

**The Institute for Water & Watersheds
Annual Technical Report
FY 2016**

Introduction

Oregonians are witnessing the difficulties caused by water limitations. Water quantity and quality issues in the Willamette, Klamath, Deschutes, and Umatilla Basins are the Governor's top environmental and water allocation priorities. For example, Governor Brown declared a drought in the southern part of the typically water-rich Willamette Basin in 2015.

This situation is paralleled around the world, and points toward a strong emerging area for growth in research, education, and outreach. Oregon State University recognized this as an opportunity and welcomed the first class of the joint Master of Science degree in Water Cooperation and Diplomacy from the University for Peace in Costa Rica, the IHE Delft Institute for Water Education in Delft, the Netherlands, and Oregon State University.

Oregon's Water Resources Research Institute, called the Institute for Water and Watersheds (IWW), coordinates interdisciplinary research, training, and technology transfer on issues related to water. The IWW program assists faculty in providing outreach and research related to water resources issues on an "as-requested" basis with a "use inspired" research focus. Partners and constituents include educational institutions, state and local governments, watershed councils, and the general public. While the IWW supports research through USGS funding, the new model for IWW supports grant preparation and the integration of undergraduate research.

The IWW is involved in promoting the effective and sustainable use of water resources in the State of Oregon. IWW serves as a hub for water resources activities, for example:

- IWW is part of the OSU's Graduate Water Resources Graduate Program (<http://oregonstate.edu/gradwater/>).
- IWW operates and maintains a water collaboratory as a teaching lab for students and faculty.
- IWW funds graduate student hydrologic events such as an annual water symposium and field trips.
- IWW staff serve as expert "volunteers" to state agency advisory committees, county water committees, local watershed councils, and citizen science committees.
- IWW initiates and coordinates transdisciplinary water resource research projects and through the USGS water institutes program,
- IWW sponsors a regional water resources seminar each spring term on topics such as drinking water, stream restoration, water quality, water economics, and water conflict. Speakers from Oregon, the United States, and abroad participate in the program which has a different focus topic each year.
- IWW assists faculty in managing complex research grants and contracts.

Research Program Introduction

Oregon State University is ideally positioned to assume a leadership role in addressing water problems, with about 125 faculty in six colleges who teach and conduct research in areas related to water and watersheds. OSU is renowned for its landscape-scale ecosystems research and continues to grow **five graduate degree programs in Water Resources**. These research and education efforts have all occurred without the benefit of programmatic coordination or strategic vision.

Oregon's Water Resources Research Institute, called the **Institute for Water and Watersheds (IWW)**, coordinates transdisciplinary research, education, and technology transfer on issues related to water and water use. The IWW program focuses on statewide water resources issues by assisting faculty within Oregon State University, as well as those located within neighboring Portland State University, University of Oregon, Western Oregon University, Oregon Institute of Technology, among many community colleges located across the state, to provide outreach and research related to water resources issues on an "as-requested" basis with a focus on "use inspired" research. Partners and constituents of include educational institutions, state and local governments, watershed councils, and citizen scientists. While the IWW supports research through USGS funding, the model for IWW is to support grant preparation and integration of undergraduate students in the research enterprise.

The IWW is involved in promoting the effective and sustainable use of water resources in the State of Oregon. IWW serves as a hub for water resources activities, for example:

- IWW is part of the OSU's Graduate Water Resources Graduate Program (<http://oregonstate.edu/gradwater/>).
- IWW is part of OSU's Institute for Natural Resources.
- IWW staff serve as expert "volunteers" to state agency advisory committees, county water committees, and local watershed councils.
- IWW initiates and coordinates transdisciplinary water resource research projects and through the USGS water institutes program,
- IWW sponsors a regional water resources seminar each spring term on topics such as drinking water, stream restoration, water quality, water economics, and water conflict. Speakers from Oregon, the United States, and abroad participate in the program which has a different focus topic each year.

The IWW is the hub for this diverse water research community. It seeks to solve complex water issues by facilitating integrative water research. The IWW's functions are to:

- Assemble diverse research teams and lead interdisciplinary and transdisciplinary water research projects.
- Help policy makers and water managers collaborate with university faculty and students.
- Offer training and access to water quality and stable isotope analysis facilities through a shared laboratory called the IWW Collaboratory.
- Encourage community and collaboration among water faculty, students and water managers by sponsoring events and producing a monthly statewide water newsletter.
- Assist water faculty with project development and management.

Why Focus on Water?

Oregon's economic vitality is directly tied to water. Water is "virtually" embedded in all Oregon products, from timber and salmon to solar panels and semiconductors. But water supply and demand in the state is changing. There is now less snowpack in mountain regions and the snow is melting earlier in the spring and

Research Program Introduction

summer. These changes have implications for irrigation, human consumption, hydropower generation and ecosystems. Shifting population, land use patterns and environmental policies will also influence the future supply and demand for abundant clean water. And the state of Oregon is updating the Integrated Water Resources Strategy, one of two western states that was without a strategic water plan until 2012, to prepare for climate change and the wave of anticipated “climate change refugees” from drier and hotter regions of the United States.

Through an integrative research approach, the IWW seeks answers to questions important for Oregon, the nation and the world, such as:

- Where are climate change and human activity most likely to create conditions of water scarcity or an overabundance of water?
- Where is water scarcity or flooding most likely to exert the greatest impact on ecosystems and communities?
- What strategies would allow communities to prevent, mitigate, or adapt to scarcity and flooding most successfully?

Oregon State University hosts strong graduate degree programs in Water Resources and is located near state-of-the-art experimental watersheds and a suite of federal environmental laboratories. Below are short descriptions of some of the university's strengths in the areas of:

- water science
- water engineering
- water policy and management
- water diplomacy

Water Science

The OSU community has one of the largest gatherings of hydrologists and ecologists in the USA. They include not only campus faculty but also courtesy faculty from the suite of federal research laboratories located adjacent to campus, as well as state and federal agencies. This combination makes for a world-class grouping of people, mapped against one of the strongest hydrological gradients (from the super-humid Oregon Coast to extreme aridity in Eastern Oregon) in the world. The campus is known for its transdisciplinary collaborations -- for example, faculty from the top-ranked forestry and conservation biology programs collaborating on salmon conservation studies. Many researchers take advantage of nearby field laboratories such as the NSF Long Term Ecological Research (LTER) facilities at the HJ Andrews Experimental Forest and industry timberland instrumented watersheds in the Oregon Coast range (Hinkle Creek, Alsea and Trask).

The OSU-Benton County Green Stormwater Infrastructure Research (OGSIR) Facility, a three-celled stormwater research facility for field-scale experiments and testing on green infrastructure (e.g., raingardens, bioswales, etc.), was completed in 2014. Stormwater Solutions, a film highlighting the creation of the OGSIR can be viewed at the following link (https://media.oregonstate.edu/media/t/0_03knf8eg).

Faculty from Oregon State University, the University of Oregon and Portland State University completed the final year of work on a five-year project funded by the National Science Foundation titled "Willamette Water 2100," a study that used Oregon's Willamette River basin as a test case for managing regional water supply. This project evaluated how climate change, population growth, and economic growth will alter the availability and the use of water in the Willamette River Basin on a decadal to centennial timescale. Water Engineering

Water Engineering

Research Program Introduction

Unlike other land-grant institutions, OSU's engineering connection gives it strengths in treatment technologies for surface water, groundwater, and wastewater systems. OSU Engineering now ranks in the top 50 programs in the US. Many OSU engineers specialize in biological treatment methods and OSU hosts a Subsurface Biosphere Initiative that emphasizes interdisciplinary research on soil and groundwater microbial ecology. Many engineering faculty are also connected to the Oregon Built Environment & Sustainable Technologies Center (Oregon BEST) that connects the state's businesses with its shared network of university labs to transform green building and renewable energy research. Partnering with the OSU College of Business places a “business face” on the sustainability of engineered solutions to water problems.

Water Policy And Management

Addressing water resource challenges and reducing conflict in the US and abroad requires that water professionals and decision-makers receive specialized resources and skills that go beyond the traditional physical systems approach to water resources management. OSU offers a post-graduate certificate as part of their Program in Water Conflict Management and Transformation. The program leverages personnel from the top-10 nationally-ranked Geosciences Department, the top nationally ranked College of Forestry, as well as specialists in water policy, social science, communication, and anthropology. The “softer side” of OSU water has close links with UNESCO, the World Bank, the US Bureau of Reclamation and the US Army Corps of Engineers.

Joint Education Programme in Water Cooperation and Peace

UNESCO-IHE Institute for Water Education in the Netherlands, the University for Peace (UPEACE) in Costa Rica, and Oregon State University (OSU) in the USA, have embarked on a joint education program in Water Cooperation and Peace. The goal of this new initiative is to broaden the scope of approach to conflict and peace, provide a more theoretical dimension to conflict, engage multi-level scales of conflict dimensions and strengthen skills through highly experiential learning opportunities. The program will provide tools and training in an international setting, with a unique opportunity to undertake coursework and hands-on experiences in Costa Rica, The Netherlands and the United States. Participants will be exposed to case studies involving diverse challenges and contexts at different scales. The first student from the US has undertaken their studies in Costa Rica and the Netherlands and will finish their degree at OSU.

Supporting Near Real-Time Reservoir Dynamics Monitoring with USGS Satellite Data

Basic Information

Title:	Supporting Near Real-Time Reservoir Dynamics Monitoring with USGS Satellite Data
Project Number:	2015OR151S
USGS Grant Number:	
Sponsoring Agency:	U.S. Geological Survey
Start Date:	10/31/2016
End Date:	6/1/2017
Funding Source:	104S
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Surface Water, Models, Water Supply
Descriptors:	None
Principal Investigators:	Todd Jarvis, Ivan DenHoek

Publications

There are no publications.

Supporting Near Real-time Reservoir Dynamics Monitoring with USGS Satellite Data

Jamon Van Den Hoek, Oregon State University

Office of Water Information WRRRI Coordination Grant report

June 2017

In the year since my last update, the research methodology employed for monitoring reservoir dynamics with USGS satellite data has evolved to take advantage of large volume environmental data accessibility and distributed processing opportunities afforded by the Google Earth Engine analytical framework and underlying cloud computing architecture. The research products have also evolved in response to pivotal developments around global-scale monitoring of surface water dynamics, principally the public release of the European Commission's Joint Research Centre's (JRC) data on location and temporal distribution of surface water from 1985 onward (Pekel et al., 2016). While JRC data are based on Landsat data time series, there are significant limitations in the use of these data for achieving temporally consistent monitoring of surface water dynamics. Indeed, the synoptic perspective offered by the JRC dataset is appropriate for long-term assessments of changes in surface water extent or frequency but has less value for sub-annual or seasonal dynamics. Such limitations are especially problematic for understanding the effects of drought, changing management practices, or precipitation variation on reservoir dynamics in persistently clouded regions or regions with other forms of missing data. In overcoming limitations, I have developed and implemented an approach for monitoring reservoir dynamics that a) leverages the full Landsat archive and available topographic and bathymetric data, and b) employs a unique spatial morphological approach that overcomes shortcomings associated with missing data to provide a more comprehensive understanding of short- and long-term reservoir dynamics.

Background

Reservoirs are critical global infrastructure for managing and mitigating the effects of climate change-driven shifts in precipitation and evaporation regimes. Reservoirs supply irrigation water for agriculture and freshwater for drinking as well as hydroelectric power generation (García et al., 2014; Vörösmarty & Sahagian, 2000), and recent research is showing the importance of reservoirs for influencing atmospheric carbon dynamics (Fearnside, 2005; Rudd et al., 1993; Tranvik et al., 2009). Remote sensing time series data offer the potential for systematic monitoring of reservoir dynamics at the global scale, ensuring broad spatial coverage as well as a deep historical data lineage. The advantages of a satellite image-based quantification of reservoir dynamics are especially pronounced for reservoirs located in geography remote or high-elevation regions, conditions which make consistent and long-term monitoring a challenge, or in regions where the cost of constructing or maintaining a hydrologic gauge network is prohibitively expensive. However, remote sensing measurements of reservoir dynamics in the tropics are complicated by persistent cloud cover over reservoir bodies (Fig. 1).

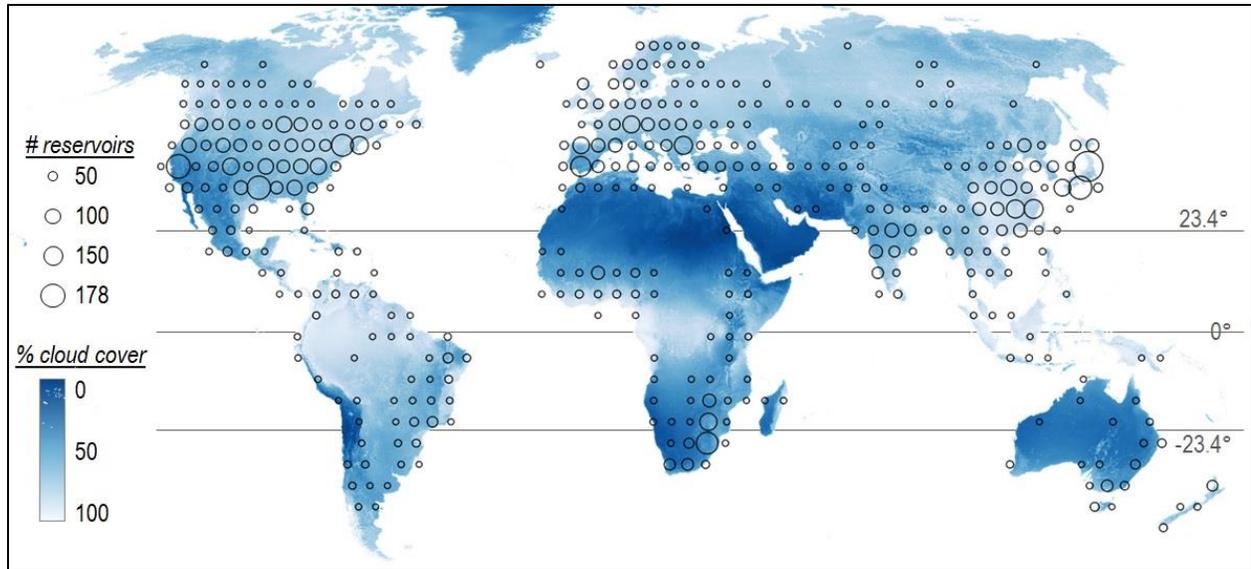


Figure 1. Approximately 15% (1,040) of the 6,824 GRanD reservoirs are located in the persistently clouded tropics (within $\pm 23.4^\circ$ latitude), which makes remote observation of reservoir dynamics especially difficult. Reservoir count is summarized within 5° square cells and cloud cover is depicted by percent daily cloud coverage from the MODIS MOD09GA product (2003-2014, 1km resolution).

Though the need for long-term, systematic reservoir monitoring is well understood, MODIS-based reservoir coverage products (e.g., the Global Lakes and Wetlands Database, the SRTM Water Body Dataset, the ESA CCI Global Land Cover Dataset, the Global Reservoir and Dam Database) only offer a single snapshot of reservoir surface area that is unfit for assessment of reservoir dynamics. While MODIS time series data have regularly been used to monitor reservoir dynamics at sub-monthly time scales (Gao et al., 2012; Zhang et al., 2014), the sensor's relatively coarse spatial resolution of 250m impedes quantification of surface area changes (e.g., Kang & Hong, 2016) with heightened consequences for monitoring reservoirs with shallow near-surface bathymetry (Smith & Pavelsky, 2009). With such spatially coarse measurements, and identification of dates of reservoir capacity minima and maxima that are relevant for assessing hydropower or irrigation potential and monitoring drought effects are also made difficult. The less than 20-year observational record of MODIS may be inadequate for longer-term reservoir dynamics associated with multi-stage water policy implementation, or decadal atmospheric carbon flux dynamics.

The 30m spatial resolution and over 40 years of global coverage at least every 16 days offered by the Landsat archive supports improved suitability for monitoring surface water (Donchyts et al., 2016; Feng et al., 2015; Mueller et al., 2016; Pekel et al., 2016). However, Landsat's revisit period means that atmospheric effects such as cloud cover or haze cannot be as readily mitigated as with 8- or 16-day MODIS temporal composites (Alsdorf et al., 2007). In addition, Landsat's swath width of 170km (8% of MODIS' 2300km swath width) necessitates mosaicking multiple near-date scenes to monitor reservoirs that span multiple scenes, and Landsat 7's Scan Line Corrector (SLC) Error eliminates 22% of otherwise viable

pixels from each image collected since March 2003. Despite these challenges, the need for higher spatial resolution monitoring over longer periods has positioned Landsat and Landsat-like data from other sensors (e.g., Sentinel 2) as central datasets for remote sensing of reservoir dynamics.

Methods

To monitor reservoir dynamics in a timely, up-to-date, and fully historical perspective, I developed an inherently scalable and cloud cover-resilient satellite data-driven approach for long term monitoring of surface water area with high spatial accuracy. Using Google Earth Engine's javascript API, I developed a framework to build time series of surface area estimates for selected reservoirs using all available Landsat surface reflectance-corrected imagery collected since 1985. Since the water body mask in Landsat's CFmask product has high accuracy for surface water pixel detection, I simply derived binary surface water maps from the CFmask rather than generate a novel surface water dataset.

While my original (Python-based) algorithmic approach relied upon near-date temporal compositing to address cloud cover and other missing data, I instead developed a novel spatial morphological approach to constructing surface area time series data. This technique assumes that a given surface elevation is directly (low variation) and consistently (over time, spatial extents, and elevation values) related to a surface area for a selected reservoir regardless of volume, surface area, or elevation. Surface area measurements are, of course, often obscured by atmospheric effects or Landsat 7's Scan Line Corrector error. However, since the surface elevation at the reservoir's extent will be consistent around the reservoir's boundary, this topographic/bathymetric isoline marks out the reservoir's extent as well. In cataloguing surface elevation values across all dates and cross-referencing these elevations values with corresponding surface area extents, missing data from any image date can be mitigated by referencing like-elevation dates (Fig. 2).

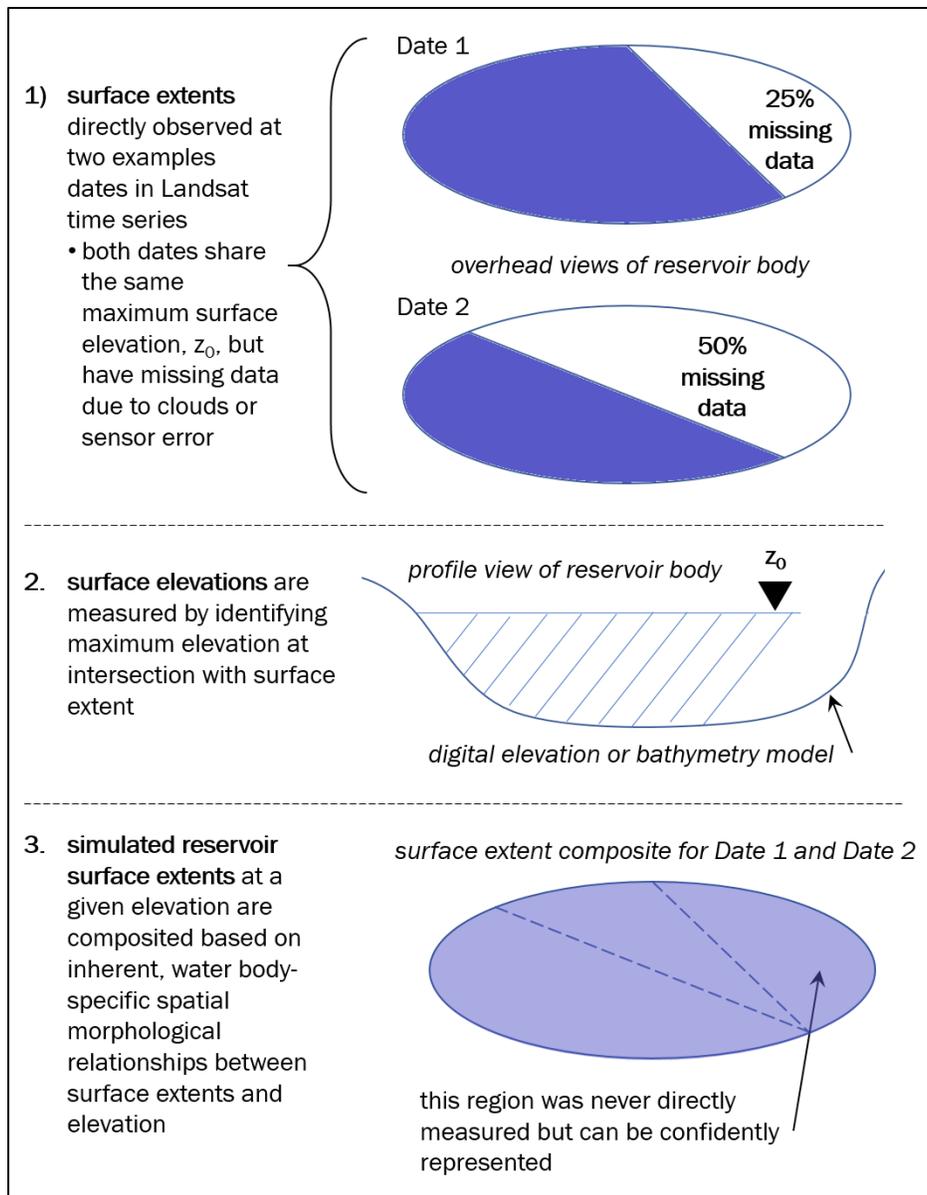


Figure 2. Overview of spatial morphology-based approach combining Landsat time series and digital elevation or bathymetry data to generate composite surface areas free of missing data. Only two example image-dates are shown though the implementation is applied for the full time series.

Lake Mead presents an ideal case study for the development and assessment of this approach for several reasons. First, because of the well documented and extensive depletion of reservoir volume, the Lake Mead reservoir displays extreme variation in surface area and elevation. Second, the high resolution (10m lateral) digital bathymetric model of Lake Mead produced by the USGS using sidescan-sonar and high-resolution seismic-reflection data (<https://data.doi.gov/dataset/surface-representing-the-floor-of-lake-mead-and-the-surrounding-area-utm-projection-10m-cellsiz>) supports measurement of the reservoir's full elevational profile across seasons and years (Fig. 3). Third, and relatedly, there are additional digital topography/bathymetry models with coverage surrounding Lake

Mead (e.g., the Shuttle Radar Topography Mission's (SRTM) with 30m lateral resolution, and the USGS' National Elevation Dataset (NED) with 1/3 arc-second lateral resolution). SRTM and NED are less useful since they adopt a 'typical' and constant surface elevation value for the minimum observable elevation, overlooking the elevational variation below the surface as represented that the USGS dataset provides. That said, these datasets are representative of the elevational data provided across the United States and globally, and are thus important to include for assessing the proposed method's relevance for reservoirs without available detailed bathymetry. Fourth, and finally, while Lake Mead does not present significant cloud cover, the data gaps resulting from Landsat 7's SLC off error (2003-present) must be addressed for historical, global monitoring of reservoir dynamics, and *can* be with the developed method.

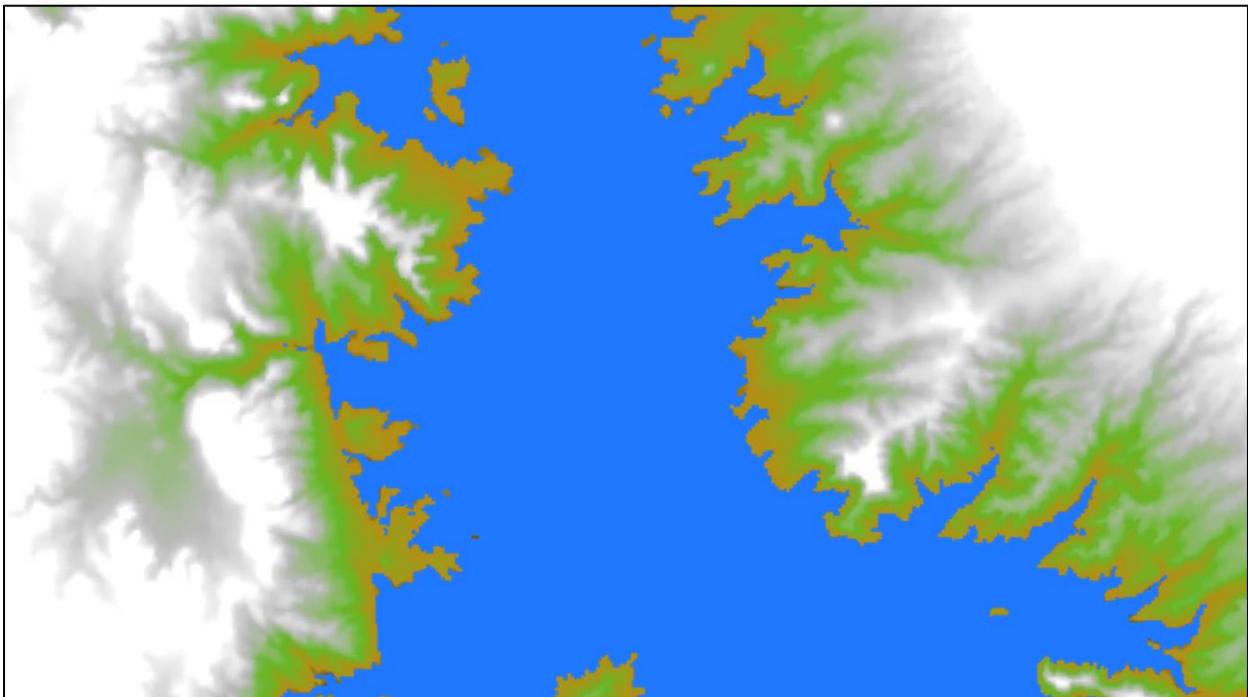


Figure 3. A snapshot of the Lake Mead reservoir surface area (blue) as detected by Landsat 8 in March 2013 with the digital bathymetric model (orange-green-grey-white) represented in the background. As is evident, the outermost extent of surface water occupies a rather consistent elevation value.

Peer-review article preparation and submission

The Google Earth Engine-based analytical approach has been successfully tested with the full Landsat 8 time series (2013-present) of 260 images (as of May 26, 2017) spanning two Landsat path-row scenes, 38-35 and 39-35. A table of wholly remote sensing-derived Lake Mead-specific relationships of surface elevation-extent values over these 260 observation dates has been generated. Immediate next steps in June 2017 is the completion of similar table generation for Landsat 5 (2000-2011) and Landsat 7 (2000-2017) time series data of 711 and 1,117 images, respectively. With these data completing the full 2000-2017 time

series, I will generate surface area-elevation plots, plot the remote sensing-derived Lake Mead surface area time series, measure volumetric dynamics following Eqn. 1, and, finally, compare measured surface elevation and volumetric time series to *in situ* data; *in situ* surface area data for comparison are not available. Python code for each of these latter analyses has been written and successfully demonstrated. Finally, the utility of the method will be evaluated with respect to available very high resolution bathymetric, high resolution topographic, and moderate resolution topographic elevation model data, which will inform the potential applications of the method across a representative range of elevation data availability scenarios.

By the end of Summer 2017, my colleagues at USGS CIDA and I will submit a Lake Mead-focused manuscript to either *Limnology and Oceanography: Methods* or *Remote Sensing* with 2015 Impact Factors of 2.008 and 3.036, respectively. Following this submission, we will extend the methodological application to a sample of three persistently clouded tropical reservoirs.

References

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Information Transfer Program Introduction

OSU's reputation for providing vital environmental information to students and the public is beyond reproach. A few of OSU's water-related outreach programs include:

The Oregon Well Water Program - An OSU Extension program designed to help Oregonians protect the groundwater that supplies their drinking water through education.

The Oregon Explorer Program - An online digital library that provides natural resources information to decision makers through a growing series of Web portals.

Oregon Digital Water Atlas - an incredible amount of datasets and hydrologic data exists on state and federal agency websites, yet little of these data have been captured and depicted in a consistent format. The Oregon Digital Water Atlas was completed this year and can be viewed at oregonwater.info

Acknowledging that academics need to communicate research in different ways with policymakers, IWW has experimented with new ways to diversify our outputs. Gone are the days of simply sending academic journal articles to policy makers and staff. IWW now completes what is termed "just-in-time" white papers or short You-Tube videos on topics of interest, promoting the notion that IWW's research is indeed "use inspired".

Other Collaborative Activities

The IWW Collaboratory was moved to a new location due to building demolition. Despite the relocation of the lab, the lab continued to process samples, the number of users (departments, entities) continues to increase and totals over 43.

The 6th Annual OSU Student Water Research Symposium put on by the Hydrophiles and the Water Resources Graduate Program and sponsored by IWW had over 135 attendees from 6 universities with 10 professional mentors over a two day period.

The IWW continues to be a teaching and technical resource for the Environmental Conflict Resolution courses at the University of Oregon Law School located in Eugene, OR.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2016OR144B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	004
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Groundwater, Floods, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Todd Jarvis

Publication

1. None available this reporting period due to staffing limitations.

IWW Collaboratory

The IWW Collaboratory offers training and access to water quality facilities through a shared laboratory.

The Collaboratory was forced to relocate to a new location due to a building demolition and reconstruction. As a consequence, the annual number of analyses decreased by nearly 50% to approximately 10,000 samples, the number users remained at approximately 45, but the new users increased, most focusing on Public Health and Human Development & Family Sciences.



Part of the USGS 104(b) funds were used to purchase a new Deionized (DI) water system for the laboratory. Water derived from the new DI system is used in many other analytical laboratories across the OSU campus.

USGS Summer Intern Program

Basic Information

Start Date:	5/1/2016
End Date:	5/10/2017
Sponsor:	US Geological Survey
Mentors:	Todd Jarvis
Students:	Maoya Bassiouni

Internship Evaluation

Question	Score
Utilization of your knowledge and experience	Acceptable
Technical interaction with USGS scientists	Acceptable
Treatment by USGS as member of a team	Acceptable
Exposure and access to scientific equipment	Acceptable
Learning Experience	Acceptable
Travel	About Right
Field Experience Provided	About Right
Overall Rating	A

Additional Remarks

Publication:

Bassiouni, M. and Scholl, M.A., in press, A Method for Quantifying Cloud Immersion in a Tropical Mountain Forest Using Time-Lapse Photography, Agricultural and Forest Meteorology AGRFORMET-D-16-00971.

The links associated with the final products from this project

(1) paper: <http://www.sciencedirect.com/science/article/pii/S0168192317301442>

(2) data release: <https://www.sciencebase.gov/catalog/item/58ffa40ae4b0e85db3a46c40>

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	3	0	0	0	3
Masters	1	0	0	0	1
Ph.D.	1	0	1	0	2
Post-Doc.	0	0	0	0	0
Total	5	0	1	0	6

Notable Awards and Achievements

IWW Director Todd Jarvis awarded **UCOWR Award for Public Service and Education** – <http://www.ucowr.org/current-recipients/2016-ed-public-service-recipients>

John Selker, Professor of Biological and Ecological Engineering, appointed **Distinguished Professor** at Oregon State University.

Gordon Grant, Professor in Water Resources Graduate Program, and Research Hydrologist with US Forest Service appointed as an **American Geophysical Union Fellow**.

IWW Director Todd Jarvis interviewed by *The Oregonian* about groundwater depletion in Oregon. (http://www.oregonlive.com/environment/index.ssf/page/draining_oregon_day_1.html)

Fatima Taha, Master of Science recipient in Water Cooperation and Diplomacy from the University for Peace in Costa Rica, the IHE Delft Institute for Water Education in Delft, the Netherlands, and Oregon State University, developed her own serious game “conserve Oregon” that requires players to solve issues resulting from historical natural events in Oregon and was awarded the **first place at the HWeekend competition** hosted by the College of Engineering and College of Business here at OSU. Taha also awarded the **Williamson Water Prize for leadership in the Water Resources Graduate Program**.