November 2016

The Water bLog newsletter

Utah Center for Water Resources Research at the Utah Water Research Laboratory

Message from the Director

As we move beyond Utah State University's 'Year of Water' celebrations and our satisfying look back at more than a half-century of water resources research here at the UCWRR, we are more than ever looking to the water challenges of the future. Some of these are Utah challenges, while others touch lives around the globe.

In this issue of the Water bLog, we highlight recent research that has direct relevance to Utah, specifically, as well as to more general applications. Air quality challenges are not unique to Utah, but one of Utah's unique air quality challenges stems from natural interactions in the air above the beautiful Great Salt Lake, while others, more general, relate to human interactions with the environment. Researchers at the UCWRR are exploring the causes and effects of some of these outcomes to better understand and manage air quality issues, both here in Utah and as far away as Palestine.

Another recent project is using computational fluid dynamics (CFD) to give practitioners the very practical information they need to optimize head loss in Venturi flow meter design to meet specific design criteria for nuclear, wastewater, and other metering applications.

These projects represent only a fraction of the active research underway at the UCWRR aimed at solving water-related natural resources problems throughout Utah, the nation, and the world.

Mac McKee, UCWRR Director

Welcome!

The Water bLog is the semi-annual newsletter of the Utah Center for Water Resources Research (UCWRR), housed at the Utah Water Research Laboratory.

The Center supports the development of applied research related to water resources problems in Utah and promotes instructional programs that will further the training of water resource scientists and engineers.

Each issue of The Water bLog reports on a small selection of current or recently completed research projects conducted at the center. More information is available online at:

http://uwrl.usu.edu/partnerships/ucwrr/

INSIDE

Research Highlights:

- *Computational Fluid Dynamics: optimizing Venturi flow meter design*
- *Understanding Air Quality Processes and Pollutants: the search for answers and improvements*
- *Abdelhaleem Khader: initiating new research to clear the air at home in Palestine*

In the News:

- *Research projects recently featured in local news outlets*

Featured Researchers:

- *Randal S. Martin & Zachary Sharp*

UtahStateUniversity.

Computational Fluid Dynamics:

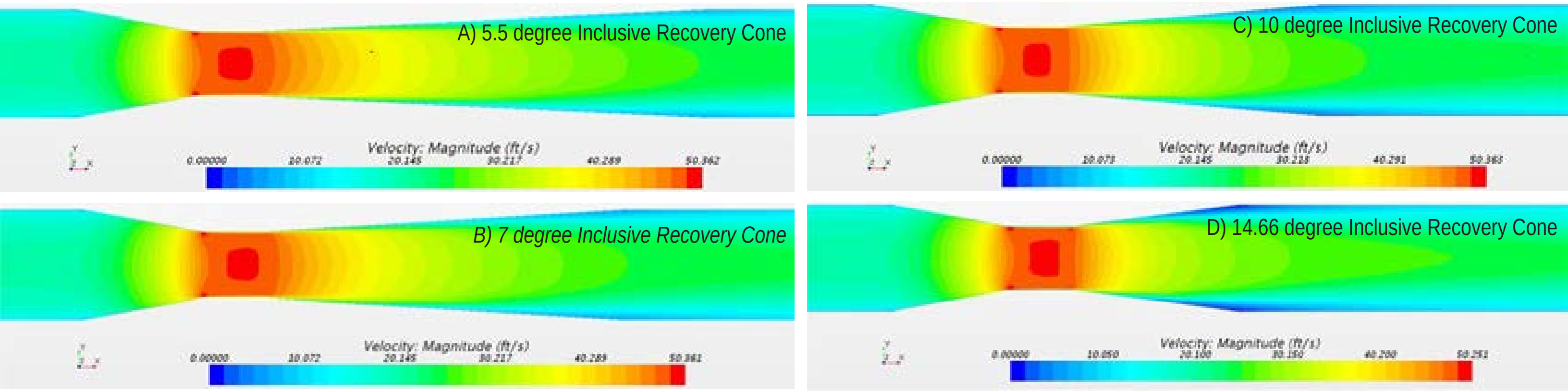
Optimizing Venturi flow meter design

"To accomplish the same research with purely physical modeling would have required 80 different Venturi recovery cones."

Venturi flow meters have been in use since the 1890s, and their accuracy is well documented. However, most Venturi designs are based on standards that don't take into account the unique needs and characteristics of specific meter installations such as minimizing head loss.

UCWRR researcher Zac Sharp recently used Computational Fluid Dynamics (CFD) to optimize Venturi recovery cone angles for head loss, which could greatly improve efficiency in commercial, municipal, and industrial applications. The research performed provides information on optimizing the recovery cone angle design; however, some instances, may require combined CFD and laboratory testing to meet design requirements.

Venturi design codes provide ranges of acceptable cone angles, but the CFD methods used in this research identify the specific optimal recovery cone angle to minimize pressure loss for particular meter designs and applications.



CFD velocity contour plots showing some different recovery cone angles tested during the research. Can you guess which design produces the least head loss?

Research

CFD uses math to predict what water will do. A wide range of different scenarios can be explored while constructing only a couple of physical models for verification. To accomplish the same research with purely physical modeling would have required 80 different Venturi recover cones, which would be prohibitively expensive.

This study used CFD and laboratory data to demonstrate the relationship between the recovery cone angle (RCA) on commonly used Venturi meter designs and the associated head loss characteristics. The objective was to determine the optimum RCA for various Venturi designs.

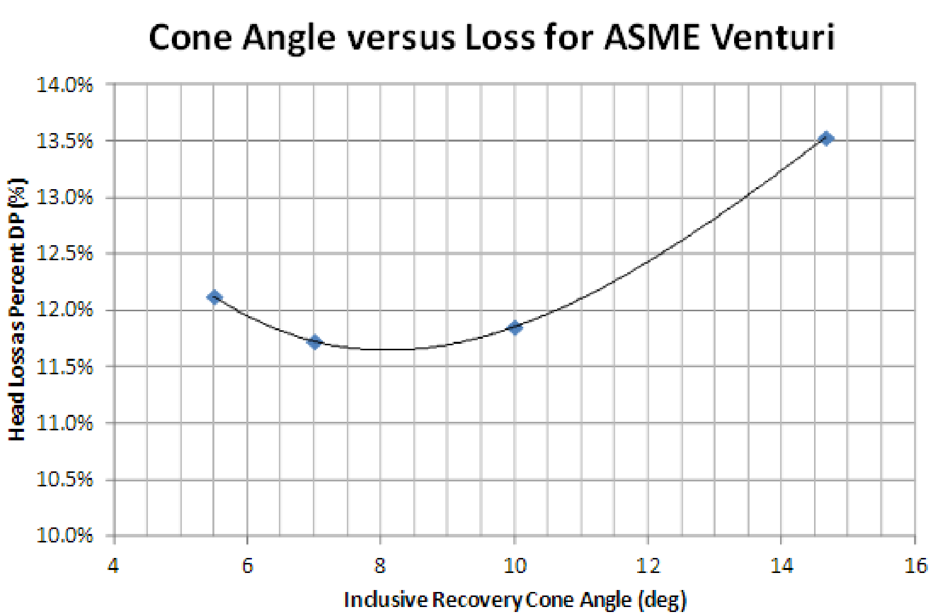
Physical and numerical data were used to determine optimum RCAs for five different Venturi designs. Parameters included:

- Four different beta ratios (0.20, 0.40, 0.60, and 0.75)
- two different Venturi wall roughnesses
- three different Reynolds numbers
- multiple RCAs

The physical model characteristics were established first, then the team used CFD to reproduce the experiment and calibrate the model. The Venturi was modeled in a CFD solver per manufacturing drawings. Pipe surface roughness was adjusted to produce the same pressure loss as that found in the laboratory steel piping and then applied to the meter, which was also fabricated using steel. The machined throat of the tested Venturi was modeled with a smooth wall in the CFD model. For comparison, the models were also run with the entire Venturi wall modeled as a smooth surface to assess how the optimum recovery cone is affected by surface roughness. The CFD models were tested over the same Reynolds number range as the laboratory tests, and the results were compared.

Results

Study results show that minimizing head loss in a Venturi meter is a function of beta ratio, RCA, and Reynolds number. The research focused on the sensitivity of recovery cone design to pressure recovery, and results identified the optimum cone angles for minimizing pressure loss, design parameters that affect optimal RCA, and the amount of change in permanent pressure loss to expect with different recovery cone designs.



Head loss versus cone angle for a 0.6 beta ASME Venturi with surface roughness. This plot shows that the meter design with the 7 degree recovery cone has the least head loss of the designs tested and that an 8 degree recovery cone would be optimal.

Key findings of this study are summarized below:

- CFD can be used to predict permanent pressure loss for many different Venturi designs.
- Slight changes in recovery cone angle can result in large increases in permanent pressure loss
- Smaller beta ratio meter designs result in smaller optimal recovery cone angles. They also make the optimal cone angle less susceptible to change from factors such as meter design, wall roughness, and Reynolds number that can change the optimal angle.
- The optimal recovery cone angle can vary widely for the same meter design with different beta ratios. The optimum angle in some meters changed as much as 8.2 degrees from a 0.20 beta ratio Venturi to a 0.75 beta ratio Venturi.
- The optimal recovery cone angle can change as much as 3 degrees from one Venturi meter design to another.
- Changes in recovery cone angle from one meter to another are greater with larger beta ratios. Changes in the optimal angle due to Reynolds number and meter roughness are also greater with larger beta ratio meters.
- Optimal recovery cone angles to minimize head loss are not necessarily included in code or in manufacturer design specifications.

Dr. Sharp found that CFD can be a powerful simulation tool. However, the results are only as good as the accuracy of the information used in the model. When properly used and verified, CFD can be used to extend the range of laboratory data, especially when collecting incrementally varying data in a laboratory is simply not feasible.

PI: Zachary Sharp
Research Engineer,
Utah Water Research Laboratory,
Utah State University
Phone (435) 797-3167
Email: zac.sharp@usu.edu

Air Quality Processes and Pollutants:

the search for answers and improvement

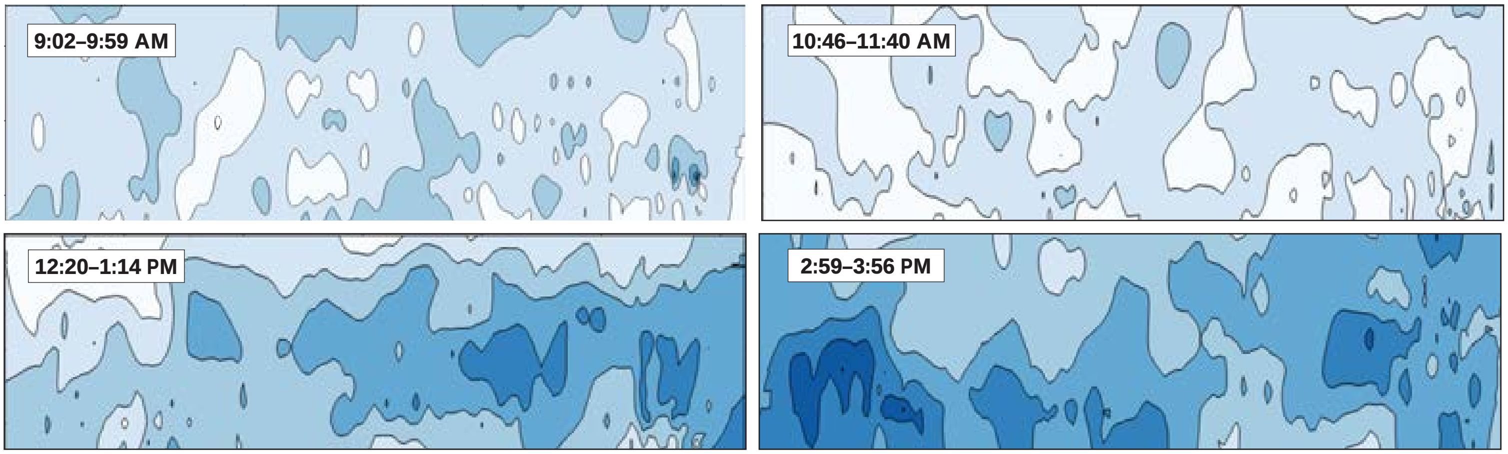
"Understanding these processes will be of key importance in developing remediation strategies"

Air quality has become a high priority in the State, and particularly so in Northern Utah. But finding ways to reduce air quality concerns requires more understanding of the processes involved in the formation of various air pollution components. Despite significant research, many questions remain unanswered. Much of Utah's wintertime air quality problems are caused by secondary particulates, which are formed by chemical reactions in the atmosphere and are dominated by a compound called ammonium nitrate.

Dr. Randy Martin has been seeking answers to such air quality questions in Northern Utah for the past 16 years. His investigations into winter and summer $PM_{2.5}$ and ozone (O_3) in Cache Valley and in the Uintah Basin, as well as the behavior of air pollutants around the Great Salt Lake, have improved understanding of these processes and will be of key importance in developing remediation strategies.

Research

For example, the recent 'Great Salt Lake Summer Ozone Study' developed and tested light airborne measurement



Ozone "curtains" or 2-D concentration maps extending WSW from Promontory Point, UT. Overall O3 increased (darker) and pushed west as the day progressed. Late afternoon flights seemed to show increased O3 at lower elevations over the GSL's open water.

systems, adaptable to platforms such as tethered balloons and AggieAir unmanned aerial vehicles (UAVs), to examine the vertical and horizontal structure of summertime ozone, measuring levels temporally and spatially over the Great Salt Lake (GSL) near Promontory Point, UT. The results showed an "ozone curtain" developing over time throughout the day, including transport of ozone and precursor species from the urban corridor out over the middle of the GSL, where it seemed to be temporally stored and enhanced until it could be transported back to the urban areas following evening changes in wind direction.

Other research has investigated components of negative wintertime air quality conditions in Cache Valley and along the Wasatch Front, as well as the effects of cold- and hot-start auto emissions compared to idling emissions and outdoor vs. indoor $PM_{2.5}$ concentrations.

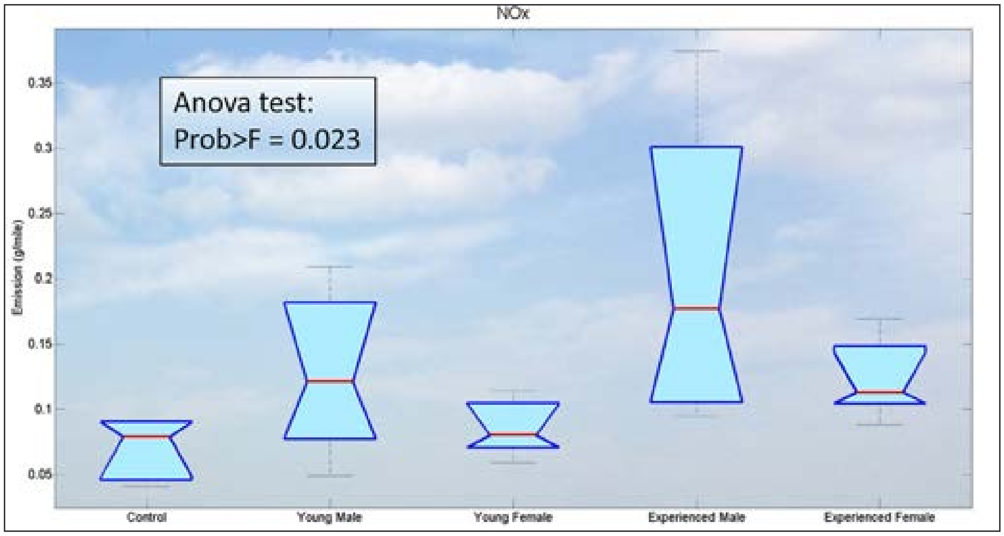
These same problems can affect areas all around the world. Dr. Abdelhaleem Khader (see companion story on p.6), professor of engineering at An-Najah National University in Palestine and former USU graduate student, recognized the need for research to address growing air quality problems there as well. Over the summer, he joined Dr. Martin as a visiting scientist to learn about techniques and equipment that will help him to implement similar research in Palestine.

Vehicle equipped to measure emissions based on driver behavior and experience.

Building on Dr. Martin's recent emissions research, they decided to examine any measurable effects of driver behavior relative to on-road automobile emissions. Twenty volunteers of various ages, genders, and driving experience drove a specific route that included a range of road conditions and driving variables. Although there was considerable variability within each group (young males, older males, young females, older females), as shown below, some surprising trends emerged.

Results

- Experienced drivers emitted more pollutants (but not statistically more) than young drivers.
- Male drivers emitted more pollutants, (but not significantly more) than female drivers.
- Carbon monoxide emissions were significantly less for female drivers, regardless of age.
- Low speed route segments resulted in significantly higher hydrocarbons (less efficient engine operation).
- Uphill route segments resulted in significantly higher nitrogen oxides (more work load on the engine).



Comparison of NOx emissions based on groups

Looking to the Future

Air quality is an ongoing challenge, and each piece of the puzzle adds to our understanding and guides new efforts to manage and mitigate the emission and formation of local and regional pollutants. Understanding the characteristics of the pollutants once they are in the atmosphere, along with information about how our individual behaviors contribute to the problems, are essential steps toward deriving effective remediation scenarios.

PI: Randal S. Martin
Research Associate Professor,
Utah Water Research Laboratory,
Utah State University
Phone (435) 797-1585
Email: randy.martin@usu.edu

Dr. Khader with his students celebrating their graduation.

Abdelhaleem Khader:

new research to clear the air at home in Palestine

Eight years ago, Abdelhaleem (Abed) Khader was sitting in his usual spot in Room EL221 for the weekly Environmental Engineering Seminar. At the time, he was an international graduate student from Palestine studying network design for ground water quality monitoring. The speaker that day was Dr. Randy Martin who was presenting his biennial Cache Valley air quality update. As the presentation progressed, Abed was intrigued. “That presentation was very interesting for me and made me realize that we need to do something similar in Palestine due to the similarity of topography and pollution sources.”

In the intervening years, Abed graduated from USU, completed a post-doctoral fellowship in Canada, and returned to Palestine to teach environmental engineering at An-Najah National University. He had become more convinced than ever of the need for air quality research. Palestine simply did not have the local research, or even the infrastructure necessary to perform the research, despite the rapidly growing air pollution sources and the noticeable increase in air quality related illnesses.

Determined to move forward into this as yet uncharted territory, he applied for and received a research (Zamala) fellowship through his university to study with Dr. Martin for a few weeks. His goal was to, “gain from his experience in this area in order to start the needed air quality research in Palestine.”

During his time here at the Utah Water Research Laboratory, Dr. Khader participated in a variety of research activities:

- Took the lead investigative role in a project to study the effects of driver behavior, experience, and road conditions on vehicle on-road emissions.
- Found ways to build particle sensors from readily available, low-cost parts. (Sensors will be used to teach high school students as part of Engineering State).
- Analyzed a large particle size distribution data set from last winter’s Salt Lake City air quality study collected using an advanced Grimm optical particle counter.

Although he has enjoyed renewing old friendships and creating new ones, Dr. Khader is excited to be back in Palestine to initiate air quality research that will eventually yield greater understanding and cleaner air at home.

Featured Researchers:

Randy Martin

is an Associate Research Professor at USU in Environmental Engineering. Since his arrival in the summer of 2000, his research has focused primarily on regional and local air-borne particulate matter commonly referred to as $PM_{2.5}$ and the unique phenomenon of elevated wintertime ozone in Utah's Uintah Basin. He has also adapted air quality instruments for UAV deployment and participated in gathering measurements with them over the Great Salt Lake and within the Uintah Basin. Dr. Martin has led or collaborated on air pollutant research in a wide variety of local, state, and regional air quality studies, including investigations in to the composition, sources, and photochemical formation of $PM_{2.5}$, the atmospheric behavior and sources of gas-phase ammonia, on-road vehicular emissions, air pollutant emissions from agricultural crop and animal production facilities, regional transport of air pollutants over the Colorado Plateau, and biogenic emissions of various hydrocarbons.

Zac Sharp

is a Research Engineer and Hydraulic Labs Manager at the Utah Water Research Laboratory, where he designs, estimates costs, and oversees the building and dismantling of the scale models at the lab. Zac earned his MS and PhD from USU in Civil and Environmental Engineering. His research has explored the use of Computational Fluid Dynamics (CFD) in flow measurement and meter design, as well as design considerations for fixed-cone valves with stationary and baffled hoods, energy losses in cross junctions, the effects of pipe wall offsets on differential pressure meter accuracy, and other topics relative to hydraulic instrumentation and data collection.

In the News:

research recently featured in local news outlets

AggieAir Helps Find the Fish When Yellow Creek Runs Dry

UCWRR researchers, along with state and federal agencies and the Nature Conservancy, are collaborating on an ongoing research project at Yellow Creek along the Utah/Wyoming border to protect native fish species during times when the creek runs dry, such as during times of drought or late summer when irrigation draws down the available water. AggieAir, an autonomous unmanned aerial vehicle (UAV) platform developed at the Utah Water Research Laboratory, has been a valuable tool for these researchers. Using remote sensing in the visual and infrared spectrums, Aggie Air helps researchers to locate pockets of water where the fish survive during the worst times so managers can protect and enhance these areas and keep these fish off the endangered species list.

For more on this story, see the video at:

http://www.ksl.com/?sid=41365477&nid=148&title=when-creeks-dry-up-where-do-the-fish-go

High Levels of Ground-Level Ozone over the Great Salt Lake

Ground-level ozone is a common air pollutant along the Wasatch Front in both summer and winter, and it can be damaging to both human health and plant ecosystems. One challenge to improving these pollution levels is the fact that ozone is not emitted but created through chemical reactions in the air. The EPA has set lower limits on allowable ozone levels, and the air along the Wasatch Front will likely exceed those limits many times in the months to come. UCWRR faculty member Dr. Randy Martin is one of several researchers from Utah universities and the Utah Department of Environmental Quality working together to collect data to shed light on why these high levels occur by monitoring the movement of ozone concentrations, with a particular focus on the Great Salt Lake.

A recent news feature explains more:

https://www.ksl.com/?sid=40225546&nid=148&title=utah-scientists-probe-ozone-pollution

Sunset over Antelope Island in the Great Salt Lake

Future Issues

"Flow measurement testing in Utah"

(Over time, small errors in flow measurement can add up to very large errors in water allocation. Researchers have assessed the accuracy of 259 of Utah's flow measurement structures & devices.)

"Mapping submerged vegetation in Fish Lake using AggieAir UAVs"

(UCWRR researchers are using AggieAir UAVs to map the progress of a non-native aquatic plant species, Eurasian Watermilfoil, for state agencies interested in mitigating this habitat threat to Fish Lake in Utah.)

Contact:

Utah Water Research Laboratory
Utah State University
Logan, UT 84322-8200
(435) 797-3157

Director:
Mac McKee

Associate Directors:
William J. Doucette &
Blake P. Tullis

uwrl.usu.edu/partnerships/ucwrr/

UtahStateUniversity
UTAH WATER RESEARCH LABORATORY