Utah Lake Water Quality Study (ULWQS)
Science Panel
June 16, 12:00 PM to 3:00 PM
Virtual Meeting
Meeting Summary - FINAL

ATTENDANCE:
Science Panel Members: Janice Brahney, Mike Brett, Greg Carling, Mitch Hogsett, James Martin, Theron Miller, Hans Paerl

Steering Committee Members and Alternates: Scott Bird, Eric Ellis, Heidi Hoven, Chris Keleher, Rich Mickelsen, Jay Olsen

Members of the Public: Jeff DenBleyker, Renn Lambert, LaVere Merritt, Dan Potts, David Richards, Gus Williams

Utah Division of Water Quality (DWQ) staff: Scott Daly, John Mackey, Chris Otto, and Ashley Sumner

Technical Consultants: Rene Camacho, Kevin Kratt, and Mike Paul

Facilitation Team: Heather Bergman

ACTION ITEMS

Who	Action Item	Due Date	Date Completed
Theron Miller and Gus Williams	Share the Bird Island atmospheric deposition data.	July 8	
	Separate the atmospheric deposition data by wet and dry samples to examine the relationship between outlier data and meteorological events.	July 15	
Theron Miller, Gus Williams, Mitch Hogsett, and Scott Daly	Identify the median total phosphorus flux with the new Bird Island data incorporated.	July 15	
Theron Miller, Gus Williams, and Mitch Hogsett	Develop a memo with a written recommendation for phosphorus fluxes from atmospheric deposition.	July 15	
Theron Miller	Check if the USGS has sediment accumulation rate data for Utah Lake.	July 15	
Mike Brett	Continue to refine his mass balance analysis based on new data.	July 15	

DECISIONS AND APPROVALS
No formal decision or approvals were made at this meeting.

GROUND RULES AND PROCESS COMMITMENTS OVERVIEW
Heather Bergman, Peak Facilitation Group, gave an overview of the Science Panel ground rules and process commitments. The ground rules and process commitments of the Science Panel are listed below.

- The Science Panel process commitments are:
  - Seek to learn and understand each other's perspective
  - Encourage respectful, candid, and constructive discussions
  - Seek to resolve differences and reach consensus
  - As appropriate, discuss topics together rather than in isolation
  - Make every effort to avoid surprises
- The Science Panel ground rules are:
  - Focus on the task at hand
  - Have one person speaking at a time
  - Allow for a balance of speaking time by providing succinct statements and questions
  - Listen with respect

MODELING NEEDS OVERVIEW
James Martin, Mississippi State University, and Rene Camacho, Tetra Tech, provided an overview of what information the modeling team needs to incorporate atmospheric deposition into the Utah Lake model. Their comments are summarized below.

- The model requires a numeric input for nitrogen and phosphorus atmospheric deposition.
- The model can incorporate atmospheric deposition based on an average daily mass (wet and dry combined) or seasonal deposition based on an observed time series. The Science Panel will need to decide how they want to address time when incorporating atmospheric deposition into the model.
- The modeling team will need to specify the forms of nitrogen and phosphorus being deposited into the lake. The model can incorporate organic deposition flux for nitrogen and phosphorus. Regarding inorganic forms, the model can incorporate orthophosphates, ammonia, and nitrate fluxes.
- The suggested approach from the modeling team is for the Science Panel to recommend an average condition with an expression of variance. The variance can then be evaluated through uncertainty and sensitivity analyses.

MASS BALANCE ANALYSIS OVERVIEW
Mike Brett, University of Washington, shared the results from the mass balance calculations on Utah Lake. His comments are summarized below.

Mass Balance Overview & Methodology

- Over the past month, Mike Brett has been working on directly estimating phosphorus accumulation in the sediments to help constrain the mass balance. Constraining the mass balance can help create a plausible range for uncertain parameters, such as atmospheric deposition.
- The basic mass balance equation is that the sum of all phosphorus inputs is equal to the phosphorus outputs (e.g., outflow) plus the loss of the phosphorus in the lake itself (e.g., sediment sequestration). The mass balance analysis accounts for internal loading because it incorporates the net loss of phosphorus in the lake, which is the difference between the phosphorus lost to the sediment and the phosphorus that the sediment releases.
- The phosphorus concentration coming into Utah Lake is very high. The mass balance analysis accounts for evaporation, which increases the phosphorus concentration input by a

magnitude of two or three. Internal loading occurs in Utah Lake. Compared to input concentrations, the internal loading is muted.

- Mike Brett estimated the phosphorus concentration input from internal loading. On average, during August, the total phosphorus concentrations increase by about 24 micrograms/liter above baseline. This result is equivalent to about 30 tonnes of phosphorus/year of internal loading. Sometimes the internal loading does not occur in August; sometimes, it occurs in July, sometimes in September. The estimate of internal loading is about 50% larger, taking into account variability in the timing. These results are based on an analysis that Mike Brett conducted using ten years of data on surface water concentrations.
- Limnology literature suggests that phytoplankton biomass in a system is a function of the nutrient concentrations in the water. In the case of phosphorus, the mass balance says that nutrients are either in the water column or the sediments at any given time. Due to stoichiometric constraints, only the phosphorus in the water column contributes to phytoplankton biomass.
- Mike Brett has been working to directly estimate the term that describes how much phosphorus in Utah Lake is lost to the sediments. Calculating phosphorus accumulation rates in the sediments allows researchers to constrain other mass balance parameters where there is less certainty.
- The sediment phosphorus accrual value is equal to the net sedimentation accumulation multiplied by the sediment dry mass conversion multiplied by the sediments' phosphorus content multiplied by the lake's surface area. This equation will indicate the net load of phosphorus getting trapped in the sediments.
- The sum of the nutrient input from the watershed, the nutrient input from the wastewater treatment plants (WWTPs), and the atmospheric deposition equals the nutrient outflow plus sediment phosphorus accrual.
- Regarding the nutrient coming from the WWTPs, Tetra Tech accounted for attenuation between the release of effluent and the point the effluent reaches the lake in the mass balance analysis. Mike Brett calculated that the attenuation of the nutrients released by WWTPs is about 16%.
- There is good data on the watershed inputs, WWTP inputs, and outflow. There is uncertainty around the atmospheric deposition value, and the Science Panel has not yet tried to estimate the sediment phosphorus accumulation.
- Assuming watershed phosphorus inputs, WWTP phosphorus inputs, and lake phosphorus outputs are consistent, the amount of atmospheric deposition phosphorus inputs will be directly related to the sediment phosphorus accumulation values. Due to this relationship, estimating sediment phosphorus accumulation will help Science Panel members constrain the atmospheric deposition inputs.

Preliminary Estimates of Sediment Phosphorus Accumulation in Utah Lake

- The sediment phosphorus accumulation estimate is preliminary. Some parameters to calculate the sediment phosphorus accumulation do not have a lot of data, particularly the annual sedimentation rate. There is a good amount of data on the sediment dry weight conversion, but it would be helpful to include all the available data.
- The preliminary estimate of sediment phosphorus accumulation in Utah Lake is 226 tonnes of phosphorus each year.
- Mike Brett has calculated uncertainty for this estimate using standard deviation, but it would be helpful to have input from the Science Panel on the best way to calculate uncertainty.

- If the sediment phosphorus accumulation is 226 tonnes of phosphorus each year, the preliminary estimate is that the phosphorus input from atmospheric deposition is about 60 tonnes/year.
- Utah Lake nutrient concentrations are well resolved. Therefore, the atmospheric deposition contribution is already incorporated into the lake concentration.
- If the atmospheric deposition rate is low, the sediment phosphorus accumulation would be around 170 tonnes of phosphorus each year. If the atmospheric deposition rate is very high (e.g., 500 tonnes of phosphorus each year), the sediment phosphorus accumulation would be linearly higher at 570 tonnes of phosphorus each year.

Next Steps for the Analysis

- The next steps for the analysis are gathering all the available Utah Lake data on annual sedimentation rate and the sediment dry weight conversion and adding it to the mass balance.
- Another next step is to calculate uncertainty for the sediment phosphorus accumulation rate. Science Panel members should weigh in on the best approach for calculating uncertainty.

Clarifying Questions

Science Panel members asked clarifying questions about the mass balance analysis. Their questions are indicated below in italics, with the corresponding responses in plain text.

Was core data used to calculate sediment accumulation?
Yes.

How does the mass balance analysis account for sediment resuspension?
By looking at the deeper layers of the core over a long period (e.g., 20 years), investigators can estimate the net effect of phosphorus accumulating in the sediment. The mass balance analysis does not produce a value for the absolute phosphorus accumulated; it produces the net difference between what is sequestered and what is released.

What is the timescale for measuring sedimentation accumulation rates in the core?
Sediment experts may be able to better identify the appropriate timescale to measure sediment accumulation in core samples. Measuring sediment accumulation too close to the top of a core may produce a result that does not fully account for the net impact. Measuring sediment accumulation too deep in a core may produce results that may not reflect contemporary conditions.

How deep did the sediment columns collected in the Randall study (2019) go?
The cores from the Randall study (2019) were from the top 10 centimeters.

How much data is available for sediment accumulation rate?

- Mitch Hogsett has sediment phosphorus concentration data for the top five centimeters.
- The University of Utah has a dated core that was not published. Several Paleolimnology Studies on Utah Lake may have information on the estimated sediment accumulation rate.
- Brahney has dry density data for every sample collected for their Paleolimnology Studies.
- The US Geological Survey (USGS) has data in its records. Theron Miller will check to see if they have sediment accumulation rate data.
- Steve Nelson has dated cores from Richard Williams' thesis.

Can the cores from the ongoing Paleolimnology Study be used to measure the sediment phosphorus accumulation rate?
The sediment phosphorus accumulation rate in the mass balance is from the Randall (2019) study. The ULWQS Paleolimnology Study has similar sediment phosphorus concentration values as the Randall (2019) study.

Science Panel Discussion
Science Panel members discussed the mass balance analysis. Their comments are organized by themes and summarized below.

Discussion Topic - Cyanobacteria and Internal Nutrient Cycling

- The internal loading rates in Utah Lake might be higher if they were being measured closer to the sediments and away from the photic zone. Phosphorus-iron decoupling occurs in shallow zones of anoxia or hypoxia. The sediment phosphorus recycling in the photic zone is a fraction of what is seen in the hypolimnion. Cyanobacteria can regulate their buoyancy. At night, cyanobacteria can descend, absorb the nutrients near the sediment, and return to the photic zone.
- If the cyanobacteria take up phosphorus in the deeper part of the lakes and migrate back to the surface, that phosphorus uptake will be accounted for in the total phosphorus concentration. The total phosphorus concertation in Utah Lake is well resolved.
- Unlike other lakes, Utah Lake is not stratified, so cyanobacteria do not need to break through a thermocline. The data indicates that the spike in phosphorus is related to an increase in volatile suspended solids. Overall, the phosphorus spike in Utah Lake is more related to an increase in fixed suspended solids, which suggests a relationship between sediment resuspension and nutrient availability.
- Mitch Hogsett has worked on an internal nutrient cycling biological mass balance based on volatile suspended solids. This analysis accounts for the volume and surface elevation of the lake at each sampling. This analysis shows the internal cycling to be 500 to 1,500 tons of phosphorus at any given point in the year, with increases occurring in the summer. The Science Panel will discuss internal cycling at a future meeting.
- The model must incorporate the spatial and temporal variability of internal nutrient fluxes and cycles. The goal is to discuss internal nutrient fluxes and cycles by the end of the summer/early fall.

Discussion Topic - Tributary Loading and Aligning Data across Time

- The loading from the tributaries and WWTPs is based on data going up to 2019 or 2020. WWTPs are continuing to upgrade their facilities over the next few years. Recent data indicates that the loading from WWTPs is closer to 60 or 70 tonnes of phosphorus each year, down from the estimated 120 tonnes of phosphorus each year.
- One goal of the mass balance equation is to identify the tendency of phosphorus to partition into the water column or sediments. The only way to quantitatively achieve this goal is to have a dataset for a defined period where inputs and outputs are well resolved. At least 90% of the phosphorus going into Utah Lake is sequestered in the sediments. The partitioning value of phosphorus entering Utah Lake between the sediments and water column is important to understand how sensitive Utah Lake is to reductions in external loading and the timeframe for response to external loading. For these mass balance calculations, there needs to be a defined period for the data.

- The mass balance framework should consider the average nutrient inputs and outputs during the same period as the sediment phosphorus content data. The period should be 10 to 15 years.
- Only the phosphorus content of the sediment is dependent on phosphorus loading. The Science Panel should consider how close to the surface layer of the cores they are aggregating the data when assessing sediment phosphorus content.

Discussion Topic – Sediment Deposition in Different Lakes

- Researchers have recorded sediment deposition rates in the Great Salt Lake of four to five millimeters annually. The Science Panel should be cautious with a sediment deposition rate of 2.7 millimeters/year as it may be higher.
- The sedimentation in Utah Lake is chemically derived. The sedimentation comes from total dissolved solids (TDS) accumulating and precipitating as calcium carbonate. The sediment in Utah Lake is 60 to 70% calcium carbonate. The sedimentation occurring in the Great Salt Lake, which is much saltier, is chemically derived as well. These different conditions make it difficult to compare the Great Salt Lake sedimentation rate to Utah Lake's sedimentation rate.
- The sedimentation in the north arm of the Great Salt Lake is primarily chemically derived. The sedimentation occurring in the south arm of the Great Salt Lake is only about 50% chemically derived. The sedimentation rate occurring in the south arm of the Great Salt Lake is indicative of the local dust and tributary sediment input.

ANALYSIS OF CONSTRAINING PHOSPHORUS FROM ATMOSPHERIC DEPOSITION BASED ON DUST DEPOSITION, SEDIMENT ACCUMULATION, MASS BALANCE, AND BOOTSTRAP MODELS

Science Panel members discussed the analysis of constraining phosphorus from atmospheric deposition based on dust deposition, sediment accumulation, mass balance, and bootstrap models. Their comments are summarized below.

Discussion Topic – Local and Global Data

- The number of urban samples collected in Provo is limited. The other urban samples collected are from global sites, which may not reflect local conditions.
- The Lake Taihu basin's atmospheric deposition fluxes would result in an atmospheric deposition phosphorus loading value of 138 tons yearly if applied to Utah Lake.
- This analysis does not account for the 1,400 samples that Wasatch Front Water Quality Council (WFWQC) has collected around Utah Lake.
- The analysis considers dust deposition, which the WFWQC has not quantified. The rest of the analysis is based on the samples collected around Utah Lake.
- The analysis shows the distribution of global phosphorus deposition rates. The proposed high deposition rates for Utah Lake in the context of global rates would be extremely high.
- Utah is in the middle of the Lake Bonneville footprint, with thousands of square miles of playa surrounding it. Utah Lake is unique in these conditions.
- Local areas like Fish Springs National Wildlife Refuge do not have high sediment accumulation rates despite being in the Lake Bonneville footprint.

Discussion Topic – Nutrient Attenuation

- There are shoreline data, but there is uncertainty in how that shoreline data translates to atmospheric deposition fluxes across Utah Lake. Using a general attenuation rate over an area of the shoreline or a Kriging method will likely not produce accurate results.

- One approach to estimate atmospheric deposition fluxes across Utah Lake would be to use atmospheric models to estimate the worst-case scenario of a particular ground source of pollution adjacent to the lake. There is a simple model that can generate a worst-case scenario. Some more complex models that account for atmospheric transport are available as well. These models could produce estimates under different climatic conditions of how sources of pollution around the lake impact water quality.
- Data at Lake Tahoe indicates a 10% reduction in atmospheric deposition inputs around 20 kilometers from the shoreline. The WFWQC also collected data at Bird Island to observe attenuation rates. There has not been any indication of bird defecation in the Bird Island samples.
- WFWQC is working with a new graduate student to put out passive air filters on the lake. They are exploring options to analyze the phosphorus fractionalization of the collected samples. There are many different sources of dust (e.g., urban, playa, etc.), and these samplers will collect the dust coming onto the lake from this mix of sources.

Discussion Topic – WFWQC Raw Data and Outliers

- It would be helpful to review the data from Bird Island in the context of the other raw data.
- The WFWQC atmospheric deposition raw data includes very high outliers. There are questions on why these outliers are occurring and how much those outliers influence the overall loading estimate.
- The outliers at the different sampling sites rarely occur simultaneously. This result indicates that most high deposition events are isolated at certain places.

PUBLIC QUESTIONS AND COMMENTS

Members of the public asked clarifying questions about the atmospheric deposition discussion and provided comments on the atmospheric deposition discussion. Their comments are summarized below.

Clarifying Questions

Members of the public asked clarifying questions about the atmospheric deposition discussion. Their questions are indicated below in italics, with corresponding responses in plain text.

One member of the public boated around the west side of Bird Island. One week the lake's depth was nine feet, but a couple of weeks later, the depth at the same location was 22 feet. This change in depth seems to be due to the movement of floc. How does the floc impact Utah Lake?

- The sediment settles regardless of the floc. There are blurry areas between the sediment and water column, but researchers can still distinguish between the water and sediment. The dataset shows spikes in phosphorus when the sediment is resuspended into the water column.
- The top layer of sediment could be up to 90% water, but it is still sediment. Researchers have collected freeze cores where they freeze the top few inches of water above the sediment. The water and sediment layers remain separate in the freeze cores.
- If researchers are collecting water quality samples, they will also measure the sediment concentrations in the samples.

Public Comments

- The floc moves around the bottom of the lake. The Science Panel should account for the influence of the floc.

- David Richards is developing a mass balance food web model for Utah Lake. There is a lot of uncertainty in the mass balance food web model.
- Fish Springs National Wildlife Refuge is a healthy ecosystem that can process atmospheric deposition inputs. Utah Lake is not a healthy ecosystem and cannot process the atmospheric deposition inputs.
- The study *The Trophic Cascade in Lakes* (Carpenter and Kitchell, 1993) states that algal concentrations in lakes can differ by orders of magnitude for any given nutrient concentration level. They also studied mean zooplankton length and found that that explained some of the variability in algal concentrations. Phosphorus concentrations and chlorophyll-a may not be directly correlated; a trophic cascade top-down control may affect algal concentrations. Top-down controls in the food web have an important role in Utah Lake.

ATMOSPHERIC DEPOSITION PHOSPHORUS LOADING ESTIMATE DISCUSSION
Science Panel members discussed their approach for recommending a range of phosphorus atmospheric deposition loading values to include in the model. Their comments are summarized below.

Discussion Topic – Modeling Input Approach and Calibration

- The Science Panel should create a placeholder for a high atmospheric deposition value. Researchers continue to collect data, and this data should be accounted for within the model.
- The Science Panel should converge on a range of atmospheric deposition phosphorus loading estimates and test different scenarios using thod range in the model.
- Tetra Tech would prefer a single value to calibrate the model. After the model is calibrated, Tetra Tech could use a range of values to test different scenarios. The Science Panel should develop a potential range of values and identify a mean or median value.
- The differences between the mean and median values for the atmospheric deposition nutrient loading rates are large. The mean value is driven up by large events that result in spikes in nutrient loading.
- The Science Panel could select a single value and develop a probability density function. A probability density function would allow the Science Panel to manage uncertainty in the future.
- The mass balance analysis produced a median value of atmospheric phosphorus loading of 60 tons/year. The analysis used the full distribution of sediment phosphorus content and sediment dry weight. The analysis incorporated the standard deviation to measure uncertainty, but the standard error may be a better method for measuring uncertainty.
- If the Science Panel agrees on a baseline level, Tetra Tech can incorporate future information on spikes in nutrient loading due to wind storms or other factors.
- The in-lake model calibration is time variable at relatively small timesteps. There will be situations where the lake model does not capture some concentration due to a short-term loading event. The calibration can help identify those short-term events in the model.
- The purpose of the calibration is to balance the nutrient speciation between organic, inorganic, and other forms. Tetra Tech is not calibrating the loads.
- Tetra Tech needs separate values for orthophosphate and organic phosphorus inputs from atmospheric deposition. They cannot use total phosphorus as an input. The Science Panel will need to identify specific fluxes for nitrate, ammonia, organic nitrogen, orthophosphate, and organic phosphate for the in-lake model.

Discussion Topic – Estimating Dust Deposition Values

- The WFWQC collected 1,200 to 1,400 bulk deposition samples, which put the atmospheric deposition phosphorus loading value at around 100 tons/year. The baseline value is based on regional data. The loading estimate should be based on local data.
- The WFWQC did not measure dust deposition in the samplers. The dust deposition is the missing link to connect the phosphorus values measured in the bucket and the constraining values presented at today's meeting. One way to fill this gap is to apply a theoretical range of dust composition (% phosphorus) to each sample collected by WFWQC and compare that to the amount of dust predicted under the constraining analysis.
- Wood Miller collected the bulk samples after the rain storms, so WFWQC has measurements of the total phosphorus and soluble reactive phosphorus in milligrams per liter of water. Science Panel members could use those values to extrapolate the total mass of the dust.
- Phosphorus does not move through the atmosphere as a gas. It only moves through the atmosphere in particulate form. Any phosphorus in the wet sampler is leached from the atmosphere.

Discussion Topic – WFWQC Raw Data and Loading Outliers

- The event scale in the modeling is important. Some nutrients, like ammonium, are sensitive to events (e.g., algal bloom die-offs). The model may need to run differently, including one version that includes event outliers and another that does not.
- The Science Panel should discuss the outliers and determine what is happening with them. The median values of the WFWQC data are close to other atmospheric deposition phosphorus loading estimates. The primary question for the Science Panel is how to reconcile the outliers.
- The data shows massive peaks in nitrates, ammonium, total phosphorus, and soluble reactive phosphorus, but those events do not simultaneously occur across Utah Lake.
- The storms depositing dust do not go across Utah Lake simultaneously. Storms are often isolated in certain parts of the lakes. Wood Miller's high outliers are often after long periods between storms, as he only collected his bulk samples after storms. Aligning meteorological data with the outliers may help give insight into the impacts of storms on atmospheric deposition.
- In the data, there are times when the soluble reactive phosphorus measurement is higher than the total phosphorus measurements. These results indicate a negative value for particulate phosphorus concentrations, which is impossible.
- It would be helpful to separate the dry and wet dust samples to understand the outliers. Distinguishing the dry and wet samples can help identify the impact of meteorological events on atmospheric deposition.
- The Science Panel could calculate nitrogen to phosphorus (N:P) ratios. The N:P ratio could help the Science Panel discern whether outliers come from organic matter or dust. The atmospheric deposition of organic matter would have a certain N:P ratio, and nutrients derived from dust would have a different N:P ratio.
- The WFWQC raw data is for shoreline measurements. There will need to be some method to calculate nutrient attenuation across Utah Lake. Large particles will not travel as far. Understanding the distribution of particle sizes would help the Science Panel estimate attenuation across Utah Lake.
- The Bird Island data is intended to measure attenuation across Utah Lake. That data will help identify attenuation rates. Theron Miller and Gus Williams will share Bird the Island data to include in the DWQ box plots and time series.

- DWQ created box plots and time series plots of the WFWQC raw data. The data shows the median value across sites is fairly consistent but that there is high variability at some sites. The modelers could use the median and variability shown in the box plots to calibrate the model.
- The Science Panel has a process for assigning confidence to scientific evidence. Kateri Salk and Mike Paul, Tetra Tech, can help assign that confidence level to the evidence.

Public Comments

- It may be helpful to combine the WFWQC into monthly data. The data is also left skewed, so a mixed effect negative binomial regression or a mixed effect log transform data to back transform the data would be appropriate.

NEXT STEPS

- Theron Miller and Gus Williams will share the Bird Island atmospheric deposition data. They will also separate the WFWQC raw data into wet and dry samples to examine the relationship between outlier data and meteorological events.
- Theron Miller, Scott Daly, and Mitch Hogsett will develop new box plots and time series incorporating the Bird Island data to identify the median total phosphorus flux. They will then develop a memo with a written recommendation for atmospheric deposition phosphorus fluxes.
- Mike Brett will continue to refine his mass balance spreadsheet.
- The next Science Panel meeting will occur once the members have completed their action items.