (feathers, feces, etc.) and sample contents were inspected for cloudiness or clumps of feces on the screen. No evidence of contamination was ever apparent. As confirmation, triplicate fresh samples of California gull droppings were collected from a Utah Lake beach and analyzed for total phosphorus and nitrogen in a certified analytical laboratory. Results indicated that if even one fecal dropping fell into the bucket, the sample would be cloudy, and both the N and P concentrations would be approximately 4X greater than the highest sample value ever collected from any sample sight throughout the history of this program. Therefore, there is no reason to remove the Bird Island sample set.

This information did not change the voting of the SP.

3. Dr. Gays comments on bees: The Science Panel document states: "They significantly raise the amount of nutrients…samples." How do we know this? Again, as I mentioned before, filtering out the bees is the correct way to analyze the sample. I can easily understand that bee bodies soaking in water might pick up ions from the sample and bias the concentrations low, but I don't think we know one way or the other.

   From my reading, it seems that all the samples with insects were considered outliers and removed from the analysis, the assumption is that N was leached from the insect and artificially increased the TN of the sample. My simple question is, do we know this? I don't think that we do. I am certainly no biologist, but N moving out from the insect is certainly a possibility. But it also seems reasonable to me that N could move into the insect and lower the liquid concentration. It also strikes me that the highest deposition rates (wet and dry) would be in the summertime. This is also the approximate time of maximum insect numbers in and around the lake (spring and summer). Therefore, by removing all of these observations, you could be removing all of the high deposition events from the analysis, which is problematic. I do think that insects should be considered, potentially, as a significant contribution (or removal) from the lake. I also do not agree that they should be necessarily considered contamination with removal from the sample. I would suggest an addition to the study, to add appropriate insects to known concentrations and allowing them to sit for a while, and evaluate the change in DIN and TP.

This experiment is currently being developed.

4. Dr. Gays comments on the Graphs: Per the discussion, everything above 15 mg/m^2 day would be considered an outlier, and I count at least 20 very large events that would be above this value. I agree that the concern for contamination is real, but they are found at approximately the same time each year (day 180 to day 230), or summer time. This is when I would expect very dry soils, and relatively high TP dust events.

   I would argue that 75th percentile is too low to automatically remove data. For auto removal, I would argue for at least 90th or even 95th percentile. For the low "outliers", I don't understand this idea, that if you look at the entire range of concentrations or fluxes (not sure which you used), everything below the 25th percentile is negative? So, no outliers are removed? This strikes me as odd; how can you have negative concentrations or fluxes? It also seems that if you automatically remove outliers on the high end, but nothing on the bottom end. Aren't you biasing your results towards the low end of concentrations/fluxes? On the idea that there are no outliers on the lower end, the box and whisker plots define the lower 25th percentile. They all appear to be about 0.3 mg/m2 day, and not negative as mentioned previously. Also, the observations at Saratoga Springs seem to be the most obviously different sample set, and this is on the low end. Were these removed from the analysis to balance the removal of the high-end "outliers"? At least roughly, the outliers are consistent with other samplers and the same general days as with the TP. I am not claiming that all these samples are valid, but it strikes me that many of them could be valid, but just very high, and I don't know if they can just be thrown out due to being above the top 75th percentile. I think, to be a little more statistically consistent, if you are going to throw out the highest 25% of values, then you should throw out the low values too (25%), with the idea you are going to focus on the middle 50% of observations (as being the best measurements)

5. Dr. Gays Comments on Method Discussion: Was the model based on only the non-contaminated measurements? I would assume so, but this builds the model with many of the high values removed and is biased towards lower depositions. I disagree with this decision, as stated previously. The modeling approach should use a range of N and P deposition values. For example, the modeling should use (1) a most probable value of N and P deposition, (2) an estimate of the lowest possible AD, and (3) an estimate of high value of AD for the lake. I am sure that the committee (and many others) would like to have one answer that will be used in all decisions, but it strikes me that the variability about the AD estimates is still rather large to condense it down to X tons of nitrogen and Y tons of phosphorus. Therefore, I would recommend this type of bracketing approach to the modeling, which would give a range of values (making decisions more difficult, I agree), but it would also show the range of potential AD that is still unknown to a specific amount.

Conclusion

Based on the analysis and careful review of all data sets and the accumulation of consistent peer-reviewed (published) papers and the review by one of the country's top AD expert, we believe that the Barrus dataset represents the most accurate estimates of atmospheric deposition.