Utah Lake Water Quality Study (ULWQS)
Science Panel
March 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, Ryan King, James Martin, Theron Miller, Michael Mills, and Hans Paerl

Steering Committee Members and Alternates: Eric Ellis, Erica Gaddis, Heidi Hoven, and Christopher Keleher

Invited Speakers: Wood Miller and Gus Williams

Members of the Public: Jon Benson, Dave Clark, Jacob Krall, Renn Lambert, Leland Myers, Scott Peters, Dan Potts, and Dave Richards

Utah Division of Water Quality (DWQ) staff: Scott Daly and Jodi Gardberg

Technical Consultants: Kateri Salk

Facilitation Team: Heather Bergman and Samuel Wallace

ACTION ITEMS

Who	Action Item	Due Date	Date Completed
Theron Miller	Add an analysis of the total nitrogen to total phosphorus ratios to the Atmospheric Deposition Research Program Summary Report.	April 6	April 8
	Update table one in the Atmospheric Deposition Research Program Summary Report to provide more context for each study's estimated values.	April 6	April 8
Scott Daly	Share the link to the comprehensive document that chronicles the Science Panel's past discussions on atmospheric deposition.	March 28	March 28

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

OVERVIEW OF THE WASATCH FRONT WATER QUALITY COUNCIL (WFWQC) ATMOSPHERIC DEPOSITION (AD) RESEARCH PROGRAM

Dr. Theron Miller, WFWQC, introduced the WFWQC AD research program and provided an overview of the underlying studies. His overview is summarized below.

- The WFWQC began 14 years ago in the Jordan River and Farmington Bay watersheds. The mission of the WFWQC was to investigate and address field data gaps on issues related to nutrients, aquatic chemistry, and ecology. The WFWQC hires and employs interns, professors, and non-governmental organizations to gather information to fill in data gaps.
- The WFWQC began conducting research on Utah Lake six years due to the one milligram/liter phosphorus criteria. At the time, there was an on and off monitoring program for phytoplankton and zooplankton, but there were data gaps. With the new nutrient criteria, there was interest in seeing the impact of nutrients on Utah Lake, including the effect of nutrients on sediment chemistry and the nutrient limitations on algal growth and the food web.
- The first WFWQC study monitored tributary flows and concentrations, including the tributaries where publicly owned treatment works (POTWs) discharge effluent. POTWs, except Timpanogos Special Service District, discharge effluent at least a half-mile upstream of Utah Lake. The study's goal was to measure what was occurring at the edge of the lake and the mouth of the tributary to evaluate the nutrient budget of Utah Lake. The ULWQS Science Panel has discussed nutrient budgets, and Scott Daly and Theron Miller field-checked some of the data to resolve data discrepancies.
- The WFWQC began measuring atmospheric deposition after field staff noticed large amounts of dust transported to the lake via wind. The WFWQC began measuring atmospheric deposition with five samplers around the lake. As the program developed, they began the bulk deposition program with Dr. Wood Miller. That study set out more dry samplers to collect dust; once there was a precipitation event, Dr. Miller would process those samples at the laboratory to measure total phosphorus, soluble reactive phosphorus, ammonium, and nitrate.
- Two years ago, the WFWQC installed two National Atmospheric Deposition Program (NADP) designed samplers. The NADP samplers have an action weigher and moisture sensor to collect wet and dry samplers. Comments from the NADP staff indicated that WFWQC represented the NADP sampler design well.

PRESENTATION ON BULK ATMOSPHERIC DEPOSITION OF NUTRIENTS TO UTAH LAKE

Dr. Wood Miller, Brigham Young University (BYU), presented the research results from the bulk atmospheric deposition program. His presentation is summarized below.

- Miller has been running the program for the past five years. He collects samples at nine locations around Utah Lake. In the past year, Miller began collecting samples at seven locations around Farmington Bay. Over the past years, he has collected 700 samples around Utah Lake and 200 samples from Farmington Bay. He takes the samples to Chemtech-Ford

Laboratories for processing. He also collects data at the BYU and Spanish Fork weather stations.

- The bulk atmospheric deposition program is not an official NADP program, but the program does follow some but not all NADP protocols. The program is a first-order approximation of bulk deposition.
- The samplers have a four-inch diameter tube with a large funnel to collect rainwater. The bulk deposition researchers collect whatever falls onto the sampler and assume the same material falls onto Utah Lake. The sampler is about seven-feet tall.
- Storms generally come from the northwest, and the day before the storm, the winds come from the southeast and bring dust.
- The nutrient map for Utah Lake based on the data from the samplers indicates it is common to see the wind depositing more nutrients on the west side of Utah Lake than on the east side.
- Dr. Miller calculated the average nutrient concentration for all nine samplers around Utah Lake using five years' data. Researchers originally analyzed concentrations less than one milligram/liter and did not incorporate concentrations above that threshold. Eventually, they set the concentration threshold at five milligrams/liter. Only twenty samples out of the 700 had a concentration greater than five milligram/liter.
- Researchers calculated daily, weekly, and monthly load rates using total lake precipitation and the average monthly surface area data. They found load rates of 70 to 80 tons/year for total phosphorus based on all the data; if they took out the samples with a concentration of more than five milligram/liter, they found load rates closer to 50 tons/year.
- Samplers at Lincoln Point and Mosida had higher total phosphorus concentrations than samplers at other locations. Additionally, phosphorus concentrations were higher in the summer than in the winter.
- Total nitrogen concentrations and loads followed similar patterns as the total phosphorus concentrations and loads.
- Over the last three years, researchers collected data on orthophosphate. The orthophosphate loads represented about half of the total phosphorus load.
- Researchers collected samples from each sampler nearly every time it stormed, beginning in 2017. They recorded total phosphorus concentrations, orthophosphate concentrations, total nitrogen concentrations, and outliers. They then used this data to generate nutrient concentration graphs over time.
- Researchers consulted with Dr. David Gay from the NAPD, and he suggested that they calculate concentrations using precipitation weighted averages. They used weekly and monthly precipitation and surface area data to weigh the concentration values. The precipitation weighted nutrient load values differed from the non-weighted nutrient load values. The precipitation weighted nutrient concentration values were higher in the spring than the non-weighted values because there was more precipitation.
- Researchers started sampling around Farmington Bay in 2021. Two of the seven samplers are on Antelope Island. There is one sampler in the North, South, and Central Davis Sewer District each, one in the Great Salt Lake Shoreline Preserve, and another near the airport.
- The average total phosphorus concentration from the Farmington Bay samplers was 0.76 milligrams/liter, including outliers. The total phosphorus concentration was 0.64 milligrams/liter, excluding outliers. There were six outliers (concentration greater than five milligrams/liter) from the Farmington Bay data.
- Researchers compared the past year's data from the Farmington Bay samplers with the past year's data from the Utah Lake samplers. The Farmington Bay total phosphorus concentrations (0.76 milligrams/liter) were less than the Utah Lake total phosphorus

concentrations (0.96 milligrams/liter). The total phosphorus load in Farmington Bay was a little less than the total phosphorus loads in Utah Lake. The orthophosphate and nitrogen concentrations were similar between Utah Lake and Farmington Bay.

- The Farmington Bay total phosphorus concentrations had a slightly positive trend over time, and the Utah Lake total phosphorus concentrations had a slightly negative trend over the past year.
- Over time, there has been an upward trend in total phosphorus concentrations in the South Davis Sewer District sampler. The Farmington Bay South Davis Sewer District sampler generally had higher total phosphorus concentrations than the other samplers around Farmington Bay. Researchers are continuing to study the reasoning for these results.

Science Panel Clarifying Questions

Science Panel members asked clarifying questions about the bulk atmospheric deposition data results. Their questions are indicated in italics below, with the corresponding responses in plain text.

Do birds perch on the samplers?

Researchers have never observed birds on the samplers nor their droppings in the sample medium.

The nutrient concentrations are expressed in milligrams/liter. What is the liter representing in this case? A liter of rainwater?

The samplers collect the rainwater into a tube. Dr. Wood Miller pours the water into a bottle and takes it to the lab. The la technicians then calculate the concentrations values based on the amount of water in the samples. It is "per liter" of the rainwater collected in the sampler.

How does the sampling account for dry fallout?

The rain washes whatever deposition lands on the sampler's funnel into the tube. The sampler collects bulk atmospheric deposition.

How often does the research collect samples from the samplers?

The research team collects samples anytime it storms. They are not collecting samples unless it storms.

Are there any data results on how much of the total phosphorus is in the non-soluble reactive fraction?

The assumption is that the orthophosphate measurements closely resemble the total soluble reactive phosphorus. The lab technicians find that the orthophosphate concentrations are about half of the total phosphorus concentration.

What composes the non-soluble fraction? Is it dust, apatite, particulate organic matter kicked into the atmosphere, etc.?

The data from Dr. Gus Williams' atmospheric deposition research includes information on the fractionation results from local soils. If the dust on the samplers is similar to the local soil fractionation, about 50% of the dust is particulate organic matter.

Why are the precipitation weighted concentrations twice as large as the non-weighted concentrations in some cases? If researchers collect rainwater, the precipitation weighted and non-weighted concentrations should be the same.

The nutrient concentration values are an average across all samplers. Researchers accounted for the weekly and monthly precipitation values when calculating the precipitated weighted concentrations across all the samplers.

How do the sample collections account for evaporation?

- The researchers are not assuming that the water in the collectors is indicative of precipitation. The precipitation that the researchers are accounting for is the actual measured weekly and monthly precipitation on Utah Lake.
- If the researchers have the same concentration for two different storm events, but one storm event resulted in twice as much precipitation, they use the weighting factor to calculate the nutrient load.

What is the significance of determining outliers using one milligram/liter and five milligrams/liter as the threshold?

The research team originally set the threshold at one milligram/liter but realized there were a lot of samples with a concentration greater than one milligram/liter. As a result, they changed the threshold to five milligrams/liter. The five milligrams/liter concentration was arbitrary, but it did limit the number of outliers in the 700 total samples.

Does the research team collect the samples after dust storms or only after rainstorms?

The research team only collects samples after rainstorms. The samplers are only collecting rainwater.

If there is a dust storm between two samplings, would the researchers not be able to identify what part of their samples is from dry deposition?

Yes, that is correct. Dr. Gus Williams' program collects dry and wet samples separately. The samplers in Dr. Miller's program are collecting bulk atmospheric deposition samples.

Are there any explanations on what could be causing the high outliers in the samples?

- Potential explanations include extra bad wind or dust storms or the presence of bugs or leaves in the samples. Additionally, sometimes the time between precipitation events is long, so a lot of dust can build up over time.
- Dr. Wood Miller plotted the daily wind data from the west desert and superimposed the result with the outlier results. In almost all cases, the outliers correlated with a high wind event.

Science Panel Comments

Science Panel members commented on the bulk atmospheric deposition program. Their comments are summarized below.

- There should be enough total suspended solids (TSS) in the sample to measure TSS. Researchers and scientists can use the TSS values to help identify the different forms of phosphorus in the dust.
- It would be helpful for biologists if the researchers calculated and plotted the total nitrogen-to-total phosphorus ratios for the bulk deposition data.

PRESENTATION ON ATMOSPHERIC NUTRIENT DEPOSITION TO UTAH LAKE

Dr. Gus Williams, BYU, presented his research on atmospheric deposition to Utah Lake. His presentation is summarized below.

Background on Sediment and Soils

- The Utah Lake watershed contains significant phosphate deposits, many of which are mineable. The Park City Formation is prominent in the Utah Lake Watershed. The phosphate deposits produce fertilizer-style dirt that has the potential to add phosphorus to Utah Lake.

- Sediment studies conducted in 1984 on the Deer Creek Reservoir found that the average amount of phosphorus in the sediments ranged from 1,107 to 2,572 milligrams of phosphorus/kilogram. About 10 to 20% of the phosphorus was readily available to the water column.
- More recent studies conducted by Dr. Gus Williams and Dr. Greg Carling, BYU, found that the Utah Lake sediments contained 280 to 1,710 milligrams of phosphorus/kilogram. About 50% of the phosphorus was available to the water column. The near-shore soils contained a similar amount of phosphorus, but only about 10% of the phosphorus in the near-shore soils was available to the water column.
- In 2018, the Deer Creek dam reconstruction exposed two miles of the Deer Creek Reservoir delta. Researchers took samples to determine the phosphorus fractionations for water-soluble, loosely sorbed, aluminum and iron-bound, calcium-bound (apatite), and residual phosphorus (most likely organic).
- Two sediment studies, Randall (2019) and Abu-Hmedian (2018), which included Dr. Gus Williams as an author, produced similar results on the amount of phosphorus in Utah Lake sediments. Researchers in Randall (2019) took 26 samples, and researchers in Abu-Hmeidan (2018) took 85 samples. The researchers in Abu-Hmeidan (2018) did not obtain phosphorus fractions from their samples due to miscommunications with the lab.
- Randall (2019) and Abu-Hmedian (2018) produced sediment total phosphorus maps for Utah Lake using slightly different mapping methods. Both maps show lower total phosphorus values on the east shore, particularly in sandy areas. The higher total phosphorus values occurred in the shallow bays, Goshen and Provo Bay, with the highest values occurring in Provo Bay. Researchers in Abu-Hmedian (2018) did not sample in Goshen Bay, but the total phosphorus values increased as they took samples closer to Goshen Bay.

Atmospheric Deposition Research

- Three Master's students completed their theses on quantifying atmospheric deposition for Utah Lake, and two Master's students are currently working on atmospheric deposition studies for their theses.
- The atmospheric deposition field sites contained wet and dry buckets. The wet buckets have a moisture sensor that opens and closes the bucket based on precipitation. Researchers generally followed the NADP methods and collected weekly wet-deposition and dry-deposition samples. They simulated the dry deposition on the lake surface with 3 liters of deionized water.
- The researchers sent the samples to the BYU Environmental Analytical Laboratory for analysis. Researchers multiplied the sample volume (in liters) by the sample concentration (in milligrams/liter) to calculate the mass. They then divided the calculated mass by the bucket surface area-time to determine the unit area deposition rates. Lastly, they multiplied the unit area deposition rates by the full Utah Lake surface area to calculate total deposition.
- Researchers collected samples at four sites for the first two Master's students' theses. Researchers are collecting samples at five sites for the last and ongoing theses. Due to access issues, researchers had to move the site location from Saratoga Springs after the first study. The site locations are away from high local dust sources (e.g., roads) and near Utah lake. The location of the sites does not follow NADP guidelines because researchers wanted to measure dust deposited on Utah Lake from regional and local sources.
- The wind rose indicates that the predominant winds come from the northwest or southeast.

- The first atmospheric deposition study (Olsen) collected data from four sample sites. In this study, researchers assigned background deposition values for total phosphorus (0.019 milligrams/meter squared/week) and dissolved inorganic nitrogen (0.112 milligrams/meter squared a week) in the middle of Utah Lake. These background deposition values were two orders of magnitude lower than the shore measurements. They used the Kriging method to estimate the average atmospheric deposition across the lake. They used two different load estimates to calculate the atmospheric deposition. The first load estimate only incorporated samples with no visible particles, including dust/soil, and the second load estimate incorporated all samples. Using two load estimates provided two bounding values for deposition rates.
- The second atmospheric deposition study (Reidhead) continued the Olsen study using similar methods and sites. The buckets in the Reidhead Study were 1.2 meters above the ground. Researchers in this study removed particles from the samples before analyzing them. Reidhead used linear fall-off from each site to estimate deposition, which did not work well. In addition to the dust samples, Reidhead took 49 soil samples from around Utah Lake to the lab for total digestion with ICP-OES. They did not collect fractionation data in the Reidhead Study.
- After the first two studies, researchers brought the results to the ULWQS Science Panel. The Science Panel had four questions/comments:
    - What can be done to prevent splash contamination of the samples during a rain event?
    - The existing one-meter tables result in inaccurate contaminated samples because they are too short.
    - The existing unscreened samplers result in inaccurate samples because of bug contamination.
    - What is the actual deposition rate as sources of atmospheric deposition progress towards the center of Utah Lake?
- From 2019 to 2020, researchers continued to collect data and adjusted their methodology to address Science Panel concerns. They raised the buckets to two meters above the ground, placed 500-micron nylon mesh screens on dry side buckets to prevent insect or plant parts from entering the bucket, moved the solar panel at least five meters from the sample table to prevent any splashback, and installed Miner's moss on the moving lid to reduce potential splash and deflection of rain droplets from the lid to the wet bucket during a rain event. The research team tested the Miner's moss to see if it reduced splashback, and it appeared that it did.
- The research team retained two low tables after installing the two-meter tall tables. The low tables were five meters away from the high tables. They found that the low tables collected less atmospheric deposition than the high tables, but these differences were not statistically different.
- The nylon mesh made a difference in filtering out bugs and leaves from the samples. There is strong evidence that the nonfiltered samples have a higher total phosphorus value than filtered samples. There is moderately strong evidence that nonfiltered samples have a higher dissolved inorganic nitrogen concentration than filtered samples. The large difference between the total phosphorus in unfiltered and filtered samples was largely due to several unfiltered samples with many bugs. There is a question on whether bugs account for valid or invalid deposition.
- Researchers added a sampling station at Bird Island, five meters above the lake surface. The Bird Island results were generally higher than the shoreline results. This difference could be

due to the prevailing winds. There are no other sampling stations aligned with the Bird Island sampling station.
- The Bird Island atmospheric deposition rates are higher than the other samplers. The data shows that deposition rates do not significantly decrease away from the shore. There is some correlation with shoreline stations, but it is weak. The previous load estimates assumed significant decreases in deposition rates from the shoreline to the inner part of the lake; based on the Bird Island data, these assumptions are not justified.
- In 2017, researchers removed the Saratoga Springs sites. From 2017 to 2019, they used ordinary Kriging methods to estimate the spatial deposition rate for each week over the entire lake. They multiplied the rate by the Utah Lake surface area and weekly timeframe to obtain the total load for the week. They then integrated the weekly values over the year. The 2017 and 2018 years had incomplete data, and the 2019 data had large spikes, likely due to insects.
- In 2020, researchers followed the same procedures but included the Bird Island data. For the seven months without Bird Island data, they estimated the data using the shoreline stations.
- Researchers found that atmospheric deposition is higher in the early spring (March/April) and at some points in the summer. These increases are likely related to spring/summer storms. Winter storms have either snow or frozen ground, so dust may not be mobilized during those events. There is not enough data to quantify or verify these hypotheses.
- On August 23, 2020, the two highest sites for atmospheric deposition were the Bird Island and Lake Shore sites. The results from the other stations indicated that most of the lake experienced average atmospheric deposition levels.
- The weekly 2019 to 2020 atmospheric deposition results indicate several major spikes in atmospheric deposition in the spring/summer.
- The atmospheric deposition studies show a wide range of estimated atmospheric deposition values. The Olsen Study, which calculated atmospheric deposition loads twice using data from all samples and samples without any particles, had the largest range of values (8 to 250 tons of total phosphorus/year). The Reidhead Study, which removed debris before analysis and used a very conservative fall-off methodology, estimated the deposition to be 153 tons of total phosphorus/year. The Barrus Study, which used buckets with and without screens, had a narrower range for atmospheric deposition (133 to 252 tons of total phosphorus/year). Dr. Wood Miller's bulk sampling methodology shows the lower average and higher precipitation weighted values (77 to 155 tons of total phosphorus/year). Based on regional and global transport literature, Dr. Janice Brahney estimated atmospheric deposition (3.5 to 13.4 tons of total phosphorus/year).

Science Panel Clarifying Questions

Science Panel members asked clarifying questions about the atmospheric deposition data results. Their questions are indicated in italics below, with the corresponding responses in plain text.

What is meant by readily available phosphorus?

- The researchers added different treatments to each sample to determine the phosphorus fractions (e.g., they would add water to determine the water-soluble fraction, sodium chloride to determine the loosely sorbed fraction, sodium hydroxide to determine the aluminum and iron-bound fraction, etc.). It is unclear whether the unbound phosphorus is orthophosphate or soluble reactive phosphorus.
- The water-soluble and loosely sorbed phosphorus fractions are available in Utah Lake. The aluminum and iron-bound phosphorus fractions in Utah Lake are readily available under

anaerobic conditions. Because the sediments are anaerobic in Utah lake, the water-soluble, loosely sorbed, and aluminum and iron-bound phosphorus fractions in Utah Lake are all considered "readily available." The aluminum and iron-bound phosphorus fractions may reprecipitate if exposed to aerobic conditions in the water column.

Do the solar panels that open and close the wet buckets interfere with wet/dry deposition?
Researchers conducted a study in the fourth year to determine whether the solar panels affect the samples.

Were the three liters considered the sampling volume after rinsing the screens?
No. The researchers put three liters in the dry bucket at the beginning of the week. They measured the actual sample volume when they measured the nutrient concentration. There was normally less than three liters of water in the bucket by the end of the week.

Do birds perch on the sampler on Bird Island?
Graduate students have said that they have not seen bird droppings on the sample buckets. Researchers have also not directly seen birds perching on the sampler. They have a webcam installed and can see if birds ever land on the sampler. Many of the birds that fly to Bird Island are non-perching birds.

Do the researchers have estimates of the bioavailable phosphorus in the sediment?
Researchers know what fraction the phosphorus is associated with, but they do not know what species the phosphorus transforms into once released into the water column. Around 50% of the phosphorus in the sediment is associated with water-soluble, ion exchange, or iron and aluminum-bound forms of phosphorus. About 10% of total phosphorus is associated with water and ion exchange, and 40% of the total phosphorus is iron and aluminum-bound.

Is there a way to use TSS measurements to determine the amount of biologically unavailable nutrients in the sample?

- Measuring TSS would help determine the different components of the deposition. There are other metrics that the research team could be collecting, such as TSS. Knowing the TSS values would help researchers identify how much the atmospheric deposition is biologically unavailable.
- Another researcher Jacob Taggart is looking at the sorption behavior in Utah Lake at a macroscale. He is coordinating with Dr. Josh LeMonte, BYU, who is looking at sorption behavior at a microscale.

Atmospheric deposition at 300 tonnes/year would result in 1.4 millimeters of new sediment deposition/year, assuming the specific gravity is 0.8 grams/centimeter. Does the research indicate that atmospheric deposition adds more sediment than the estimated sedimentation rate in Utah Lake?
The research team would like to check some assumptions in that assessment.

What is the primary wind direction at Mosida? The assumption is that there is a south/southwesterly wind direction at Mosida.
There has not been a long-term weather station at Mosida, so the primary wind direction is unknown.

In one of the studies, the dry bucket was placed next to a bucket with one liter of sodium chloride solution. There was 9.5 times more phosphorus in the bucket with the sodium chloride solution than in the dry bucket. In a later experiment, there was three times more phosphorus in unscreened samples than in screened samples. The screening alone does not explain why the bucket with the sodium chloride solution would have almost ten times more phosphorus than the dry bucket. Why do the water buckets capture more phosphorus than the dry buckets?
The study showing that phosphorus concentrations were three times higher in unscreened samples than in screened samples did not compare water buckets to dry buckets. The screen and unscreened samples both had a solution. One hypothesis is that the screen prevents some dust from entering the bucket. Researchers are also reducing dust capture efficiency by using a screen to reduce insects and plant materials from falling into the bucket.

Science Panel Comments
Science Panel members commented on the atmospheric deposition research. Their comments are summarized below.

- Researchers should measure TSS in the samples to help parse out information on the amount of inorganic phosphorus in the samples. Researchers can calculate the amount of phosphorus fixation occurring by subtracting the amount of volatile suspended solids from the amount of TSS.
- The US Geological Survey (USGS) conducted a sediment capture study in Gilbert Bay. They found that the annual deposition was 0.4 centimeters/year at the deepest part of the lake. That was the highest amount in the lake. The average sediment deposition rate may be one to two millimeters/year.

Public Comments
Members of the public commented on the atmospheric deposition research programs and results. Their comments are summarized below.

- It would be beneficial to compare the data from Dr. Wood Miller's and Dr. Gus William's Study to see how storm events influenced the bulk atmospheric deposition approach in Dr. Miller's study. The intention of collecting samples in Dr. Miller's study is to calculate bulk atmospheric deposition. More than likely, the bulk sample underestimates dry deposition values.

SCIENCE PANEL ATMOSPHERIC DEPOSITION RESEARCH PROGRAM QUESTIONS AND DISCUSSION
Members of the Science Panel asked questions and provided comments on the Atmospheric Deposition Research Program Summary Report. Their questions and discussion are summarized below.

Science Panel Clarifying Questions
Science Panel members asked clarifying questions about the Atmospheric Deposition Research Program Summary Report. Their questions are indicated in italics below, with the corresponding responses in plain text.

What is the effect of volatilization or transformation of nitrogen sitting in the samplers?

- As long as the samplers stay neutral or slightly acidic, volatilization should not be a problem, particularly for ammonium. Ammonium would only be volatile at a pH of nine, which is conceivable, but nitrate is also more prevalent than ammonium or ammonia in the samples.

- The nitrogen phase may depend on the source. Ammonia and nitrate originate from the urban system and the burning of fossil fuels. Ammonia could also come from agricultural sources or fertilizer. There are not many large animal operations in the area, but there is a lot of fertilizer being applied to farms. It is unclear how that would affect the samples.
- There is likely not a lot of material loss to outside systems, so volatility is likely not a large concern in sample collection.

The researchers would need to measure total nitrogen to calculate the total nitrogen to total phosphorus ratio. Does the atmospheric deposition research program measure total nitrogen?
The atmospheric deposition research program measures nitrate and ammonium concentrations.

After collecting data over the past several years and putting together the summary report, what recommendations does the atmospheric deposition research team have to improve modeling inputs and assumptions?

- The atmospheric deposition research team generated a graph that shows the atmospheric deposition estimates from several studies.
- The atmospheric deposition research team plans to investigate the nylon screens' impact on the samplers to improve their estimates. They also plan to rinse the screen with deionized water and use different screen sizes to determine the effect of the nylon screens on the sampler.
- The atmospheric deposition research team only has one year of data from the mid-lake sampler, so they would like another year's data before drawing conclusions. They plan on putting the sampler on Bird Island a lot earlier this year.
- The atmospheric deposition research team would like to gather more fractionation data from the samples. A Ph.D. student is working with Dr. Josh LeMonte to better identify the fractionation in the samples. More fractionation data will help determine how much deposition is coming from local sources.
- Several factors exacerbate atmospheric deposition, including storm events and shrinking lake levels. Because storm events are highly variable from year to year, one recommendation is that the Science Panel use a low and high number to estimate atmospheric deposition into Utah Lake.

What would the atmospheric deposition research team recommend as the atmospheric deposition value for Utah Lake?
One recommendation is to use 150 to 200 tons of phosphorus per year and 400 to 1,000 tons of nitrogen per year. These numbers still need to be confirmed by the researchers and discussed among the Science Panel.

How does the model incorporate atmospheric deposition values? Does the model integrate annual or monthly loads? Does it differentiate between bioavailable nitrogen and phosphorus from total nitrogen and phosphorus?
The water quality model (WASP) inputs are time series for atmospheric deposition of nitrate, ammonia, orthophosphate, organic nitrogen, and organic phosphorus in milligrams/meter squared-day units. Once the particles enter the system, the partitioning coefficient will determine how much of the deposition is biologically available. The time series allows for a single variation in time, so the Science Panel could decide on a daily, monthly, or yearly value.

What is the fingerprint of the local sources?
The research team is looking at doing fingerprinting this summer. They are working with Dr. Greg Carling on methods based on his existing data.

What is the size distribution of the particles in wind events?

- Dr. Greg Carling has measured total phosphorus concentrations in dust emissions from Sevier Dry Lake, Great Salt Lake, and other regional playas in the range of 1,000-3,000 milligrams/kilogram.
- Dr. Janice Brahney has estimated that dust typically ranges from 0.7-5 grams/kilogram.

Science Panel Discussion
Science Panel members discussed the Atmospheric Deposition Research Program Summary Report and how to incorporate atmospheric deposition values into the model. Their comments are summarized below.

Comments on Studies and Estimating Nutrient Loading from Atmospheric Deposition

- Dr. David Gay recently provided additional feedback on the atmospheric deposition research program and findings.
- Adding a total nitrogen-to-total phosphorus ratio analysis to the Atmospheric Deposition Program Summary Report would be useful. Calculating the total nitrogen-to-total phosphorus ratio can help identify the potential sources of nutrients and the potential impact of atmospheric deposition on Utah Lake. It could also help provide insight into the outlier phosphorus values.
- The nitrogen values in the bulk deposition program are volatile. Some nitrogen is bound to the particulates in the water, but it is unknown what fraction is volatile on its own merits. The Science Panel should consider the volatilization or transformation of nitrogen in the sampler when interpreting the results of the studies.
- The atmospheric deposition researchers should look at the Kjeldahl digestion to determine the organic fraction of nitrogen. The Kjeldahl value could be related to volatile suspended solids.
- The graph that displays the atmospheric deposition loads by month suggests a baseline of atmospheric deposition (around five milligrams/squared meter-month) occurring throughout the year. Discrete events lead to atmospheric deposition spikes (around 100 milligrams/squared meter-month). It would be helpful to take out some of the outliers to identify the baseline atmospheric deposition flux rates. Science Panel members could review the pictures of the samplers after some of these storm events (samples with a flux greater than 15 milligrams/squared meter-month) and provide feedback on what they think is happening.
- In the Olsen Study, Olsen removed any samples that had any visible particles. Even if the vast majority of the particles are biologically unavailable, some of them dissolve into the water. The Olsen Study is best used as a bounding study; values are likely not to go lower or higher than his evaluated range.
- The Science Panel should use data on total nitrogen and total phosphorus loads and the soluble forms of nitrogen and phosphorus to assess the response from algae. It would be helpful to see how algae respond to spikes in atmospheric deposition. This information is not needed to develop an atmospheric deposition value for the model, but this information would be helpful as the Science Panel seeks to understand the big picture issues.

Comments on Estimating Atmospheric Deposition for Modeling

- The ULWQS timeline requires that the Science Panel decides on atmospheric deposition values to develop the model this year. Tetra Tech needs to be able to calibrate the model this fall so that the Steering Committee and Science Panel can work on developing numeric nutrient criteria and the implementation plan this year.
- The modeling team is in the process of calibrating the lake model. The Science Panel should seek to establish an atmospheric deposition value for the model over the next two meetings and ideally by the end of April. The modelers need an estimate for atmospheric deposition in the next four to five weeks for the model. If the modelers do not receive an atmospheric deposition value in that time frame, the options for modeling are to move ahead with the current atmospheric deposition estimates, pause the modeling efforts until the Science Panel develops a new estimate, or move ahead with current estimates and provide additional resources to adjust the model in the future. The practical implication is that it will take more time and money the longer it takes to develop an atmospheric deposition value.
- The Science Panel will eventually need to consider how to incorporate atmospheric deposition estimates into the watershed model to help guide the implementation plan. The more immediate request for the Science Panel is to set atmospheric deposition values for the lake model. Still, the Science Panel will need to consider how to incorporate atmospheric deposition in the watershed model in the future.
- Dr. Brahney examined literature values to estimate atmospheric deposition. Her estimated values overlap with the low-end values estimated by the WFWQC atmosphere deposition research program. One difference may be that the literature values did not account for local sources. Dr. Brahney's research used data from the NADP, dust deposition from local mountain ranges, wet deposition from the NADP, dust deposition from Provo and other local urban sources, and seven consistent measurements from urban lowland locations in Utah.
- The Science Panel needs to look more closely at the data before setting an atmospheric deposition total phosphorus value in the model. One reason that there maybe three to five times more phosphorus from atmospheric deposition in the Utah Lake system is because the local soils have a high amount of phosphorus.
- A subgroup of the Science Panel could meet to review the available studies more closely and refine the atmospheric deposition assumption in the model. Science Panel members did not express interest in forming a subgroup to discuss the atmospheric deposition values.
- The Wood Miller Study shows a strong alignment between high deposition values and big wind events. The atmospheric deposition research team is trying to figure out if they can predict the large spikes or associate them with specific types of weather events. There is interannual variability in storm events. The Science Panel should define how atmospheric deposition rates change by season and incorporate that seasonality into the model, if possible.
- Dr. Mike Brett's mass balance model could help assess the system's sensitivity to a range of atmospheric deposition values. The Science Panel should rely on the range of atmospheric values from the studies where Science Panel members had the opportunity to review the raw data. Science Panel members did not have the opportunity to review the raw data from the Olsen Study, so they should not use those numbers.
- Dr. Josh LeMonte's study on bioavailable phosphorus in the sediment will help inform this discussion. Dr. LeMonte has committed to providing data from his study in the fall.
- The model will assume that ammonia or organic matter coming into Utah Lake is in a soluble form unless it comes in as particulate matter. The modelers will need a time-series

best estimate for the current loading conditions. The estimates can come in as events or an interpolated time series.
- The Science Panel could develop an average input and create reasonable bounds on that input. It should be relatively easy for Tetra Tech to put in a value that would change or reduce the loadings by some fraction (to be determined). Tetra Tech could then determine the impacts the loading would have on the calibration. If Tetra Teach demonstrates that different loading estimates will have a large impact, Dr. Mike Brett can run his model to see if he gets similar results. The results could demonstrate the need to refine the model/estimates.
- The model can use whatever timestamp the Science Panel finds appropriate (annually, weekly, monthly, etc.). The model runs through multiple years, so the Science Panel could consider repeating a representative year across multiple years.

Public Comment

Members of the public commented on the atmospheric deposition discussion. Their comments are summarized below.
- Dr. Hans Paerl recently appeared on a radio show and provided some great insight into Utah Lake.
- Table 1 in the Atmospheric Deposition Research Program Summary Report shows the loading estimates from different studies. The atmospheric deposition research team should consider adding another column to contextualize the study results (i.e., this estimate was high because of bug/leaf contamination in the sampler).
- The final sentence of the executive summary recommends using an estimate of 175 tons/year of total phosphorus and 700 tons/year of dissolved inorganic nitrogen for atmospheric deposition. This recommendation only appears in the executive summary. It would be helpful to have more detail on how the atmospheric deposition team arrived at those numbers.
- The Atmospheric Deposition Research Program Summary Report should clarify whether the tons unit used in the report are metric tons or US short tons.
- The atmospheric deposition research team will have time to make an addendum to the report, but they will not have time to rewrite it. The Science Panel should incorporate the information from the atmospheric deposition research program into the model.

NEXT STEPS
- Dr. Theron Miller will update the Atmospheric Deposition Research Program Summary report with an analysis of the total nitrogen to total phosphorus ratios and update table one with more context for each study by April 6. The Science Panel will review the report once Theron Miller has updated it.
- The Science Panel will meet again in April to begin setting a value for atmospheric deposition with the goal of setting a value by the end of April.