Logan River Observatory Annual Report

2021–2022

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In partnership with:
Preface

This report provides a summary of data collected within the Logan River Observatory as required by funds provided by the Utah State Legislature, which are managed and overseen by the Utah Division of Water Resources. The primary objectives of the report are to highlight the data types and availability within the Logan River Observatory and to summarize recent and ongoing research and outreach affiliated with the observatory.

Cite this report as:

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2021-2022 SUMMARY OF LOGAN RIVER OBSERVATORY
ACTIVITIES AND ACCOMPLISHMENTS

*(More details are provided in subsequent sections)*

Collecting detailed watershed data (discharge, water quality, climate):
We have maintained 16 discharge stations, 8 full water quality stations, 8 partial water quality stations, 3 full climate stations, and 2 partial climate stations. Raw data are automatically updated online every few hours at 8 flow gaging locations and 8 full water quality stations. All other flow gaging stations with a subset of water quality measurements are downloaded and updated online periodically. Raw field data have been quality controlled and are publicly available via [http://lrodata.usu.edu/](http://lrodata.usu.edu/). Quality controlled data are updated quarterly.

Advancing training and expertise:
Logan River Observatory (LRO) data are consistently used in ~12 upper division/graduate classes (~300 students) and were used in a Senior Design project and 3 theses for students completing Master of Science (MS) degrees in early 2021. The data are currently being used in 5 ongoing PhD dissertations, 4 MS theses, and another Senior Design group project. We currently support and continue to train 4 undergraduate student LRO technicians. For more information, see [https://uwrl.usu.edu/lro/resources](https://uwrl.usu.edu/lro/resources) and [https://uwrl.usu.edu/lro/people/students](https://uwrl.usu.edu/lro/people/students).

Addressing existing water issues in the state:
The LRO currently supports the Logan River Task Force mission by providing data and hosting their website ([https://uwrl.usu.edu/lro/logan-river-task-force](https://uwrl.usu.edu/lro/logan-river-task-force)). LRO-affiliated faculty and students have provided support via modeling efforts and additional data collection to assist the Logan River Task Force’s restoration efforts and other ongoing Cache Water District water management projects in the Logan River ([https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ut/programs/planning/wpfp/?cid=nrcseprd1723235](https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ut/programs/planning/wpfp/?cid=nrcseprd1723235)). In particular, flow and temperature information are being used to guide the Environmental Assessment associated with proposed changes to a key irrigation diversion that will alter flow throughout the Logan City portion of the river. LRO infrastructure and personnel also support Logan City via stormwater monitoring and data dissemination via the LRO website.

Supporting new research to advance understanding of Utah’s watersheds:
LRO-affiliated faculty continue to attract new funding for research projects that further the mission of the LRO and depend on LRO data, including the following:

1. Quantifying Watershed Dynamics in Snow-Dominated Mountainous Karst Watersheds Using Hybrid Physically Based and Deep Learning Models (National Science Foundation) $777,921, 2021-2024
2. Assessing the sources, transport, and fate of microplastic in the Logan River Watershed (USGS 104(b)) $90,993, 2021-2022
3. Logan River Watershed LiDAR data collection, bare earth and snow on (USGS 104(b)) $166,062, 2020-2021
LRO researchers submitted or are revising four additional proposals and had 4 journal articles published in 2021, one accepted for publication, and one in review. Seven presentations were given at professional conferences and a senior design group presented their findings to the Cache Water District. All of these articles and presentations highlight the LRO or report research results from the Logan River watershed based on data from the LRO.

Focusing on future challenges associated with limited water supplies:
Collaborations with the Logan River Task Force and Cache Water District focus on water availability and distribution. Due to low flow conditions in summer 2021, the LRO also collaborated with local canal companies to better understand and track water distribution throughout the river and a subset of the associated canals. Additionally, a recently funded project focuses on anticipating or predicting future changes in water availability and on potential changes in water quality.

BACKGROUND

Water is the lifeblood of Utah. Utah’s residents depend on a safe and adequate water supply, not only for drinking water, but for other municipal, agricultural, industrial, and recreational uses. Much of Utah’s water supply comes from reservoirs or streams that are fed by snowmelt. Utah’s climate can be highly variable, with large changes in water availability from year to year. Furthermore, as Utah’s climate shifts, historical data may not be predictive of future water supply, raising new questions. For example: As weather patterns change to more rain and less snow, what will be the effect on springtime river flows that fill our reservoirs and summer flows crucial for meeting agricultural and urban demands? How will Utah’s rapidly growing population impact our already limited water supply? How will climate and population changes affect Utah’s drought resiliency? Reliable data are essential for answering questions like these, and monitoring Utah watersheds is necessary for making informed water management decisions. The Logan River Observatory (LRO) is a watershed monitoring network that is helping to meet these challenges by providing data to fill these important knowledge gaps.

Origins

In 2012, the three major Utah universities (Utah State University, University of Utah, and Brigham Young University) proposed a new collaborative project for scientists and practitioners to collect, integrate, and share physical, biological, and social water data to advance understanding and generate knowledge needed to solve urban- and arid-region water sustainability problems. The project included infrastructure (human, observational, and cyber) to lay a foundation for addressing water, population growth, and climate change issues that confront the State of Utah. The resulting EPSCoR (Established
Program to Stimulate Competitive Research) program funding award from the National Science Foundation launched iUTAH (innovative Urban Transitions and Aridregion HydroSustainability): a 5-year, multi-institution, interdisciplinary project focused on water sustainability in Utah. A lasting legacy of the iUTAH project was its environmental observations via the GAMUT (Gradients Along Mountain to Urban Transitions) network. In the Logan River watershed, eight aquatic monitoring stations and four climate stations were established to measure, record, and publicly distribute a wide range of climate (e.g., precipitation, snow depth, air temperature, relative humidity), hydrology (e.g., water depth, flow rates), and water quality (e.g., water temperature, dissolved oxygen, pH, turbidity, nitrate) information. The sensor network was deployed to log and transmit the data, which is stored in databases and made publicly available via web-based tools and an online data repository. The monitoring sites and information streams established by iUTAH laid a solid foundation for data collection to support better water management in Cache Valley and provided an opportunity to study the long-term impacts of rapidly growing rural counties on water use and quality across the state of Utah.

Logan River Observatory Overview

In 2018, iUTAH’s GAMUT network for the Logan River was reorganized into the Logan River Observatory (LRO). The overarching goal of the LRO is to provide long-term, comprehensive hydrologic data to inform local and statewide water management decisions based on Utah-specific hydrologic research. In support of this goal, the LRO is an outdoor laboratory and classroom for training the next generation of engineers and scientists who will be Utah’s future water managers. Detailed watershed data (discharge, water quality, climate) combined with this increase in expertise provide opportunities to (1) address existing water issues in the state, (2) support new research to advance understanding of Utah’s watersheds, and (3) focus on future challenges associated with limited water supplies.

The LRO team has established partnerships with local stakeholders to support and improve existing monitoring infrastructure, including the Utah Division of Water Resources, Utah State University, Logan City, and Cache Water District. The LRO Team also coordinates with the Logan River Task Force and supports their efforts via data collection and modeling efforts.

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**LRO DATA TYPES AND AVAILABILITY**

The LRO data provides critical information to guide northern Utah’s water resources planning and management decisions and offers foundational information to support water-related research, which is a primary focus for scientists and engineers at the Utah Water Research Laboratory, other USU departments, and collaborators.

In the original GAMUT network, aquatic monitoring stations were placed within the Logan River watershed (see Appendix A for a detailed description) (1) in a high-elevation first-order stream (Logan River Near Franklin Basin), (2) in a mid-elevation second- or third-order stream (Logan River Near Tony Grove), (3) at a low elevation valley site (Logan River at Main Street (Highway 89/91) Bridge), and (4) near the terminus of the stream below the Logan City urban area of interest (Logan River at Mendon Road (600 South)) in order to span a range of elevations and mountain-to-urban environments. The climate and terrestrial monitoring stations were located at (1) a high-elevation mountain headwater area (Climate Station at Franklin Basin), (2) a mid-elevation area (Climate Station at Tony Grove), and (3)
a low elevation area in a valley/urban location (Climate Station at Logan River Golf Course). As detailed by Jones et al. (2017), standard designs for both aquatic and climate stations were established.

As the LRO has become more established, additional sites have been added, and adaptations to site specifications have been made to expand the original GAMUT network into what is now the LRO monitoring network. For example, many new aquatic stations that measure flow, temperature, and specific conductance have been added. These new stations capture the influence of tributaries on the Logan River and fill gaps in the initial infrastructure.

The LRO website includes an interactive map of the station locations (https://uwrl.usu.edu/lro/locations) (Figure 1) with classifications of sites maintained by the LRO and complementary sites maintained by the United States Geological Survey (USGS) and the Utah Division of Water Rights. Data for each site can be accessed by clicking on the location markers in the web map. A simplified schematic of primary LRO sites along the Logan River and major inflows and outflows (Figure 2) provides a brief overview of key data collection locations.

Figure 1. LRO and other relevant monitoring locations that provide complementary data (find this navigable map at https://uwrl.usu.edu/lro/locations).
Figure 2. Simplified schematic of primary LRO mainstem and tributary site locations. The vertical line represents the Logan River, with flow from top to bottom. Arrows pointing toward the river (blue) indicate measured inflows, and arrows pointing away from the river (orange) indicate measured withdrawals. Lines that cross the river indicate the locations of continuous aquatic monitoring sites. Other mainstem sites that are downloaded periodically are not shown. Flow rates of all diversions are monitored by the Utah Division of Water Rights but are included here to provide an overview of primary inflows and diversions that are monitored.

The more comprehensive list of all LRO monitoring sites, frequency of data updates, status, and the data types or parameters available (Table 1) illustrates the extent of data gathered within the LRO. Given the variety of site types, the data types and frequency of updates can be important factors when using these data for different applications. A similar table is provided for the weather stations in Appendix B (Table B1).

All of the data collected within the LRO are openly and publicly shared within the HydroShare repository. Datasets for monitoring sites at which continuous data are collected are automatically updated regularly and LRO technicians conduct routine quality control for continuous datasets. Many additional periodic monitoring sites are also shared via separate HydroShare resources. These data are downloaded periodically and undergo routine quality control. See all of the sites and links to their respective datasets at [http://uwrl.usu.edu/lro/locations](http://uwrl.usu.edu/lro/locations).

In Fall 2020, we obtained 0.5 m resolution LiDAR data for the canyon portion of the Logan River watershed. It includes a bare earth digital terrain model (DTM) and a first return digital surface model (DSM) that captures the height of the vegetation. We additionally collected detailed snow-on LiDAR data for a portion of the upper watershed in Franklin Basin in spring of 2021. Given the size of the LiDAR data, they are available on request.
Table 1. Aquatic sites and variables measured at each site within the Logan River Observatory*.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Code</th>
<th>Updates</th>
<th>Water Temperature (°C)</th>
<th>Specific Conductance (µS/cm)</th>
<th>pH</th>
<th>Dissolved Oxygen (optical, local % saturation, and mg/L)</th>
<th>Turbidity (NTU)</th>
<th>Gage Height (cm)</th>
<th>Water Surface Elevation (m, with respect to benchmark)</th>
<th>Discharge** (cms)</th>
<th>Blue Green Algae (RFU)</th>
<th>Chlorophyll CDOM (QSU)</th>
<th>Nitrate (mg/L)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s)</th>
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</thead>
<tbody>
<tr>
<td>Logan River near Franklin Basin</td>
<td>LR_FB_BA</td>
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<tr>
<td>Logan River near Tony Grove</td>
<td>LR_TG_BA</td>
<td>Continuously</td>
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<td>Logan River Above Wood Camp</td>
<td>LR_WC_A</td>
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<td>Logan River at Wood Camp Bridge</td>
<td>LR_WCB_A</td>
<td>Periodically</td>
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<td>Logan River at the Utah Water Research Laboratory west bridge</td>
<td>LR_WaterLab_AA</td>
<td>Continuously</td>
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<td>Logan River at Main Street (Highway 89/91) Bridge</td>
<td>LR_MainStreet_BA</td>
<td>Continuously</td>
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<td>Logan River at Mendon Road (600 South)</td>
<td>LR_Mendon_AA</td>
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Tributary Sites

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<th>Specific Conductance (µS/cm)</th>
<th>pH</th>
<th>Dissolved Oxygen (optical, local % saturation, and mg/L)</th>
<th>Turbidity (NTU)</th>
<th>Gage Height (cm)</th>
<th>Water Surface Elevation (m, with respect to benchmark)</th>
<th>Discharge** (cms)</th>
<th>Blue Green Algae (RFU)</th>
<th>Chlorophyll CDOM (QSU)</th>
<th>Nitrate (mg/L)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s)</th>
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<td>Ricks Spring</td>
<td>RS_CONF_A</td>
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<td>Right Hand Fork</td>
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<td>Spring Creek above confluence with Logan River</td>
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<td>Blacksmith Fork above confluence with Logan River</td>
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Canal Sites

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<th>pH</th>
<th>Dissolved Oxygen (optical, local % saturation, and mg/L)</th>
<th>Turbidity (NTU)</th>
<th>Gage Height (cm)</th>
<th>Water Surface Elevation (m, with respect to benchmark)</th>
<th>Discharge** (cms)</th>
<th>Blue Green Algae (RFU)</th>
<th>Chlorophyll CDOM (QSU)</th>
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<td>South Logan Benson Canal at Benson Irrigation Company Flume</td>
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Storm Drain Sites

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<th>pH</th>
<th>Dissolved Oxygen (optical, local % saturation, and mg/L)</th>
<th>Turbidity (NTU)</th>
<th>Gage Height (cm)</th>
<th>Water Surface Elevation (m, with respect to benchmark)</th>
<th>Discharge** (cms)</th>
<th>Blue Green Algae (RFU)</th>
<th>Chlorophyll CDOM (QSU)</th>
<th>Nitrate (mg/L)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s)</th>
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<tr>
<td>River Heights Storm Drain</td>
<td>LR_RH_SD</td>
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*● indicates that data are presently being collected for this parameter; ○ indicates that data were historically collected for this parameter; Continuously = real-time updates of data online and available via time-series analyst; Periodically = periodic downloads of sensors with data posted on time-series analyst and/or HydroShare [http://www.hydroshare.org/].

** For the continuously updated stations that have discharge, the underlying data and details of the rating curves can be found by clicking “Explore Rating Curve” button below the “Most Recent Instantaneous Measurements” on each site’s details accessed from [http://lrodata.usu.edu/]. The data for these sites, as well as the periodically updated sites, can also be found directly by going to [http://www.hydroshare.org] and searching for “Logan River rating curves.” The exception is the Northwest Field Canal site.
LOGAN RIVER OBSERVATORY RESEARCH

LRO Research Findings/Outcomes

The following paragraphs summarize recent relevant research efforts within the LRO. We have provided a brief description for each along with a listing of significant outcomes from each effort.

Logan River Observatory support of local canal companies

Drought conditions throughout the western US have prompted significant interest in ensuring that the water distribution throughout rivers and canal systems is well understood. The LRO worked with multiple canal companies in summer 2021 to:

1. Determine flow measurement accuracy at various Utah Division of Water Rights gaging locations,
2. Estimate flows in unaged diversions, and
3. Estimate flow gains and losses in various portions of the river and canal system.

Outcome: A spreadsheet that can be used to understand the flow distribution throughout the upper valley portion of the Logan River at any time during the irrigation season is being developed to help water masters and other interested stakeholders.

Logan River Observatory as part of a network of worldwide research and observatory catchments

The Logan River Observatory was included in a Special Issue of the Hydrological Processes journal entitled “Research and Observatory Catchments: the Legacy and the Future” ([https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1099-1085.research-catchments](https://onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1099-1085.research-catchments)). To further promote the contributions of the LRO to the broader research community, a presentation was given at the Research and Observatory Catchments: The Legacy and the Future Seminar Series. The map to the left shows the worldwide network of observatories involved. ([https://www.youtube.com/watch?v=q1mmI2QzAjM&list=PLPG5EdSL1SY7T_1cb15fD-oQV6nvZsQTw&index=7](https://www.youtube.com/watch?v=q1mmI2QzAjM&list=PLPG5EdSL1SY7T_1cb15fD-oQV6nvZsQTw&index=7)).

Outcome: Neilson et al. (2021) (see Research Products 2021–2022) highlighted the LRO as one of the only karst observatory watersheds that has detailed subwatershed flow measurements. This article highlights the importance of flow data in understanding watershed hydrologic responses and the role in future water planning. The State of Utah’s investment in long term hydrologic monitoring was discussed and was highlighted as a unique attribute of the LRO. Tennant et al. (2021) (see Research Products 2021–2022) also provided additional analyses and further illustrated the utility in the detailed flow measurements that the LRO network provides.
Logan River LiDAR

Light Detection and Ranging (LiDAR) topography data (0.5-m resolution) was collected over the entire canyon portion of the Logan River watershed in Fall 2020. This data collection is a collaborative effort between Logan City, the LRO, and USGS 104(b). This new LiDAR data augments data already available for the valley section of the Logan River and will provide coverage of the full watershed to facilitate ongoing and future hydrologic studies.

Outcome: These data are foundational to various on-going or planned research activities. For example, two different PhD students associated with the NSF grant mentioned above are working to establish new methods for mapping sinkholes (or groundwater recharge locations) based on this detailed dataset.

Snow LiDAR

Snow-on LiDAR data were collected during March 2021 in the Franklin Basin portion of the watershed. The resulting data have been combined with LRO snow-off LiDAR data to further our understanding of snow distributions and water availability.

Outcome: These data are being used to determine future options for using crowdsourced data for understanding water availability via more accurate representation of snow distribution.

A hydraulic routing and river temperature model of the valley portion of the Logan River

Buahin et al. (2019) (see Appendix C), developed and calibrated a temperature model for a large section of the lower Logan River. The model provided estimates of lateral inflow volumes and temperatures which were used to indicate whether lateral inflows originated from colder groundwater or warmer urban/agricultural runoff.

Outcome: This analysis resulted in improved understanding of the dynamic inflows and outflows to the river system. The model will be used in various projects to assess the impacts of different instream flow management options on instream temperatures and impact on fisheries.
**Lateral inflow sources in the valley portion of the Logan River**

Building on Buahin et al. (2019), Tennant et al. (2021) (see Research Products 2021–2022 section) used detailed measurements and flow and mass balances to further investigate where gaining and losing conditions occur, when they occur, the source of the flow (urban versus agricultural areas), and whether it joined the river via surface or subsurface flow.

**Outcome:** Similar to above, these findings will help guide decision making by assessing the impact of different water distribution scenarios on lateral inflows to Logan River that will change as canals are lined/pressurized or stormwater practices are altered.

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**Precipitation changes in snowmelt dominated watersheds with karst geology**

Neilson et al. (2018) (see Appendix C) found that significant amounts of river water were repeatedly exchanged between the river and the local aquifer and that the majority of the groundwater entering the river moves quickly through the watershed via karst aquifer conduits. These findings suggest that river flow each summer is highly dependent on very recent aquifer recharge from snow accumulation during the prior winter. Future research will focus on quantifying how changes to snowpack will influence summer streamflow.

**Outcome:** This initial work within the Logan River watershed has led to a number of newly funded research projects (see complete list below). The most notable is the 3-year National Science Foundation grant “Collaborative Research: Quantifying Watershed Dynamics in Snow-Dominated Mountainous Karst Watersheds Using Hybrid Physically Based and Deep Learning Models.” This project will provide insight into relationships among snowmelt, groundwater, and instream flow in the complex, karst portion of the watershed and will guide water management as we deal with potential changes in water availability.
Currently Funded LRO Related Research Projects

The LRO monitoring and data infrastructure provide a scaffolding onto which new, synergistic, and collaborative research projects can be built. The following are ongoing or newly funded research projects that use LRO data and/or research infrastructure:

2. Improving the Hydraulics of Urban Flooding, Z.B. Sharp, USGS 104(b), 2020 – 2022
4. Leveraging LiDAR and Citizen-Science for Low-Cost, High-Resolution Snow-Depth Estimation, Carlos A. Oroza, USGS 104(b), 2020-2021, $90,000
5. Obtaining LiDAR Data to Support Research in the Logan River Watershed, B.T. Neilson, 2020UT304B Utah Water Research Laboratory and USU Civil and Environmental Engineering Department, 2020-2021, $76,062
8. Determining the mobility, fate, and ecological consequences of dust-derived constituents in mountain watersheds, J. Brahney, National Science Foundation, $742,072, 2020-2025.

LRO Related Proposals 2021–2022

3. Quantifying summer stream temperature patterns and controls in irrigated western river basins, B.A. Lane and B.T. Neilson, National Science Foundation, $386,471. Submitted March 2020; will be resubmitted summer 2022.

Research Products 2021–2022

See Appendix D for a complete list of prior research products.

*=Post-Doctoral Researcher, ** = Graduate Student, *** = Undergraduate Student
Journal Publications:


Conference Presentations:


Faculty Involvement

The LRO is a collaborative facility that provides opportunities for collaboration across departments, institutions, and agencies. Faculty that have been involved in the last year include:

1. Bethany Neilson, Utah State University, CEE (LRO leadership and involvement on a number of projects)
2. Jeff Horsburgh, Utah State University, CEE (LRO leadership and involvement on a number of projects)
3. Dennis Newell, Utah State University, Geology (Co-PI of karst hydrology NSF collaborative proposal)
4. Tianfang Xu, Arizona State University (PI of karst hydrology NSF collaborative proposal)
5. Jim McNamara, Boise State University (Co-PI of karst hydrology NSF collaborative proposal)
6. Ruijie Zeng, Arizona State University (has a PhD student working on image analysis)
7. Carlos Oroza, University of Utah (PI on Snow-on LiDAR project in Franklin Basin)
8. Zac Sharp, Utah State University, CEE (has a MS student focused on modeling detailed impacts of flooding in the urban section of the Logan River)
9. Belize Lane, Utah State University, CEE (PI on NSF proposal that includes the Logan River, but it will also help expand the LRO to the Blacksmith Fork)
10. Kyle Moor, Utah State University, CEE (PI on USGS 104(b) project focused on fate of microplastics in the Logan River, collaborating with Janice Brahney and Beth Neilson)

1. Janice Brahney, Utah State University, WATS (PI on projects focused on atmospheric deposition of nutrients, metals, and microplastics and how they are transported through the Logan River and throughout the Great Salt Lake Basin, as well as projects examining terrestrial microplastic sources to the Logan River. She is working with Kyle Moore, Beth Neilson, and Phaedra Budy and has 1 current MS student, one undergraduate student, and 2 former MS students that have worked within the Logan River and depended on the LRO data).
2. Sarah Null, Utah State University, WATS (working throughout the Bear River Basin on NSF Career Grant)
3. Colin Phillips, Utah State University, CEE (has a MS student working on hydraulic geometry scaling throughout the Logan River based on LiDAR and flow data, PI on pending NSF proposal based in part on the Logan River).

LOGAN RIVER OBSERVATORY OUTREACH AND EDUCATION

In addition to its value as a platform and data source for research, the LRO also supports education by:

1. Continuing to work to increase public awareness of the connection between the landscape, humans, and water.
2. Supporting stakeholders in water related decision making:
   o The LRO completed a shading analysis to guide the Logan River Task Force regarding invasive tree species removal in the lower Logan River to limit temperature increases.
   o We will continue to collect detailed temperature data throughout Logan City to support various ongoing Logan River Task Force efforts and help meet monitoring needs.
We will continue to expand and refine existing hydraulic routing and temperature models developed for the valley section of the Logan River to guide future water quantity and quality related decisions.

The LRO has provided detailed temperature and flow analyses to the Logan River Task Force, Cache Water District, and others involved in the Logan River Watershed Project to guide scenario development regarding instream flow rates needed to maintain instream temperatures as part of the Environmental Impact Statement for the Crockett Diversion replacement.

The LRO is working with the Cache Water District to mentor a second senior design group that is working on feasibility of different design scenarios for the new Crockett Diversion rebuild.

3. Serving as an outdoor laboratory and classroom for training the next generation of engineers and scientists to address water issues in the state:

- LRO serves as a data source for real-world classroom exercises for many different USU classes (approximate number of students each year shown in parentheses).
  - CEE 3610 – Environmental Management (80)
  - CEE 3430 – Hydrology (70)
  - CEE 3500 – Fluid Mechanics (65)
  - CEE Senior Design (10) – Each year there is at least one group of senior design students focused on different aspects of the Logan River.
  - CEE 5003/6003 – Remote Sensing of Land Surfaces (8)
  - CEE 5190/6190 – GIS for Civil Engineers (40)
  - CEE 5470/6470 – Sedimentation Engineering (15)
  - CEE 6110 – Hydroinformatics (15)
  - CEE 6400 – Physical Hydrology (20)
  - CEE 5500/6500 – Open Channel Hydraulics (25)
  - CEE 6740 – Surface Water Quality Modeling (8)
  - CEE 6930 – Hydrologic Field Methods (7)

- Worked with Dr. Erin Rivers of USU Extension to explain karst hydrology and Logan River complexities to a group of Utah K-12 teachers as part of a week-long workshop.
Worked with Hope Braithwhite of USU Extension to deploy temperature sensors in First Dam, an impoundment at the mouth of Logan Canyon, to investigate reservoir temperatures during the very dry summer of 2021. This effort will be repeated this summer and include volunteers as part of the Water Quality Extension outreach activities.

4. Supporting the research for many graduate and undergraduate students that will generate a better understanding of potential challenges related to our water supplies.

- Current LRO Undergraduate Student employees and mentees:
  - Abby Johnson, BS, CEE
  - Abby Englund, BS, CEE
  - Chelsey Cowburn, BS, CEE
  - Devon Hill, BS, CEE
  - CEE Senior Design Group – Neilson Faculty Mentor – Crockett Diversion Replacement Project

- Appendix D (Table D1) provides a description of the graduate students and projects focused on the Logan River watershed.
Appendix A:
Logan River Watershed Overview

The Logan River watershed is located in the Bear River mountain range east of Logan, Utah. With headwaters near the Utah-Idaho border, the upper, or canyon, portion of the basin is steep and flows southwest through mostly natural land cover (forest and rangeland) with little development other than paved and dirt roads, a ski resort, and a small number of summer homes. Currently, the majority of precipitation falls as snow, resulting in a snowmelt-dominated hydrograph. Peak flows occur in the late spring, with an average annual flow at the mouth of the canyon of approximately 230 cfs (6.5 cms). The geology of the upper portion of the watershed is primarily limestone and dolomite (Dover, 1995). The topography is characterized by sinkholes and fractures formed by dissolution of the rocks (also known as karst features), which creates underground drainage systems. According to Spangler (2001; 2011), some Logan Canyon geologic layers (e.g., the Garden City Formation and Laketown Dolomite) have more karst development than other layers, but all units have the ability to transmit water via fractures, faults, and bedding planes created and enhanced by dissolution. The exception is the Swan Peak Formation, primarily composed of quartzite, which minimizes vertical groundwater movement between some of the karst layers and intersects the river in multiple places (Spangler, 2011). Groundwater movement is also influenced by the Logan Peak Syncline and the merger of the Naomi Peak Syncline and Cottonwood Canyon Anticline near Wood Camp Spring (Bahr, 2016).

Three major karst springs in Logan Canyon (Ricks, Wood Camp, and Dewitt Springs) provide significant flow to the river throughout most of the year. Numerous smaller springs (both karst and non-karst) feed the Logan River or its tributaries and may or may not flow year-round. Many tracer studies have been conducted in an effort to establish subsurface connectivity between the karst aquifer and these major springs (Spangler, 2001, 2011), as well as other short-residence-time intrabasin and interbasin subsurface connectivity. Dewitt Springs is a primary drinking water source for Logan City, and a large portion of its flow is diverted before entering the Logan River. Three additional perennial tributaries also join the Logan River (Beaver Creek, Temple Fork Creek, and Right Hand Fork Creek). Other tributaries are either limited in their contribution or are intermittent, with no flow reaching Logan River during parts of the year.

In lower Logan Canyon, a series of three small dams (First, Second, and Third Dam) divert flow for hydropower generation. An irrigation diversion between First and Second Dams supplies water to the Highline Canal. Once the river enters the valley portion of the watershed, it flows through residential areas, then more urbanized portions of Logan City, then residential areas again, and finally through agricultural areas west of Logan City. During the summer growing season, most, and sometimes all, of the river’s flow is diverted into three additional canals for residential and agricultural irrigation (Sumac, Crockett, and Young Ward Canals). Two major tributaries, Spring Creek and the Blacksmith Fork River, as well as many other smaller inflows, also contribute to the river in the residential, urban, and agricultural areas. These inflows are primarily sourced from stormwater, groundwater drainage, and irrigation return flows. Various restoration efforts led by the Logan River Task Force (https://uwrl.usu.edu/iro/logan-river-task-force) have been implemented in the valley portion of the river to address human impacts throughout the watershed and along the river corridor.
Appendix B:
Climate Site and Parameters Measured
Table B-1. Climate site and parameters measured at each site within the Logan River Observatory.

| Site Name                  | Site Code       | Updates           | Vapor Pressure (kPa) | Barometric Pressure (kPa) | Cumulative Precipitation (cm) | Snow Depth (cm) | Wind Speed (m/s) | Wind Direction | Air Temperature (°C) | Relative Humidity (%) | Incoming Shortwave Radiation (W/m²) | Outgoing Shortwave Radiation (W/m²) | Incoming Longwave Radiation (W/m²) | Outgoing Longwave Radiation (W/m²) | Net Radiation (W/m²) | Incoming PAR (μmol/m² s) | Outgoing PAR (μmol/m² s) | Soil Temperature @ 5,10,20,50,100 cm (°C) | Soil Permittivity @ 5,10,20,50,100 cm | Soil Volumetric Water Content @ 5,10,20,50,100 cm (%) |
|----------------------------|-----------------|-------------------|----------------------|--------------------------|-------------------------------|-----------------|-----------------|----------------|-----------------------|---------------------------|------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|
| Climate Station at Logan River Golf Course | LR_GC_C         | Continuously Updated | ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● |                |            |                |                |                |                |            |                |                                    |                                    |                                    |                                    |                                    |                                    |                                    |
| Climate Station at Franklin Basin | LR_FB_C         | Continuously Updated | ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● |                |            |                |                |                |                |            |                |                                    |                                    |                                    |                                    |                                    |                                    |                                    |
| Wilkins Repeater            | LR_Wilkins_R    | Continuously Updated |                             | ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● |                |                |                |                |            |                |                                    |                                    |                                    |                                    |                                    |                                    |                                    |
| Climate Station at TW Daniels Experimental Forest | Decommissioned | Continuously Updated | ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● |                |            |                |                |                |                |            |                |                                    |                                    |                                    |                                    |                                    |                                    |                                    |
| Climate Station at Tony Grove | LR_TG_C         | Continuously Updated | ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● |                |            |                |                |                |                |            |                |                                    |                                    |                                    |                                    |                                    |                                    |                                    |
| Climate Station at Temple Fork |                 | Periodically Updated | ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● |                |            |                |                |                |                |            |                |                                    |                                    |                                    |                                    |                                    |                                    |                                    |
Appendix C:
Prior Logan River Observatory Research Products

Annual Reports:


Journal Publications:


Conference Presentations:


Appendix D:
Graduate Student Involvement with Logan River Observatory
Table D1. Graduate students that use LRO data for part of their thesis/dissertation or worked on a project focused on some aspect of the Logan River watershed.

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Degree</th>
<th>Department</th>
<th>University</th>
<th>Advisor</th>
<th>Date of Completion</th>
<th>Thesis/Dissertation Title</th>
<th>Overview of Research</th>
<th>Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyrum Tennant</td>
<td>PhD</td>
<td>CEE</td>
<td>USU</td>
<td>B.T. Neilson</td>
<td></td>
<td>Variability of groundwater storage in karst geology and its effects on streamflow.</td>
<td></td>
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</tr>
<tr>
<td>Gabriel Benitez</td>
<td>MS</td>
<td>CEE</td>
<td>USU</td>
<td>C. Phillips</td>
<td></td>
<td>Linking deviations from hydraulic geometry scaling to causal mechanisms and instream processes.</td>
<td></td>
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</tr>
<tr>
<td>Nate Ashmead</td>
<td>MS</td>
<td>Hydrological Sciences</td>
<td>Boise State University</td>
<td>J. McNamara</td>
<td></td>
<td>Snowmelt dynamics and streamflow at the watershed scale.</td>
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<tr>
<td>Macy Gustavus</td>
<td>MS</td>
<td>WATS</td>
<td>USU</td>
<td>J. Brahney</td>
<td></td>
<td>Sources of plastic to the Logan-Bear river system</td>
<td></td>
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<tr>
<td>Daniel Thurber</td>
<td>MS</td>
<td>CEE</td>
<td>USU</td>
<td>B. Lane</td>
<td></td>
<td>Exploring potential thesis topics surrounding the relationships between seasonal snowpack storage and the timing/magnitude of Spring and Summer streamflow signatures and the sensitivity of those relationships to climate change.</td>
<td></td>
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<tr>
<td>Dane Liljestrand</td>
<td>PhD</td>
<td>CEE</td>
<td>University of Utah</td>
<td>C. Oroza</td>
<td></td>
<td>Improving basin-scale snow depth estimation through adaptation of citizen-science collected measurements and LIDAR terrain data.</td>
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<tr>
<td>Ruoyao Ou</td>
<td>PhD</td>
<td>CEE</td>
<td>Arizona State University</td>
<td>T. Xu</td>
<td></td>
<td>Understanding response of snow-dominated karst watersheds to climate variability using a hybrid physically-based and data-driven modeling approach</td>
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<tr>
<td>Longyang Qianqiu</td>
<td>PhD</td>
<td>CEE</td>
<td>Arizona State University</td>
<td>R. Zeng</td>
<td></td>
<td>Developing physically interpretable deep learning models to simulate hydrologic processes</td>
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<tr>
<td>Amber Jones</td>
<td>PhD</td>
<td>CEE</td>
<td>USU</td>
<td>J. Horsburgh</td>
<td></td>
<td>Machine learning techniques to investigate surrogate relationships, to develop automated methods of quality assurance/quality control of hydrologic and water quality time series data, and to better understand lateral inflow variability throughout the Logan River watershed.</td>
<td></td>
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</tr>
<tr>
<td>Dane Brophy</td>
<td>MS</td>
<td>CEE</td>
<td>USU</td>
<td>B.T. Neilson</td>
<td>May-21</td>
<td>Testing remote sensing methods for mapping the karst features within Logan Canyon</td>
<td>Dane worked to determine if satellite imagery had high enough resolution information for mapping karst features. He also coarsened very high-resolution UAV imagery to determine the resolution of data needed to map known features.</td>
<td>Brophy, Dane P., &quot;Testing Methods of Surficial Sinkhole Identification Using Remotely Sensed Data&quot; (2021). All Graduate Plan B and other Reports. 1526. <a href="https://digitalcommons.usu.edu/gradreports/1526">https://digitalcommons.usu.edu/gradreports/1526</a></td>
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<tr>
<td>Student Name</td>
<td>Degree</td>
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<td>Advisor</td>
<td>Date of Completion</td>
<td>Thesis/Dissertation Title</td>
<td>Overview of Research</td>
<td>Publications</td>
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<tr>
<td>Hyrum Tennant</td>
<td>MS</td>
<td>CEE</td>
<td>USU</td>
<td>B.T. Neilson</td>
<td>May-21</td>
<td>Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory.</td>
<td>Hyrum used flow, ion, and isotope data to establish detailed spatial estimates of flow losses, flow gains from ungaged lateral inflows, and flow source information throughout the urban and agriculturally influenced portion of the Logan River.</td>
<td>Tennant, H. 2021. &quot;Ungaged inflow and loss patterns in urban and agricultural sub-reaches of the Logan River Observatory.&quot; M.S. Thesis. Utah State University. All Graduate Theses and Dissertations.</td>
</tr>
<tr>
<td>Conor Tyson</td>
<td>MS</td>
<td>CEE</td>
<td>USU</td>
<td>T. Xu/B.T. Neilson</td>
<td>May-21</td>
<td>Effects of Climate Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed</td>
<td>Conor modeled snow accumulation and melt over the entire canyon portion of the Logan River watershed. These model results are being combined with machine learning approaches to link the spatial and temporal snowmelt patterns with streamflow. Conor has successfully completed his thesis and in the process of preparing a journal article for publication.</td>
<td>Tyson, Conor. 2021. “Effects of Climate Forcing Uncertainty on High-Resolution Snow Modeling and Streamflow Prediction in a Mountainous Karst Watershed” M.S. Thesis. Utah State University. All Graduate Theses and Dissertations</td>
</tr>
<tr>
<td>Madison Alger</td>
<td>MS</td>
<td>CEE</td>
<td>USU</td>
<td>B. Lane</td>
<td>Jan-21</td>
<td>Controls on summer stream temperature patterns in irrigation-depleted streams</td>
<td>Madison collected a significant amount of flow and temperature data in portion of the Blacksmith River that was dewatered due to upstream diversion structures. She used these data to investigate temperature patterns throughout this section and how these changed when shallow groundwater from nearby irrigation canals returned to the river.</td>
<td>Alger, Sara Madison, &quot;Summer Stream Temperature Patterns and Controls in an Irrigation Depleted Western Stream&quot; (2021). All Graduate Theses and Dissertations. 8029. <a href="https://digitalcommons.usu.edu/etd/8029">https://digitalcommons.usu.edu/etd/8029</a></td>
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<tr>
<td>Desneiges Murray</td>
<td>MS</td>
<td>WATS</td>
<td>USU</td>
<td>J. Brahney</td>
<td>Jan-21</td>
<td>The fate and cycling of nitrogen, phosphorus, and trace heavy metals in beaver-altered headwater streams</td>
<td>Deni collected a significant amount of inflow, outflow, and within beaver pond physical and chemical data. She used these data how beaver dams influence the fate and transport of nonpoint source pollution.</td>
<td>Murray, Desneiges. 2021. “The fate and cycling of nitrogen, phosphorus, and trace heavy metals in beaver-altered headwater streams.” M.S. Thesis. Utah State University. All Graduate Theses and Dissertations. 8035. <a href="https://digitalcommons.usu.edu/etd/8035">https://digitalcommons.usu.edu/etd/8035</a></td>
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<td>Publications</td>
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<tr>
<td>Murray**</td>
<td>D.</td>
<td>B.T. Neilson</td>
<td>J. Brahney</td>
<td>Dec-20</td>
<td>Environmental Controls on Didymosphenia geminata Bloom Formation</td>
<td>Lindsay investigated controls on Didymosphenia geminata (or didymo) growth in controlled and natural systems. Didymo is a stalk forming benthic diatom species that can diminish the recreational and aesthetic value of a stream, can cause infrastructure problems such as the fouling of water intakes, and can have significant ecosystem and ecological impacts. Didymo samples are being collected downstream of the UWRL site to monitor time variable responses where blooms have repeatedly occurred. LRO data at the UWRL site will be key in interpreting didymo trends.</td>
<td>Murray”, D., B.T. Neilson, J. Brahney. 2021. “Source or Sink? Quantifying beaver pond influence on non-point source pollutant transport in the Intermountain West.” Journal of Environmental Management.285, 112127. <a href="https://doi.org/10.1016/j.jenvman.2021.112127">https://doi.org/10.1016/j.jenvman.2021.112127</a></td>
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<tr>
<td>Lindsay Capito</td>
<td>MS</td>
<td>WATS</td>
<td>USU</td>
<td>J. Brahney</td>
<td>Dec-20</td>
<td>Improving Aquatic Habitat Representation in Utah Using Large Spatial Scale Environmental Datasets.</td>
<td>Goodrum, Gregory C., “Improving Aquatic Habitat Representation in Utah Using Large Spatial Scale Environmental Datasets” (2020). All Graduate Theses and Dissertations. 7902. <a href="https://digitalcommons.usu.edu/etd/7902">https://digitalcommons.usu.edu/etd/7902</a></td>
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<tr>
<td>Beth Ogata</td>
<td>PhD</td>
<td>Biology</td>
<td>USU</td>
<td>M. Baker</td>
<td>Aug-20</td>
<td>Anthropogenic Influences on Bacterial Assemblages in Stream Biofilms</td>
<td>Beth worked to understand anthropogenic influences on bacterial assemblages within stream biofilms, which are an integral component of stream ecosystems, after stream biogeochemistry. More specifically, her research examined how nutrients and pharmaceuticals, ubiquitous pollutants in streams worldwide, affect bacterial assemblages in stream biofilms.</td>
<td>Ogata, Elizabeth M., “Anthropogenic Influences on Bacterial Assemblages in Stream Biofilms” (2020). All Graduate Theses and Dissertations. 7889. <a href="https://digitalcommons.usu.edu/etd/7889">https://digitalcommons.usu.edu/etd/7889</a></td>
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