Mission Statements

The U.S. Department of the Interior protects and manages the Nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The mission of the U.S. Department of Commerce is to create the conditions for economic growth and opportunity.

The National Institute of Standards and Technology promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.
The Reclamation-NIST Exploratory Research Symposium was held August 4-5, 2015, at the Bureau of Reclamation (Reclamation) facility in Lakewood, CO, and the National Institute of Standards and Technology (NIST) facility in Boulder, CO. The workshop objective was to identify specific areas in ongoing research where collaboration between Reclamation and NIST would be mutually beneficial. Three topics areas were identified as high priority for future collaboration: composite materials, concrete shrinkage and cracking, and water quality. This report summarizes the topics discussed at the workshop and next steps for future collaboration between the two agencies.
PEER REVIEW DOCUMENTATION

Project and Document Information

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Materials Engineer, NIST Material Measurement Laboratory, Applied Chemicals and Materials Division

Review Certification

Peer Reviewer: I have reviewed the assigned items/sections(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Peer Review: Bobbi Jo Merten
Chemist, Reclamation Technical Service Center, Engineering & Laboratory Services Division

Peer Review: Timothy Quinn
Mechanical Engineer, NIST Material Measurement Laboratory, Applied Chemicals and Materials Division
Executive Summary

The Reclamation-NIST Exploratory Research Symposium was held on August 4-5, 2015, at the Reclamation Denver Federal Center facility in Lakewood, CO, and the NIST facility in Boulder, CO. Staff from the Bureau of Reclamation (Reclamation) and the National Institute of Standards and Technology (NIST) participated, as well as guest representatives from the Federal Highway Administration (FHWA) and the National Oceanic and Atmospheric Administration (NOAA).

The workshop objective was to identify specific areas in ongoing research where collaboration between Reclamation and NIST would be mutually beneficial. Reclamation has wide-ranging responsibility for water infrastructure and supply in the western United States. NIST provides the measurement science, in support of standards, needed for efficient use of materials such as steel, concrete, and polymers, as well as expertise in a range of environmental measurements. It was recognized that the two agencies have complementary capabilities in applied engineering and basic science research. The Reclamation-NIST Exploratory Research Symposium was organized as a forum for specific information exchange on mission-critical research projects in two topic areas: Infrastructure Sustainability and Water Management and Measurement.

Three topics areas were identified as high priority for future collaboration: Composite Materials, Concrete Shrinkage and Cracking, and Water Quality. These topics were deemed focus areas for both Reclamation and NIST and had specific staff members from each organization interested in co-leading potential collaborations. Collaboration opportunities between the two organizations were defined to range from simple goals, such as a commitment to share information, to joint research projects with a shared goal and interdependent research tasks.
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Overview and Purpose

The Reclamation-NIST Exploratory Research Symposium was held August 4-5, 2015, at the Reclamation Denver Federal Center facility in Lakewood, CO, and the NIST facility in Boulder, CO. Ten staff each from the Bureau of Reclamation (Reclamation) and the National Institute of Standards and Technology (NIST) participated, as well as guest representatives from the Federal Highway Administration (FHWA) and the National Oceanic and Atmospheric Administration (NOAA) and two Department of the Interior (DOI) facilitators. The participant list and agenda are included in Appendices A and B, respectively.

Reclamation, part of the Department of the Interior, has wide-ranging responsibility for water infrastructure and supply in the western United States. NIST, part of the Department of Commerce, provides the measurement science, in support of standards, needed for efficient use of materials such as steel, concrete, and polymers, as well as expertise in a range of environmental measurements. It was recognized that the two agencies have complementary capabilities in applied engineering and basic science research. This, combined with the proximity of the Reclamation Technical Service Center in Denver and the NIST campus in Boulder, warranted further discussions on the possibility of collaboration. The Reclamation-NIST Exploratory Research Symposium was created as a forum for specific information exchange on mission-critical research projects in two topic areas: Infrastructure Sustainability and Water Management and Measurement.

The workshop objective was to identify specific areas in ongoing research where collaboration between Reclamation and NIST would be mutually beneficial. Specifically, the outcome of the workshop was identification of high priority areas for collaboration in research, testing, demonstrations, and technology transfer. These collaboration opportunities are presented in the following report. Specific steps for collaboration between Reclamation and NIST on specific topics are outlined. Collaboration opportunities between the two organizations are defined to range from simple goals, such as a commitment to share information, to joint research projects with a shared goal and interdependent research tasks.

Plenary and Guest Talks

Plenary talks were given by Levi Brekke, Chief of the Reclamation Research and Development Office, and James Fekete, Chief of the NIST Applied Chemicals and Materials Division. The talks provided an overview of the management organization, funding mechanisms, research portfolios, and unique facilities for each agency. The presentation slides for each talk are included in Appendix C: Plenary and Guest Presentation Slide.
Dr. Brekke began with a brief introduction to the mission of Reclamation for “Managing Water in the West,” including the types of infrastructure that Reclamation manages and its impact on power production, agriculture, and recreation in the 17 western states. He then introduced the Reclamation Research Office’s funding programs in Desalination and Water Purification Research (DWPR), Science and Technology (S&T), and the Open Water Data Initiative. Within the S&T program, he highlighted focus areas of Advance Water Treatment, Infrastructure and Safety, Renewable Energy, Climate Change and Variability, and Invasive Mussels. The recent Reclamation-led effort to engage U.S. citizens through Technology Prize Competitions was summarized, as well as other avenues available for technology transfer.

Dr. Fekete presented an overview of NIST and the Material Measurement Laboratory (MML). He provided a few facts on the history of NIST and its mission and assets, including staffing, facilities, and programs. He then introduced the organizational structure of the MML, which houses much of the research related to the topics of this symposium, and research focus areas. Dr. Fekete next highlighted his division, Applied Chemicals and Materials Division, which is a division of MML, located on the Boulder, CO, campus. This division operates in all three MML focus areas: biology, chemistry, and materials. It has six groups that represent significant expertise in thermophysical properties of fluids and materials reliability/mechanical testing. The presentation concluded by featuring two state-of-the-art facilities on the Boulder campus: the Precision Imaging Facility and the Boulder Microfabrication Facility.

On the second day of the symposium, guests from FHWA and NOAA were invited to present an overview of relevant work ongoing at their agencies. Victoria Peters, the Director of Innovation and Technology Deployment at FHWA, outlined ongoing work with a presentation titled “Driving Innovation.” FHWA provides engineering support for public roads that service federal and tribal land, a $1.2 billion annual program. FHWA has a current R&D strategy that aims to improve the long-term performance and durability of infrastructure, provide accelerated highway construction in an environmentally sensitive manner, move towards performance-based specifications, and ensure an integrated approach to asset management. Ms. Peters provided several examples of how FHWA is deploying innovative technologies to support this strategy. Much of this work overlaps with Reclamation needs in Infrastructure Sustainability, and there was interest in maintaining communication channels between FHWA, Reclamation, and NIST in several topic areas which will be specified in the prioritization section.

Kelly Mahoney, with Rob Cifelli as co-author, presented ongoing collaborations between Reclamation and NOAA in a talk titled “Water Management Application-Based Research in PSD.” Both Mahoney and Cifelli are part of the NOAA Earth System Research Laboratory-Physical Sciences Division (PSD). Their mission is to characterize and predict weather, water, and climate extremes
and to develop capabilities to predict conditions associated with too much or too little water. They have ongoing collaborations with Reclamation dedicated to improving extreme precipitation estimation using model-based methods, diagnosing moisture sources for these extreme precipitation events, and using this information to address water management needs.

**Infrastructure Sustainability Shorts**

The two main sessions of the workshop consisted of a series of “Shorts,” or brief presentations describing a project, identifying the principle investigators, and suggesting potential areas for collaboration. A summary of the Infrastructure Shorts is presented in Table I, and the full presentation slides are included in Appendix D: Infrastructure Shorts. This session was held on Day 1 of the Symposium.

<table>
<thead>
<tr>
<th>Reclamation Shorts</th>
<th>Principle Investigators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion Mitigation System Monitoring</td>
<td>Jessica Torrey</td>
</tr>
<tr>
<td>Composites Research Roadmap</td>
<td>Dave Tordonato, Jessica Torrey</td>
</tr>
<tr>
<td>Reducing Concrete Shrinkage and Cracking</td>
<td>Katie Bartojoy</td>
</tr>
<tr>
<td>Extending the Useful Service Life of Wire Hoist Ropes using Nondestructive Testing</td>
<td>Chrissy Daniels</td>
</tr>
<tr>
<td>Protective Coating In-Situ Performance</td>
<td>Bobbi Jo Merten</td>
</tr>
<tr>
<td>Detecting Cavitation in Hydraulic Turbines</td>
<td>John Germann</td>
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<tr>
<td>Short Convergent Intake Discharge by Deployable Acoustic Array</td>
<td>Dave Hulse</td>
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<tr>
<td>Direct Shear Roughness by Photogrammetry</td>
<td>Matthew Klein</td>
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<tr>
<td>Detecting and Imaging Canal Seepage</td>
<td>Justin Rittgers</td>
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**NIST Shorts**

<table>
<thead>
<tr>
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<th>Principle Investigators</th>
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<tr>
<td>Corrosion Detection via Antiferromagnetic Resonance</td>
<td>Ed Garboczi</td>
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<tr>
<td>3D Particle Shape Measurement</td>
<td>Ed Garboczi</td>
</tr>
<tr>
<td>Computational Design for Concrete</td>
<td>Ed Garboczi, Jeff Bullard</td>
</tr>
<tr>
<td>Overview of NIST Research on Infrastructure Sustainability</td>
<td>Ken Snyder</td>
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<td>Green Concrete for Sustainable Structures</td>
<td>Ken Snyder</td>
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<td>Life Cycle of Polymers for Infrastructure</td>
<td>Ken Snyder</td>
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<tr>
<td>Pipeline Safety</td>
<td>Dash Weeks, Nick Barbosa</td>
</tr>
<tr>
<td>Probing Molecular Mechanisms Underlying Failure in Semi-crystalline Polymers for Pipes</td>
<td>Chad Snyder, Ron Jones, Kalman Migler</td>
</tr>
<tr>
<td>Advanced Joining Techniques</td>
<td>Jeff Sowards, Nick Barbosa</td>
</tr>
<tr>
<td>Microbial Induced Corrosion Monitoring</td>
<td>Danielle France, Tim Quinn</td>
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</table>

**Water Management and Measurement Shorts**

The second topic area “Shorts” in Water Management and Measurement were presented on Day 2 of the Symposium. A summary of the Shorts is presented in Table II, and the full presentation slides are included in Appendix E: Water Management & Measurement Shorts.

**Table II. Short Presentation Titles and Principle Investigators in the Topic Area of Water Management and Measurement**

<table>
<thead>
<tr>
<th>Reclamation Shorts</th>
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<tbody>
<tr>
<td>Water Supply/Demand Analyses</td>
<td>Ian Ferguson</td>
</tr>
<tr>
<td>Design and Calibration of Open-Channel Flow Measurement Flumes</td>
<td>Tony Wahl</td>
</tr>
<tr>
<td>Acoustic Doppler Velocity Measurements</td>
<td>Tony Wahl</td>
</tr>
<tr>
<td>Removing Fine Debris from Water Using Coanda-Effect Screens</td>
<td>Tony Wahl</td>
</tr>
<tr>
<td>Detection of Environmental DNA</td>
<td>Denise Hosler</td>
</tr>
<tr>
<td>Water Reuse: Detection and Impact of Pathogens and Chemicals</td>
<td>Denise Hosler</td>
</tr>
<tr>
<td>Concentrate Management &amp; Trace Contaminant Detection</td>
<td>Saied Delagah</td>
</tr>
<tr>
<td>Improving Data Access</td>
<td>James Nagode, Doug Clark</td>
</tr>
</tbody>
</table>
Facility Tours

On the afternoon of Day 1, Symposium participants were able to tour the Reclamation Hydraulics, Materials and Corrosion, and Concrete, Geotechnical, and Structural Laboratory facilities. The tour was introduced by Bob Baumgarten, Chief of the Engineering and Laboratory Services Division. The tours were led by Tony Wahl and Janet White. Participants were able to see several scale models in the Hydraulics Lab, including the St. Mary Diversion Dam study and the Inskip Dam hydraulic studies for the protection of bull trout and salmon, respectively. The tour also included the low ambient pressure chamber, for studying cavitation, and the canal model research and training facility.

In the Materials and Corrosion Laboratory, the group toured the Corrosion and Protective Coatings Labs, in which researchers study the effects of corrosion, as well as corrosion protection methods and alternative infrastructure materials. Participants walked through the Concrete, Geotechnical, and Structural Lab, including the concrete mix lab, thermal properties labs, sample preparation lab, and the 100% humidity curing room, a.k.a. the Fog Room, culminating at the 5-million pound testing machine. These laboratories are uniquely equipped to produce and study large-batch custom concrete mixes for use on Reclamation projects.

On the afternoon of Day 2, participants of the Symposium were given a tour of several of the facilities in the Applied Chemical and Materials Division at NIST. Dave McColskey and Dash Weeks gave an overview of the Mechanical Testing Labs, including displays of samples for curved-wide plate testing, crack tip...
opening angle testing, and the 3D laser scanner. Ed Garboczi explained the Micro-CT Lab, and Jim Fekete led the group through a tour of the Boulder Microfabrication Facility and Precision Imaging Facility.

Prioritization of Topic Areas

The final task each day was to assign priority rankings for each of the topics presented and any others that may have been discussed during the sessions. Where appropriate, contacts at each agency were identified as point people to kick-start the collaboration process. Priorities were defined as:

1. Good to know- no further action required at this time.
2. Information exchange- assign contact person from each agency and agree to information exchange
3. Reclamation/NIST Nexus- explore full collaboration on topic

Three topics were given a ranking of 3, meaning they were deemed focus areas for both Reclamation and NIST and had specific staff members from each organization interested in leading collaborations. The three topics were:

- **Composite Materials**: Discussion in this priority area focused on reliably predicting performance of the materials over service lives up to and beyond 50 years. This could include studying existing longevity data and trying to draw correlations to service conditions or developing new accelerated test methods that can be used to extrapolate long-term performance predictions. It was felt that a solid understanding of mechanisms relating to failures of components in the field would be a key component to facilitating laboratory efforts. Sponsors of future work in this area are Jessica Torrey from Reclamation and Nick Barbosa and Ken Snyder from NIST.

- **Concrete Shrinkage and Cracking**: Typically, concrete will shrink during curing, and this can sometimes results in cracking if the mix design and curing procedures are not properly managed. With much of Reclamation’s infrastructure based on concrete, this has been an area of study at Reclamation for quite some time and evaluation of new commercial products in ongoing. NIST has developed some new techniques using digital imaging to provide resolution of micro-strains in materials, and this technique might have applications in concrete. In addition, FHWA has several projects in this area and might be able to contribute. Contact person at Reclamation is Katie Bartojay and at NIST is Nick Barbosa. Victoria Peters would be the initial point of contact at FHWA.

- **Water Quality**: Seven presentations and their discussions were grouped into an overarching theme of water quality. This included subtopics such
as concentrate management, membrane characterization, detection of contaminants, and nanotechnology for water treatment. Both agencies have significant ongoing research in water quality, and many of the subtopic areas overlap, as well. NIST has developed expertise and facilities for membrane characterization and detection of contaminants in water streams. Reclamation has a focus on desalination and water reuse, and manages facilities such as water treatment plants and the Brackish Groundwater National Desalination Research Facility. Point of contact at Reclamation is Saied Delagah and at NIST is Tom Duster or Tim Quinn.

Two topic areas also received a 2/3 rating, meaning they are high priority research areas at each agency, but need further discussions as to if and how collaboration might be beneficial. The topics are:

- Measuring Water Supply and Demand- This topic area brought together applied research at Reclamation that focuses on using evaporation and precipitation data, among others, to forecast water supply and research at NIST to use spectroscopy techniques to accurately measure water and gas vapor concentrations over long distances. There was also discussion that some of the research in NIST’s Thermodynamic Research Center could apply to data collection, calibration, and validation problems that Reclamation sees in the data sets it uses. Sponsor for continued discussion in this area are Ian Ferguson, Reclamation, Nathan Newbury and Eleanor Waxman, NIST, and Kelly Mahoney, NOAA.

- Microbiologically-Influenced Corrosion (MIC) - MIC and biofouling has historically been a costly problem for infrastructure corrosion and longevity of membranes used for water treatment. NIST has an ongoing project to understand the adhesion of microbial communities to various surfaces in relevant environments. This information could eventually be used to develop antifouling treatments for pipelines, tanks, membranes, etc., an area that is of interest to Reclamation. In addition, Reclamation has made recent advance in eDNA identification of microbes. Contacts for potential collaboration would be Jessica Torrey, Denise Hosler, Chuck Hennig, and Saied Delagah. Contact at NIST would be Tim Quinn.

**Next Steps**

The Reclamation-NIST Exploratory Research Symposium was successful in bringing together staff from each agency to discuss areas of mutual interest and potential collaboration opportunities. Three topic areas were identified that can immediately benefit from close communication and information by the two agencies. Two other topics were identified that warrant continued discussions. Having made introductions of people, research strengths, and research needs, it is the hope of the symposium organizers that the sponsors of the each of the topics
identified as priority collaboration areas will now have the means to pursue further inter-agency collaborations. Reclamation and NIST have many areas of shared interest and complementary expertise and facilities that could result in mutually beneficial research. The following specific next steps were identified to further explore collaborative opportunities:

**Detailed Follow Up Meetings Between Key Contacts:**
- Composite Materials – Among Jessica Torrey, Ken Snyder, and Nick Barbosa (Nick Barbosa will arrange.)
- Concrete Shrinkage and Cracking – Among Katie Bartojay, Nick Barbosa, and Victoria Peters (Nick Barbosa will arrange.)
- Water Quality – Between Saied Delagah and Tom Duster (Tom Duster will arrange.)

**Other Actions:**
- Infrastructure Prize Competition – Nick Barbosa and Brandi Clark (NIST Corrosion Expert) will participate in opportunity development and judging.
- Periodic Research Exchange Meetings – Staff from Reclamation, NIST, and other federal stakeholders have the opportunity to share new areas of interest or need (Nick Barbosa and Jessica Torrey will organize).
- Water Infrastructure Initiative Development – NIST is pursuing internal initiative funding focused on water infrastructure. When possible, Reclamation will work with NIST to provide a stakeholder input as a federal agency responsible for water infrastructure.
# Appendix A: Participant List

## RECLAMATION

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone</th>
<th>Email</th>
<th>Position</th>
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<tbody>
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</tr>
</tbody>
</table>

## NIST

<table>
<thead>
<tr>
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<td>Material Measurement Laboratory, Applied Chemicals and Materials Division</td>
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## PARTNERS

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone</th>
<th>Email</th>
<th>Position</th>
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</thead>
<tbody>
<tr>
<td>Kelly Mahoney</td>
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</tr>
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## FACILITATORS

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<tr>
<td>Kimberley Prill</td>
<td>406-247-7702</td>
<td><a href="mailto:kprill@usbr.gov">kprill@usbr.gov</a></td>
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<tr>
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<td>DOI- Interior Business Center</td>
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## Appendix B: Agenda

### Day 1, Tuesday 8/4 - Reclamation, Lakewood

<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>7:00</td>
<td>Carpool Leaves NIST Campus for Fed Center</td>
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</tr>
<tr>
<td>8:00</td>
<td>Welcome</td>
<td>Nick Barbosa and Jessica Torrey</td>
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<tr>
<td>8:05</td>
<td>Logistics (e.g., facilities, safety)</td>
<td>Jessica Torrey</td>
</tr>
<tr>
<td>8:10</td>
<td>Meeting Overview and Review Agenda</td>
<td>Kimberly Prill</td>
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<tr>
<td>8:15</td>
<td>Introductions</td>
<td>Kimberly Prill</td>
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<tr>
<td>8:30</td>
<td>Reclamation R&amp;D Plenary Presentation</td>
<td>Levi Brekke</td>
</tr>
<tr>
<td>9:00</td>
<td>NIST R&amp;D Plenary Presentation</td>
<td>James Fekete</td>
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<tr>
<td>9:30</td>
<td>Discussion/Q&amp;As</td>
<td>Kimberly Prill</td>
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<td>9:45</td>
<td>BREAK (15 min)</td>
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<tr>
<td>10:00</td>
<td>Infrastructure Sustainability</td>
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<td>Reclamation Shorts</td>
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<td>11:00</td>
<td>Discussion/Q&amp;As</td>
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<td><strong>LUNCH ON YOUR OWN</strong></td>
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<td>NIST Shorts</td>
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<td>Discussion/Q&amp;As</td>
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<td>Infrastructure Roadmap – Discuss Topic Areas for Collaboration, Identify Key Players, Assign Action Items</td>
<td>Kimberly Prill</td>
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<tr>
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<td>BREAK (10 min) and Move to Lobby</td>
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<tr>
<td>16:00</td>
<td>Tour of Reclamation</td>
<td>Bob Baumgarten, Janet White, Tony Wahl</td>
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<td>17:00</td>
<td>Adjourn to Old Chicago for Social Hour</td>
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<td>Carpool Leaves for NIST Campus</td>
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<td>Presenter(s)</td>
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<tr>
<td>7:00</td>
<td>Carpool Leaves Fed Center for NIST Campus</td>
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<tr>
<td>8:00</td>
<td>Welcome</td>
<td>Nick Barbosa and Jessica Torrey</td>
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<td>Logistics (e.g., facilities, safety)</td>
<td>Nick Barbosa</td>
</tr>
<tr>
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<td>Review Agenda</td>
<td>Kimberly Prill</td>
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<td>8:15</td>
<td>Guest Presentations (NOAA/FHWA)</td>
<td>Victoria Peters and Kelly Mahoney</td>
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<td>BREAK (15 min)</td>
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<td>Water Management and Measurement</td>
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<td>Discussion/Q&amp;As</td>
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<td>Discussion/Q&amp;As</td>
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<td>11:35</td>
<td>LUNCH ON YOUR OWN</td>
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<td>Water Management and Measurement Roadmap – Discuss Topic Areas for</td>
<td>Kimberly Prill</td>
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<td>Collaboration, Identify Key Players, Assign Action Items</td>
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<td>14:00</td>
<td>BREAK (10 min) and Move to Lobby</td>
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<tr>
<td>14:15</td>
<td>Tour of NIST</td>
<td>Nick Barbosa, James Fekete</td>
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<td>BREAK (10 min)</td>
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<tr>
<td>15:30</td>
<td>Wrap-up</td>
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<tr>
<td>15:30</td>
<td>Prioritize Areas for Collaboration and Review/Finalize Roadmaps</td>
<td>Kimberly Prill</td>
</tr>
<tr>
<td>16:45</td>
<td>Conclusions</td>
<td>Nick Barbosa and Jessica Torrey</td>
</tr>
<tr>
<td>17:00</td>
<td>Carpool Leaves for Fed Center</td>
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Appendix C: Plenary and Guest Presentation Slides
The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.
By its mere presence and ownership of facilities, Reclamation directly influences water use and supply patterns in most major western river basins.
Research & Development

Programs Overview

Customers

• Primary: Reclamation resource and facility managers, customers, and stakeholders.

• Secondary: As federally funded research, we serve the broader communities of practice in water and water-related resources and the U.S. public.
Programs & Authorities

http://www.usbr.gov/research/

• Programs
  – Desalination and Water Purification Research (DWPR) Program
  – Science and Technology Program (S&T)

• Authorities
  Reclamation Act of 1902…coupled with 1966 Solicitor Opinion that derives research authority from authority to “develop waters”.
  Public Law 92-149: "all costs heretofore or hereafter incurred from funds appropriated to the Bureau of Reclamation and costs transferred to it for general engineering and research studies shall be non-reimbursable"
  1986 Technology Transfer Act (15USC 3710a)
    • 2014 DOI Issues Department Manual (DM) on Technology Transfer Agreements
  2010 Prize Competition Authorities (15 USC 3719)
  2009 Public Law 111-11 SECURE Water (cooperative agreement research authorities in sections 9504 and 9509)

DWPR Program: Overview

• Provide “new” sources of water for the West
  – Reduce costs & environmental impacts of advanced water treatment
  – research solicitation, external collaborations
  – Authorities: Reclamation Act and SECURE Water Sec 9509

• DWPR supports:
  – Operations: O&M at Brackish Groundwater National Desalination Research Facility, Program Management
  – Research: lab-scale studies, pilot-scale studies
• **Membrane Bioreactor Technology**
  
  - Have funded over 10 studies since 1998 to advance and evaluate the feasibility of MBR systems
  
  - Major reduction in footprint when compared to conventional treatment
  
  - MBR technology being used all over the US, a recent example is at the Jordan Basin Water Reclamation Facility in Utah

---

**2014 Highlights**

- Updated country map of DWPR funded projects
- Subsurface intake study
- Halophyte farming at BGNDRF

**2015 Highlights**

- External Solicitation: Implementation of 2-Phase review process (full proposals, revised full proposals), followed by awards via cooperative agreements
S&T Program: Overview

- Identify solutions to mission-related, technical obstacles
- Traditional Research Areas:
  - Environment, Infrastructure, Conserving/Expanding Water Supplies, Decision-Support
- Current Areas of Emphasis:
  - Advanced Water Treatment, Infrastructure & Safety, Renewable Energy, Climate Change, Invasive Mussels
- Other S&T Activities:
  - Open Water Data Initiative, Technology Prize Challenges, Regional Director Needs projects, Program Administration

S&T: Annual Solicitation Process

Open Research Competition
Proposals submitted by Reclamation employees through the annual S&T call for proposals

Directed Research
Critical research needs identified by priority area leads that were not fulfilled through the open competition call for proposals

Relevancy Review (Regional and Area Offices)
Technical Review (Reclamation and External Experts)

Program Review Team Recommendations
SAT Program Review Teams Provides Funding Recommendations to the Chief of Research

Recommendations Presented to Commissioner’s Office

Internal Researchers and Priority Area Leads often partner with external researchers (federal, academic, other)

Fiscal Year Selections Announced
Advanced Water Treatment

2014 Highlights
- Robust remote controlled Ultrafiltration/RO system
- Primer on “produced water” treatment technologies and cases
- Photovoltaic-powered Reverse Osmosis (RO)
- Continue development of chlorine resistant membranes

2015 Highlights
- Wetlands as treatment for concentrate and wastewater
- Primer on concentrate management tools

Infrastructure and Safety

2014 Highlights
- Reducing noise in BOR powerplants with engineering controls
- Managing sediment deposits in reservoirs
- Measuring soil erodability

2015 Highlights
- Detecting corrosion damage to determine when to replace wire ropes
- Developing 3D point models from ordinary pictures
- Improving Safety in the Field
Renewable Energy

2014 Highlights
- Cavitation Testing at J.F. Carr

2015 Highlights
- Hydrokinetic Testing in Roza Canal
- White Paper on Solar Over Canals

Climate Change and Variability

2014 Highlights
- Airborne Snow Monitoring: Value in Spring Water Management?
- Improve Methods for Projecting Future Climate and Hydrology; collaboratively serve Results

2015 Highlights
- Mussel Impacts on Transformer Fire Suppression Systems
- Web-tool for judging Global Climate Model skill, information for planning

Addressing Flood and Drought preparedness through streamflow forecasting research
Invasive Mussels

2014 Highlights

- Development of foul resistant coatings
- Testing UV light to prevent settlement
- Improving methods for early detection of mussel larvae or DNA

2015 Highlights

- Large-scale testing of pulse-pressure devices to prevent settlement over large areas

Open Water Data Initiative

Goals:
- comply with the President’s Open Data Policy; support ACWI Open Water Data Initiative
  - modernize management of water and related data
  - increase data management consistency
  - improve accessibility
  - enhance compatibility with other agencies, be

FY15: work plan development; include this topic as new area of emphasis in internal FY16 Call for Proposals

FY16: initial implementation supported through S&T Program;
  - key areas of activity include needs assessment, directed research and implementation of any projects awarded in FY16 Call

K. Gallagher and N. Booth (USGS), “Open Water Data Initiative,” Advisory Committee on Water Information’s Annual Meeting, August 19, 2014
Technology Prize Competitions

Overview:
• Engage U.S. citizens and private sector to solve some of the most critical mission problems.
• Engage with Reclamation Regions, and Federal Community in design and sponsoring of competitions.
• Initial Competitions scheduled for Spring/Summer 2015.

Water Prize Competition Center
• Water Availability
• Aquatic Ecosystem Restoration
• Infrastructure Sustainability

2015 Competition Example:
The Desal Prize
Burning Man for Water Geeks – Bloomberg
https://youtu.be/kCL3Eq-9F4w
2015 Competition Example: Fish Tracking (7/27/15-8/26/15)

https://www.usbr.gov/research/challenges/index.html

http://www.challenge.gov/challenge/new-concepts-for-remote-fish-detection/

https://www.innocentive.com/ar/challenge/9933646

https://youtu.be/mCw_1zhLybg

Technology Transfer (T²)

Fed Push

Industry Pull

Technology Transfer Agreements

• Authorizes feds to join forces with the private sector to create, mature, develop, or test new solutions that are aligned with Reclamation’s mission objectives.

• Protect, manage, and/or license associated federal and non-federal intellectual property and confidential information, as needed, in mutually beneficial ways.
2014 T² Example: CRADA w/ FujiFilm Hunt Smart Surfaces, LLC

Early Stage R&D

Manufacturing Know-How

Field Testing

Solution

BOR and Fuji tech experts jointly developing new chemical formulations

Fuji Facilities and Know-How

BOR Dams and Facility Operators and Tech Experts

Good Progress

RECLAMATION
NIST Overview

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Chief, Applied Chemicals and Materials Division
james.fekete@nist.gov

USBR-NIST Exploratory Research Symposium
August 4, 2015

National Institute of Standards and Technology

Non-regulatory agency within U.S. Department of Commerce

Founded in 1901 as National Bureau of Standards
NIST-at-a-Glance

Major Assets
• ~ 3,000 Employees; 1800 Scientists and Engineers
• ~ 2,800 Associates and Facilities Users
• ~ 400 NIST Staff on ~1,000 national and international standards committees

Total FY15 Appropriations for Discretionary Funding $863.9 Million

- 78% Scientific and Technical Research and Services
- 16% Industrial Technology Services
- 6% Construction of Research Facilities

NIST Programs

NIST Laboratories
• Provide measurement solutions

Hollings Manufacturing Extension Partnership
• Helps smaller manufacturers compete globally

Baldrige Performance Excellence Program
• Promotes and recognizes performance excellence

Advanced Manufacturing Technology Consortia
• Industry-led precompetitive basic and applied research
Standards for Water Quality Testing

**Goal:** Ensure accurate testing of water quality

- Organic contaminants
- Inorganic contaminants
- Heavy metals
- Microbial populations
- Pharmaceuticals, perfluorinated compounds, brominated flame retardants, and other chemicals of emerging concerns

NIST provides SRMs, calibrated lab methods and instruments, qualification of field sensors, and reference data for satellite imagery
**Optimizing Water Treatment**

**Goal:** Provide data on the structure, chemistry, and dynamic response of reverse osmosis membranes so that membrane designers can improve efficiency.

NIST’s extensive capabilities for polymer characterization have enabled new understanding of the link between structure and function in thin polymer films.

**Sensor Development**

Water quality in 65% of estuaries and coastal areas are impacted by nutrient pollution (nitrites and phosphates).

$2.2B in economic impact annually as harmful algal blooms affect water quality and wildlife in the region.

Current sensors are too expensive and cannot rapidly detect the complexity or location of nutrient pollutants.
**Applied Chemicals & Materials Division**

- Significant expertise in chemical thermodynamics and materials reliability/mechanical testing
- Strongly tied to customer needs and standards development
- Operates in all three MML focus areas (Bio, Chemistry, Materials)
- Uniquely organized to facilitate crosscutting programs
  - Alternative Fuels/Pipeline Safety/Biocorrosion
  - Additive Manufacturing/Laser Welding (with PML)
  - Materials Reliability in Biological Environments
  - TRC moving into alloys
Precision Imaging Facility

By combining electron and ion microscopy with optical and surface characterization tools, the PIF provides comprehensive imaging and spectroscopy capabilities to address a wide range of materials characterization challenges at multiple length scales.

- **Helium ion microscope (HIM)**
  - High-resolution surface-sensitive imaging with large depth of field
  - Ability to image insulating samples very effectively
  - Ultra-high resolution lithography capabilities

- **Aberration-corrected TEM (TEM)**
  - Atomic-scale imaging and spectroscopy
  - Full analytical capabilities including electron and X-ray spectroscopies at sub-nanometer resolution

- **Dual-Beam FIB/SEM**
  - Sample preparation workhorse for Atom Probe and TEM
  - Ability to do nano-scale milling, nanofabrication, and nano-deposition
  - Full suite of analytical capabilities and advanced detectors for enhancing elemental or surface contrast
  - Lithography/nano-patterning package

- **Atom Probe**
  - Chemical analysis at the atomic scale with sub-nm spatial resolution in three-dimensions
  - Equal detection efficiency for all elements and isotopes
  - Ability to analyze buried interfaces and grain boundaries
  - Can analyze metals, semiconductors, and insulators

**NIST Precision Imaging Facility**

e-flood gun-assisted He ion microscopy

**A new tool for imaging insulating materials:**

Amazing fidelity in imaging of insulating materials like bacteria-laden water treatment membranes (left) and cellulose for biofuels (right)
Boulder MicroFabrication Facility

BMF
- 18,000 square feet class 100 clean room
- state-of-the-art microelectronic and microelectromechanical systems (MEMS) fabrication capability

NIST Overview

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Chief, Applied Chemicals and Materials Division
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USBR-NIST Exploratory Research Symposium
August 4, 2015
Federal Highway Administration
Office of Federal Lands

Victoria Peters
Director of Innovation & Technology

FHWA – Office of Federal Lands

• Project delivery arm of FHWA;
• Engineering support for public roads that service Federal and Tribal lands since 1914;
• Administer an annual $1.2B program
Transportation Predictions

Year 2050

• Passenger vehicles weigh less than 200 lbs;
• Vehicle cost less than $5,000;
• Traffic courts a distant memory.
Transportation Predictions

Once the flying car takes off there will be a gradual decay of the existing highway system. Highways will go away by 2070.

Current FHWA R&D Strategies

- Long-Term Infrastructure Performance
- Durable Infrastructure Systems
- Accelerated Highway Construction
- Environmentally Sensitive Highway Infrastructure
- Performance-Based Specifications
- Integrated Infrastructure Asset Management
Transportation Challenges on Federal Lands

- Climate Change Adaptation and Resilience
- Material Durability
- Structural Health of Bridges
- Unpaved Roads: Dust Abatement
- Infrastructure to Support Smart Vehicles
- Data Management
- Optimizing Service Life
- Energy/Resource Related Roadway Impacts

Climate Change Adaptation & Resilience

- Infrastructure Techniques for Improving Coastal Highway Resilience
- Risk Mitigation Strategies for Extreme Weather Events and Climate Change in Asset Management Plans
Structural Health of Bridges

1 dot = 1 bridge

There are over 215 million daily crossings on 61,064 U.S. structurally deficient bridges in need of repair.

Need: Smart bridge technologies including high-performance steel, self-healing materials and more use of wireless systems to monitor performance.

Material Durability

- Maintaining Traffic Sign Retroreflectivity
- Corrosion – corrugated metal pipes
- Alkali Silica Reactivity
- Acid Sulfate Soils
Unpaved Roads: Dust Abatement

- Resistance to traffic abrasion
- Resistance to erosion by wind and water

Need: A rapid, inexpensive, standardized method for evaluating these two factors to allow managers to reliably predict field performance of products.

Internally Cured Concrete

Fort Pulaski Bridge, Savannah GA
- Marine Environment
- Highly Aggressive Environment for Chloride Based Corrosion of Reinforcing Steel
- High Salinity of Sea water and Sea Water Spray
- Warm Temperatures Increase Rate of Corrosion
- High Humidity/ Ready source of Moisture to Provide Electrolyte to Transport Chlorides
Internally Cured Concrete

75 year service life
- Changing the w/c ratio from 0.50 to 0.33
- Substitute 20% Type F Fly Ash
- Substitute 10% Microsilica to the Concrete Mixture in Addition to the Fly Ash

This will get us the 75 Year Service Life – but there is not enough water available at that w/c ratio to fully hydrate the cementations material – so we get autogenous shrinkage!

Robotics Assisted Bridge Inspection Tool (RABIT)

- Panoramic Camera and High-Definition Imaging
- Electrical Resistivity to characterize the corrosive environment
- Impact Echo and Ultrasonic Surface Waves to evaluate concrete delamination and concrete deck strength.
- Ground Penetrating Radar to “map” rebar and other metallic objects below the surface using electromagnetic waves. GPR also provides a qualitative assessment of concrete deck deterioration.
- GPS to record and mark location data, making testing grids virtually obsolete.

4,000 square feet per hour
In-Situ Scour Testing Field Device

Scour – Most common cause of bridge failure in the U. S.

- Tests a wide range of soils types to depths of 20 meters
- Operates by circulating water down the auger casing, between the erosion head and the soil surface at the bottom of the casing, and back through outlet piping.
- Data used for foundation analysis and design in a manner similar to present-day soil borings
- Soil erosion rate information collected will refining future scour estimating methods and procedures.

Deploying Innovation

- Every Day Counts Initiative
- Strategic Highway Research Program
- Coordinated Technology Implementation Program
Every Day Counts (EDC)

- 3D Engineered Models
- e-Construction
- eNEPA and IQED
- GRS-IBS
- Railroad Coordination
- Regional Models of Cooperation
- Road Diets
- Smarter Work Zones
- Stakeholder Partnering
- Ultra-high Performance Concrete Connections
- Data-Driven Safety Analysis

Strategic Highway Research Program (SHRP2)

SHRP2 offers products in four focus areas:

- Renewal
- Reliability
- Capacity
- Safety
Coordinated Technology Implementation Program (C TIP)

- Established in 1987
- Mutually funded NPS, USFS, USF&W, BLM, USACE and BIA
- Developed to deploy innovative, unique, or under-used transportation technologies

Emphasis on deploying proven real world solutions to address challenges, inefficiencies, and barriers within the Federal and Tribal programs and establish them as mainstream practices.
Water Management Application-Based Research in PSD

Kelly Mahoney and Rob Cifelli

USBR-NIST Exploratory Research Symposium
August 5, 2015
Boulder, Colorado

NOAA ESRL Physical Sciences Division
Priority Research Goals

1. Rigorously characterize and predict weather, water, and climate extremes and their uncertainties.

2. Develop scientific capabilities to predict conditions associated with too much and too little water.

PSD Scientific Expertise

- Problem-focused observations
- Physical Sciences Research
  - Processes
  - Phenomena
  - Predictability
  - Predictions
  + Partnerships
Bureau of Reclamation partnerships

• A few examples…

Improving extreme precipitation estimation using regional, high-resolution, and ensemble model-based methods

Collaborators/Source of Support

• Collaborators: CIRES, NOAA-ESRL PSD, Reclamation
• October 2011 – present (multiple related projects)
• Funding: CIRES-Reclamation cooperative agreement

Research Questions

1. Does the intensity of extreme warm-season precipitation events change in future climate scenarios?
2. Which storm-scale physical processes are most affected by changes in large-scale climate?
3. Do elevation thresholds for storms, flooding, and hail change?
4. How can simulation results be best utilized within water resource management, dam safety framework?

Current/ongoing work

• Ensemble-based modeling approach: Explore spectrum of extreme event possibilities for Reclamation sites of interest
• Coupled Atmosphere-Hydrology modeling to more directly explore hydrologic impacts

Example: Collection (“ensemble”) of simulations (forecasts) for Sep 2013 Front Range Floods

High-resolution weather modeling framework provides insight into how changes in large-scale climate parameters may affect small-scale storms
Diagnosing the Moisture Sources for Extreme Precipitation Events in the Intermountain West

Collaborators/Schedule/Source of Support
- U. Colorado/CIRES & NOAA ESRL PSD
- Flood Hydrology & Consequence Group (FHCG)
- Reclamation Research & Development Office
- Funding: CIRES-Reclamation cooperative agreement
- 2012 - present

Research Questions/goals
- How does the large volume of water necessary to sustain intense precipitation events in the intermountain west reach its destination given the distance from the moisture source in the Pacific and the complex regional topography?
- Improve use of existing weather, climate and/or hydrologic predictions in the development of operations outlooks

Forecast Informed Reservoir Operations (FIRO)
- Competing demands in Russian River watershed
  - Flood control, water supply, fisheries, recreation
- FIRO Pilot Project
  - Explore feasibility of using improved forecast information to address water management needs
  - NOAA, ACE, BoR, CA-DWR, Scripps, Sonoma County Water Agency
Lake Mendocino – Russian River

- Issue: can rule curves be relaxed without compromising dam safety?
  - Store some water in flood pool if no precipitation is forecast
  - Evacuate water below base of flood pool if needed in advance of big event
- For planning: chance of no-rain as important as rainfall forecast
Appendix D: Infrastructure Shorts
Corrosion Mitigation System Monitoring

• Reclamation and USACE manage billions of dollars of Hydraulic Steel Structures (HSS) that require corrosion protection including pipelines, gates, tanks, etc.

• We need to improve:
  • the effectiveness of corrosion protection systems for HSS with complex geometries
  • the monitoring and assessment procedures for our corrosion protection systems

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Materials Engineering & Research Lab
Denver, CO

Corrosion Mitigation System Monitoring

• Goal: Use remote health monitoring to provide facility managers early warning of potential changes in performance of corrosion mitigation system

• Results to Date
  – USACE-CERL: built scale model of structure to map polarization potentials around geometric features
  – USACE-CERL: prototype of sensor for monitoring polarization potentials on steel
  – Reclamation: planning field demonstration for FY16

• Potential Areas for Collaboration:
  – Developing sensor that can accurately measure polarization potential on HSS
  – Define boundary conditions that would indicate remedial action needs to be taken
**Composites Research Roadmap**

- Reclamation and USACE are examining the use of composite materials as replacements for steel in burial and immersion:
  - Pipelines, pipeline repair, vaults, manholes, etc.
  - Gates
  - Low risk Infrastructure (fish screens, trash racks, stoplogs, etc.)
  - Coatings

- We design structures for minimum 50-year service life. How can we predict the performance of composite materials for these applications over the life of the structure?

**Dave Tordonato, P.E., PhD**  
*Materilas Engineer*  
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Materials Engineering & Research Lab  
Denver, CO

**Composites Research Roadmap**

- Goal: Produce a short and long-term roadmap for the research and implementation of composite materials as a steel alternative (report due end of FY15)

- Problems to address:
  - Effects of environmental degradation: pH, chlorides, sulfates, temperature, humidity
  - Fatigue behavior under dynamic loading, freeze-thaw, etc.
  - Resistance to fire, impact, abrasion
  - Joining/fusing

- Potential Areas for Collaboration:
  - What are appropriate accelerated test procedures to predict performance to 50 years?
Reducing Concrete Shrinkage and Cracking

Problem Statement:

- Random cracks in concrete alleviate internal strains and are unpredictable and often need ongoing maintenance.
- Internal strains can be generated by restraint, temperature, chemical shrinkage, and/or drying shrinkage.
- Newer concrete admixtures claim to help reduce cracking

Measurement Challenge

- Micro strains are hard to capture in hardened concrete and current testing methods are arduous.

Katie Bartojay, P.E.
Sr. Concrete Specialist
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Concrete & Structures Laboratory
Denver, CO

Comparative Analysis

- **Goals of Project:**
  - To evaluate newer shrinkage reducing admixtures (SRA) on concrete
  - Compare the results of numerous tests
  - Each phase will include a new suite of SRAs

- **Results to Date**
  - Scoping Study Complete in 2015
  - Research currently underway at USACE/ERDC on mortars

- **Potential Areas for Collaboration:**
  - Evaluating new ways to measure strain
**Magnetic Flux NDT of Wire Ropes**

**Issue:** Due to deterioration of wire ropes from mechanical loads and environmental exposure, it is necessary to replace them periodically. Policy is to replace the ropes when a given amount of corrosion is observed on the exterior or other visual damage.

**Question:** Is the wire rope still within the required safety factor regardless of visual deterioration? Is there a better way to ascertain remaining service life?

**Method:** Magnetic Flux Leakage (MFL) is a magnetic NDT method to detect corrosion damage of wire ropes.
- Uses a powerful magnet to magnetize the steel as it is run along the length of the wire rope
- At locations of missing metal, the field induced on the rope will indicate "leaks"

---

**Magnetic Flux Leakage NDT Method**

- **Goals of Project:**
  - Tension testing of wire ropes
  - Comparison to Silver State Wire Rope MFL data
  - Does this MFL Method indicate a safe reliable method for determining if visually inspected rope is within the safety factor allowed for continued service life?

- **Potential Collaboration/Measurement Challenge:**
  - Other potential methods to examine remaining wire rope service life
  - Better signal analysis
  - Is there a way to detect corrosion without having a baseline measurement of the un-corroded wire rope?
Protective Coating In-Situ Performance

• Improved determination of corrosion protection and coating degradation

• Develop field-ready, hand-held instrument for evaluating coating health and/or level of corrosion protection

Bobbi Jo Merten  
Coatings Chemist  
303-445-2380  
bmerten@usbr.gov  
Materials Engineering & Research Laboratory

Goals of Project:
– Reliable measurement of properties in-situ
– Analysis method to predict remaining service

Results to Date
– Electrochemical impedance spectroscopy
  • No connection to substrate
  • Reduced to 5-min test time
– Polarization curves

Potential Areas for Collaboration:
– Non-destructive measurement of corrosion beneath the coating
– Analysis method to predict remaining service
Protective Coating In-Situ Performance

- Electrochemical impedance spectroscopy

![Graph showing electrochemical impedance spectroscopy results for USACE 3-Coat Vinyl]

- Tafel analysis of potentiodynamic experiment
- Corrosion rate is approximately 0.01 nm / yr

![Graph showing Tafel analysis results for potential vs. log(current)]
Detecting Cavitation in Hydraulic Turbines

- **Problem/Need**
  Increase turbine component life and shorten inspection and repair outages by studying cavitation and developing instrumentation to detect cavitation erosion.

- **Measurement Challenge**
  To accurately measure damaging cavitation that is occurring in an inaccessible, extreme environment and isolate this from non-damaging cavitation that is occurring.
  To correlate these measurements respective to operating conditions to develop an absolute cavitation metal erosion rate.

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Detecting Cavitation in Hydraulic Turbines

- **Goals of Project:**
  Expanding industries knowledge base of the cavitation phenomenon in hydroelectric turbines. Development of an affordable and accurate cavitation monitor for use in hydro-turbines.

- **Results to Date**
  Development of a shaft mounted instrument to better measure damaging (erosive) cavitation. (This is temporarily installed due to power requirements)
  Design & installation of cavitation monitors at a Reclamation powerplant. This equipment is currently undergoing testing.

- **Potential Areas for Collaboration:**
  Improved measurement analysis techniques
  Better data mining and trending methods
  Continued testing of various cavitation scenarios occurring within different types of turbines
Short Convergent Intake Discharge By Deployable Acoustic Array

• Short Convergent Intakes are...?????
  (what are they, where are they, and what are we trying to measure?)

• Installation of Transit Time Meters
  – Time consuming
  – Precision
  – Alignment
  – Field Quality Control Measures

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Model of Intake

Sometimes installation is complex with Scaffolding and logistics
Outage time to be considered.
Installation of Lower Granite

• Example of original Installation 1995
• 18 Paths Bay A
• 8 Paths in both Bays B & C
• 3 Week outage

Other Intake Discharge Methods

• Current Meters Require Frames
• Scintillation Requires Frames
• Why Not Acoustic Transit Time Flow Meters?
Acoustic Transit Time Demonstrated to Work At Kootenay Canal

- Comparative results to the 95th Confidence Interval

Acoustic Frame in Deployment
Direct Shear Roughness

• Concrete and rock roughness values are reported according to ASTM D5607 and USBR 4915 (JRC – see chart). The chart is based on profiles of 10 samples increasing in shear strength. Is this the best way to define roughness?

• Measurement Challenge: Use photogrammetric analysis to compute the inherent properties of roughness

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TSC, MERL, Denver

Direct Shear Roughness

• Goals of Project:
  – Update methods for analyzing direct shear properties
  – Apply photogrammetric techniques to direct shear analysis
    • Contact area for stress calculation
    • Roughness coefficient

• Results to Date
  – Photogrammetric model with ± 1 thousandth of an inch error
  – Contact area calculation

• Potential Areas for Collaboration:
  – Define and measure roughness
Detecting and Imaging Seepage

• Aging Water Conveyance Infrastructure:
  – Over 80,000km of levees in the U.S.
  – Increasing potential for failures/increased consequences within urban corridors
  – Geophysical surveying/modeling can help a lot
  – Robust/Rapid reconnaissance is virtually non-existent
  – Standard survey production rates are very slow...

• Measurement Challenge:
  – System noise/Sensor drift issues for focused time-lapse monitoring efforts (e.g., permanent instrumentation of critical & high-risk structures).
  – Integration of Geophysics and remote sensing for rapid regional-scale canal embankment recon

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USBR Seismotectonics & Geophysics Group, TSC

Detecting and Imaging Seepage

• Goals of Current Project:
  Develop & test cart-mounted time/frequency-domain EM profiling system for rapid canal embankment scanning
  Develop workflows for integrating geophysical and remote sensing data
  Develop anomaly detection algorithms for features likely related to anomalous seepage/poor health conditions

1000ft of data collection 24 to 32 staff hours

• Related Future Research Topics:
  Improve self-potential (half-cell) sensor technology for long-term monitoring apps.
  Improve inexpensive wireless sensor network (WSN) technologies for monitoring apps.
  Sensitivity analysis for better understanding limitations of resistivity/EM profiling

• Potential Areas for Collaboration:
  Future Commercialization of ground-based EM profiling services
  Sensor and open-source WSN R&D
**USBR-NIST Exploratory Research Symposium**

**Infrastructure Sustainability**

**NIST Mission** - “To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.”

*NIST*

National Institute of Standards and Technology
U.S. Department of Commerce
Corrosion Detection via AFMR

- Detect steel corrosion under layers like concrete (rebars)
- Steel corrosion is a $200B/year national problem
- One of 11 Grand Challenges for U.S. Corrosion Science (NRC, 2011)
- Need to penetrate 50 mm of concrete or more, detect what kind of corrosion, not just presence
- **New idea**: Use antiferromagnetic resonance spectroscopy

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Applied Chemicals and Materials Division
Boulder, CO

Goals of Project:
- Detect hematite and goethite
- Temperature dependence of peaks
- Hematite through 50 mm of concrete

Results to Date:
- Successful detection of both
- Temperature dependence documented in 2 journal papers
- Working on high power thru-50 50 mm concrete detection

Potential Areas for Collaboration:
- Application of this technology for USBR needs
- Suggestions of where technology could be best used
3D Particle Shape Measurement

- Particle shape is a 3-D quantity
- Shape and size are not independent quantities
- Particle shape is important in many contexts
  - Cement, sand, gravel (and larger)
  - Soils, asphalt, pores, cells
- New idea: Use combination of X-ray CT and spherical harmonic expansions – result in analytical, mathematical expression for surface of random particles

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Applied Chemicals and Materials Division
Boulder, CO

3D Particle Shape Measurement

- Goals of Project:
  - Quantify particle shape
  - Measure enough particles to get good statistics
  - Apply methods widely

- Results to Date
  - Lunar soil simulant, two types of lunar soil
  - Cement, sand, gravel databases
  - Algorithms to simulate large collection of random shape particles
  - Approximate shape invariance for more than three orders of magnitude in size – blasted and crushed quarry rock

- Potential Areas for Collaboration:
  - Identify areas where particle shape matters to USBR
  - Identify methods of obtaining particle shape data (e.g., LIDAR) for particles too large for X-ray CT
Computational Design for Concrete

- Concrete is a random, complex, multi-scale porous composite material
- **New idea**: Use a suite of computational models to promote material design, use to interpret and suggest experiments
- **Virtual Cement and Concrete Testing Laboratory (VCCTL)**
- **Plus on-going work in microstructural models that incorporate more thermodynamics and kinetics – will enable true chemical/physical design**

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Materials and Structural Systems Division  
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Computational Design for Concrete

**Goals of Project:**
- Complete virtual testing of concrete in computer
- Formulation, hydration, property measurements, degradation

**Results to Date**
- VCCTL 9.0 is available
- HydratICA is next phase, true kinetics and thermodynamics

**Potential Areas for Collaboration:**
- Help in understanding concrete behavior
- Potential assessment of new concrete designs?
Overview of NIST Research on Infrastructure Sustainability

Kenneth Snyder
Edward Garboczi
Chiara F. Ferraris
Stephanie Watson
Engineering Lab (EL) Mission

To promote U.S. innovation and industrial competitiveness in areas of critical national priority by anticipating and meeting the measurement science and standards needs for technology-intensive manufacturing, construction, and cyber-physical systems in ways that enhance economic prosperity and improve the quality of life.

Materials and Structural Systems Division

- Community Resilience Group
- Structures Group
- Sustainable Engineered Materials
- Net-Zero Energy, High-Performance Buildings
- Fire Risk Reduction in Buildings
- Structural Performance Under Multi-hazards
- National Earthquake Hazards Reduction Program (NWIRP)
- D&FSP
MSSD Develops Partnerships at Many Levels

- Consortia
  - Building Joint Sealant
  - CRÊME
  - COMAX
  - Photovoltaic Systems
  - Polymer Interface

- CRADA’s with Industry
  - US Gypsum
  - AASHTO
  - Lafarge
  - Sika
  - Cement Barriers Partnership

US GOVT NIST

MSSD Develops Partnerships at Many Levels

SDO’s:
ACI, ASCE, ASTM, ICC

Strong Industrial and Federal Partnerships

- Federally Sponsored Research
  - CPSC
  - DHS
  - DoD
  - FHWA
  - NIJ
  - NRC

New collaborations with other agencies always welcome
**Sustainable Engineered Materials**

**Program Objective:** To develop and deploy advances in measurement science for sustainable materials used in infrastructure, manufacturing, and construction.

**Performance Measurement**

**Inorganic Material Group**

- Corrosion detection
- Cracking
- Industrial by-product characterization
- Early age
- Pumping
- Sulfate attack
- Mechanical properties
- Transport
- Reaction

**Polymeric Materials Group**

- Fatigue
- Combined mechanical properties
- Crack growth
- Humidity
- Temperature
- Additivity
- UV

**Concrete**

**Service Life Prediction**
Green Concrete for Sustainable Structures

Kenneth Snyder
Edward Garboczi
Chiara F. Ferraris

Sustainable Engineered Materials

Program Objective: To develop and deploy advances in measurement science for sustainable materials used in infrastructure, manufacturing, and construction

Performance Measurement
**Inorganic Materials Group**

**Functional Statement**

- Develops, advances, and deploys measurement science to improve the life-cycle performance of cementitious building materials. Carries out mission-related measurement science research and services to:
  - increase service life of concrete used in construction applications;
  - develop standard reference materials and standardized test methods;
  - develop new computational tools for predicting performance of cement and concrete building materials; and
  - develop advanced techniques to characterize cement and concrete materials.

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**Sustainable Engineered Materials:**

**Program and Projects**

**Goal**

**Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure**

**Program**

**Sustainable Engineered Materials**

**Properties of Sustainable Fresh Concrete**

**Chemical, Structural, and Kinetic Measurement Technologies for Cementitious Materials**

**Performance of Infrastructure Repair Materials**

**Measurement Science to Assure the Performance of Innovative Green Concretes**

*Two projects related to Polymer (next talk)*
Properties of sustainable fresh concrete
Chiara Ferraris, Nicos Martys, William George, Nicholas Dagalakis

Objective: Ensuring constructability through predictable workability

Science: Rheology
Equipment adapted for granular material in a fluid matrix
New test methods for dense suspensions
Models to predict flow
Tools to design concrete for workability

Cement Paste
Calibrated concrete rheometers for QC/QA
SRM for paste rheometer calibration: Bingham paste
SRM 2492: 1st worldwide standard reference material for paste
SRM 2493 (Mortar) = SRM 2492 + 1 mm glass beads
SRM 2497 (Concrete) = SRM 2493 + 10 mm glass beads

Mortar & Concrete
1st SRMs for mortar or concrete
Equipment adapted for granular material in a fluid matrix
Models to predict flow

SRM 2493 (Mortar) = SRM 2492 + 1 mm glass beads
SRM 2497 (Concrete) = SRM 2493 + 10 mm glass beads

Measurement science-based tools to support improved Specifications & Codes for workability
Ensuring pumpability
High-through-put paste rheometer to optimize chemical dosage and identify cement incompatibility

Repair Materials with Internal Curing: Bonding and Performance

Repair Materials (Bags): Manufacturer One
Manufacturer Two

Repair Materials (Bags):
Manufacturer One
Manufacturer Two

Base mortar: I/II cement
Standard blend of 4 sands
Cured for 28 d

Auxiliary testing:
Mortar cube strength (ASTM C109)
Setting time (ASTM C191)
Chemical shrinkage (ASTM C1608)
Autogenous shrinkage (ASTM C1698)
Drying shrinkage (ASTM C596/C157)
Isothermal calorimetry (ASTM C1702)
Semi-adiabatic calorimetry
Electrical resistance

Internal curing options:
Pre-weted Lightweight aggregate (LWA)
Superabsorbent polymer (SAP)
SAP-coated sand (AQS)

Materials characterization:
PSD (laser diffraction/X-ray CT) Density (He pycnometry)
Absorption/Specific gravity of LWA (ASTM C128)
PSD/LWA (sieving) Heat capacity (Hot Disk)
XRD (phase depletion/formation)
Microtomography (SAP sizes)
Neutron imaging (NCNR)

Shear slant test
ASTM C882

Pull-off test
ASTM C1583

NIST primary researcher: Dale Bentz
Potential USBR collaborator: Kurt Von Fay
Reducing Early-Age Cracking Today
Strategies for REACT (Web portal)

http://concrete.nist.gov/REACT.html

Best Practices
- High volume fly ash
- Thermal properties
- Mechanical properties
- Mitigating delayed setting

Choose a coarser cement
Blend existing cement with a coarse cement

Cement/Fly Ash Engineered Particle size distributions

Potential collaborators
NIST: Dale Bentz
USBR: Katie Bartojay

Other properties
- Plastic shrinkage
- Sorptivity
- Reduced diffusion
- Service Life

Other properties
- Plastic shrinkage
- Freezing susceptibility
- Reduced diffusion

Coarser cements
Increase w/c ratio
Coarse limestone addition
Internal Curing
Shrinkage reducing admixtures

Coarse cements
Increase w/c ratio
Coarse limestone addition
Internal Curing
Shrinkage reducing admixtures

Measurement Science to Assure the Performance of Innovative Green Concretes

New project:
- **Identify critical performance-related components of fly ash**, to ensure performance based selection of FA
- **Limestone-cement concrete**: Replacement of cement up to 40% without loss of performance (reducing environmental impact)
- Ensure that ASTM test generally designed with portland cement in mind, are applicable for blended cements with high SCMs content.
  - determining cement sulfate resistance, **NIST approach would reduce the testing time for sulfate resistance of a cement by 25 %** (3 months instead of a year),
- **3D-Printing of grouts**: NIST will build a 3-D printer for cementitious materials and then develop the necessary metrology to qualify the materials used for such applications.
  - The performance requirements demand rapid rigidity (to withstand the dead load of subsequent layers), a mechanical bond between adjacent layers, and sufficient structural capacity.
Inorganic Materials Group

Core Competencies

- Quantitative Microscopy
- Rheology of Non-Newtonian Dense Suspensions: measurement and modeling
- Concrete Cracking mitigation strategies
- Cement Chemistry / Cement Hydration Mechanisms
- Modeling Transport and Reaction in Concrete

Facilities and Equipment

Measuring Performance:
- Paste /mortar / concrete rheometers
- Concrete pump: instrumented to monitor flow and pressures
- Isothermal/semi-adiabatic calorimeters

Materials Characterization:
- X-ray Powder Diffraction
- SEM w/ X-ray micro-Analysis
- Field Emission SEM
- BET: particle surface area
- Thermogravimetric analysis (TGA)
- Helium Pycnometer: powder density
Sustainable Engineered Materials

Program Objective: To develop and deploy advances in measurement science for sustainable materials used in infrastructure, manufacturing, and construction

Service Life Prediction
Polymeric Materials Group

Functional Statement

• Develop and implement methodologies/metrologies for determining scientific origins of materials degradation required for predicting the service life of polymeric materials exposed in their intended or accelerated exposure environments using:
  ▪ measurements at the molecular and nanometer scales of chemical, physical, mechanical, optical, and morphology property changes in polymeric materials as they degrade;
  ▪ novel instrumentation and sensors for material property characterization and accelerated aging of polymeric materials;
  ▪ analytical, laboratory, and field research on the performance of polymeric materials such as coatings, sealants, adhesives and composites; and
  ▪ technical bases for improved performance standards for evaluation, selection, and use of these polymeric materials and composites.

Sustainable Engineered Materials: Program and Projects

Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure

Program

Sustainable Engineered Materials

Projects

NIST Accelerated Weathering Laboratory: Metrology and Operations

Measurement Science Tools for Accelerated Weathering of Polymers

Four projects related to Concrete
**Predicting Outdoor Performance from Laboratory Exposure**

**New Methodology**

Reliability-based Methodology for Service Life Prediction

Laboratory Exposure

- **Light**
- **Heat**
- **Moisture**

Outdoor Exposure

- **Linkage**

**New Standard of Performance**

Experiments designed (critical exposure variables); weathering factors highly controlled; all measurements quantitative and of known precision and accuracy

Database; Predictive Models

- Parameters of predictive models are estimated solely from laboratory experiments; outdoor exposure results are used to verify models using field exposure conditions as input (*Prediction models suitable to different climates*).

**Quantitatively link laboratory and field exposure results**

**NIST Accelerated Weathering Laboratory: Metrology and Operations**

- **Objective**: To maintain, improve and expand capabilities at the NIST Accelerated Weathering Laboratory (AWL) and to use the facility to conduct safe, accurate and traceable aging experiments. Enable the technology transfer of the SPHERE technology to industrial stakeholders.

- **Expected Outcomes**:
  1. Publicly available database to provide exposure (temperature, relative humidity and ultraviolet) data and real-time sample irradiance data,
  2. Operational 6-port MUUSIC and Strain SPHERE systems,
  3. Capability to perform round robin tests for ASTM standards.

- **Major Product**: NIST traceable accelerated weathering devices with unparalleled accuracy and control for temperature, relative humidity and ultraviolet.

PI: Eric Byrd
Nano-engineered Fiber Composites

Need: Measurement science for life cycle of hierarchical, multifunctional composites

- Develop a database of mechanical properties as a function of environmental exposure for novel engineered nanocomposites,
- Develop in situ measurements for characterizing stress transfer at the fiber-matrix interface in engineered nanocomposites,

Aerospace Comp.

Accelerated Aging

Bulk properties

New Materials

Impacts: MGI, ChiMaD, manufacturing, design

Fusion Joint Measurements: Pipes

Developing measurements for large diameter pipe in three areas that provide input to Models: Material properties shared with Gas Technology Institute (Ernest Lever)

Materials in Pipe Systems

Polymer crystal Microstructure

Structure (location) specific properties

Creep

Hardness Testing

Thermal history

Failure

Crack damage and microstructure in CRB geometry

Link the local microstructure to the mechanical/failure properties

Utilizing nanoindentation to measure local viscoelasticity and plasticity.

bCARS measurement of crystal microstructure in a bimodal polyethylene. Green represents D-HDPE and red indicates H-LLDPE, which is the high molecular weight branched component.

Lee et al. ACS MacroLett. 1, 2012, 1347 - 1351

Assessment of Electrical Cable Condition Monitoring Tests

- Selected condition monitoring tests (CMTs) evaluate a set of commercial electrical cables, each exposed to static, well-controlled exposure conditions.

- Each cable will be:
  - characterized to establish baseline values for cable properties using the set of predetermined CMTs
  - subjected to a series of static, well-controlled temperature, relative humidity and operational aging radiation exposure environments
  - periodically removed from each exposure environment and evaluated using the predetermined CMTs
  - analyzed to assess temporal changes in cable performance and CMT results

Impacts: NRC, DOE, Dow, Exxon, Cable Manufacturers, EPRI

Polymeric Materials Group Core Competencies

- Service life prediction metrologies for polymer materials in their intended or accelerated exposure environments
- Analytical, laboratory, and field research on the performance of polymeric materials
- Development of novel instrumentation and sensors for characterization and accelerated aging of materials
- Multi-scale measurements of chemical, physical, mechanical, optical, and morphology property changes in polymeric materials
Facilities and Equipment

- **Applied Mechanics and Physical Testing**
  - Rheometer
  - Tensile Testers (varying loads)
  - Servohydraulic and electromechanical (2) driven load frames
  - Nanoindenter

- **Rheometer**
- **Tensile Testers (varying loads)**
- **Servohydraulic and electromechanical (2) driven load frames**
- **Nanoindenter**

- **Thermal Characterization Testing**
  - Differential Scanning Calorimetry (DSC)
  - Thermogravimetric analyzer (TGA)
  - Dynamic Mechanical Thermal Analyzer (DMTA)

- **Differential Scanning Calorimetry (DSC)**
- **Thermogravimetric analyzer (TGA)**
- **Dynamic Mechanical Thermal Analyzer (DMTA)**

- **Analytical Measurements**
  - Gas chromatography mass spectroscopy (GC-MS)
  - High Pressure Liquid Chromatography (HPLC)
  - Moisture isotherm Analyzer
  - Dynamic Light Scattering (multi-angle)
  - Contact Angle Analyzer

- **Microscopy Methods**
  - Atomic Force Microscopy (AFM)
  - Scanning Laser Confocal Microscopy
  - Scanning Electron Microscopy (SEM)
  - Cryo-Microtome

- **Spectroscopy Methods**
  - Fourier Transform Infrared Spectroscopy (FTIR) [attenuated total reflectance (ATR), Photoacoustic, FTIR microscope]
  - Ultraviolet-visible spectroscopy
  - Raman microscopy
  - Electron Paramagnetic Resonance Spectroscopy
  - Optical Surface Scattering Instrument

- **Other NIST facilities we have access:**
  - MML- X-ray photoelectron spectroscopy (XPS), fluorescence spectroscopy, ICP, Raman spectroscopy
  - NCNR-neutron scattering measurements
  - CNST- Transmission Electron Microscopy (TEM)

Questions?
Pipeline Safety

Manufacturers, operators and regulators of pipelines and other infrastructure require increased understanding of fatigue, fracture and non-destructive evaluation (NDE) to improve safety, reliability and economics.

- Aging and failing pipeline infrastructure systems require accurate condition assessments fed to risk based decision models to determine mitigation strategies and priorities.
- Advanced high-strength steels require standards and design requirements for implementation.

Scalability of test data is a significant challenge to ensure that laboratory scale tests provide information that is relevant to full scale conditions.

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ACMD, Structural Materials - Boulder

### High Rate Ductile Failure

- **Goals of Project:**
  - Develop 3D Constitutive Material Model (CMM)
  - Develop 3D Predictive Damage/Material Model
  - Develop Medium-Scale High-Rate Test
  - Validate predictive model with full scale results

- **Results to Date**
  - High-rate ductile failure is preceded by significant plastic zone
  - Developed pre-strain method and small scale tests to calibrate CMM
  - Preliminary designs of medium-scale high-rate tests

- **Potential Areas for Collaboration:**
  - Applicable to other infrastructure systems
Small Scale Fracture Mechanics

- Goals of Project:
  - Establish scalability and transferability to full scale conditions
  - Develop rigorous technical justification for consensus standards and regulatory requirements

- Results to Date
  - Established controls for comparing multiple non-standard industry test methods
  - Published results of comparisons and new insight on material parameters of interest
  - Lead ASTM efforts on consensus standard development

- Potential Areas for Collaboration:
  - Methodology development can be universally applied to all infrastructure

NIST National Institute of Standards and Technology • U.S. Department of Commerce

NDE Calibration References – Fatigue Flaws

- Goals of Project:
  - Develop a reference standard that best matches the fatigue flaws measured in real structures
  - Complete blind round robin study to determine efficacy of new references
  - Produce improved references for the NDE industry

- Results to Date:
  - Developed/Published a method to produce well characterized fatigue flaws
  - Phase I – Feasibility study documented the gross error associated with “expert” evaluations in laboratory settings
  - Manufactured six reference sets with four plates, each having a different internal flaw geometry
  - Phase II – Round Robin study underway

- Potential Areas for Collaboration:
  - NDE is used in nearly every industry


Presented by:

Chad Snyder, Ron Jones & Kalman Migler
Material Measurement Lab
Materials Science and Engineering Division

NIST Mission - “To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.”

Problem/ Needs

• Semi-crystalline polymers are pervasive in our daily life and their long term reliability is often critical. Uncertainties related to product lifetime for new systems often slow adoption
• Branched high MW component increases the resistance to slow crack growth (SCG; prevailing failure mode in today’s PE pipe for potable water distribution), but no firm basis for 100 year lifetime and performance after fusion (joints) is potentially worse!
• Need to know the actual molecular mechanisms to properly model lifetime

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642, Functional Polymers – Gaithersburg, MD
MSED Measurements

• Goals of Project:
  – Measure molecular level fusion and failure processes

• Results to Date
  – CARS Microscopy enables label-free, chemically resolved imaging of chain fractions in PE bulk crystalline and amorphous regions (tie chains, etc)
  – Vapor-flow SANS experiments enable nanomechanical measurements of interlamellar amorphous regions presumed responsible for SCG
  – Raman/Rheological measurements probe pre-crystalline phases in PE

• Potential Areas for Collaboration:
  – Fundamental evaluation of source materials and methods for infrastructure replacement materials
  – Forensic analysis of failure modes in plastic pipe?

ACS Macro Lett. 1, 1347–1351 (2012)
**Materials Joining Project**

- Materials joining is a critical and enabling technology in U.S. manufacturing & infrastructure recovery since about half the U.S. GNP involves welding.
- Even small improvements to our understanding of weld behavior can translate to $M of cost savings for industry.

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Applied Chemicals and Materials Division, Structural Materials Group, Boulder, CO

**Materials Joining Project Overview**

- **Goals of Project:**
  - Develop a “smarter weld” through improved physical and material measurements (e.g., laser welding)
  - Develop structure-property relationships for novel joining processes (e.g., additive manufacturing)

- **Results to Date:**
  - Multiscale microstructural analysis (nm to mm)
  - Correlative imaging of mechanical behavior (e.g., neutron imaging)
  - Customer driven: focus on producing data for engineering models

- **Potential Areas for Collaboration:**
  - Robust welds in water piping infrastructure
  - Failure analysis of welded materials
  - Structural monitoring of welds

**New technologies can greatly enhance productivity, e.g. single-pass welding of heavy pipe**

**Electrical Resistance Welding**

**Friction-stir welding**

**Dissimilar Welding of differing materials enables flexible engineering designs**

**Laser Welding**

**Additive Manufacturing**

**Fracture**

**Mini Charpy Specimen**

**Build Direction**

**Instrumented Mini Charpy Striker**
Microbiologically Influenced Corrosion (MIC)

Biofilms are everywhere.

![Image of biofilms](image1.png)

Microbial adhesion is a common intervention point for any type of biofouling

**Impact:** Corrosion costs the U.S. about $276 billion annually* (up to 50% due to MIC)

**Measurement Challenge:** Non-invasive, high-throughput adhesion measurements of relevant microbial communities in relevant environments

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ACMD, Materials for Biological Environments

**Microbial Adhesion Measurements**

- **Goals of Project:**
  - Bond maturation time
  - Bond stiffness
  - Bond characteristics in multispecies environments
  - Intervention points discovered through fundamental measurements

- **Results to Date**
  - Equipment in place

- **Potential Areas for Collaboration:**
  - Microbial corrosion of pipelines, tanks, etc.
  - Membrane biofouling
  - Natural biofilms

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Appendix E: Water Management & Measurement Shorts
Water Supply/Demand Analyses

• Problem / Need Statement:
  - Reclamation conducts numerous studies requiring information on water supplies and demands over large areas (obs-based and model-based).
  - Measurements of most water supply/demand components are sparse and/or highly uncertain. Other components are not measured directly and must be estimated.
  - Measurement limitations result in large uncertainties in estimated water budget; however, uncertainties are difficult to quantify.

• General Measurement Challenges:
  - More More More! (AKA Cheaper Cheaper Cheaper!)
    … Reduce cost of instruments, installation, O&M to allow for more measurement sites
  - Better Better Better!
    … Improve accuracy of individual measurements
    … Improve characterization of measurement uncertainty for individual sites and across multiple measurements

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Water Resources Planning and Operations Support Group
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Evaporation and ET
Evaporation from open water and evapotranspiration from land are not measured directly – both are estimated from multiple measurements of atmospheric parameters (eddy covariance method) and/or energy fluxes (Bowen ratio and remote sensing methods).

• Measurement Challenges:
  - Many sensors – small errors in each can accumulate into large errors in estimated evaporation / ET
  - Numerous sources of error – e.g., scalar path averaging, digital sampling, sensor separation, sensor time delay, unleveled instruments, etc, etc.
  - Numerous assumptions required … many are frequently violated.
  - Total error commonly exceed 100% of estimated flux!
  - Need for improved and standardized methods to assess and correct for errors.
**Water Supply/Demand Analyses**

- **Evaporation and ET**
  Evaporation from open water and evapotranspiration from land are not measured directly – both are estimated from multiple measurements of atmospheric parameters (eddy covariance method) and/or energy fluxes (Bowen ratio and remote sensing methods).

- **Example: Reservoir Skin Temperature**
  - Temperature of reservoir surface (top ~1mm) is required for Bowen ratio method
  - Current buoys measure skin temperature using infrared radiometer
  - Measurement of open water surface temperature is highly uncertain due to rapid fluctuation in water elevation and rapid mixing

**Water Supply/Demand Analyses**

- **Precipitation**
  Traditional precipitation gages are sparsely distributed, subject to variety of measurement errors (e.g., wind effects). Remote sensing estimates (satellite and radar) are highly uncertain. Many studies rely on gridded precipitation datasets that interpolate gage records across large areas, resulting in substantial errors and uncertainties.

- **Measurement Challenges:**
  - Improve traditional gages, radar and satellite precipitation estimates to reduce errors
  - Better methods needed to quantify precipitation errors
  - Better methods needed to estimate precipitation over large areas – e.g., by combining gage, radar, and satellite measurements.
**Water Supply/Demand Analyses**

**Surface Water**
Instantaneous flow measurements are commonly made using mechanical current meters and acoustic Doppler instruments. Continuous measurements commonly made based on stage-discharge and velocity-discharge relationships.

**Measurement Challenges:**
- Large uncertainties/errors in rating curves due to changing channel conditions, effects of windthrow on stage, and other issues
- Large uncertainties in instantaneous measurements due to effects of instruments on flow, interpolation/extrapolation of measured data across flow profile, short-term effects of vegetation and windthrow on flow profile

**Groundwater**
Quantifying groundwater recharge and discharge—including discharge to wells, streams, lakes, and wetlands—is important for water budget analyses in many basins. However, recharge and discharge are not measured directly and must be estimated. Estimates are highly uncertain, particularly over large areas.

**Measurement Challenges:**
- Groundwater recharge and discharge are notoriously difficult to measure ... nearly always estimated using models
- Methods needed to measure recharge/discharge directly and/or to constrain model estimates
**Water Supply/Demand Analyses**

**Soil Moisture and Snowpack**

Point measurements are error prone due to a variety of site- and instrument-related issues. Point measurements are also generally sparse, and extrapolation of point measurements over a basin is highly uncertain. Remote sensing methods are limited to near-surface soil moisture (not integrated over soil column) and areal estimates of snowpack (no information on thickness or water equivalent).

**Measurement Challenges:**

- Better methods needed to reduce (and quantify) uncertainties in point measurements of soil moisture
- Methods needed to facilitate distributed estimates of soil moisture and snowpack over large areas – e.g., integration of point-based and remote sensing data

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**Water Supply/Demand Analyses**

**Model Inputs, Calibration/Verification**

Water budget analyses often rely on hydrologic and water operations models. Observational data is used to develop model inputs and to calibrate/verify models. Uncertainties in observations are often ignored when developing inputs and computing calibration/verification metrics.

**Measurement Challenges:**

- Characterization of measurement uncertainties as relevant to model inputs and calibration/verification
- Methods to evaluate propagation of uncertainties from observations to model inputs to model results.
Most irrigation water in western U.S. is delivered through open canals
- USBR annually delivers 10 trillion gallons of water to 31 million people and 10 million acres of farmland
- Piped conveyance systems are slowly becoming more common and some deliveries to water users are made through pipe, but most are made through open ditches

Flow measurement options for open channels
- Stream gaging: Direct measurement of velocity, depth and flow area on a section-by-section basis
  - NIST involvement might focus on the velocity measurement instrument (current meter)
- Stream rating curves: consistent relation between flow depth and discharge
- Dedicated water measurement structures

Traditional measurement devices
- Sharp-crested weirs
- Flumes of many specific designs
  - Parshall, H-flume, Palmer-Bowlus, Cutthroat, etc.
- Calibrated by laboratory testing of scale models or field calibration vs. independent flow measurements (stream gaging)
- Lab testing was needed because flow through the “critical section” was curvilinear

Long-throated flumes
- Developed beginning in 1970s with rise of low-cost computing capability
- Device with nearly straight/parallel flow in critical section could be calibrated analytically using established hydraulic concepts
- Calibration requires iterative solution of many empirical and non-linear equations

Computer codes
- 1970s: FORTRAN calibration programs
- 1990: MS-DOS based interactive design program
- 1997: WinFlume graphical interactive design program
Design and Calibration of Open-Channel Flow Measurement Flumes

- WinFlume, computer program written ca. 1997 for Windows 95/NT platform, needs to be rewritten
  - Total rewrite needed because of language changes from VB4 to VB.NET
  - Dual-platform PC and Tablet app possible?
- Long-throated flumes are the most accurate critical-flow measurement devices
  - Low head-loss requirement facilitates adding flow measurement capability to existing canals
  - Computer calibration avoids need for lab tests

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WinFlume Upgrade

- Goals of Project:
  - Write new WinFlume application for PC
  - Also develop tablet or mobile device app?
- Results to Date
  - Started to collaborate this year with Joe Manns, a long-time WinFlume user at Metropolitan Council Environmental Services (St. Paul, MN) - (volunteered to help with WinFlume rewrite)
  - Mostly strategizing so far
- Potential Areas for Collaboration:
  - Programming talent?
  - Application standardization?
  - USBR could aid NIST in improving open-channel flow measurements
Measuring Flow at Canal Control Structures - Radial Gates and Slide Gates

• Many canal systems are controlled by undershot-type check gates (radial gates and vertical slide gates)
  – Ability measure flow with same device used to set flow improves operations
  – Transitions from free-flow to submerged-flow have been a calibration problem
  – Combine energy-momentum equations
• New algorithms require iterative solution of flow equations
  – Computer software to do this is in beta test, but needs refinements and documentation

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WinGate Software Completion

• Goals of Project:
  – Complete software and release for public use
  – Implement rating table “book” feature?
  – Develop user documentation

• Results to Date
  – Collaboration on algorithm development with Bert Clemmens (USDA-ARS, Retired), Gilles Belaud (France)

• Potential Areas for Collaboration:
  – Programming talent?
  – Application standardization?
  – Modularization could make final product more useful
  – USBR could aid NIST in understanding canal flow measurement needs
Acoustic Doppler Velocity Measurements in the Hydraulics Lab

- Acoustic Doppler Velocimeters widely used for scale model hydraulic studies since 1993
- WinADV provides platform for filtering and post-processing data
  - Data management
  - Spike removal, velocity scaling
  - Velocity adjustments for moving probe
- Software is outdated (VB4 source code)
- ADV manufacturers have created similar programs, but none that fully meet Reclamation’s hydraulic laboratory needs

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WinADV Upgrade

- Goals of Project:
  - Develop new program compatible with SonTek and Nortek data files, using modern programming tools
- Potential Areas for Collaboration:
  - Code development
  - Standardization of spike removal techniques
  - US Army Corps of Engineers is a potential partner
Removing Fine Debris from Water Using Coanda-Effect Screens

• Traditionally USBR has only removed coarse debris from water we deliver
  – Trashracks to catch large or bulky debris that would clog waterways or damage large hydropower equipment (Remove trees and/or bulky aquatic vegetation with racks having 2- to 4-inch spacing)

• Many evolving reasons to remove finer debris from water
  – Conversions
    • open channel to pipe
    • flood irrigation to sprinkler and drip
  – Small-scale hydro
  – Environmental (fish protection, invasive species control)
  – Water quality
Removing Fine Debris from Water Using Coanda-Effect Screens

- Self-cleaning water screens for fish screening and removal of fine debris (organic or sediment)
  - Irrigation, fish protection, stormwater runoff
- Reclamation research has quantified clean-water flow capacities
- Working now to understand effects of debris clogging, screen wear, and how screen design affects self-cleaning capability

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Coanda-Effect Screens Research

- Goals of Project:
  - Test clean-water capacity of other screen materials and over a wider range of flow conditions
  - Test debris exclusion capabilities
  - Understand what design parameters affect self-cleaning
  - Test ways to enhance hydraulic self-cleaning action

- Potential Areas for Collaboration:
  - Measurement of screen properties (wire tilt)
  - Establish standard test methods
Detection of Environmental DNA (eDNA)

- eDNA sample collection is less destructive than traditional field monitoring and it can provide a more accurate measure and identification of small populations of invasive and endangered species

- eDNA samples contain free floating DNA and tissue that can not be identified by traditional visual taxonomic methods

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Detection of Environmental DNA (eDNA)

- eDNA collection and detection are site and organism specific, making it difficult to develop uniform standards and protocols for sample collection and analysis

- **Goals of Project:**
  - Develop standard site specific sampling methods
    - wetland, river, reservoir, terrestrial
  - Determine sampling frequency required to estimate population size
  - Develop standard DNA extraction and PCR assays
Detection of Environmental DNA (eDNA)

• Research and Application
  – Reclamation Detection Laboratory for Exotic Species (RDLES) has researched eDNA sampling for early detection of quagga and zebra mussels
  – RDLES is researching how eDNA can be used to monitor endangered species (MacNeill’s sootywing butterfly)
  – eDNA is currently used by other agencies for invasive species management decisions (Asian carp)

• Potential Areas for Collaboration:
  – Development of standard sampling methods
    • Sample depth and quantity
    • Sample frequency
    • Size of filters
    • Amount of tissue or DNA required for detection
    • Standardize DNA extraction and PCR assays
Water Reuse: Detection and Impact of Pathogens and Chemicals

• Water supply challenges in the West are increasing interest in water reuse
  – Reusing wastewater for drinking water and irrigation

• Three areas of on-going research
  – Develop tables of pathogens and chemicals of concern
  – Literature search on current detection methods for pathogens in reused water
    • Eventually test these methods in the laboratory
  – Literature search on water reuse for agriculture irrigation
    • Design field experiment to determine the impact of reused water on specific crops

Goal: Develop tables of pathogens and chemicals of concern

  – What are the human health risks associated with these pathogens and chemicals?
  – Do government regulations exist for the pathogen or chemical?
  – What kinds of water treatments need to be in place to remove certain contaminants?
  – What are the best detection methods? Can the pathogens be detected by eDNA methods?
Water Reuse: Detection and Impact of Pathogens and Chemicals

- Goal: Develop laboratory methods to detect pathogens of concern in reused water
  - Literature search to find the current methods and technologies used to detect pathogens in reused water
  - Develop PCR based assays for detecting the presence of pathogens in water by eDNA
    - Validate the PCR assays with water that has been spiked with the pathogens and also test real world samples

- Goal: Assess the impact of using reused water for agricultural irrigation
  - Literature review
  - What research has been done on plants and soil to look at the impact of water reuse?
    - How are plants analyzed to test for impact of water reuse?
    - How are contaminants analyzed in soil and plant samples?
  - Design field studies to measure the impact of reused water on agricultural products
RLDES is building on its knowledge of water testing and eDNA to investigate methods for detecting pathogens in reused water

Potential areas for collaboration
- Develop standard methods for measuring pathogens in reused water
  - Determine best detection methods
  - Validate methods in control and real world samples
- Develop methods for measuring the impact of reused water on agricultural products
Concentrate Management & Trace Contaminant Detection

- Emerging Contaminants in RO Concentrate

- No Fed Regulatory Limits
  - States will set precedent CA/TX
  - Emerging contaminants limits unknown

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CECs

- Goals of Project:
  - Survey of CEC in Concentrate
  - Removal Mechanisms

- Results to Date
  - 127 CECs – mainly pharma
  - UV/H₂O₂ - Ozonation

- Potential Areas for Collaboration:
  - ug/L or below CEC detection
  - Protocol for detection based on Fed/State Limits

CEC Distribution

- Pharmaceuticals 88
- Steroids 4
- Pesticides 10
- Personal Care Products 8
- Flame Retardants 4
- Industrial Chemicals 6
- Hormones 7

CECs Graph:

- North America
- Europe
- Australia
Improving Data Access

Using data domains to develop Communities of practice (CoPs) and Data Standards for better communication and share-ability among stakeholders.

The challenge is to obtain senior level management buy-in

Typically, USBR data are presented in Non-machine-readable formats

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Improving Data Access

- *Expanded* Community of Practice for Water Data
- Poll community for the most widely accepted export format
- Learn and write the coding
- Create ‘alternate’ data export with new format standard
- Publish
**Improving Data Access**

• **Goals of Project:**
  – Water data community
  – Adopt / develop export standard
  – Publish data

• **Results to Date**
  Project complete. Data are now directly machine-readable.

• **Potential Areas for Collaboration:**
  – Organize around OMB A-119 to encourage adoption of voluntary consensus standards in the data arena.
  – Develop standardized processes for data release and formatting.
USBR-NIST Exploratory Research Symposium

Water Management & Measurement

**NIST Mission** - “To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.”

[Logo of NIST]

National Institute of Standards and Technology
U.S. Department of Commerce
Pore structure and fluid flow in porous materials

- More of a capability than a current project
- Many successful applications where we:
  - Obtain pore structure from model or X-ray CT
  - Compute simple saturated flow = permeability
  - Compute multi-fluid or unsaturated flow
  - Incorporate different wetting regimes for each fluid on solid and interfaces between each other
- Programs are mainly in Fortran, parallel MPI versions
  - Navier-Stokes equations via direct finite difference equations, Lattice-Boltzmann formulation
- Can also compute linear elastic properties of solid frame

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Goals of Project:
- Compute all manners of fluid flow in a given pore structure of interest
- Predict fluid flow properties of models of cement paste, mortar, concrete

Results to Date
- Sandstone rocks
- Crack networks
- Model random porous media

Potential Areas for Collaboration:
- Fluid flow through: soils, engineered barriers near canals, dams, reservoirs?
- Other?
NIST Office of Data and Informatics

- Increasingly large and information-rich data sets are now common in many disciplines presenting the challenges of handling, archiving, storing, and analysis

- ODI provides guidance, assistance and resources for optimizing the discoverability, usability, and interoperability of data products in ways that support NIST scientists and stakeholders, especially in cases where advanced manipulation, visualization, and analysis of large data sets are needed to advance knowledge.

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Example: MML DSpace Server

Goal of Project:
The NIST materials science data repository was created to establish data exchange protocols and mechanisms that will foster data sharing and reuse across a wide community of researchers, with the goal of enhancing the quality of materials data and models.

Potential Areas for Collaboration:
- ODI is a resource for NIST and NIST’s stakeholders
- Data challenges associated with water and water infrastructure are large and wide ranging (contaminates, corrosion, data access)
- Learning more from the data should be considered with any work moving forward.
**H₂Omics: Comprehensive Contaminant Profiling to Guide Water Management in the Future**

- Climate change and overuse are stressing the quality of our nation’s water supplies, yet there are currently no comprehensive, validated methods for determining the full range of contaminants in water.

- NIST will develop validated, broad spectrum methods for characterizing the chemical and microbial contaminants in water. These methods will be used to validate field methods and sensors, and to guide fit-for-usage water management strategies in the future.

- Comprehensive measures of water quality are extremely difficult due to the wide range of individual compounds and microbes that could be present. The identification of completely unknown contaminants is exponentially more difficult because of the extremely low levels that might be present.

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**Goals of Project:**
- Develop comprehensive methods for organic contaminants with chromatography/MS
- Develop comprehensive methods for microbial contaminants based on genomics measurements (with NIST Biosystems and Biomaterials Division)

**Results to Date**
- Project just getting started – stay tuned!

**Potential Areas for Collaboration:**
- Samples needed with variable contaminant compositions, particularly from ‘alternate’ sources: wastewater, gray water, brackish water, desalinated water, energy production water, rainwater etc.
- Access to field methods and sensors for validation
- Data analysis and modeling for water systems
**Reclamation-NIST Exploratory Research Symposium**

**Frequency-comb based spectroscopy for detection of multiple chemicals**

**Presented by:**

Eleanor Waxman on behalf of Nate Newbury

Physical Measurement Laboratory, NIST-Boulder

Quantum Electronics and Photonics Division

Sources and Detectors Group

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**NIST Mission** - “To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.”

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**Dual Comb Spectroscopy**

- **Need:** Single instrument to detect multiple gases with high sensitivity, high accuracy & over relevant path-averaged distances
- **Approach:** Broadband spectroscopy using frequency combs – broad spectrum, coherent sources
- **Challenge:** Sensitive measurement of greenhouse gases + VOCs

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**Gas Sample**

\[
\ln \left( \frac{I}{I_0} \right) = A = \frac{c I}{\lambda}
\]

measured known calculated

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Trace Gas Measurements

• Goals of Project:
  – Measure greenhouse gases (CO₂, water, CH₄, isotopes)
  – Measure VOCs in outdoor air
  – Measure gas emissions at gas/oil fields

2 kilometer open path above NIST.
Lab-based test system; moving towards portable system.

Rieker et al. (2014) Optica

Trace Gas Measurements

• Results to Date
  – Measurements of CO₂, CH₄, and H₂O across outdoor, 2-km open-path measurements.
  – Currently developing portable system.

Rieker et al. (2014) Optica
Future Directions

• Potential Areas for Collaboration:
  – Monitor off-gasing from oil/gas sites, fracking sites, bodies of water, other potential sources?
  – Species we hope to measure:
    • CO₂ (carbon dioxide)
    • CH₄ (methane)
    • C₂H₆ (ethane)
    • C₃H₈ (propane)
    • C₂H₄ (ethene)
    • C₃H₆ (propene)
    • C₂H₂ (acetylene)
    • CH₂O (formaldehyde)
  – We are currently evaluating system sensitivity for these species.

Rieker et al. (2014) Optica
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Nanotechnology for Sustainable Water
- Chemical Measurements for Nanomaterial Sorbents -

Problems
1. Empirical
2. Assume all sites are identical
3. Non-mechanistic
4. Conditional
   - pH
   - IS
   - >S:A_{aq} ratio
Nanotechnology for Sustainable Water
- Chemical Measurements for Nanomaterial Sorbents -

Nanotechnology for Sustainable Water
- Chemical Measurements for Graphene Oxide Sorbents -

Potentiometric Titration
[Material] / [Titrant]
pH / IS Range

FITEQL 2.0 Modeling
\( >S^+ H^+ \leftrightarrow >S_i^- + H^+ \)

Batch Metal Sorption
[Material] / [Metal]
pH / IS Range

FITEQL 2.0 Modeling
\( >S_i^- + M^{2+} \leftrightarrow >S_M^+ \)

Model Types
Non-Electrostatic
Constant Capacitance
Diffuse Layer
Triple Layer

Known equilibrium constants

\[ K = \frac{[>S_{Aq}]}{[>S][A_{aq}]} \]

Cook Time (hours) Solid Content (wt. %)

2 hr 0.26%
3 hr 0.98%
4 hr 1.41%
8 hr 1.76%
Nanotechnology for Sustainable Water
- Chemical Measurements for Graphene Oxide Sorbents -

Collaboration opportunities?

- Materials characterization & development
- Water/wastewater treatment
- Environmental transport modeling
- Process modeling & engineering

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Problem Statement

• There is increasing demand for & dwindling supplies of clean water. Polymer membrane-based separation technologies are playing an increasing role in clean water production.
• In TFC membranes, we still do not know the fundamental material properties that define permselectivity, and thus we cannot rationally design new membranes.
• Measurements of solubility, diffusivity of both water and salt in thin films need to be developed, in tandem with model membranes of controlled thickness and chemistry.

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\[ J_w = D_w \frac{\rho}{1-\phi_w} \frac{\Delta \phi_w}{h} \]
\[ J_s = D_s \frac{\Delta c_s}{h} \]
Membranes for Clean Water

• **Goals of Project:**
  – Develop method for making model membranes (controlled chemistry and thickness)
  – Develop methods for assessing permeability (solubility & diffusivity) of both water and salt

• **Results to Date**
  – Built automated platform for making model membranes based on layer-by-layer deposition
  – Measured swelling of model RO and NF membrane chemistries, and applied network swelling theory to deduce network parameters and polymer/water interaction parameter
  – Developed poromechanics approach to study water transport (diffusion) in thin membranes

• **Potential Areas for Collaboration:**
  – Identifying/classifying emerging contaminants based on fundamental descriptors; identifying membrane/contaminant interactions for efficient rejection
Laser-Induced Cavitation as a Hydro-Acoustic Source to Prevent Zebra Mussel Attachment in Water Cooling Infrastructure

Presented by:
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NIST Mission - “To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.”

Summary

• **Need:** Efficient/effective method of preventing invasive mussel settlement in piped water systems.

• **Impact:** Demonstration of efficacy of laser-based pulsed-pressure for mussel control

• **Challenge:** Develop portable, robust, autonomous system to operate unaided for months at Davis dam and analyze results.

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Physical Measurements Laboratory
Quantum Electronics & Photonics Division, Sources & Detectors Group – Bldg. 1-M3410
Details

• Goals of Project:
  - Can laser pulsed-pressure achieve acoustic threshold?
  - Develop portable pulsed laser system for on-site testing
  - Operate portable system at mussels site and evaluate results

• Results to Date
  - Laser pulsed-pressure demonstrated in laboratory setting
  - Threshold attained at USBR facility
  - Gained understanding of acoustic optimization

• Potential Collaboration:
  – Device design
  – On site testing at Davis dam
  – Implications of measurement results

Schaefer, J. of AWWA, 102, 113 (2010)
Summary

- Need: Monitor changes in particulate and organic content of water
- Impact: Better understanding of possibilities for using in situ lidar to monitor water properties in identified locations
- Measurement Challenge: Model performance of measurement of backscatter of timed laser pulses (lidar) to obtain optical properties of water and infer water particulate and organic matter content
**Goals**

- **Goals of Project:**
  - Radiometric modeling of sub-surface vertical profiles of water-penetrating LIDARs for in-situ monitoring of water backscatter and attenuation
    - Explore effectiveness in situ lidar measurements for water property monitor

- **Results to Date**
  - N/A

- **Potential Areas for Collaboration:**
  - NIST brings instrument performance expertise
  - USBR brings water properties expertise

- **Expected water properties and changes to properties**
  - Understand/predict impact of mussels on local water properties and incorporate into model

**Background**

- Model is based on a simplified radiative transfer theory developed by Jim Churnside at NOAA
- Derives equations for the power as a function of time in the initial linear polarization and the power as a function of time in the orthogonal polarization
- Information about the total attenuation, the total backscatter, and the depolarization of the backscatter allows the content of organic and particulate matter to be inferred
- NIST expertise in fast detectors and laser performance provides fidelity to the instrument model so that detectible levels and overall performance can be predicted

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X-ray CT for Pore/Micro Structure

- Skyscan 1172 and Versa XM-500
- Can take images of polymer foams to 5 mm diameter steel cores
- Obtain a quantitative 3D image of material micro/pore structure ranging from 0.5 μm/voxel to 50 μm/voxel
- Typically, $500^3$ to $1000^3$ voxel image sets, therefore sample sizes from 250 μm to 50 mm
- Suite of Fortran software tools for computing fluid flow through pores, linear elastic properties of solid/solid phases

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X-ray CT for Pore/Micro Structure

- **Goals of Project:**
  - Support NIST materials projects

- **Results to Date**
  - Many different materials (images)

- **Potential Areas for Collaboration:**
  - Porous/composite materials of interest to USBR