INSTITUTE OF TECHNOLOGY | UNIVERSITY OF MINNESOTA

ST. ANTHONY FALLS LABORATORY

CHANNEL

FALL 2008

RESEARCH FLOWS IN THE OUTDOOR STREAMLAB

ALSO INSIDE

fall 2008

SAFL CHANNEL

departments

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The St. Anthony Falls Laboratory is a research unit of the University of Minnesota's Institute of Technology in the Department of Civil Engineering. The laboratory is also closely affiliated with the Department of Geology and Geophysics, and the Department of Ecology, Evolution, and Behavior.

Cover: Anne Lightbody, research director of the Outdoor StreamLab at SAFL

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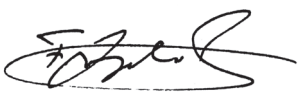
THE DIRECTOR'S PERSPECTIVE

SAFL has long been a leader in interdisciplinary fluid dynamics research and we are now at the forefront of developing science-based approaches to stream and river restoration, as evidenced by the inauguration of our Outdoor StreamLab (OSL) this summer. A joint project between SAFL and NCED, the OSL began its life when the first trickle of water flowed in early June. As part of SAFL's three-pronged StreamLab research strategy (including the Indoor StreamLab and Virtual StreamLab), the OSL has been designed to serve as a powerful tool for aquatic habitat restoration research. We are proud to provide the scientific community with a unique facility that combines the advantages of field research with the precise experimental controls that can only be achieved in a laboratory setting. With environmental restoration at the heart of its mission, it seems only appropriate that the OSL revived an old St. Anthony Falls flood bypass channel that had been abandoned since 1967. Once funding has been secured, the OSL will proceed to its second stage, the Riverine Corridor, and take a similar route by reviving the much larger adjacent flood bypass channel, which had been abandoned in the 1980s.

As we are always pleased to welcome in so many new faces at SAFL, we will be sad to see a familiar one depart with the retirement of Professor Roger Arndt at the end of this academic year. Dr. Arndt received his Ph.D. from M.I.T. in Civil Engineering. He came to SAFL in 1977 from Penn State, where he was an associate professor in the department of Aerospace Engineering, to become the first externally-hired director of the laboratory. Under his leadership, the laboratory emphasized the integration of education with basic and applied research and ventured into new research areas in computational and experimental fluid dynamics, water quality, hydroacoustics, and wind engineering. After he stepped down as SAFL director in 1993, Dr. Arndt became Director of the Fluid Dynamics and Hydraulics Program at the National Science Foundation, returning to the U of M in 1998 as a full-time member of the graduate faculty in Civil Engineering, Aerospace Engineering and Mechanics, and Mechanical Engineering. His academic career has been long and distinguished and he is highly regarded by his peers for his pioneering research in cavitation and bubbly flows. Professor Arndt has shaped this laboratory, his efforts leaving their mark in SAFL's reputation and identity, and I am confident that they will continue to do so even in his retirement years.



—Fotis Sotiropoulos
Professor and Director, SAFL

honors & awards

Assistant Professor **Kimberly Hill** is the head PI (co-PI Prof. **Fernando Porté-Agel**) on a new $295k award from the National Science Foundation for the project entitled "Multi-scale studies on the effects of fluid and bed variability on particle entrainment and transport." This research focuses on fluid-driven particle transport where particle-particle interactions are important, specifically bedload transport in river channels. The central goal of this research is to combine computational, experimental and theoretical efforts to develop a better understanding of bedload transport from first principles that can be applied to local particle transport in steady and variable conditions and subsequently to develop a model that can be applied to local and long-range bedload transport.

Professor and NCED Director **Efi Foufoula-Georgiou** recently received two new research grants from the National Science Foundation. The first, a $390K Cyber-Enabled Discovery and Innovation (CDI) grant in collaboration with Electrical Engineering Professor Guillermo Sapiro, is designed to study high-resolution, multiscale, and dynamic topography with the goal of extracting channel networks and landslide prone areas which contribute to increased sediment production and thus stream habitat deterioration. The second award, a $400K collaborative project with PIs from University of Columbia and Michigan State, is entitled "Collaborative Research: Geomorphic transport laws, landscape evolution, and fractional calculus," and is designed to help gain new insights into the mechanisms of sediment transport, which will enable better predictions of the results of river flooding and aid in disaster management.

Efi Foufoula-Georgiou has been named Director of the National Center for Earth-surface Dynamics.

Professor and Director **Fotis Sotiropoulos** received a three year, $600,000 grant from the National Cooperative Highway Research Program of the National Academies aimed at developing design methods for stream-restoration structures. The project will integrate laboratory-flume experiments, experiments in the SAFL Outdoor StreamLab, field studies, and 3D unsteady numerical simulations to develop comprehensive and quantitative design guidelines for in-stream structures. Drs. Anne Lightbody and Omid Mosheni (SAFL), and Professor Panayiotis Diplas (Virginia Tech) are co-investigators in this project.

Sotiropoulos was also appointed James L. Record Professor in the Department of Civil Engineering.

Professor **Roger Arndt** received the first increment in a $700,000 research grant from the Office of Naval Research for a new three year program aimed at studying the effects of supercavitation. To date the project budget has totaled over $1.6 million.

Arndt was also honored for his contributions to the field at the 24th IAHR Symposium on Hydraulic Machinery and Systems.

in other news

>>OSL Media Frenzy Research and researchers in the Outdoor StreamLab made headlines in the ***Star Tribune***, ***MarketWatch***, ***Minnesota Daily***, ***Minnesota Public Radio***, ***University News Service***, and on ***Channel 5's Eyewitness News***! Visit www.safl.umn.edu for links to all stories about the Outdoor StreamLab and its grand opening.

>>University Foundation The River Runs Through Us: Located on the continent's most important river, the U of M keeps the Mississippi River central to its academic and cultural life. View the U Foundation video (at www.safl.umn.edu.) to learn about SAFL's important contributions to the University's river research.

>>The New York Times Follow the Silt: SAFL/NCED stream restoration research featured in the June 24 ***New York Times***. Read all about it at www.nytimes.com.

>>Access Minnesota SAFL Director Fotis Sotiropoulos was interviewed by local radio station *Access Minnesota* about the effect of dams on river ecology. Listen in at www.safl.umn.edu.

>>Downtown Journal Jeff Marr was featured in "From the Desk of..." section of the September 15 online *Downtown Journal.*

>>Pioneer Press Toxic Trouble Building Up: Aging stormwater retention ponds trouble suburbs, homeowners, and scientists: Professor John Gulliver comments on stormwater management in the suburbs in the September 10 *Pioneer Press*.

>>Civil Engineering Simulated Outdoor Stream Adds Realism to Restoration Research: The Outdoor StreamLab was featured in the October 2008 issue of ASCE's *Civil Engineering Magazine*.

>>Stormwater The Journal for Surface Water Quality Professionals November/December 2008 issue featured SAFL's work on maintenance of stormwater BMPs: www.stormh2o.com.

>>PBS An interview with Fotis Sotiropoulos regarding the role of hydropower along the Mississippi River is expected to air on the *PBS Nightly Buisness Report* on November 19.

RESEARCH FLOWING IN THE OUTDOOR STREAMLAB

MOST SCIENTISTS ARE NOT USED TO WORKING IN THE SPOTLIGHT, under the watchful eye of curious passers-by, but it has become common-place for researchers stationed in the Outdoor StreamLab this summer to be the subject of much gawking.

Nestled among the St. Anthony Falls Laboratory, the Mississippi River, and Xcel Energy's public Water Power Park, the Outdoor StreamLab (OSL) is in a prime location for conducting environmental research in the heart of a city that is becoming increasingly aware, and supportive, of progress in this field.

Originally a flood bypass channel for the St. Anthony Falls, what is now the OSL sat abandoned since 1967. Dubbed the "Riparian Basin," this channel is currently a 130-foot long thriving field site for interdisciplinary research activity. This fall, SAFL and NCED hosted a grand opening and invited the public to come for an afternoon and observe (up close) what the OSL is all about.

ABOVE
Research assistants Katie Kramarczuk and Jordan Theissen monitor flow and benthic organisms in the OSL.

Historically, there has been no reliable method to test and compare restoration approaches, leading to inconsistent results and failed projects. Stream scientists and engineers seek to bring a greater understanding to the field, but are faced with the challenges of an unpredictable science. Although laboratory modeling and field site research have led to some progress, it has been difficult to develop design guidelines when faced with a complex ecological system such as a stream.

Fortunately, the Outdoor StreamLab provides the benefits of both lab and field— the reality of an actual (albeit small) stream system, with the ability to control flow rates, sediment loading, topography, man-made structures, and floodplain vegetation. Now, researchers and students with expertise in stream ecology and biology, engineering, hydrology, hydraulics, and geomorphology have an experimental facility for detailed study and evaluation of restoration approaches. Research benefits from collaboration with restoration organizations,

policy makers, and practicing engineers, including the members of the Partnership for River Restoration and Science in the Upper Midwest (PRRSUM). Results are shared with undergraduate and graduate students, including members of NCED's Stream Restoration Certificate Program.

As part of the StreamLabs system at SAFL, research in the Outdoor StreamLab complements both the Indoor StreamLab and Virtual StreamLab, bringing together a spectrum of research approaches (physical modeling, field-scale experimentation, and computational methods) to study the underlying mechanisms that govern stream processes, and how streams respond to natural and human disturbances.

Although the grand opening of the OSL was held on September 19, research had already been underway since June of this year, when the first water flowed down the man-made meander. This summer the channel swarmed with interns, graduate students, postdoctoral associates, NCED visitor program participants, and stream restoration certificate students. Researchers across the board took full advantage of the opportunity to dive in to collecting data in the unique facility.

ABOVE
Professor Jacques Finlay (Ecology, Evolution & Behavior) takes groundwater water quality samples.

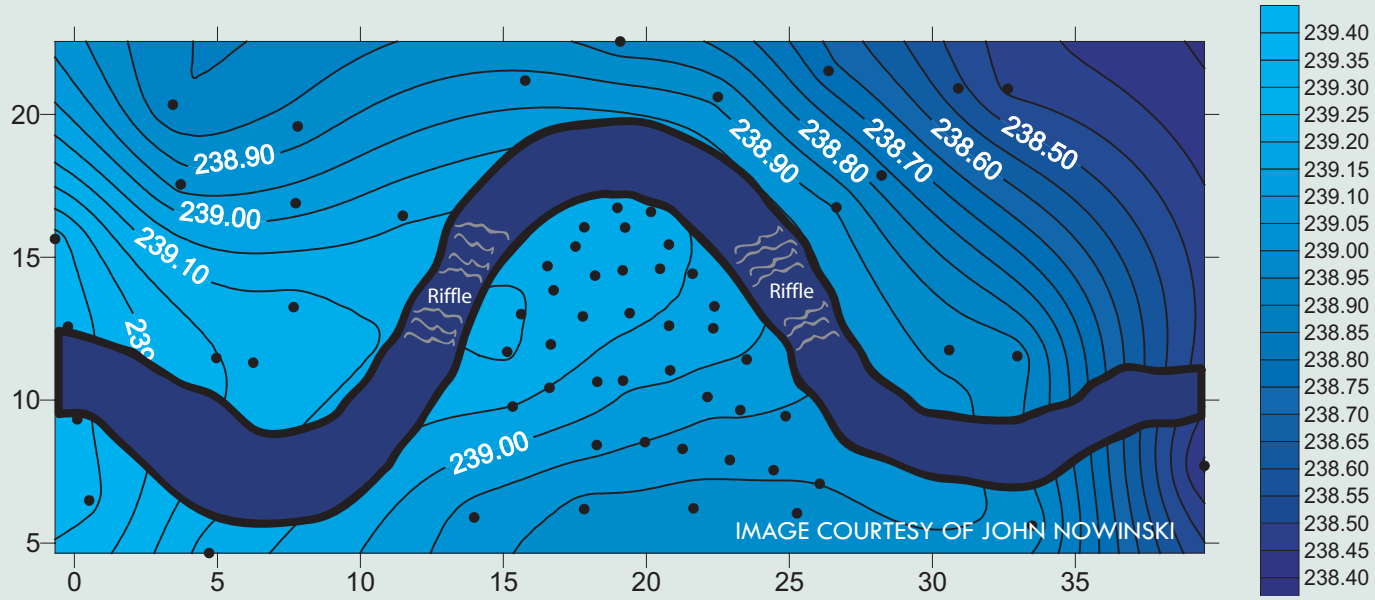
OSL research director Anne Lightbody orchestrated the development and progress of five inaugural projects in the formerly abandoned spillway's new role as research facility. The amount of data collected in the interim was immense, and although analysis is expected to continue throughout the year, preliminary findings are starting to trickle in.

LEFT
SAFL students Mark Morris and Eric Johnson monitor water velocity and turbulence.

PROJECT OVERVIEWS AND PRELIMINARY RESULTS

Project 1: Equilibrium topography of a sand-bed channel within a floodplain

Stream restoration projects often seek to improve physical properties and to rehabilitate the ecological processes of a channel; however, project designs are often based on limited scientific knowledge. In this project, researchers designed a sinuous sand-bed channel incorporating the best current knowledge of equilibrium channel properties. Various methods of channel design were compared, including stream restoration manuals and comparison to existing sand-bed streams. The predicted river slope matched observations. In addition, during the first season, the river reshaped its initially flat bed to create point bars on the inside of meander bends. In the long term, a river within an erodible floodplain will sculpt its banks to create dynamic equilibrium (that is, although any position along the channel may change, the channel's mean properties will remain constant). Monitoring of bank and bed topography will continue throughout the life of the OSL.



ABOVE
OSL groundwater table during base flow.

BELOW
Jordan Theissen captures aquatic insects during an experimental flood.

Project 2: Dominant control of cross-stream super-elevation within meander bends

The cross-stream water elevation profile within meander bends is typically sloped, so that the water elevation at the outer bank is elevated above that of the inner bank. This slope creates a helical secondary circulation cell, which moves flow across the river bed toward the inner bank and builds point bars at the inside of meander bends. In the OSL, researchers found that the secondary circulation cell is affected by bed roughness. The presence of fringing riparian vegetation decreases near-bank flow, increasing the centrifugal force outside of the vegetation but decreasing deposition on the vegetated bar.

Project 3: Appropriate metrics for sediment-related total maximum daily loads

The most common cause of impaired rivers and streams in the United States is sediment pollution. High levels of suspended sediment reduce aquatic health both through direct physical mechanisms (interfering with the operation of fish gills and macroinvertebrate feeding, abrading benthic organisms, reducing hyporheic exchange, and smothering fish eggs) and indirectly by reducing light transmission and increasing turbidity. In this project, OSL researchers compared various metrics for determining the effect of sediment pollution. To do so, water with different compositions of suspended load (e.g., different proportions of fine sand, silt, and mud and different levels of organic matter and nutrients), but the same turbidity level was introduced half way down the OSL channel. Researchers then observed the impacts of sediment on physical metrics (embeddedness, permeability), macroinvertebrates, and warm-water fish (smallmouth bass and whitesuckers). Trials were performed under high-flow conditions, typical of storms which exert substantial stress on aquatic ecosystems. Results indicated that suspended sediment affected benthic habitat but that turbidity readings did not fully explain the observed community response. These results will help federal and state agencies to modify their regulations and to better protect the water quality of the nation's rivers and streams.

Project 4: Residence times and ecological implications of geomorphology-driven subsurface flow

Rivers and aquifers are three-dimensionally connected at multiple scales, and fluid flux between surface and subsurface zones mediates important naturally occurring biogeochemical and ecological processes. Here, OSL researchers designed, installed, and monitored a high-resolution three-dimensional network of near-stream piezometers to characterize hyporheic water flow and to determine the change and variability in nutrient concentrations. The resulting high-resolution flow-path map revealed that the surface topography increased water flux through the meander bend. Nutrient levels within the subsurface and soil conductivity also changed across the point bar as a result of intense microbial activity. These components will advance the long-term goal of understanding and predicting the feedbacks between surface geomorphology, subsurface residence times, microbial community dynamics, and nutrient processing.

Project 5: Water residence time and sedimentation within patches of aquatic vegetation

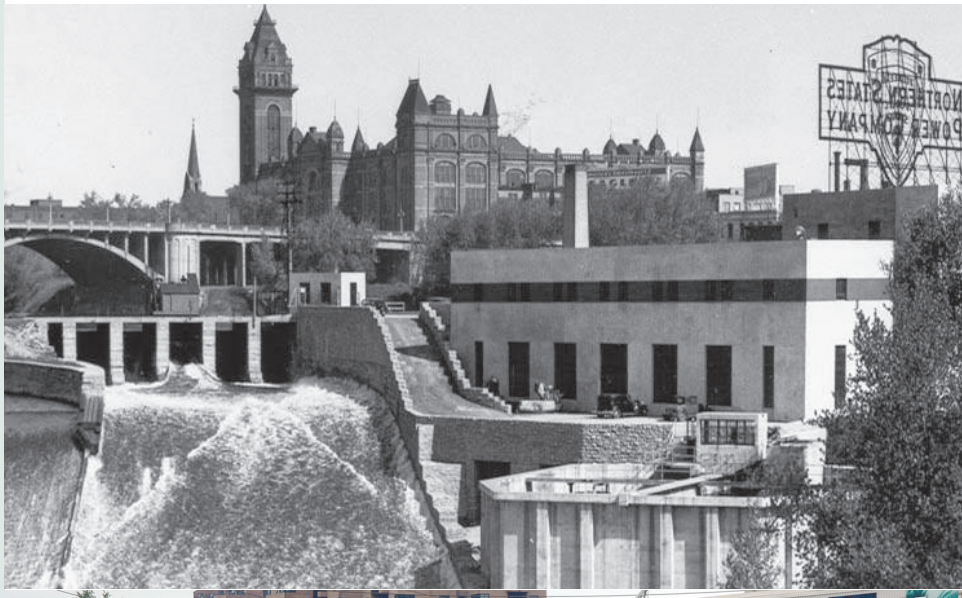
The presence of aquatic vegetation in river channels results in an increase in flow resistance and a reduction in conveyance capacity. However, by enhancing water quality, creating ecologically productive riparian zones, improving in-stream habitat, and stabilizing banks, aquatic vegetation plays a crucial role in river restoration in the United States. This project validated models that predict the residence time and turbulence levels of a patch of aquatic vegetation under field conditions. In particular, OSL researchers found that the size and stem density of aquatic vegetation patches determines turbulence levels within the vegetation, and the lateral and vertical exchange of dissolved solutes and sediment between the vegetation and the free stream. Patch-scale measurements of velocity, turbulence, tracer retention, and sedimentation were compared to simultaneous reach-scale tracer studies to document the effect of vegetation on increasing flow diversity and sediment storage within the reach.

WHAT LIES AHEAD

These and similar projects will continue to run year-round within the Riparian Basin. Future plans also include reviving an adjacent, longer flood bypass channel that has been abandoned since the 1980s. Pending funding resources, developing the 430-foot "Riverine Corridor" will proceed during the next few years.

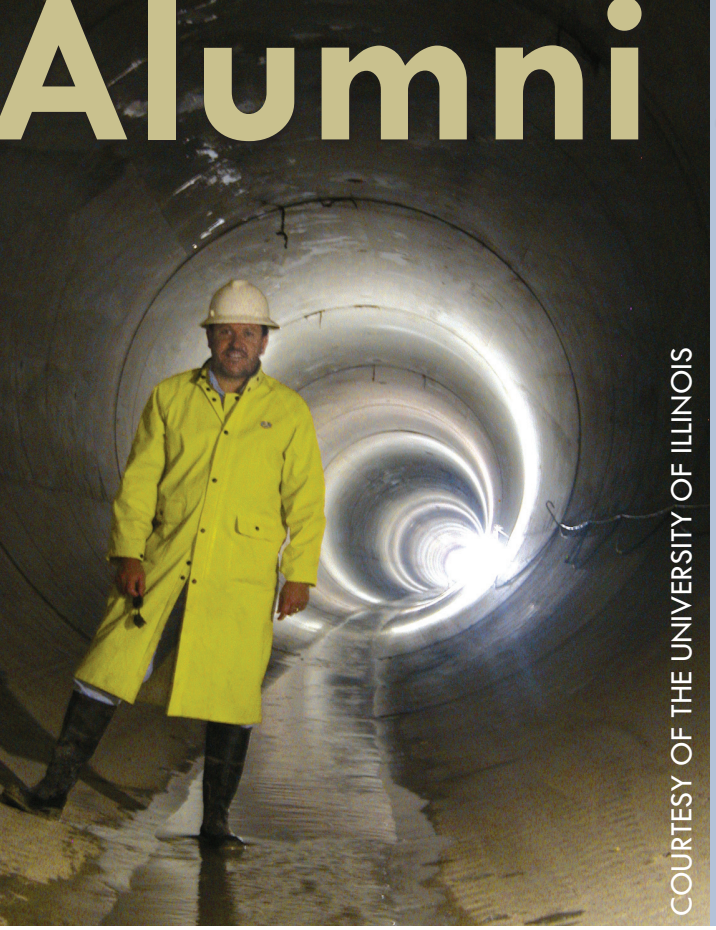
Of the public open house this fall, Lightbody said, "The grand opening was a huge success. Over 300 people from inside and outside the University joined us to hear about environmental research at the St. Anthony Falls Laboratory. The enthusiasm and curiosity of those who attended was a great way to celebrate this exciting first summer of research in the Outdoor StreamLab."

FOR MORE INFORMATION visit www.safl.umn.edu/OSL



BELOW:
THEN & NOW
SAFL and adjacent spillway circa 1950, and SAFL and the OSL Riparian Basin in 2008.

Alumni Spotlight:



COURTESY OF THE UNIVERSITY OF ILLINOIS

Marcelo Garcia

SAFL graduation year: 1989
Degrees: M.S. and Ph.D. (Civil Engineering/SAFL)
Advisor: Gary Parker
Ph.D. Thesis title: "Depositing and Eroding Sediment-Driven Flows: Turbidity Currents"

Marcelo Garcia is currently the Chester and Helen Siess Endowed Professor in Civil and Environmental Engineering, and founding director of the Ven Te Chow Hydrosystems Laboratory at University of Illinois at Urbana-Champaign. He is editor and co-author of the American Society of Civil Engineers' **Manual of Practice 110—Sedimentation Engineering: Processes, Measurements, Modeling and Practice**, *published this summer. Professor Garcia has received numerous awards, including SAFL's Anderson Award in 1989, Arthur Thomas Ippen Award from IAHR in 2001, and the Hans Albert Einstein Award from ASCE in 2006.*

THERE IS A LONG HISTORY OF CONNECTION between our two institutions, beginning with Lorenz G. Straub, who received his undergraduate and graduate degrees from University of Illinois at Urbana-Champaign before going on to become the founder of SAFL. Currently there are three SAFL alumni holding faculty positions at UIUC- you, Gary Parker, and Praveen Kumar. How do you feel these connections helped form the identities of the Ven Te Chow Hydrosystems Laboratory and SAFL, two of the world's top water resources and environmental engineering labs?

The Illinois-Minnesota connection started with Straub's education at Illinois in structural engineering but was also influenced by Mary Marsh, an Illinois graduate and long-time administrator of SAFL during the early years of the lab. Professor emeritus Hall Maxwell joined the faculty at Illinois after completing his Ph.D. at SAFL in the early 1960s, and was the person responsible for the design of the Hydrosystems Laboratory. In 1997, the laboratory was named after Ven Te Chow, who was the person that brought world-wide attention to Illinois with his classic books: "Open Channel Hydraulics" and "Handbook of Applied hydrology." In many ways it's fair to say that we have come full circle.

In your career at UIUC you have been involved with some interesting projects on the city of Chicago's waterway systems, namely solving the mystery of the Chicago River's change in direction. In 1900, engineers reversed the flow of the river to prevent wastewater from polluting Lake Michigan and Chicago's water supply; over 100 years later, through your research on density currents, you convinced city officials that the river had not lost its memory. How do you feel the field of environmental engineering has changed in your lifetime?

In the case of Chicago, the standards for water quality and aquatic life keep getting more stringent and this presents many new challenges. For instance, nowadays pharmaceuticals are finding their way into waterways and this generates public concern. It is likely that in the past there were many drugs that went through wastewater treatment plants as well, but they were not detected. At the same time there is increased pressure on wastewater treatment plants to disinfect the treated wastewater before putting it back into the waterways. The field of environmental engineering is extremely dynamic and we need to continue to find innovative ways to ensure public health and a safe environment.

You have also had a leadership role in the $3.1 billion Tunnel and Reservoir Plan (TARP) built by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) to improve operation of Chicago's sewer overflow management, guiding graduate and undergraduate students through computational and physical modeling of the overburdened system. What do you find rewarding about combining research and teaching in your career?

One of the most rewarding aspects of my career has been working with many bright students on a wide range of projects. I enjoy doing the research needed for engineering purposes and in this sense, Chicago presents some incredible challenges in water and wastewater management that are fairly unique, although one can find similar situations in other large metropolitan areas around the world. I am particularly proud of the work done with my students to prevent drowning accidents at low-head dams in Illinois. At the Glen Palmer Dam located on the Fox River at Yorkville, Illinois, approximately 30 people have drowned in as

many years. We sought a solution using a stepped-spillway that was finally constructed about a year ago and has been working very well, which makes me very happy.

What projects are you currently working on at UIUC?
We are currently developing a 3D Environmental Fluid Dynamics Code for the Chicago area waterways. There are about 80 miles of waterways so this is a challenging exercise, but it has to be done for water management purposes given that Lake Michigan is the main source of water supply. We also have ongoing research on river meandering with the help of a "Kinoshita" flume. Tools developed through this project can be used for the restoration of streams that were channelized in the past, and can thus be improved from biological and ecological points of view. We are also doing research on submarine flows (turbidity currents), as well as benthic boundary layer flows, with a large oscillatory flow tunnel (the only one of its kind in the world).

What do you think is the most important trait for a successful career in academia?
Believing in what you want to do is perhaps one of the most important qualities for an academic. Being able to articulate what you want to do— be it in writing or orally— is also very important. When you give a presentation about a potential research project, you want everyone to feel the same level of excitement that you have about the subject at hand. However, the most challenging aspect of being a professor is teaching. It's not easy to gain the respect of students, but when you do it's a great feeling.

If you could conduct your ideal class or design your ideal experiment, what would it be?
The ideal class for me is in the lab, where you can show the students how sand grains move along the bottom, and the beauty of a hydraulic jump. Experiments bring students in direct contact with fluid phenomena that are otherwise difficult to explain. By the way, many of our teaching flumes were designed by the late Sig Anderson Sr., who worked at SAFL for many years and then went on to build wind tunnels and flumes with his children. Another Illinois-Minnesota connection!

What's your favorite body of water and why? If you could conduct field research anywhere in the world, where would it be?
My favorite body of water is the Parana River in Argentina. It's a magnificent river and I grew up very close to it, in Santa Fe. Instead of taking a siesta during hot summer afternoons, my cousin and I used to go fishing on the Parana. Being able to catch fish and eat them on the spot is one of my fondest childhood memories. I want to make sure that future generations can have similar experiences. This is where I want to do field research in the future.

Do you have any words of advice for current or future students?
Enjoy your experience as a graduate student at SAFL. The courses you take and the grades you get are important, but with time they become anecdotal. The people you meet from all over the world and the friends you make are for life.

Thank you donors!

SAFL gratefully acknowledges the following individuals, who have generously provided support during this past calendar year.

Mrs Geneva N Anderson
Prof Roger E A Arndt
Jane E Arndt
Nadyne A Balke
Barr Engineering Co
Mr Curtis W Bauers
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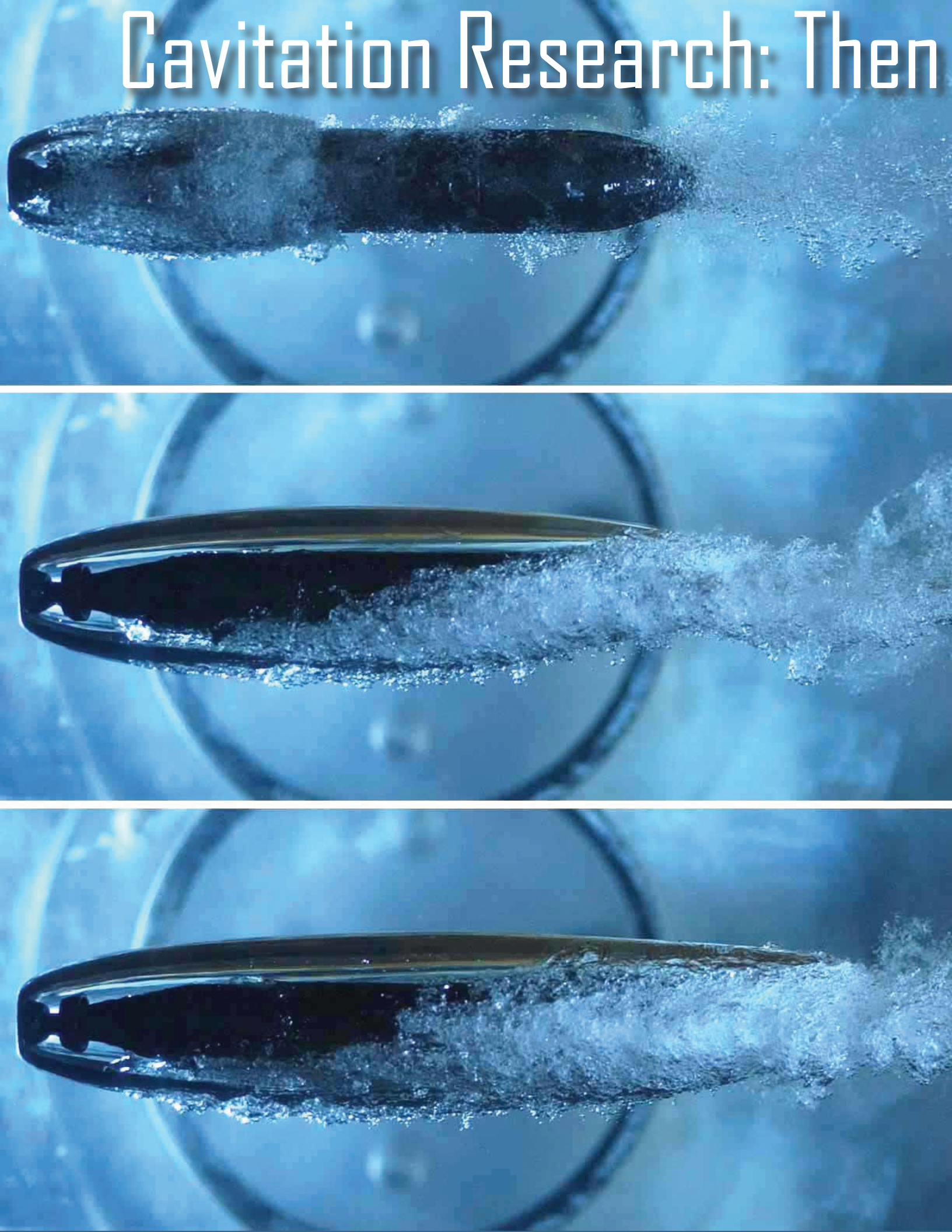
Cavitation Research: Then



and Now

PROFESSOR ROGER ARNDT'S WORK ON CAVITATION HAS LED TO A DECADES-LONG TRADITION OF INTERNATIONAL COLLABORATION, NOW A HALLMARK OF SAFL RESEARCH

SAFL HAS LONG BEEN HAILED for its international reputation, reflected in its early and well-established connection with students and researchers from abroad, and collaborative studies with organizations around the world. SAFL's founder, Lorenz G. Straub, was an early pioneer of initiating joint research projects with colleagues across the ocean, and his personal interest in photography has served the lab's archives well in documenting these alliances. Since arriving as SAFL director in 1977, Professor Roger Arndt has continued this tradition of cooperation across continents and countries throughout his own research on cavitation, adding to the list of partners that have worked with the lab on a wide variety of research topics. In fact, the high cost of the equipment necessary for cavitation research has had a beneficial effect for cooperative research, and Arndt credits his success in the field to the assistance and friendship of the international associations he has made throughout the years.

From its earliest beginnings, cavitation research has been built on a foundation of elegant mathematics and sophisticated experimentation. Over the past 100 years, it has transitioned from separate, and often unrelated, mathematical and experimental studies towards a more integrated experimental/numerical approach. Much of the progress of the past several decades has been due to the collaboration among researchers like Arndt, allowing for data results to be shared across research centers, and thus maximizing typically limited resources. Of particular note is the progress in our understanding of the physics of cavitation as influenced by water quality, specifically, the strength of the water as influenced by the concentration of free and dissolved gas.

LEFT
Axisymmetric ventilated supercavitation: ventilation increases and cavitation index decreases from top to bottom.

ABOVE
Axisymmetric, turbulent bubbly wake resulting from the collapse of a ventilated supercavity.

Traditionally, cavitation research has focused on operational and design issues in the maritime and hydraulic engineering fields. Limitations on propeller design due to cavitation sparked much of this research, followed by projects dealing with hydraulic turbines and pumps, and more recently on a much broader range of topics. Significant progress has been made at SAFL in the development of the tools necessary to carry out this research, such as Laser Doppler Anemometry (LDA), Phase Doppler Anemometry (PDA), Particle Imaging Velocimetry (PIV), holography, high-speed video cameras, and an exponential growth in Computational Fluid Dynamics (CFD), have now made many of the earlier challenges in experimental research almost routine. Despite the benefits these new tools have provided however, many of the details of the physics of cavitation remain elusive.

BREAKING NEW GROUND

The Vacutank at the Marin Institute Netherlands (MARIN) is a unique facility that was specially designed for propeller research using large ship models. Arndt's sabbatical year there in 1974 led to collaborations with resident researcher Dr. Gert Kuiper and Dr. Andreas Keller of the Technical University of Munich. It was during these early years when they observed that in some cases the cavitation patterns on model propellers differed from patterns created in the field, yet in other cases, good correlation appeared to be associated with propellers that had more uniform pressure distribution. Several avenues of research were then explored by Arndt and Keller to address this problem, and a series of tests was performed in both the MARIN large water tunnel and the Vacutank, to compare inception data obtained in both facilities. This comprehensive study identified the significant role of water quality, breaking new ground in the techniques of making acoustic measurements and providing new data on cavitation inception in turbulent shear flows at high Reynolds number. Both nuclei size and number as well as dissolved gas content were found to be important, and a need for a more user-friendly technique to monitor water quality was also identified. These findings were influential in establishing the future directions of cavitation research at SAFL and elsewhere.

Nearly a decade later, tip vortex cavitation studies initiated at SAFL indicated that nuclei size and number play a critical role in the inception process. Tension had been observed, and nuclei supplied from regions of separated flow on the hydrofoil generating the tip vortex were found to act as sources of nuclei when the separated flow was supersaturated. When cavitation is entirely due to the ingestion of free-stream nuclei, very small nuclei were apparently the trigger for the inception process, in spite of the availability of larger nuclei in the flow.

A follow-up to these studies was then initiated at cavitation facilities of the Technical University of Munich in Obernach, Germany in 1989. A larger foil, identical in planform blade section to that used by Arndt's lab at SAFL, was tested over the same Reynolds number range. This research was aided by an automated water quality measurement system based on Dr. Keller's "vortex nozzle" which had been installed in the Obernach tunnel. During a 1991 visit, Keller installed a similar device at SAFL, and also developed a new oil drop visualization technique to aid testing of new foil shapes.

Further studies at Obernach in the early '90s were significantly aided by the loan of a specialized high-speed camera by BMW, which at the time was not available in the U.S. Some of the issues were resolved using this system, aiding in the discovery of a substantial difference in the nucleation process in weak and strong water. Numerical calculations at SAFL confirmed this trend, as did SAFL's own observations of the nucleation process using a simpler photographic technique. The level of tension that can be sustained was found to depend on blade loading, and in fact, experimentation in "strong water" can lead to erroneous scaling with lift coefficient. Researchers at both institutions learned that careful attention must be paid to water quality when carrying out prediction experiments, as each facility is different and experience has shown that the proper procedure to be used to eliminate this effect is not universal. In fact, the two facilities also have very different water quality characteristics: the SAFL tunnel's design provides more stable water quality over time, and the Obernach facility responds more quickly to changes that are induced by cavitation experimentation. This proved to be an advantage in obtaining new effects of water quality on fully cavitating flows, and the two groups cooperated on further studies of sheet/cloud cavitation, conducting experiments at different scales in their respective facilities to investigate dynamic response of size effects.

Studies at SAFL throughout the past ten years have included collaborative research with the Norwegian University of Science and Technology (NTNU) and the Flow Design Bureau, a small Norwegian

company, focusing on issues of sheet/cloud cavitation, pumping of gas loaded liquids, and research on improvements in the efficiency of hydroturbines, resulting in collaborative papers with NTNU's Morten Kjeldsen, a frequent visitor to SAFL. Arndt's work with Professor Yoshinobu Tsujimoto of Osaka University has also led to several collaborative papers and cross-continental visits, including an NSF-funded program for SAFL graduate students to work with Tsujimoto at Osaka.

CURRENT STUDIES

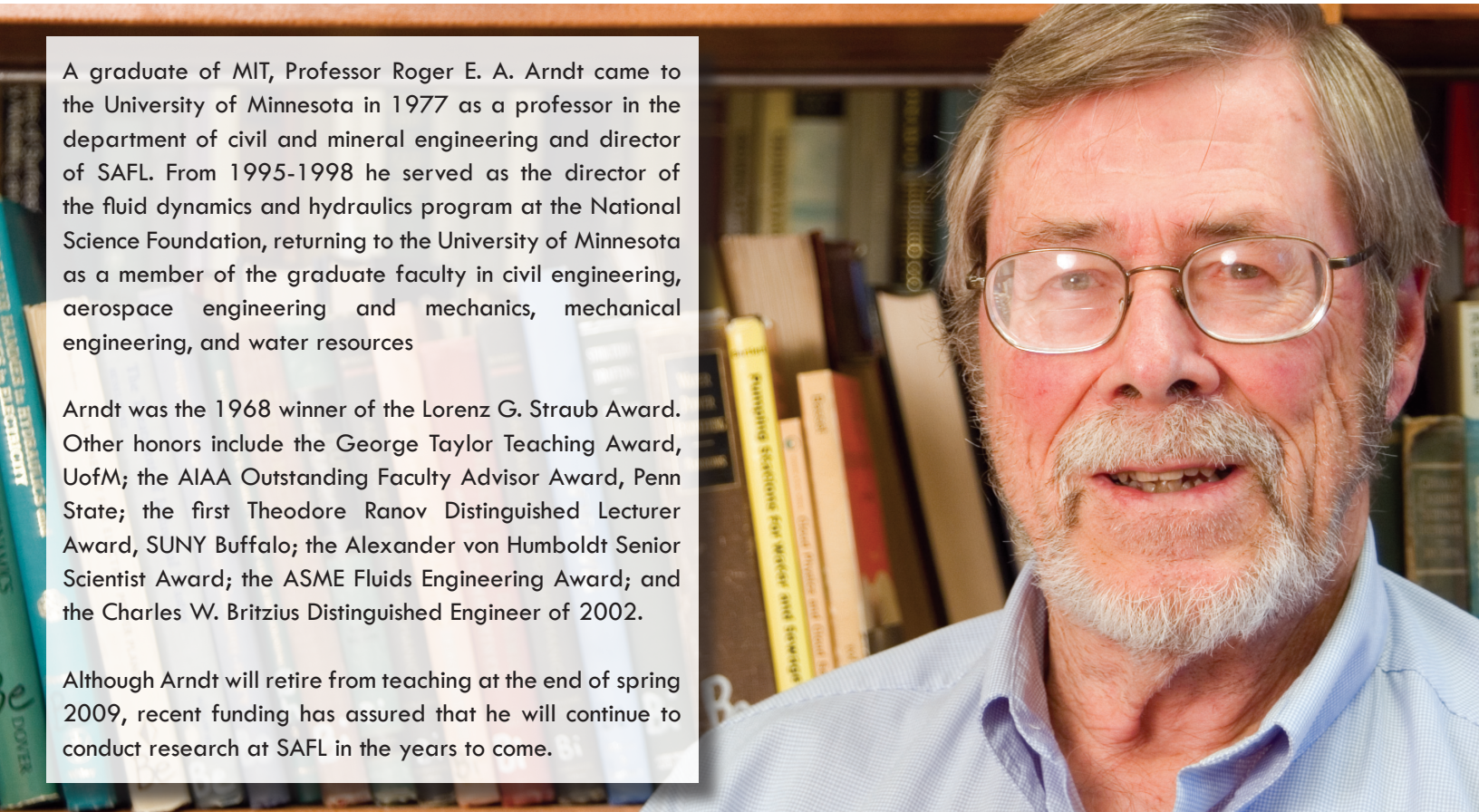
Thanks in part to a new three-year award from the Office of Naval Research, Arndt's research group has recently been engaged in several projects to study the detailed physics of marine vehicle enhancement. Under certain conditions, cavitation can improve the performance of a variety of marine vehicles. In order to fully utilize the benefits of cavitation, ventilation is used to obtain a favorable effect at lower speeds. The group's research topics include the study of ventilated hulls for improved surface ship performance, the design of a new ventilated hydrofoil for optimal performance of hydrofoil ships in a mid-range of speed, and the study of very high-speed supercavitating underwater bodies.

FUTURE DIRECTIONS

For more than a century cavitation research has focused on problems closely related to the operation of ships, various types of hydraulic machinery and a variety of hydraulic structures. But the field's horizons continue to expand, with many new applications emerging in other fields, such as medicine and environmental restoration. The National Center for Earth-surface Dynamics (NCED) has provided the stimulus to consider the possible influence of cavitation in geomorphic processes, specifically the impact of vortex cavitation created by high-speed flow around obstacles in the path of a major flood. Although this work is very preliminary in nature, it brings many of the elements of classical cavitation research to bear on some fundamental geophysical issues, opening up some interesting possibilities to continue SAFL's tradition of collaboration.

A wedge-shaped fin partially piercing a supercavity. Note the partial cavity forming from the leading edge of the fin.

FOR MORE INFORMATION see http://cav.safl.umn.edu



A graduate of MIT, Professor Roger E. A. Arndt came to the University of Minnesota in 1977 as a professor in the department of civil and mineral engineering and director of SAFL. From 1995-1998 he served as the director of the fluid dynamics and hydraulics program at the National Science Foundation, returning to the University of Minnesota as a member of the graduate faculty in civil engineering, aerospace engineering and mechanics, mechanical engineering, and water resources

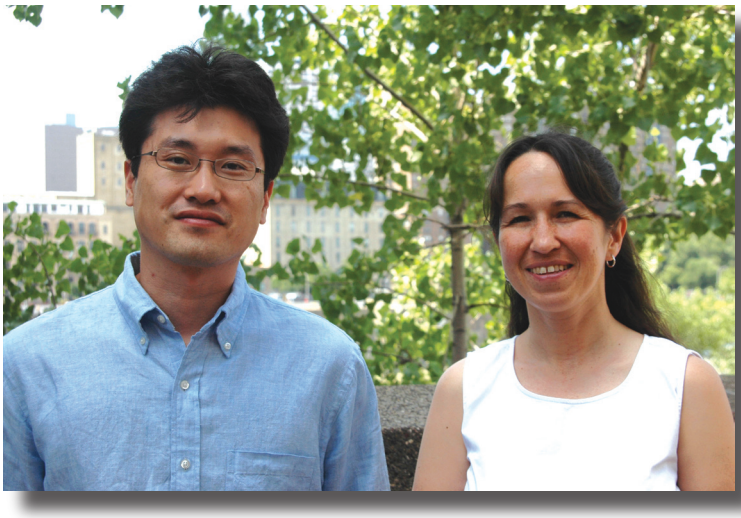
Arndt was the 1968 winner of the Lorenz G. Straub Award. Other honors include the George Taylor Teaching Award, UofM; the AIAA Outstanding Faculty Advisor Award, Penn State; the first Theodore Ranov Distinguished Lecturer Award, SUNY Buffalo; the Alexander von Humboldt Senior Scientist Award; the ASME Fluids Engineering Award; and the Charles W. Britzius Distinguished Engineer of 2002.

Although Arndt will retire from teaching at the end of spring 2009, recent funding has assured that he will continue to conduct research at SAFL in the years to come.

congrats grads

Iman Borazjani (Ph.D. ‘08) with advisor Fotis Sotiropoulos

Cristian Escauriaza (Ph.D. ‘08) with advisor Fotis Sotiropoulos



Jeho Yoo (M.S. ‘08) with advisor Kimberly Hill

In Memoriam...

John B. Herbich, Ph.D., P.E., F.ASCE, a professor emeritus at Texas A&M University, died on June 19 in Honolulu at the age of 85. Born in Warsaw, Poland in 1922, Herbich fled his homeland and then left France following the Nazi invasions. In the United Kingdom he joined the Polish army and later enrolled as a student at the University of Edinburgh. He then worked as a research engineer in the hydraulics laboratory at the Technische Universiteit Delft, in the Netherlands. After working in Canada for several years, he moved to the United States in 1953 and earned a master’s degree in 1957 from the University of Minnesota at St. Anthony Falls Laboratory under the guidance of Lorenz G. Straub. He went on to earn his doctorate degree in civil engineering in 1963 from Pennsylvania State University. After completing postdoctoral research at the University of California at Berkeley, Herbich joined the civil engineering department at Texas A&M University in 1967 and was instrumental in founding the university’s coastal and ocean engineering program. He lectured and taught at many venues worldwide, served as a consultant on government and international projects, and authored more than 200 papers and several textbooks, including the *Handbook of Dredging Engineering*, first published in 1992. Herbich was active in many professional societies and was the recipient of numerous awards. He is survived by his wife of 57 years, Margaret, and their three children.

Setting Stormwater Standards

THE EXPANSION OF URBAN AND SUBURBAN DEVELOPMENT HAS BROUGHT TO LIGHT A NUMBER OF ISSUES SURROUNDING STORMWATER MANAGEMENT. AT SAFL, SCIENTISTS COMBINE BASIC RESEARCH WITH ENGINEERING SERVICES TO PROVIDE SOLUTIONS FOR ALL STAKEHOLDERS AFFECTED BY THE NATURAL AND MAN-MADE ENVIRONMENT.

ABOVE
Assistant engineer Andrew Fyten is shown here monitoring an Environment21 stormwater management device, one of many such systems under evaluation at SAFL.

Recent stormwater assessment projects at SAFL have included a focus on underground stormwater devices, specifically on hydrodynamic separators. Hydrodynamic separators are used as Best Management Practices (BMPs) for removing contaminants from stormwater, and are favored in urban areas for their small footprint. Researchers at SAFL have utilized both lab and field testing to develop new protocols for testing the performance of hydrodynamic separators in removing suspended sediments from stormwater runoff as well as their performance against scouring and wash out under high flow conditions.

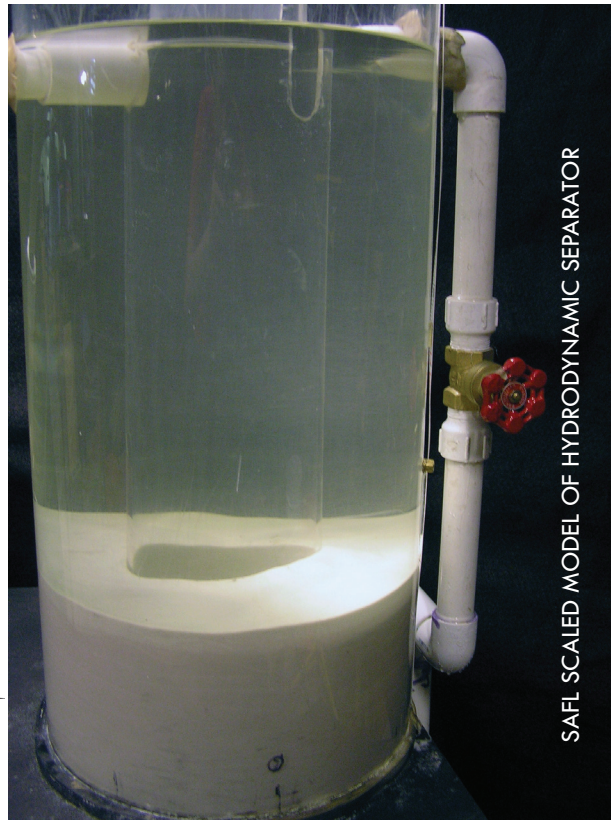
In particular, graduate student Dave Saddoris, researcher Omid Mohseni and Professor John Gulliver are currently focusing on developing methods to test and quantify scouring, resuspension and washout of accumulated sediments in hydrodynamic separators, which control the sediment retention capabilities of these devices. Graduate student Adam Howard is working with Mohseni and Gulliver to evaluate standard sumps and whether these sumps can be used for treating stormwater runoff.

Recently SAFL researchers began using load cells to assess sediment accumulation or washout in hydrodynamic separators. This exciting development allows for improved efficiency in testing while retaining accuracy and repeatable results.

Sediment removal performance, sediment retention, and maintenance demands are all important considerations when selecting and sizing hydrodynamic separators for use as urban stormwater BMPs. By utilizing drainage area characteristics, and understanding the properties of suspended sediments in stormwater runoff, scientists and engineers at SAFL are working toward improved accuracy of device selection and optimization of maintenance schedules to achieve sediment removal targets while minimizing costs.

Mohseni is also currently working with the American Society for Testing and Materials (ASTM) to provide the first industry standard for testing of hydrodynamic separators. In addition, Mohseni and Gulliver are working with the ASCE/EWRI to develop certification guidelines for manufactured BMPs.

SAFL utilizes thorough protocols that provide accurate, reproducible, and cost effective assessments of stormwater BMPs, saving clients valuable time and money. Testing is available for all stormwater BMP devices including, but not limited to, those that operate on hydrodynamic, filtration, sedimentation, and biological processes. For more information please visit SAFL's website: www.safl.umn.edu.



SAFL SCALED MODEL OF HYDRODYNAMIC SEPARATOR

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