RECLAMATION

Managing Water in the West

Reclamation-NIST Exploratory Research Symposium Summary Report

Research and Development Office
Science and Technology Program
ST-2015-3913-1
Technical Memorandum MERL-2015-072

U.S. Department of the Interior
Bureau of Reclamation

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

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.

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14. ABSTRACT *(Maximum 200 words)*

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.

15. SUBJECT TERMS research symposium, collaboration, Reclamation, NIST

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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.

Contents

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 I. Short Presentation Titles and Principle Investigators in the Topic Area of Infrastructure Sustainability- Reclamation

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

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

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

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

NIST Shorts	
Pore Structure and Fluid Flow in Porous Materials	Ed Garboczi, Nick Martys
NIST's Data and Informatics Efforts	Bob Hanisch
H_2Omics: Comprehensive Contaminant Profiling to Guide Water Management in the Future	Mary Bedner
Frequency-Comb Based Spectroscopy that Should be able to Support High Resolution Detection of Multiple Chemicals.	Eleanor Waxman, Nathan Newbury, Ian Coddington
Nanotechnology for Sustainable Water	Tom Duster
Relating Structure and Transport in Polymeric Thin Film Composite Membranes	Christopher Stafford
Laser-Induced Cavitation as a Hydro-Acoustic Source to Prevent Zebra Mussel Attachment in Water Cooling Infrastructure	Paul Williams
Radiometric Modeling of Sub-Surface Vertical Profiles of Water-Penetrating LIDAR for In-Situ Monitoring of Water Backscatter and Attenuation.	Michelle Stephens

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

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Jessica Torrey	303-445-2376	jtorrey@usbr.gov	Reclamation Symposium Organizer/ Materials Engineering & Research Laboratory
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Edward J. Garboczi	303-497-7032	edward.garboczi@nist.gov	Material Measurement Laboratory – NIST Fellow
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Appendix B: Agenda

Day 1, Tuesday 8/4 - Reclamation, Lakewood		
7:00	Carpool Leaves NIST Campus for Fed Center	
8:00	Welcome	Nick Barbosa and Jessica Torrey
8:05	Logistics (e.g., facilities, safety)	Jessica Torrey
8:10	Meeting Overview and Review Agenda	Kimberly Prill
8:15	Introductions	Kimberly Prill
8:30	Reclamation R&D Plenary Presentation	Levi Brekke
9:00	NIST R&D Plenary Presentation	James Fekete
9:30	Discussion/Q&As	Kimberly Prill
9:45	BREAK (15 min)	
Infrastructure Sustainability		
10:00	Reclamation Shorts	
11:00	Discussion/Q&As	
11:30	**LUNCH ON YOUR OWN**	
12:30	NIST Shorts	
13:30	Discussion/Q&As	
14:00	BREAK (10 min)	
14:10	Infrastructure Roadmap – Discuss Topic Areas for Collaboration, Identify Key Players, Assign Action Items	Kimberly Prill
15:45	BREAK (10 min) and Move to Lobby	
16:00	Tour of Reclamation	Bob Baumgarten, Janet White, Tony Wahl
17:00	Adjourn to Old Chicago for Social Hour	
18:30	Carpool Leaves for NIST Campus	

Day 2, Wednesday 8/5 - NIST, Boulder		
7:00	Carpool Leaves Fed Center for NIST Campus	
8:00	Welcome	Nick Barbosa and Jessica Torrey
8:05	Logistics (e.g., facilities, safety)	Nick Barbosa
8:10	Review Agenda	Kimberly Prill
8:15	Guest Presentations (NOAA/FHWA)	Victoria Peters and Kelly Mahoney
8:45	BREAK (15 min)	
Water Management and Measurement-		
9:00	Reclamation Shorts	
10:00	Discussion/Q&As	
10:15	BREAK (5 min)	
10:20	NIST Shorts	
11:20	Discussion/Q&As	
11:35	**LUNCH ON YOUR OWN**	
12:40	Water Management and Measurement Roadmap – Discuss Topic Areas for Collaboration, Identify Key Players, Assign Action Items	Kimberly Prill
14:00	BREAK (10 min) and Move to Lobby	
14:15	Tour of NIST	Nick Barbosa, James Fekete
15:20	BREAK (10 min)	
Wrap-up		
15:30	Prioritize Areas for Collaboration and Review/Finalize Roadmaps	Kimberly Prill
16:45	Conclusions	Nick Barbosa and Jessica Torrey
17:00	Carpool Leaves for Fed Center	

Appendix C: Plenary and Guest Presentation Slides

RECLAMATION

Managing Water in the West

Research and Development
Programs and Activities

U.S. Department of the Interior
Bureau of Reclamation

Reclamation Mission Statement

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.

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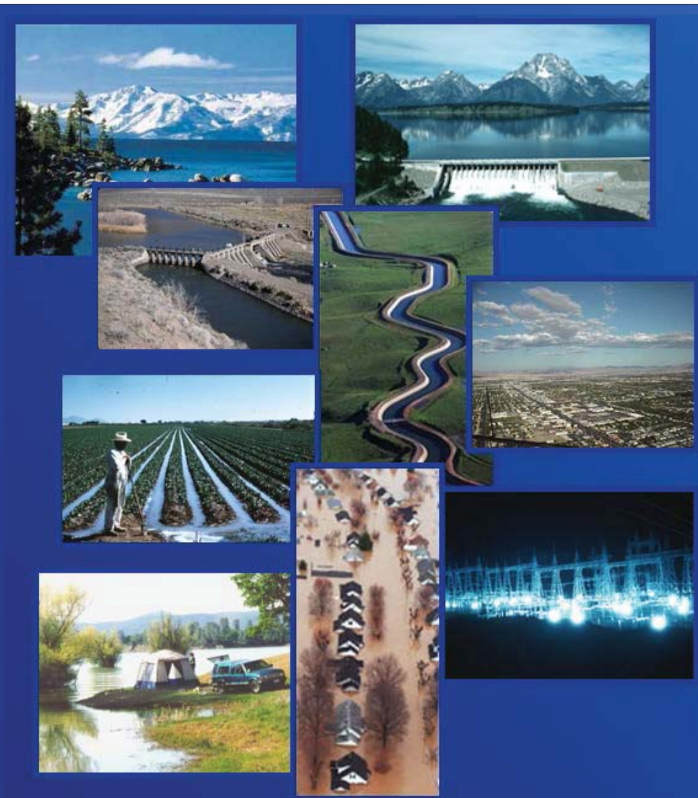

348 Reservoirs

245 Million acre-feet of water storage

254 Diversion dams

16,000 Miles of canals

$9 Billion annual agricultural benefits

M&I benefits to more than 31 million people

58 Hydropower facilities powering over 6 million homes

308 public recreation areas visited by more than 90 million people each year

More than $12 billion avoided flood damages since 1959

By its mere presence and ownership of facilities, Reclamation directly influences water use and supply patterns in most major western river basins

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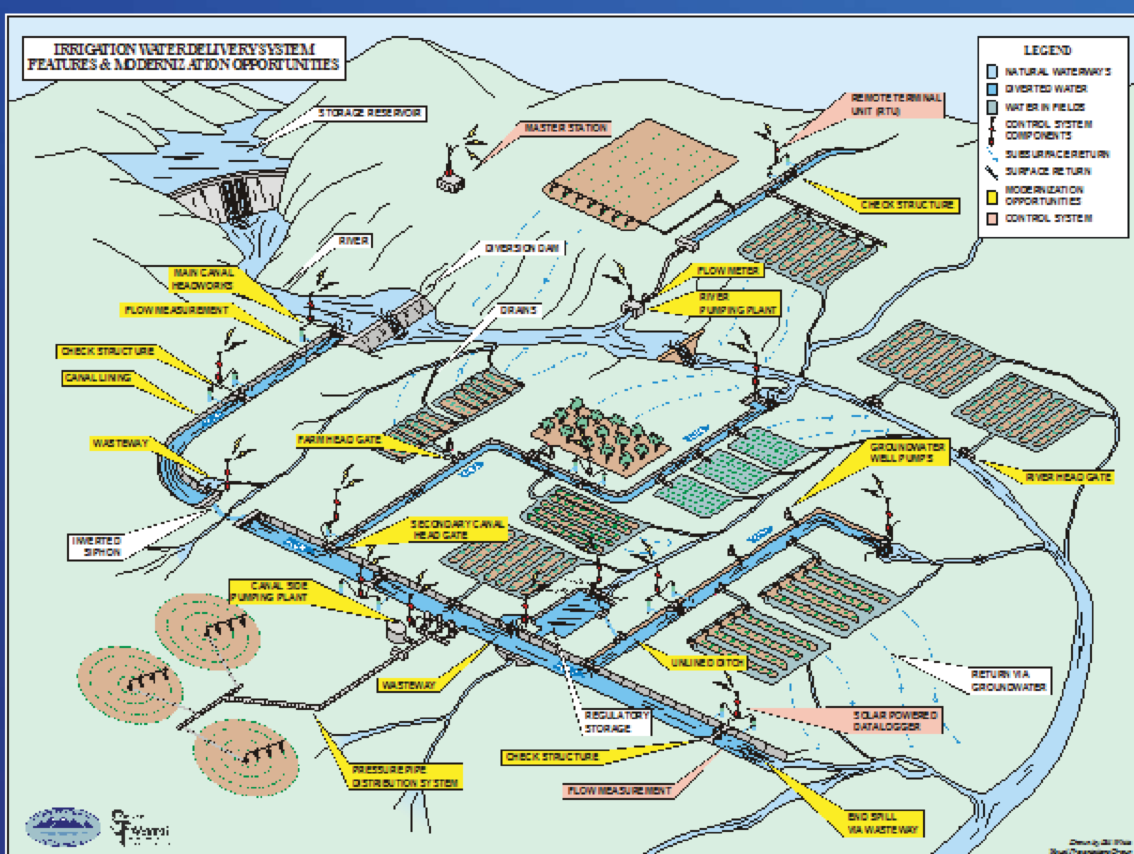

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Research & Development `Programs Overview

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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.

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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)

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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

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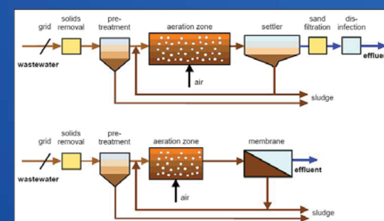
DWPR Research Used Today…..

- **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

http://www.svsewer.com/treatment/jordan basin water reclamation facility/



https://en.wikipedia.org/wiki/File:MBRvsASP_Schematic.jpg#/media/File:MBRvsASP_Schematic.jpg

http://www.usbr.gov/research/AWT/reportpdfs/report103.pdf

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DWPR Highlights

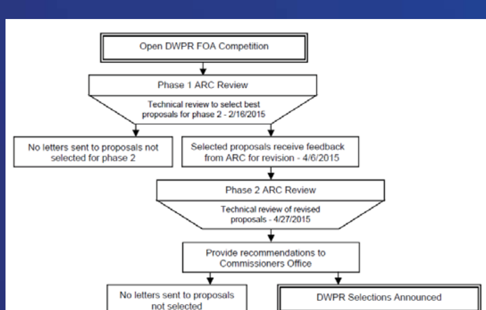
2014 Highlights

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

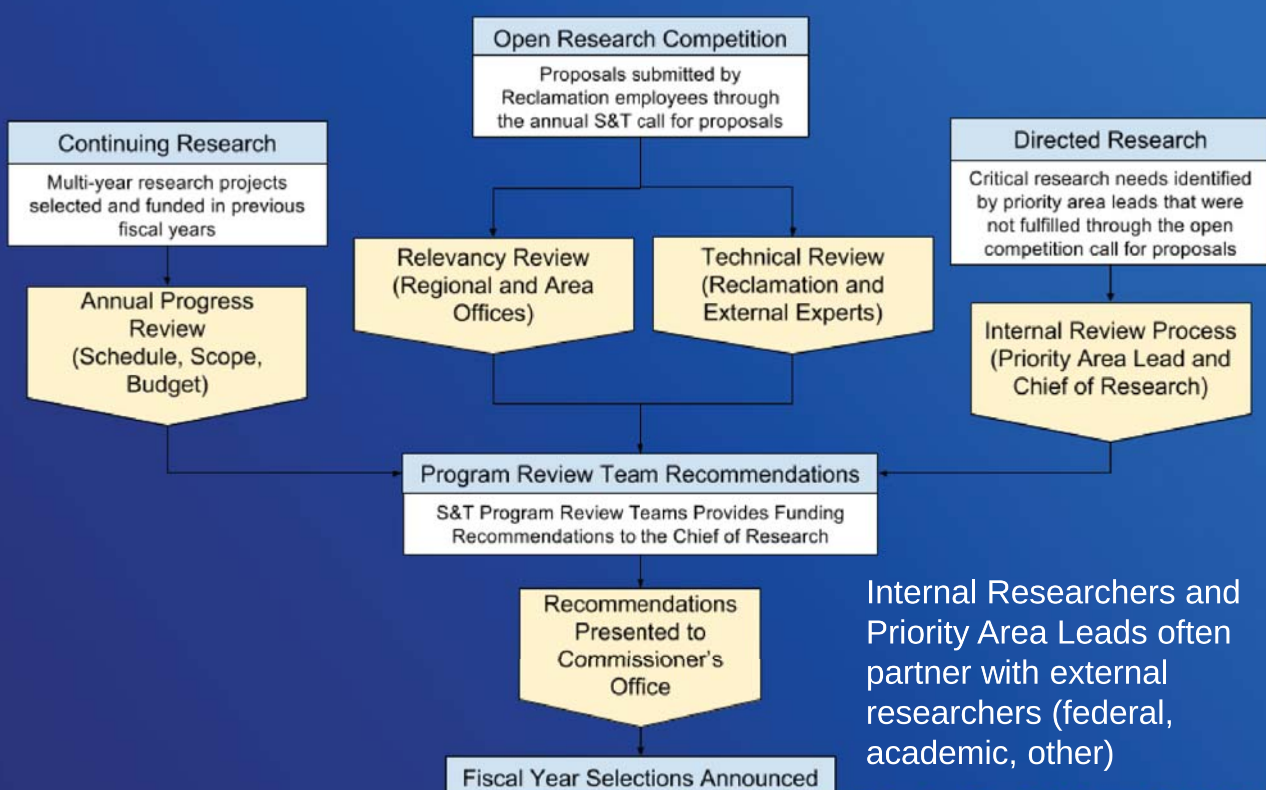
RECLAMATION

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

RECLAMATION

S&T: Annual Solicitation Process



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

RECLAMATION

Advanced Water Treatment

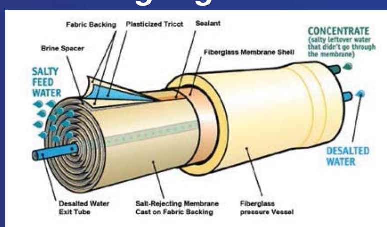
2014 Highlights

Photovoltaic-powered Reverse Osmosis (RO)

Primer on "produced water" treatment technologies and cases

Robust remote controlled Ultrafiltration/RO system

2015 Highlights



Continue development of chlorine resistant membranes

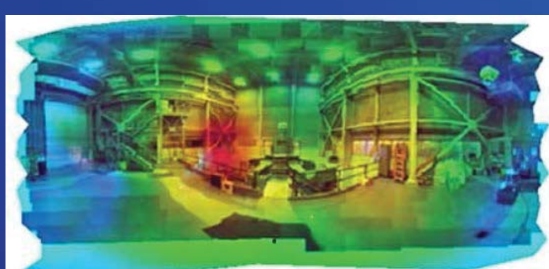
Wetlands as treatment for concentrate and wastewater

Primer on concentrate management tools

RECLAMATION

Infrastructure and Safety

2014 Highlights



Reducing noise in BOR powerplants with engineering controls

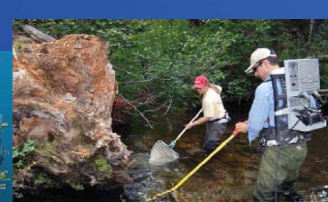
Managing sediment deposits in reservoirs

Measuring soil erodability

2015 Highlights

Detecting corrosion damage to determine when to replace wire ropes

Developing 3D point models from ordinary pictures



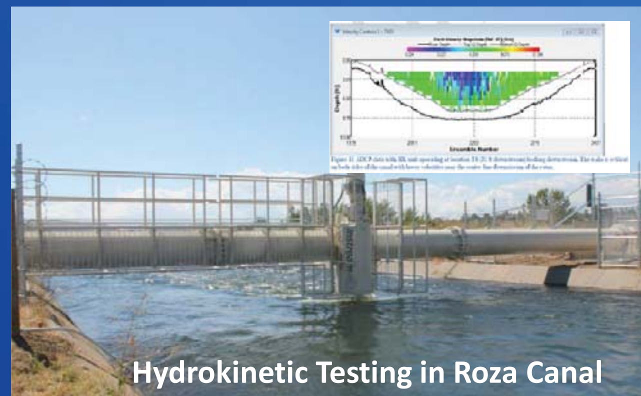
Improving Safety in the Field

RECLAMATION

Renewable Energy

2014 Highlights

Cavitation Testing at J.F. Carr



Hydrokinetic Testing in Roza Canal

2015 Highlights

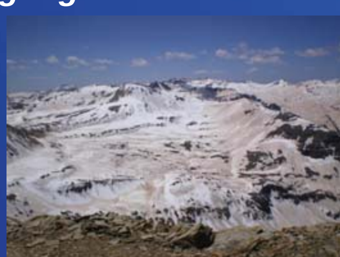
White Paper on Solar Over Canals

Mussel Impacts on Transformer Fire Suppression Systems

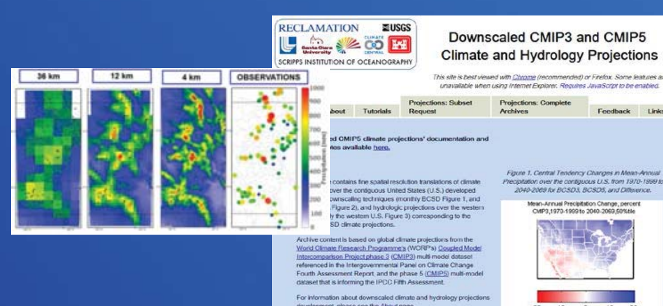
RECLAMATION

Climate Change and Variability

2014 Highlights

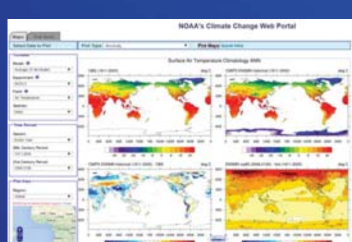


Airborne Snow Monitoring: Value in Spring Water Management?

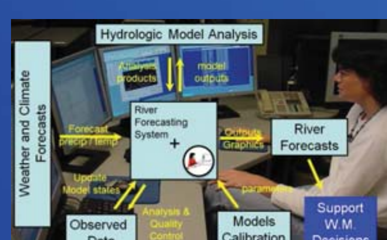


Improve Methods for Projecting Future Climate and Hydrology; collaboratively serve Results

2015 Highlights



Web-tool for judging Global Climate Model skill, information for planning



Addressing Flood and Drought preparedness through streamflow forecasting research

RECLAMATION

Invasive Mussels

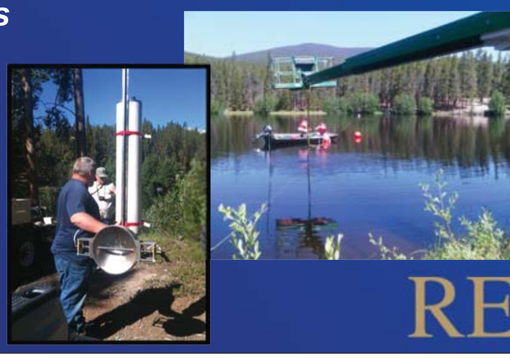
2014 Highlights

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

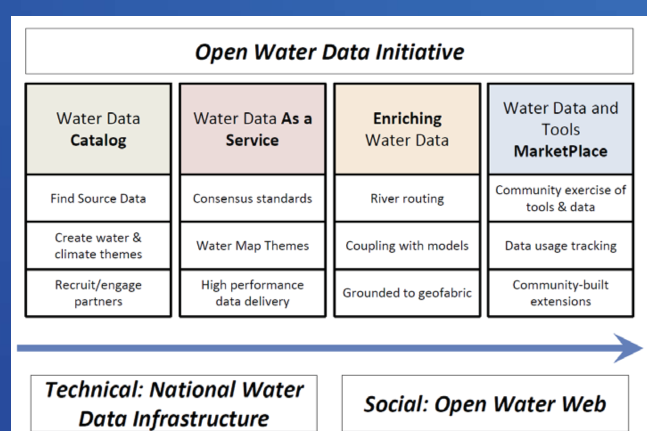
RECLAMATION

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



K. Gallagher and N. Booth (USGS), "Open Water Data Initiative," Advisory Committee on Water Information's Annual Meeting, August 19, 2014

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

RECLAMATION

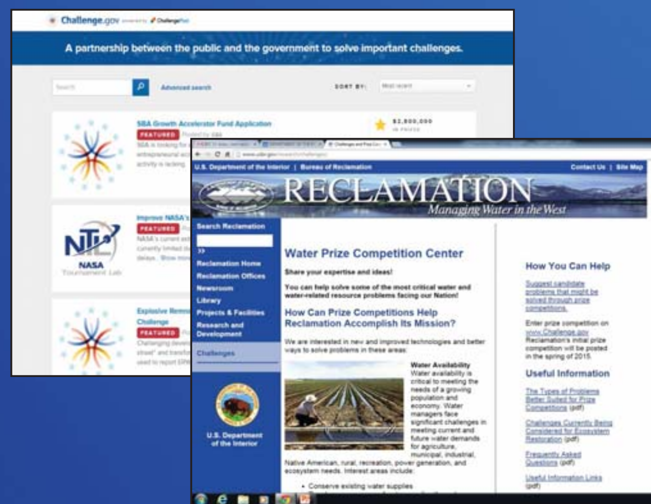
Technology Prize Competitions

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



RECLAMATION

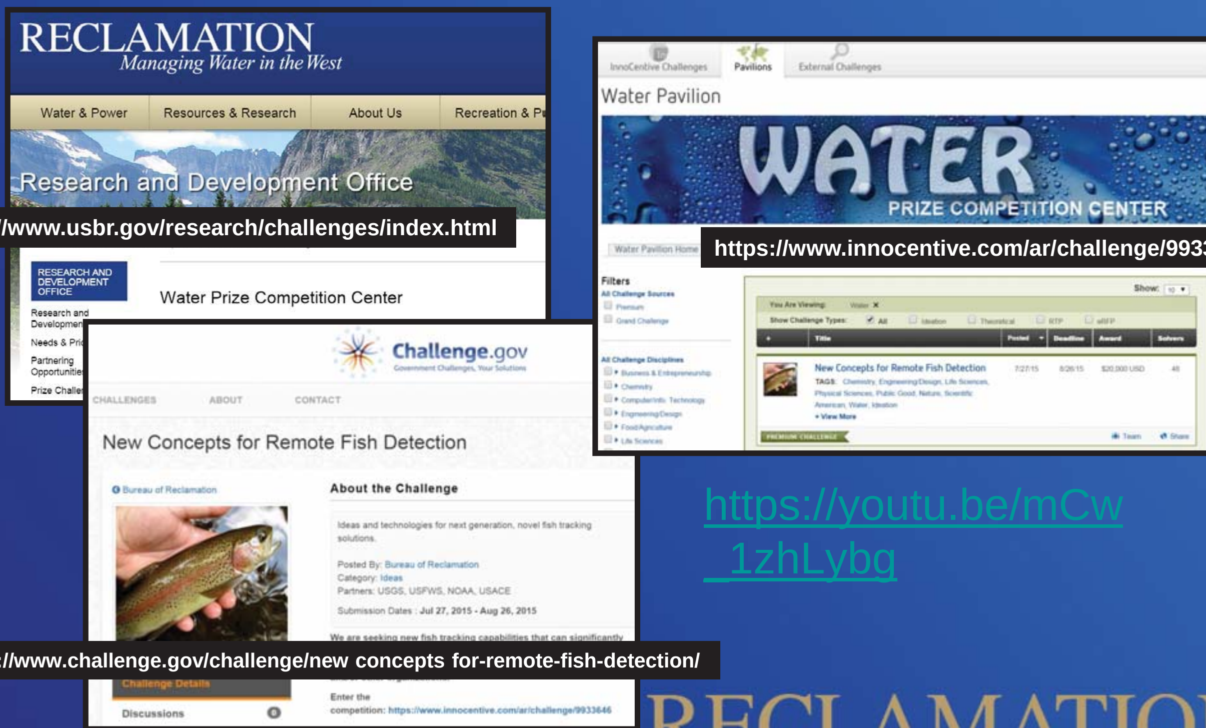
2015 Competition Example: The Desal Prize

Burning Man for Water Geeks – Bloomberg

https://youtu.be/kCL3Eq-9F4w

RECLAMATION

2015 Competition Example: Fish Tracking (7/27/15-8/26/15)



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

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

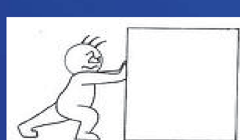
https://www.challenge.gov/challenge/new concepts for-remote-fish-detection/

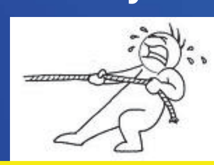
https://youtu.be/mCw_1zhLybg

RECLAMATION

Technology Transfer (T^2)

Fed Push **Industry Pull**





Technology Transfer Agreements

New Solutions → BOR/Fed needs

New Solutions → Commercial markets

- 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.

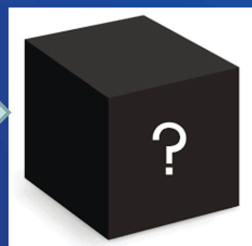
RECLAMATION

2014 T^2 Example: CRADA w/ FujiFilm Hunt Smart Surfaces, LLC

Early Stage R& D

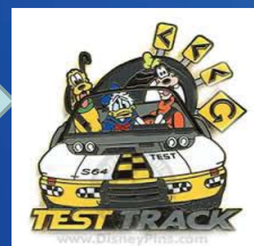
BOR and Fuji tech experts jointly developing new chemical formulations

Manufacturing Know-How



Fuji Facilities and Know-How

Field Testing



BOR Dams and Facility Operators and Tech Experts

Solution

Good Progress

RECLAMATION

NIST Overview

James R Fekete, Ph.D., P.E.
Chief, Applied Chemicals and Materials Division
james.fekete@nist.gov

USBR-NIST Exploratory Research Symposium
August 4, 2015

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

MATERIAL
MEASUREMENT
LABORATORY

National Institute of Standards and Technology

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

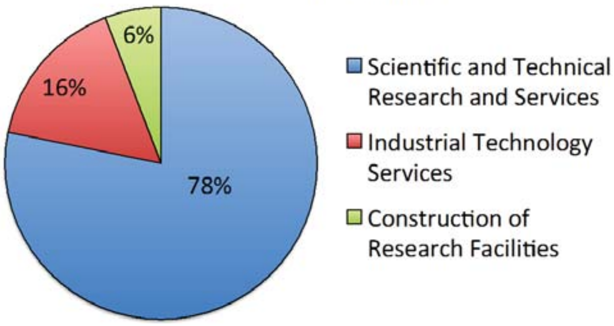
Founded in 1901 as National Bureau of Standards

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



Gaithersburg, MD

Boulder, CO

Inst. for Bioscience and Biotech. Research (IBBR)
University of Maryland

Hollings Marine Laboratory (HML)
Charleston, SC

Brookhaven National Labs (BNL)
Upton, NY

Joint Initiative for Metrology in Biology (JIMB)
Stanford Univ, CA

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

NIST LABORATORY PROGRAMS

Standards Coordination Office
Standards Services Division
NIST Quality Manager

- Material Measurement Laboratory
- Physical Measurement Laboratory
- Engineering Laboratory
- Information Technology Laboratory
- Communication Technology Laboratory
- Center for Nanoscale Science and Technology
- NIST Center for Neutron Research

Metrology Laboratories	Technology Laboratories	National User Facilities
Driving innovation through Measurement Science and Standards	Accelerating the adoption and deployment of advanced technology solutions	Providing world class, unique, cutting-edge research facilities

MATERIAL MEASUREMENT LABORATORY


R. Hanisch, Dir Office of Data and Informatics


R. Watters, Assoc Dir for Measurement Services


L. Locascio, Director


M. Fasolka, Dep Director


N. Alderoty, Exec Officer

Lab Office

Executive Officer

Offices of Reference Materials, Data and Informatics

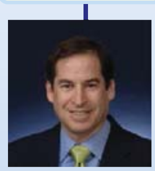
Technical Divisions

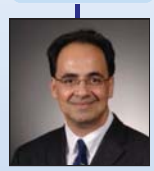
- Materials Science and Engineering (642)
- Materials Measurement Science (643)
- Biosystems and Biomaterials Science (644)
- Biomolecular Measurement (645)
- Chemical Sciences (646)
- Applied Chemicals and Materials (647)

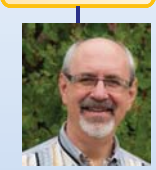

E. Lin


J. Small


S. Choquette


M. Tarlov


C. Gonzalez


J. Fekete

MML Research Focus Areas

Energy

Environment/ Climate

Manufacturing

Advanced Materials

Safety, Security and Forensics

Fotocrisis

Biosciences and Health

Information Technology and Cybersecurity

Physical Infrastructure

Food Safety and Nutrition

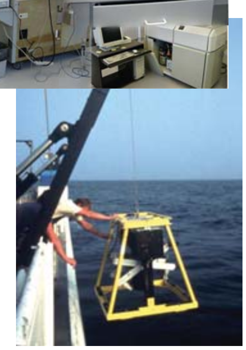
All photos courtesy Shutterstock.com

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

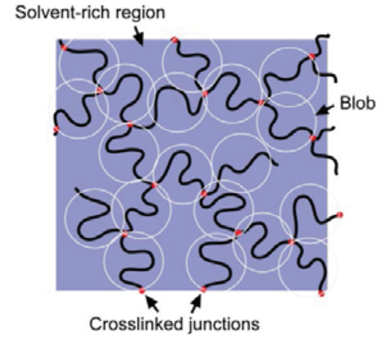
NIST provides SRMs, calibrated lab methods and instruments, qualification of field sensors, and reference data for satellite imagery



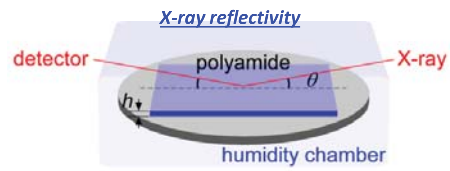
Optimizing Water Treatment

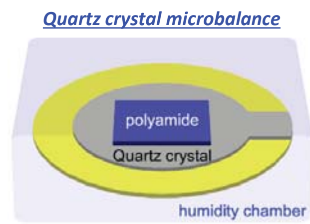
Goal: Provide data on the structure, chemistry, and dynamic response of reverse osmosis membranes so that membrane designers can improve efficiency

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



Graphical representation of a swollen network





Sensor Development

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

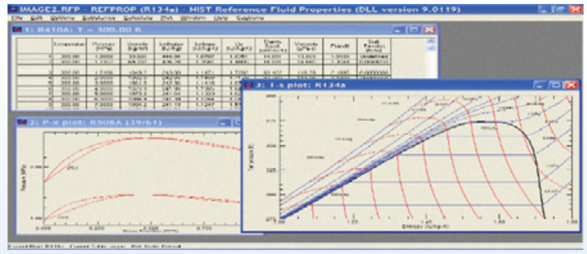
$2.2B in economic impact annually as harmful algal blooms affect water quality and wildlife in the region

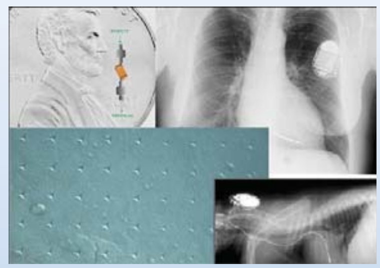
Current sensors are too expensive and cannot rapidly detect the complexity or location of nutrient pollutants

Nutrient Sensor Challenge

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





Applied Chemicals and Materials Division

Material Measurement Laboratory

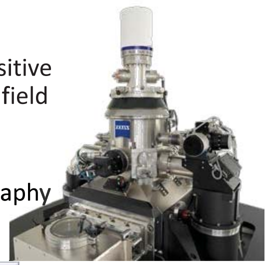
NIST

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

- 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

- 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

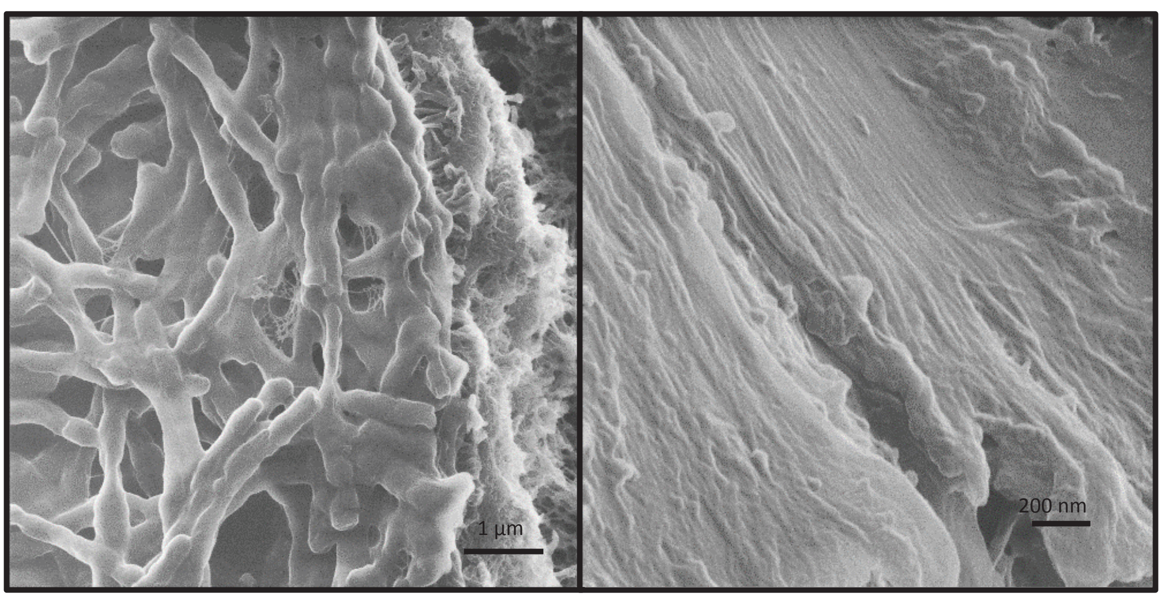
Atom Probe

- 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

e- flood gun-assisted He ion microscopy

A new tool for imaging insulating materials:

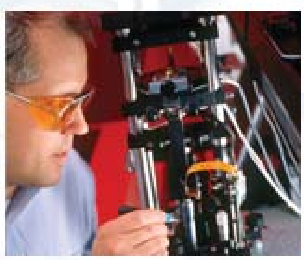
Amazing fidelity in imaging of insulating materials like bacteria-laden water treatment membranes (left) and cellulose for biofuels (right)



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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USBR-NIST Exploratory Research Symposium
August 4, 2015

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

MATERIAL
MEASUREMENT
LABORATORY

Driving Innovation

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

- ➢ ong-Term Infrastructure Performance
- ➢ Durable Infrastructure Systems
- ➢ Accelerated Highway Construction
- ➢ Environmentally Sensitive Highway Infrastructure
- ➢ Performance-Based Specifications
- ➢ Integrated Infrastructure Asset Management

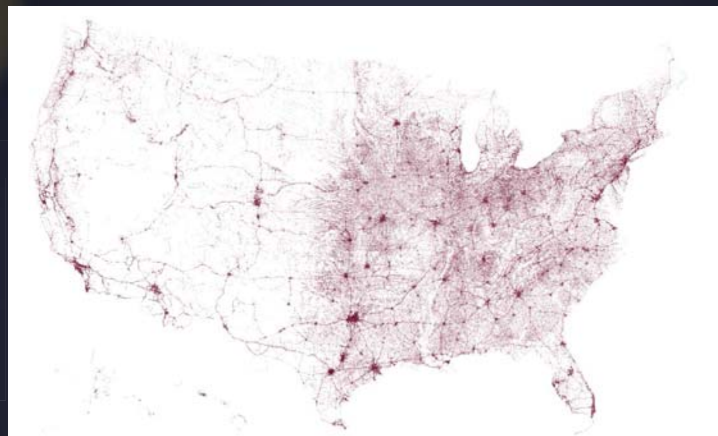
Transportation Challenges on Federal Lands

- Climate Change Adaption 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



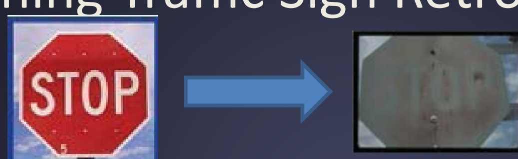
1 dot = 1 bridge

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

Need:Smart bridg e 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

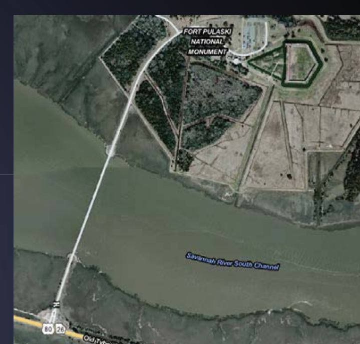
- Acid Sulfate Soils

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

- ✓ very 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)

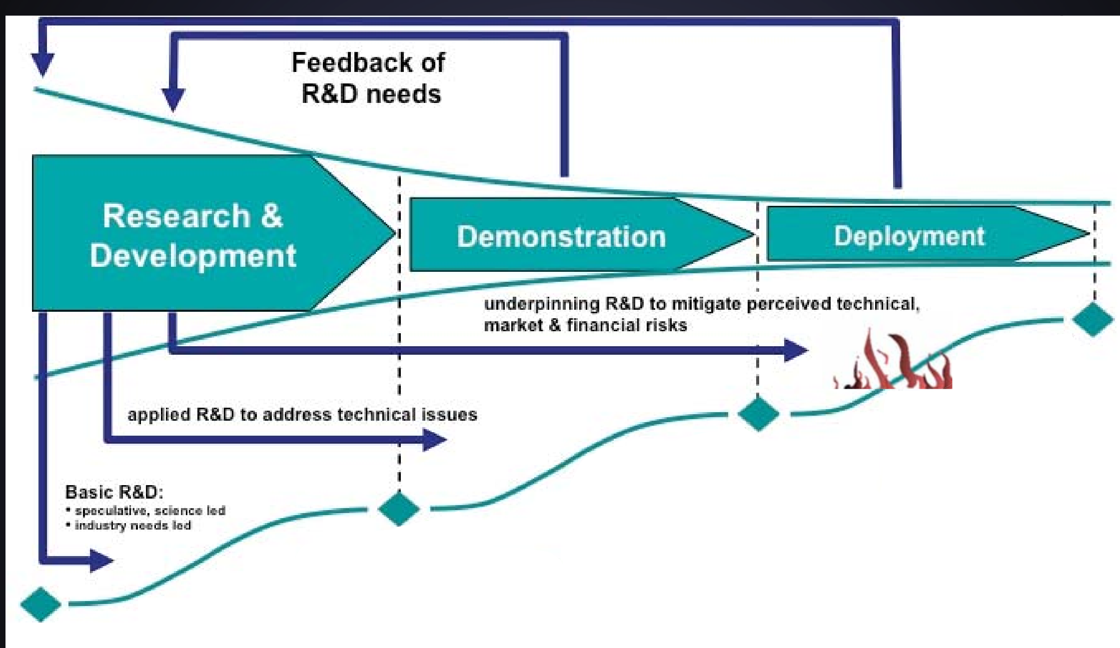
SHRP2 offers products in four focus areas

- 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



NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

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

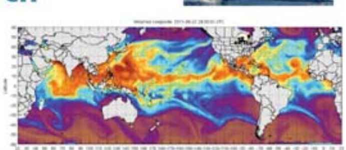
1. **Rigorously characterize and predict weather, water, and climate extremes and their uncertainties.**

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

- Attribution and Predictability Assessments
- Boundary Layer Observations and Process
- Forecast and Modeling Development
- Hydrometeorology Observations and Processes
- Atmosphere-Ocean Process
- Dynamics and Multiscale Interactions
- Hydrometeorology Modeling and Applications
- Polar Observations and Processes

PSD Scientific Expertise

- **Problem-focused observations**
- **Physical Sciences Research**
  - Processes
  - Phenomena
  - Predictability
  - Predictions



\+ **Partnerships**

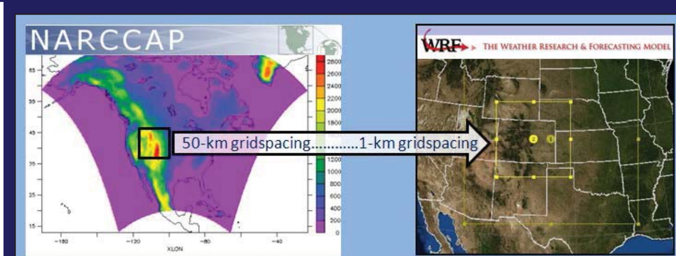
Bureau of Reclamation partnerships

- 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



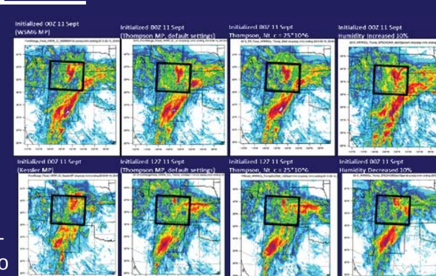
High-resolution weather modeling framework provides insight into *how* changes in large-scale climate parameters may affect small-scale storms

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 Sept 2013 Front Range Floods

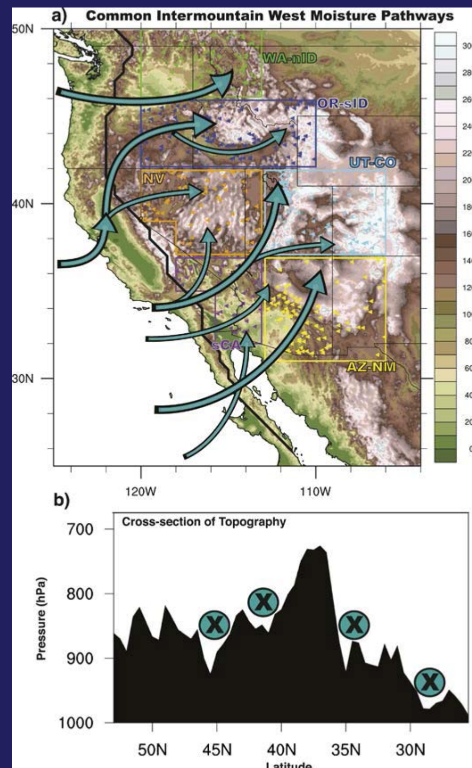
Diagnosing the Moisture Sources for Extreme Precipitation Events in the Intermountain West

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



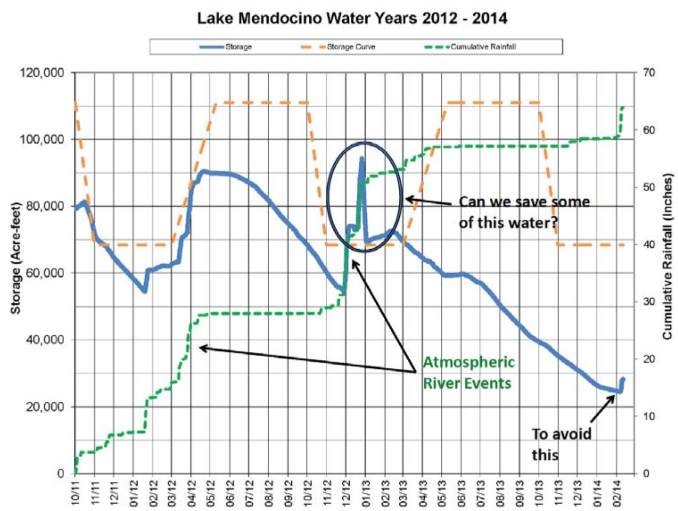
Slide courtesy Michael Alexander NOAA ESRL PSD

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

RECLAMATION

Managing Water in the West

Reclamation-NIST Exploratory Research Symposium

Infrastructure Sustainability

U.S. Department of the Interior
Bureau of Reclamation

RECLAMATION

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**


USBR- Angostura Dam Radial Gates


USACE- Claiborne Lock Miter Gate

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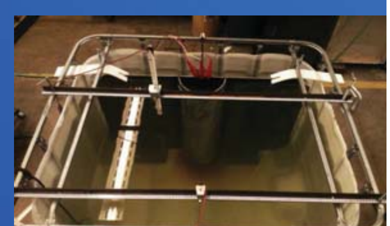
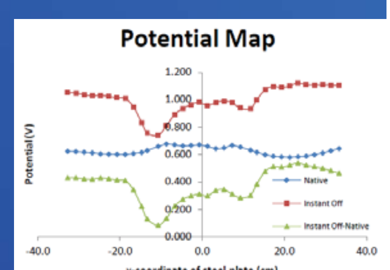
RECLAMATION

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**

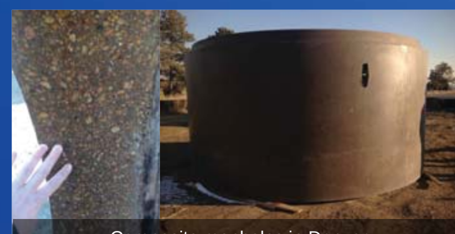




RECLAMATION

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?



Composite manholes in Denver

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RECLAMATION

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?

USACE- Testing Abrasion-Resistant Composite Coatings

USACE- Bridge Rehab, West Virginia

RECLAMATION

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.

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RECLAMATION

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

RECLAMATION

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”

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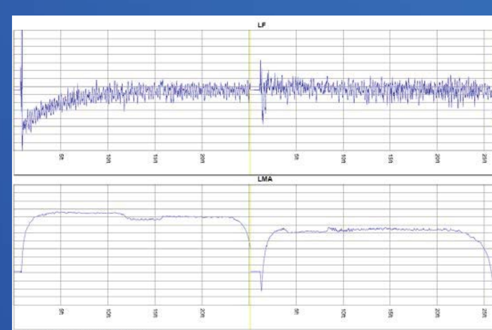
Note: This photo shows the NDT device as the rope passes through it. Debris from rope exterior is shed off both ends of the device.

RECLAMATION

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?

RECLAMATION

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

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RECLAMATION

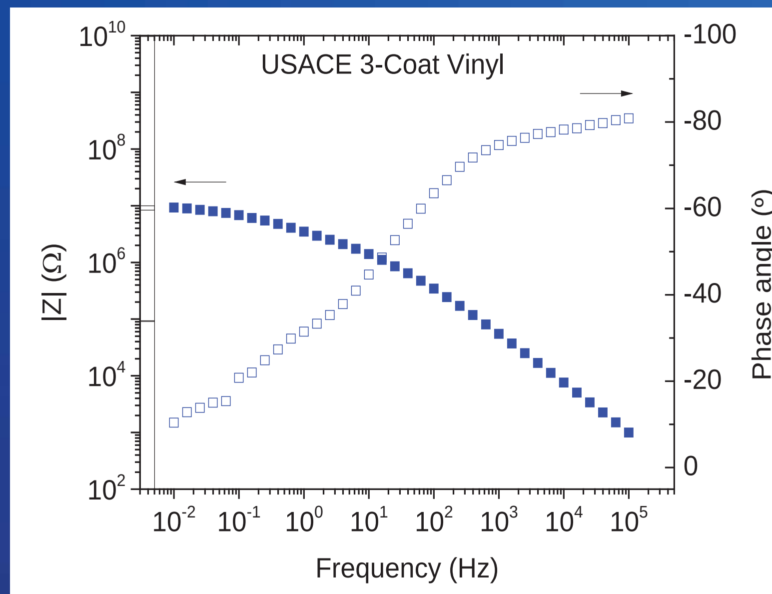
Protective Coating In-Situ Performance

- 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

RECLAMATION

Protective Coating In-Situ Performance

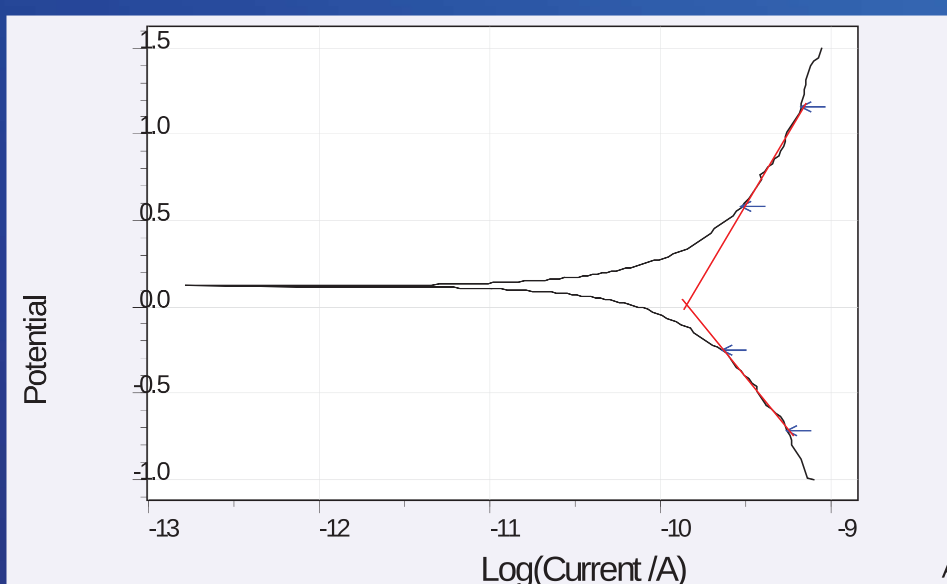
- Electrochemical impedance spectroscopy



RECLAMATION

Protective Coating In-Situ Performance

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



RECLAMATION

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 a inaccessible, extreme environment and isolate this from non-damaging cavitation that is occurring.

  To correlate these measurements respective to operating conditions to develop a absolute cavitation metal erosion rate.

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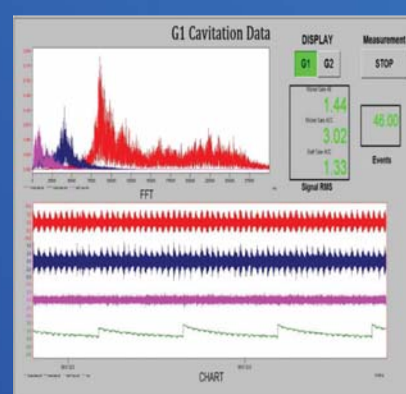
RECLAMATION

Detecting Cavitation in Hydraulic Turbines

- **Goals of Project:**

  Expanding industries knowledge base ofthe 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.

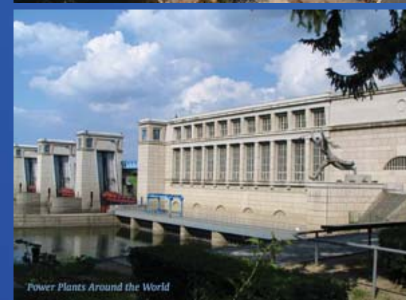
- **Potential Areas for Collaboration:**

  Improved measurement analysis techniques
  Better data mining and trending methods
  Continued testing of various cavitation scenarios occurring within different types of turbines

RECLAMATION

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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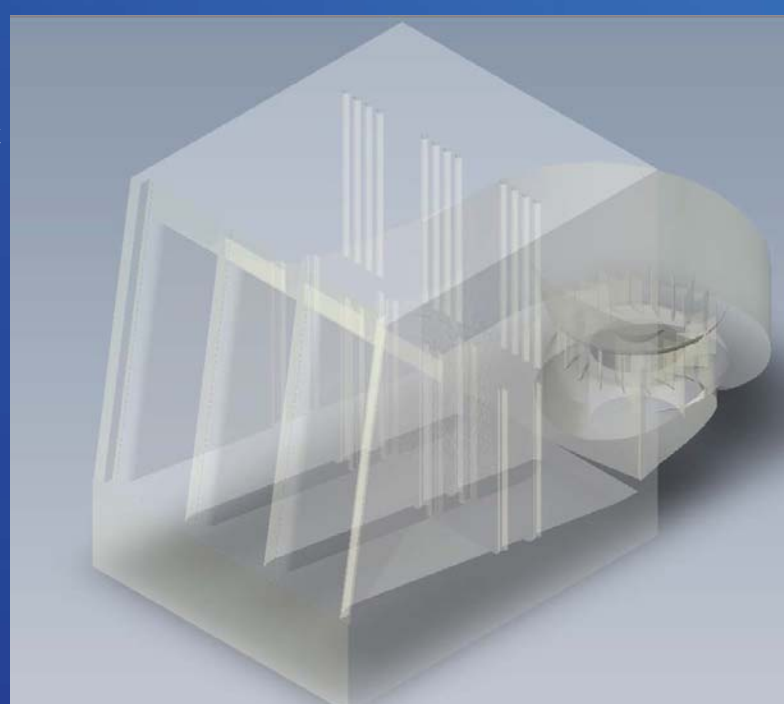
Model of Intake

Sometimes installation is complex with Scaffolding and logistics

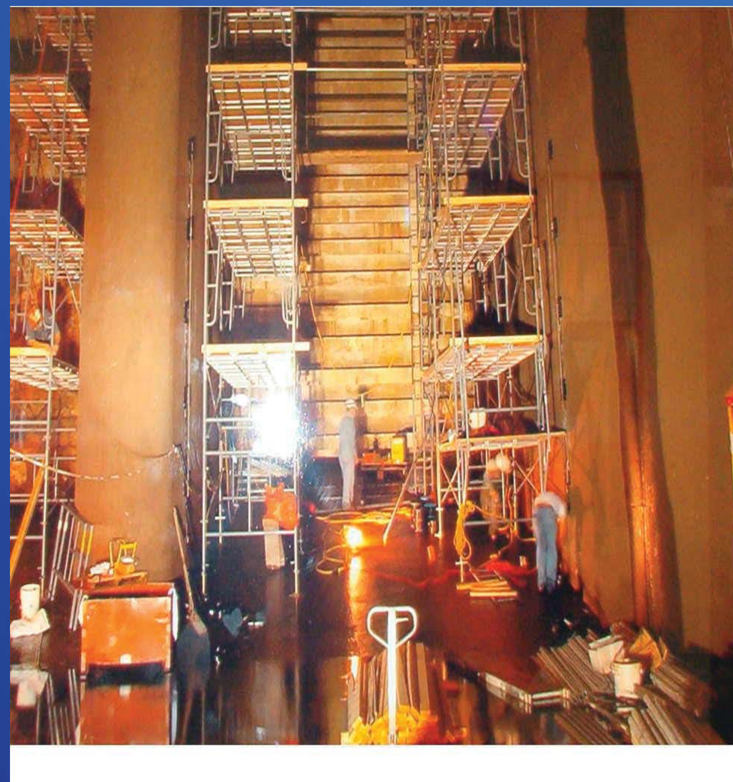
Outage time to be considered.



RECLAMATION

Installation of Lower Granite

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



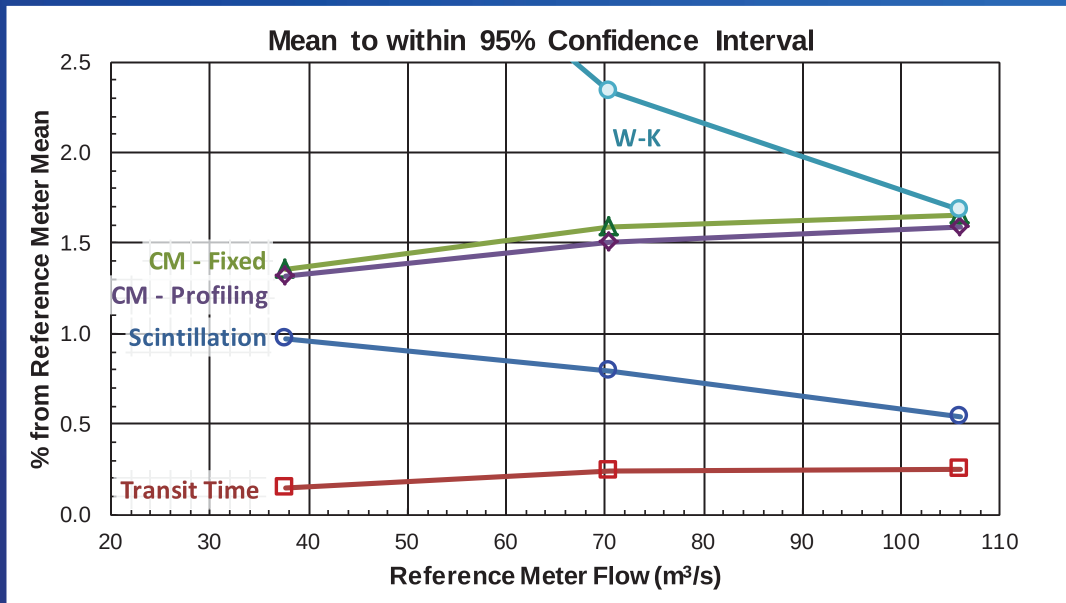
RECLAMATION

Other Intake Discharge Methods

- Current Meters Require Frames
- Scintillation Requires Frames
- Why Not Acoustic Transit Time Flow Meters?

RECLAMATION

Acoustic Transit Time Demonstrated to Work At Kootenay Canal



- Comparative results to the 95th Confidence Interval

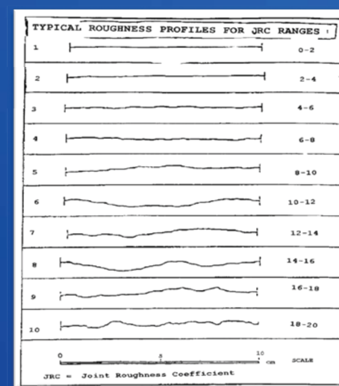
RECLAMATION

Acoustic Frame in Deployment

RECLAMATION

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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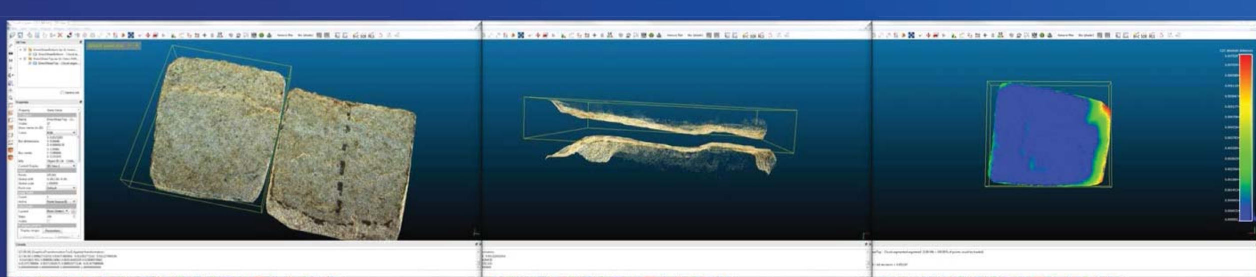
Direct Shear Roughness

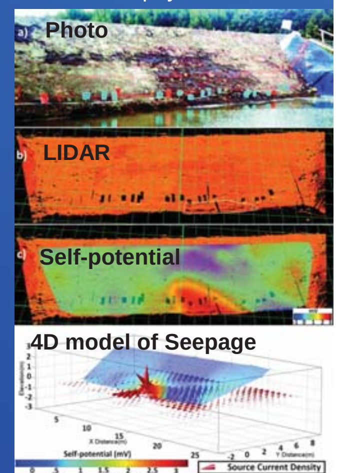
- Goals of Project:
  - Update methods for analyzing direct shear properties
  - Apply photogrammetric techniques to direct shear analysis
    - Contact area for stress calculation
    - Roughness coefficient
- Results to Date
  - Photogrammetric model with ± 1 thousandth of an inch error
  - Contact 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

4D seepage monitoring with Passive Geophysics & LIDAR:



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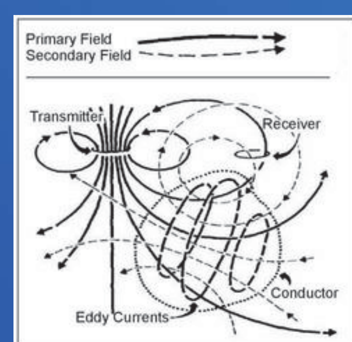
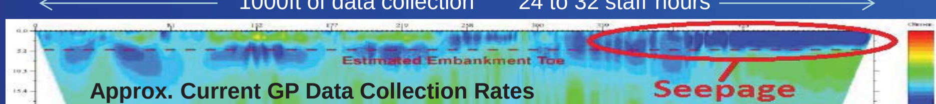
RECLAMATION

Detecting and Imaging Seepage

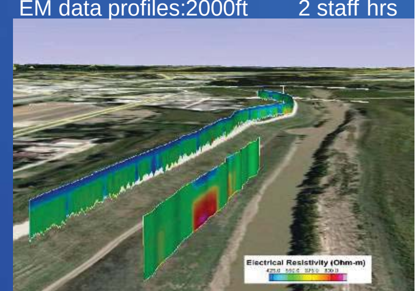
- **Goals of Current Project:**
  Develop & test cart-mounted time/frequency-domain EM profiling system for rapid canal embankment scanning
  Develop workflows for integrating geophysical and remote sensing data
  Develop anomaly detection algorithms for features likely related to anomalous seepage/poor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



← 1000ft of data collection 24 to 32 staff hours →



EM data profiles:2000ft 2 staff hrs



- **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

RECLAMATION

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."*

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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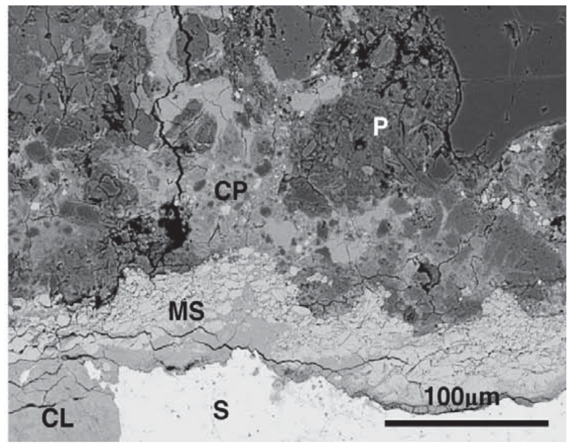
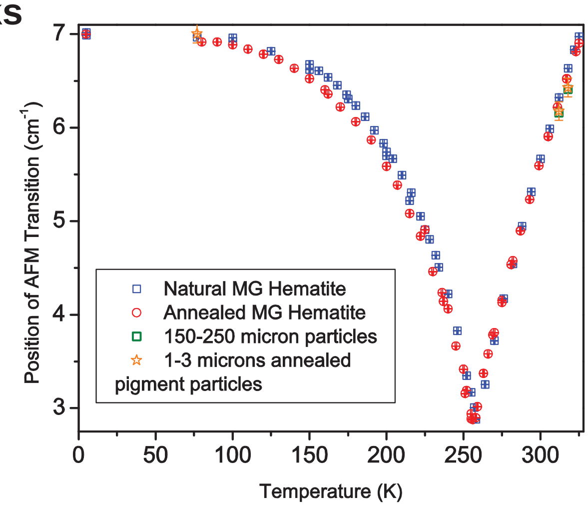


Corrosion Detection via AFMR

- **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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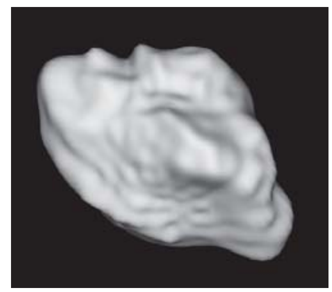
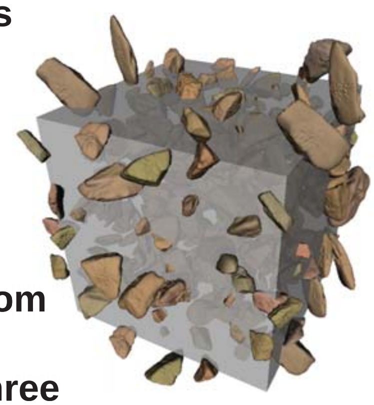


3D Particle Shape Measurement

- **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 ….ters to USBR**
  - **Identify methods of obtaining particle shape data (e.g., LIDAR) for particles too large for X-ray CT**

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

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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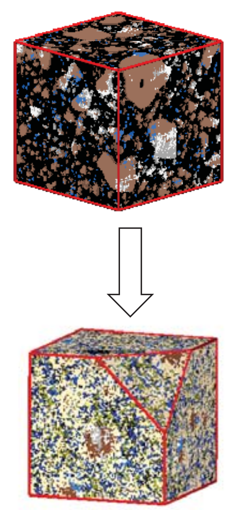
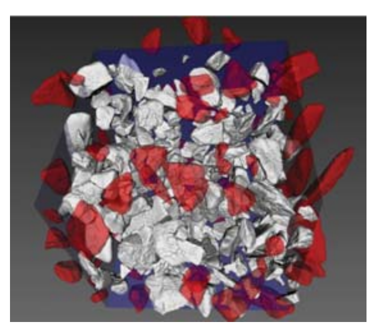
Computational Design for Concrete



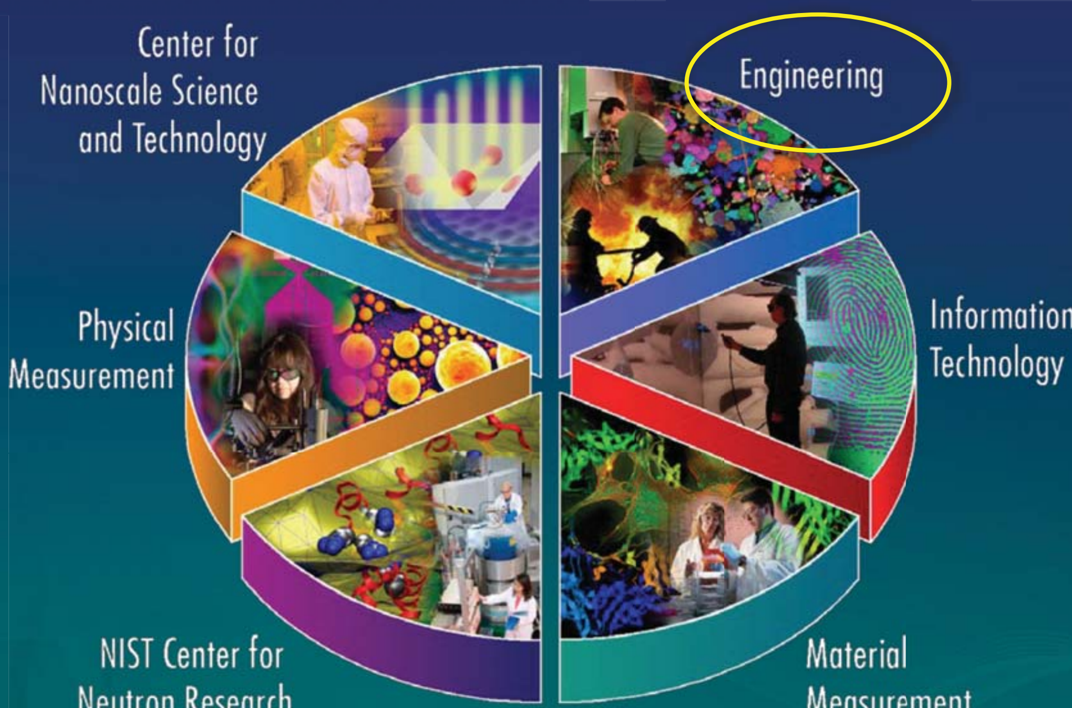
- **Goals of Project:**
  - Complete virtual testing of concrete in computer
  - Formulation, hydration, property measurements, degradation
- **Results to Date**
  - VCCTL 9.0 is available
  - HydratiCA is next phase, true kinetics and thermodynamics
- **Potential Areas for Collaboration:**
  - Help 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

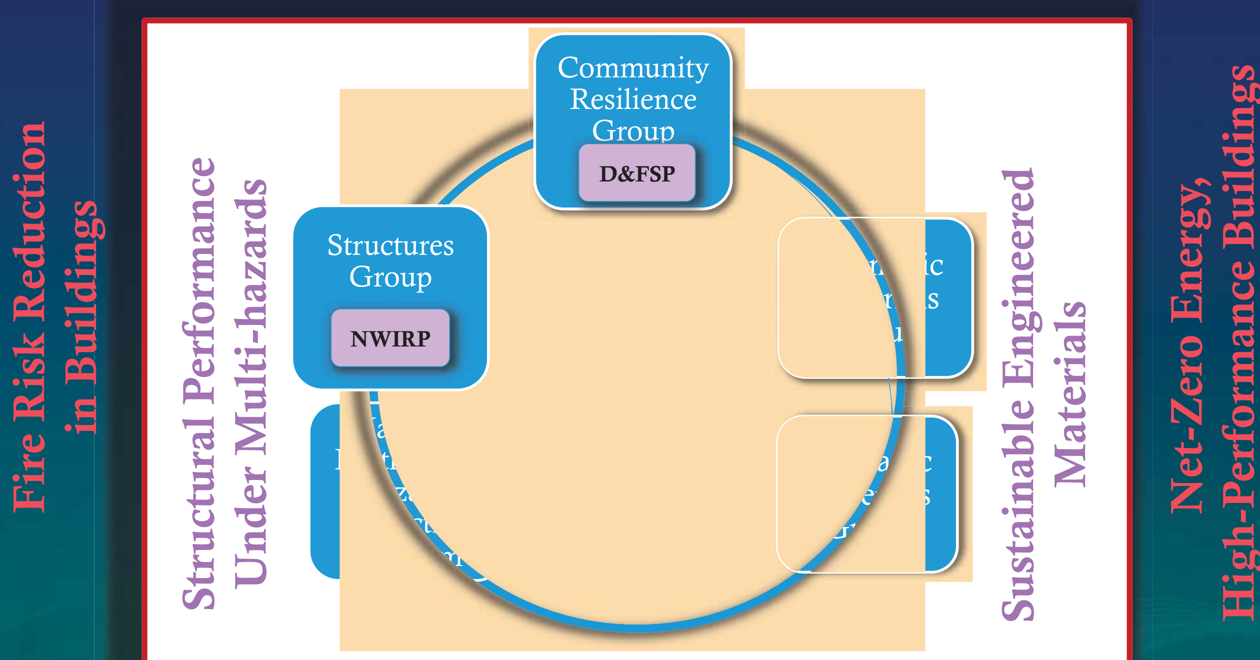
NIST Laboratories



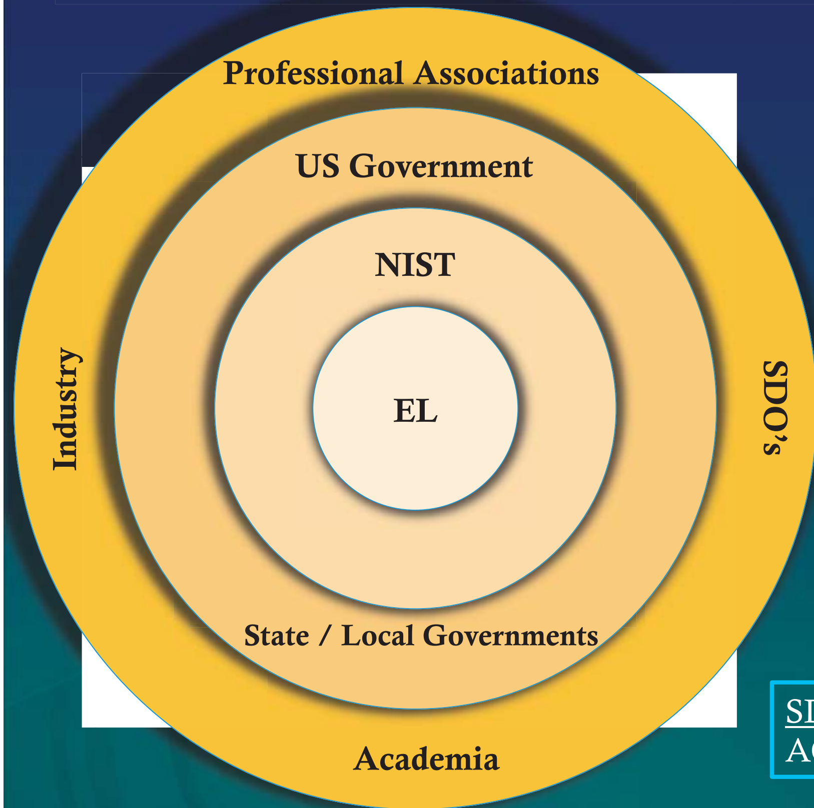
Engineering Lab (EL) Mission

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



MSSD Develops Partnerships at Many Levels



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

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

SDO's:
ACI, ASCE, ASTM, ICC

Strong Industrial and Federal Partnerships

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

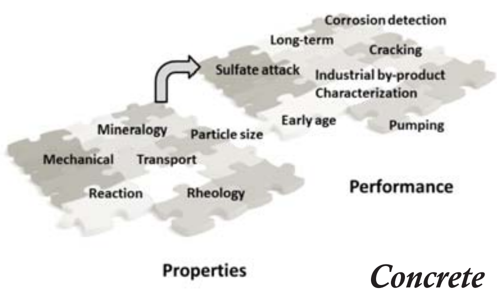
New collaborations with other agencies always welcome

Sustainable Engineered Materials

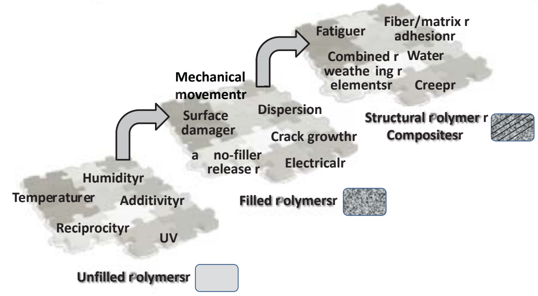
Program Objective: To develop and deploy advances in measurement science for sustainable materials used in infrastructure, manufacturing, and construction.

Performance Measurement

Inorganic Material Group



Polymeric Materials Group



Service Life Prediction

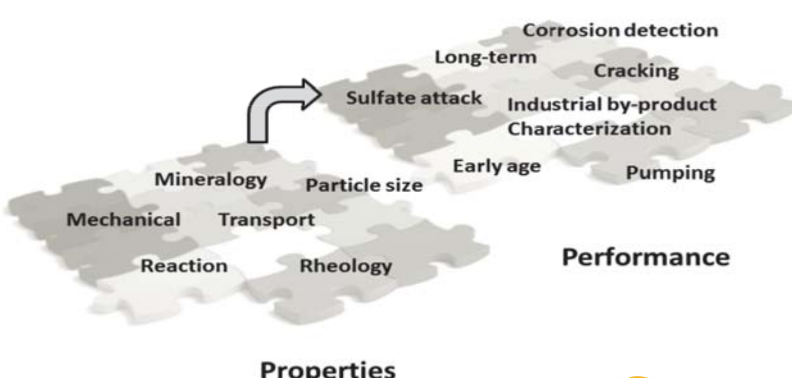
Green Concrete for Sustainable Structures

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



Concrete

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.

Sustainable Engineered Materials: Program and Projects

Goal

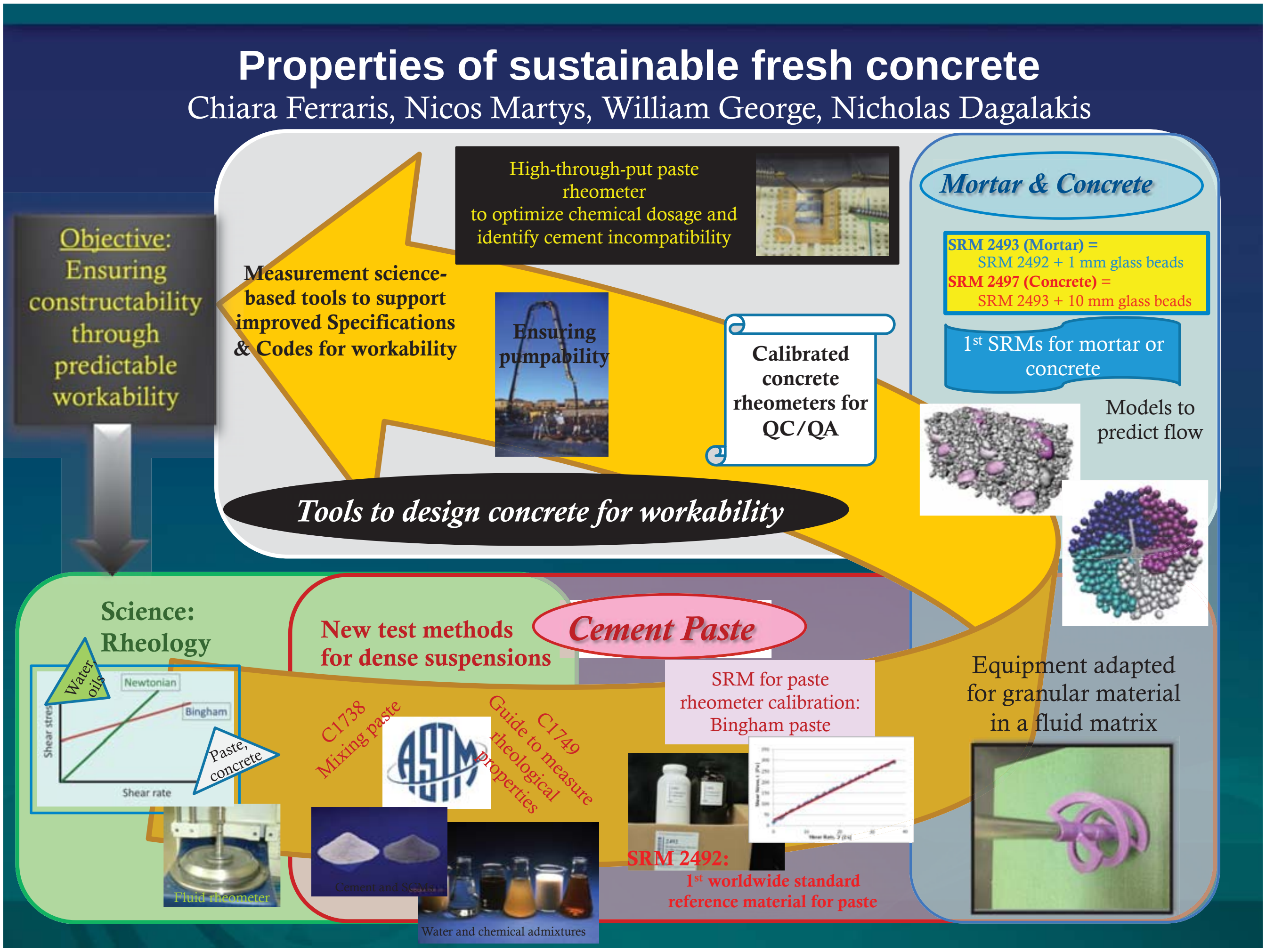
Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure

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)*

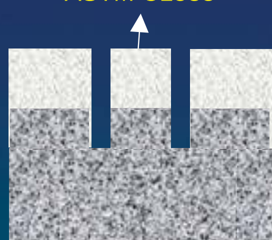
Projects



Repair Materials with Internal Curing: Bonding and Performance

Shear slant test
ASTM C882

Pull-off test
ASTM C1583



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

Repair Materials (Bags):
Manufacturer One
Manufacture Two

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

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

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)

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

Coarser cements

Increase *w/c* ratio

Coarse limestone addition

Internal Curing

Shrinkage reducing admixtures

Best Practices

High volume fly ash

Thermal properties

Mechanical properties

Mitigating delayed setting

Choose a coarser cement

Cement/Fly Ash Engineered Particle size distributions

Blend existing cement with a coarse cement

Other properties

Plastic shrinkage

Sorptivity

Reduced diffusion

Service Life

Other properties

Plastic shrinkage

Freezing susceptibility

Reduced diffusion

Potential collaborators
NIST: Dale Bentz
USBR: Katie Bartojay

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:

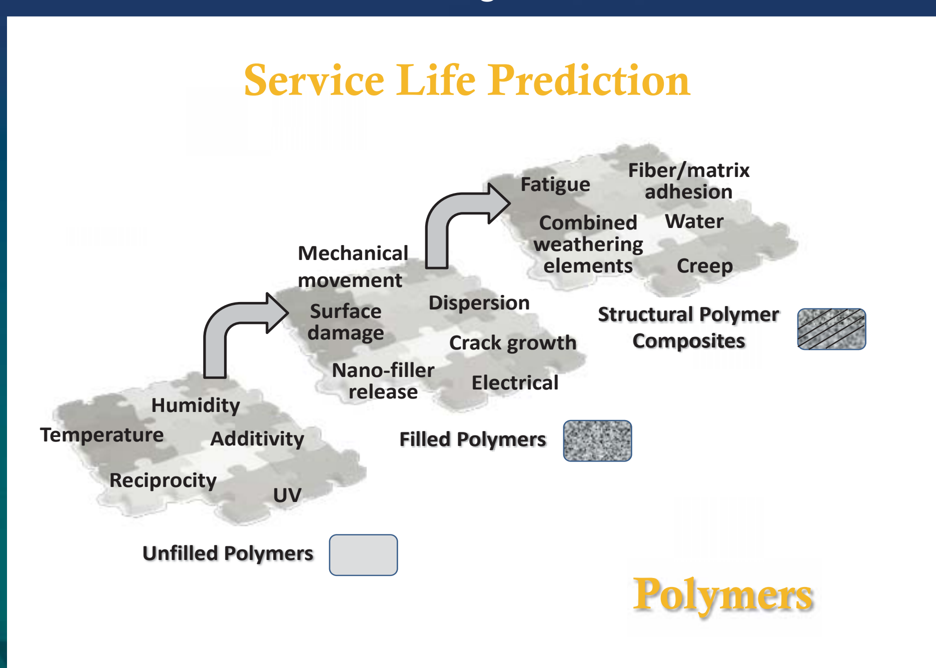
- X-ray Powder Diffraction
- SEM w/ X-ray micro-Analysis
- Field Emission SEM
- BET: particle surface area
- Thermogravimetric analysis (TGA)
- Helium Pycnometer: powder density

Life Cycle of Polymers for Infrastructure

Kenneth Snyder
Stephanie Watson

Sustainable Engineered Materials

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



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

Goal

Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure

Program

Sustainable Engineered Materials

NIST Accelerated Weathering Laboratory: Metrology and Operations

Measurement Science Tools for Accelerated Weathering of Polymers

Four projects related to Concrete

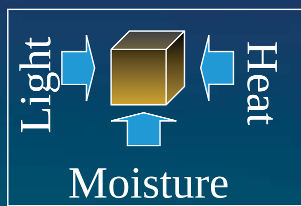
Projects

Predicting Outdoor Performance from Laboratory Exposure

New Methodology

Reliability-based Methodology for Service Life Prediction

Laboratory Exposure



Linkage

Outdoor Exposure

Just another lab experiment

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

Weathering factors cannot be controlled, but all measurements quantitative and of known precision and accuracy

- 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) Publically 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.

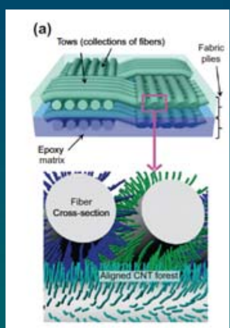
PI: Eric Byrd

Nano-engineered Fiber Composites

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

Products
- 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.

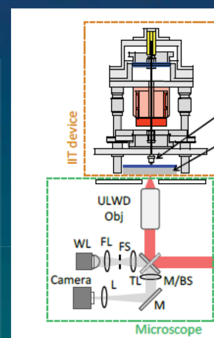


Yamamato Composites Science and Technology (2012)

MIT and University of Delaware Collaboration for materials

molecular

Accelerated Aging



Indenter probe

sample

Raman signal

**Courtesy Gerbig NIST*

Bulk properties

New Materials

database

- Novel Interface Measurements
- Applicability to Stds
- Database for Design based on DOE protocol for carbon fiber

Impacts: MGI, ChiMaD, manufacturing, design

Fusion Joint Measurements: Pipes

Developing measurements for large diameter pipe in three areas that provide input to Models:

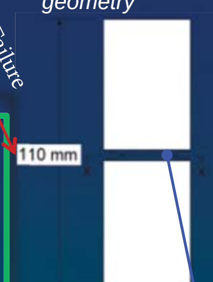
Material properties shared with Gas Technology Institute (Ernest Lever)

Materials in Pipe Systems

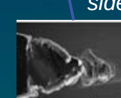
Thermal history

Failure

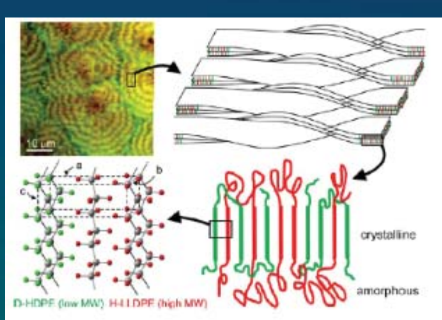
Crack damage and microstructure in CRB geometry



side



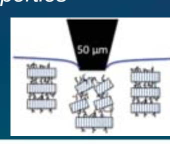
Polymer crystal Microstructure



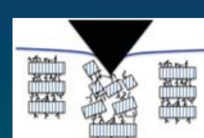
bCARS measurement of crystal microstructure in a bimodal polyethylene. Green represents D-HDPE and red indicates H-LLDPE, which is the high molecular weight branched component.

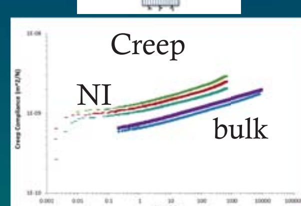
Lee et. al. ACS MacroLett. 1, 2012, 1347 - 1351

Structure (location) specific properties



Hardness Testing





Utilizing nanoindentation to measure local viscoelasticity and plasticity.

Link the local microstructure to the mechanical/failure properties

Link structure in joint to bulk failure of joint

Pandya and Williams, Poly Eng Sci 2000, 40, 1765-1776. Ting, Williams, Ivankovic, Poly. Eng. & Sci. 46, (2006) 763-777; & 778-791

Assessment of Electrical Cable Condition Monitoring Tests

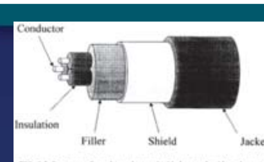
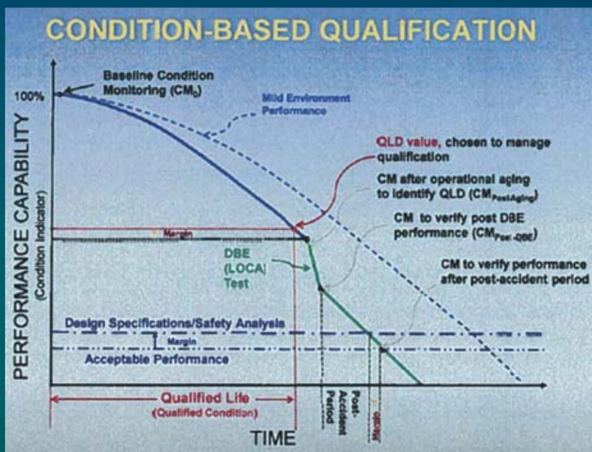


FIG. 2.3. Structure of a multiconductor shielded control cable (schematic).

- 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
- **Thermal Characterization Testing**
  - 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
- **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
- **Microscopy Methods**
  - Atomic Force Microscopy (AFM),
  - Scanning Laser Confocal Microscopy
  - Scanning Electron Microscopy (SEM)
  - Cryo-Microtome
- **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.

Timothy (Dash) Weeks
Pipeline Safety Project Leader
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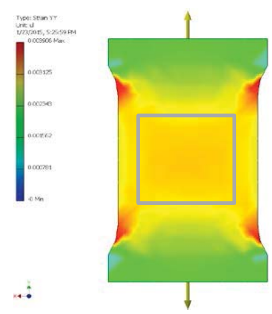
timdash@nist.gov

ACMD, Structural Materials - Boulder

San Bruno Accident

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



Predictive model for Pre-strained material testing

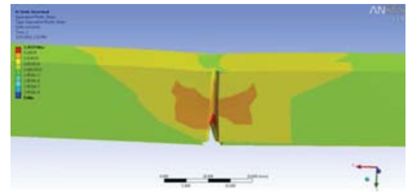
- **Results to Date**
  - High-rate ductile failure is preceded by significant plastic zone
  - Developed pre-strain method and small scale tests to calibrate CMM
  - Preliminary designs of medium-scale high-rate tests

- **Potential Areas for Collaboration:**
  - Applicable to other infrastructure systems

Concept for High-Rate Modified Middle Crack Tension Tests

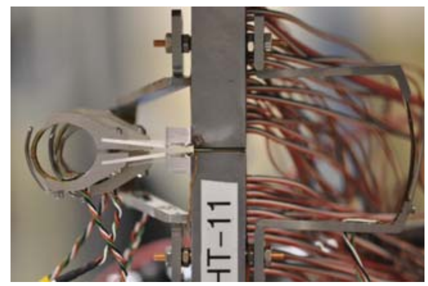
Small Scale Fracture Mechanics

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



SENT specimen Model Predictions

- **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



Fully instrumented Multi-method SENT specimen

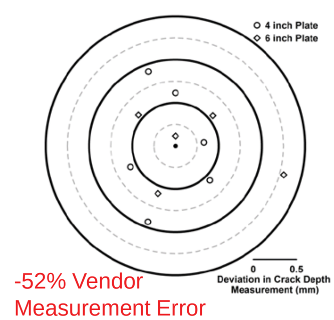
- **Potential Areas for Collaboration:**
  - Methodology development can be universally applied to all infrastructure

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

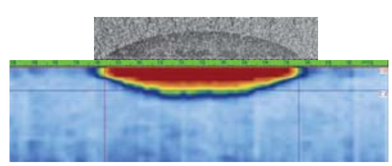
Current reference standards have machined artifacts

- **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



Phase I round Robin Results

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



Graphic of good agreement between NDE and actual fatigue flaw

Reclamation-NIST Exploratory Research Symposium

Probing molecular mechanisms underlying failure in semicrystalline polymers for pipes

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."*

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

Jan 11, 2010 - large water main break near Dupont Circle (www.myfoxdc.com)

Problem/ Needs

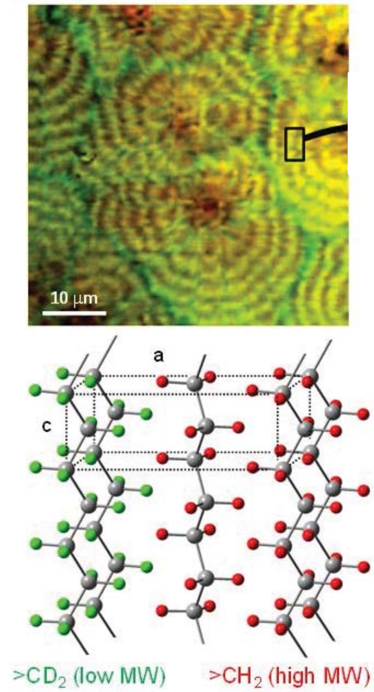
- Semi-crystalline polymers are pervasive in our daily life and their long term reliability is often critical. Uncertainties related to product lifetime for new systems often slow adoption
- Branched high MW component increases the resistance to slow crack growth (SCG; prevailing failure mode in today's 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

Chad Snyder
Research Chemist
301-975-4526
Chad.Snyder@nist.gov

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?



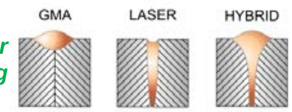
ACS Macro Lett. **1**, 1347–1351 (2012)

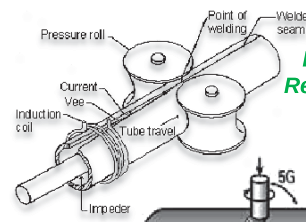
Materials Joining Project

- 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.
- Measurement Challenge: Improvement of joining processes necessitates measuring of a set of complex, multi-physics, multidisciplinary processes including: metallurgy, process control, mechanical behavior & performance, & quality inspection.

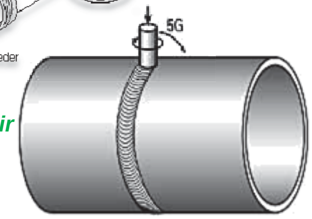
New technologies can greatly enhance productivity, e.g. single-pass welding of heavy pipe

Hybrid Laser Arc Welding





Electrical Resistance Welding



Friction-stir welding

Jeffrey Sowards
Metallurgist, Project Leader
303-497-7960
Jeffrey.sowards@nist.gov

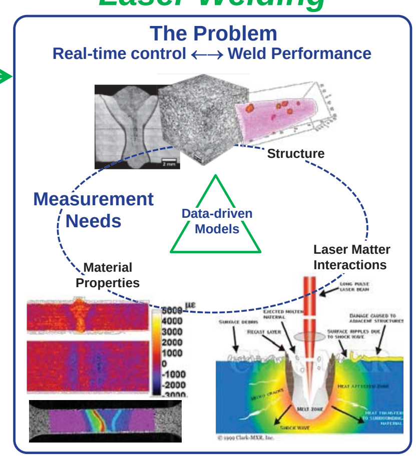
Applied Chemicals and Materials Division,
Structural Materials Group, Boulder, CO

Dissimilar Welding of differing materials enables flexible engineering designs

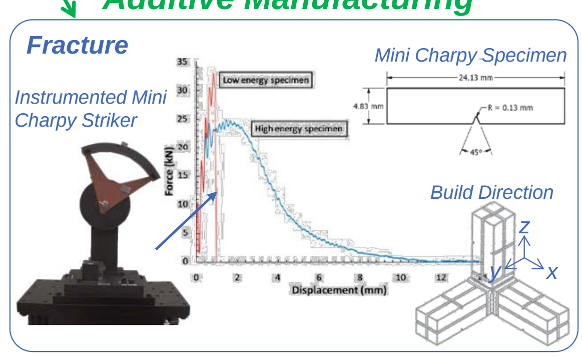
Materials Joining Project Overview

- **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

Laser Welding



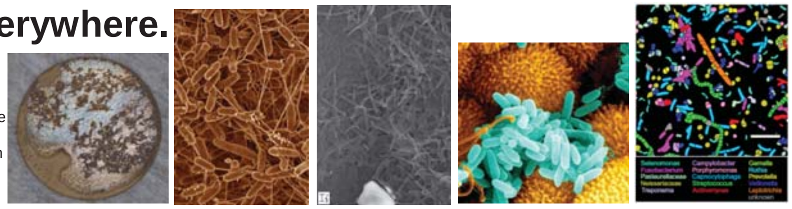
Additive Manufacturing



Microbiologically Influenced Corrosion (MIC)

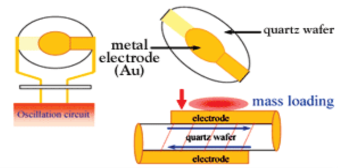
Biofilms are everywhere.

(L-R) *Shewanella* biofilm on carbon steel | Electrically conductive nanowires of the bacteria *Shewanella oneidensis* | *Mycobacteria* on reverse osmosis membrane after ozone treatment | *Pseudomonas aeruginosa* bacteria (blue) on ciliated human nasal epithelium | Fifteen types of oral bacteria. *PNAS* 108(10) 2011.



NIST

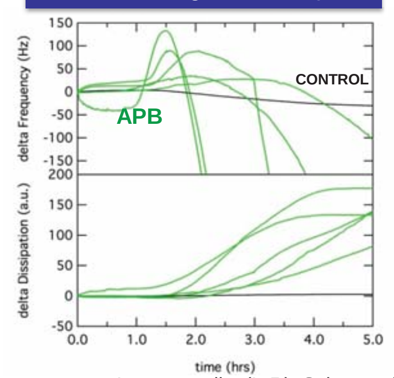
Microbial adhesion is a common intervention point for any type of biofouling



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

A. aceti binding to iron on QCM



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ACMD, Materials for Biological Environments

Image credits (L-R): Schwartz | Bencheikh & Arey | Kirschling | Berger | Valm

*BJ Little, JS Lee. Microbiologically Influenced Corrosion (2007)

Microbial Adhesion Measurements

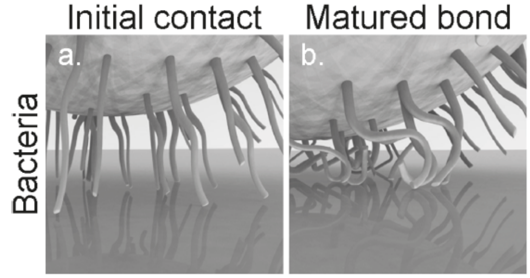
- **Goals of Project:**
  - **Bond maturation time**
  - **Bond stiffness**
  - **Bond characteristics in multispecies environments**

  Intervention points discovered through fundamental measurements

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

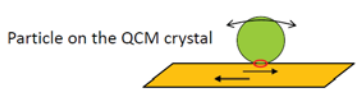
- **Potential Areas for Collaboration:**
  - **Microbial corrosion of pipelines, tanks, etc.**
  - **Membrane biofouling**
  - **Natural biofilms**

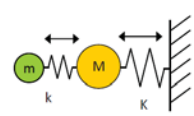
At 0s Initial contact | At 300s Matured bond

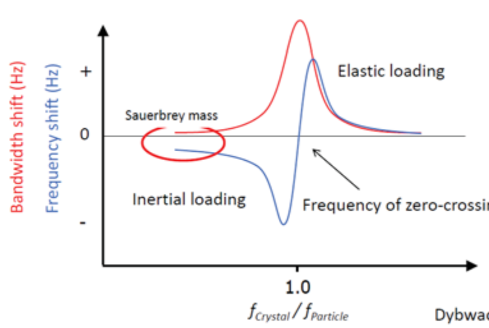


Olsson *et al.* 2010 *Langmuir*

Coupled resonance model







$$f_{Crystal} = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$$

$$f_{Particle} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Dybwad, *J. Appl. Phys.*, **1985**
Pomorska et al., *Anal. Chem.*, **2010**
Olsson et al., *Anal. Chem.*, **2012**

Appendix E: Water Management & Measurement Shorts

RECLAMATION

Managing Water in the West

Reclamation-NIST Exploratory Research Symposium

Water Management & Measurement

U.S. Department of the Interior
Bureau of Reclamation

RECLAMATION

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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RECLAMATION

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).

- **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.

RECL

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

RECLAMATION

Water Supply/Demand Analyses

- **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

RECLAMATION

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)

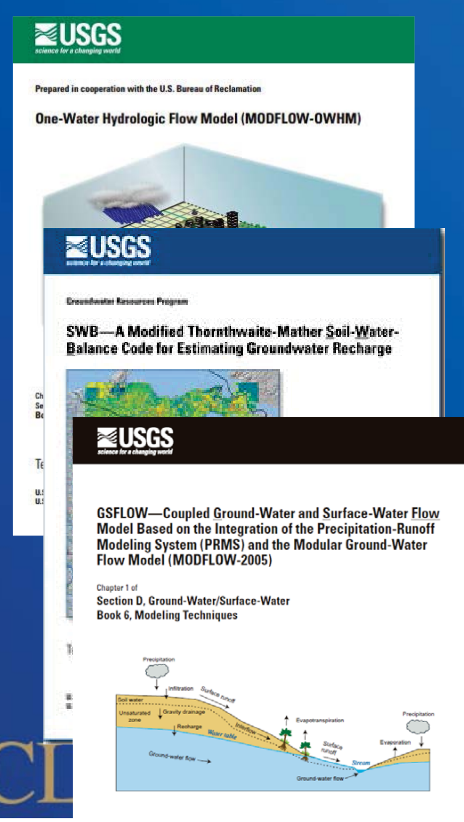
- **Measurement Challenges:**
  - ➢ Better methods needed to reduce (and quantify) uncertainties in point measurements of soil moisture
  - ➢ Methods needed to facilitate distributed estimates of soil moisture and snowpack over large areas – e.g., integration of point-based ond remote sensing data

RECLAMATION

Water Supply/Demand Analyses

- **Model Inputs, Calibration/Verification**

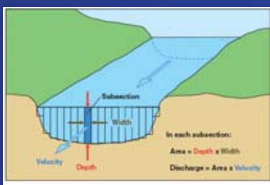
  Water budget analyses often rely on hydrologic and water operations models. Observational data is used to develop model inputs and to calibrate/verify models. Uncertainties in observations are often ignored when developing inputs and computing calibration/verification metrics.



- **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.

Design and Calibration of Open-Channel Flow Measurement Flumes- Background

- 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



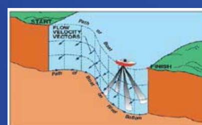
Current-meter discharge measurements are made by determining the discharge in each subsection of a channel cross section and summing the subsection discharges to obtain a total discharge.

(Photograph courtesy of Michael Nolan, U.S. Geological Survey)

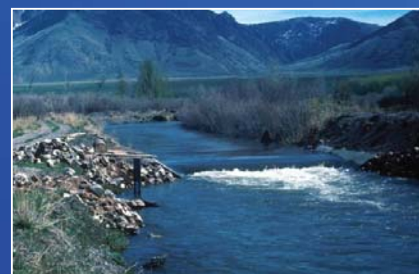
The current-meter method uses equipment such as (A) the Price AA current meter; (B) the Price AA current meter attached to a wading rod; and (C) the Price AA meter suspended above a heavy weight.

(Photograph courtesy of Michael Nolan, U.S. Geological Survey)

To measure velocity beneath ice, a mechanical current meter with a polymer rotor is attached to an ice rod and submerged through a hole drilled in the ice.



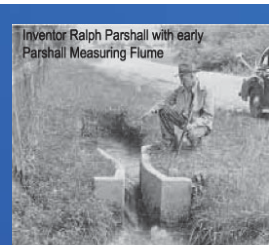
Acoustic Doppler Current Profiler (ADCP) mounted in a small watercraft, is used for measuring the discharge of a river. The ADCP acoustic beams are directed down into the water as it is guided across a river channel.



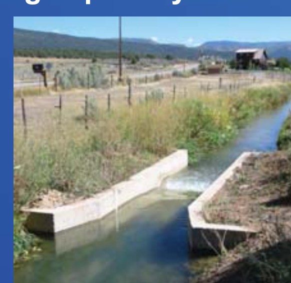
RECLAMATION

Design and Calibration of Open-Channel Flow Measurement Flumes- Background

- 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



RECLAMATION

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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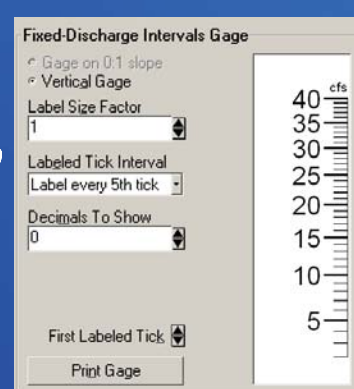
RECLAMATION

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

RECLAMATION

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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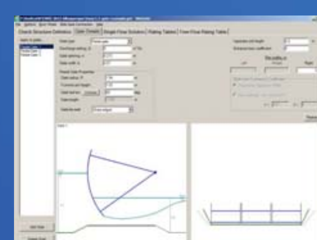
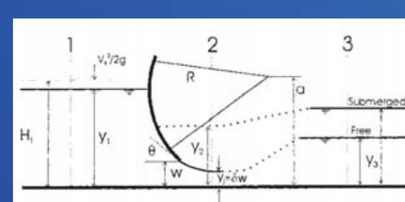
RECLAMATION

WinGate Software Completion

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



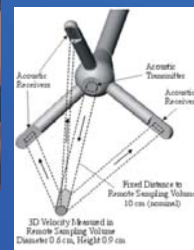
- Results to Date
  - Collaboration on algorithm development with Bert Clemmens (USDA-ARS, Retired), Gilles Belaud (France)
- Potential Areas for Collaboration:
  - Programming talent?
  - Application standardization?
  - Modularization could make final product more useful
  - USBR could aid NIST in understanding canal flow measurement needs

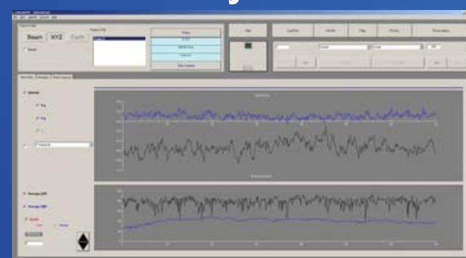


RECLAMATION

Acoustic Doppler Velocity Measurements in the Hydraulics Lab

- Acoustic Dopper 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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RECLAMATION

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

RECLAMATION

Removing Fine Debris from Water Using Coanda-Effect Screens

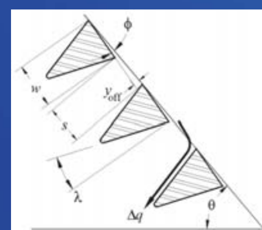
- **Traditionally USBR has only removed coarse debris from water we deliver**
  - **Trashracks to catch large or bulky debris that would clog waterways or damage large hydropower equipment (Remove trees and/or bulky aquatic vegetation with racks having 2- to 4-inch spacing)**
- **Many evolving reasons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

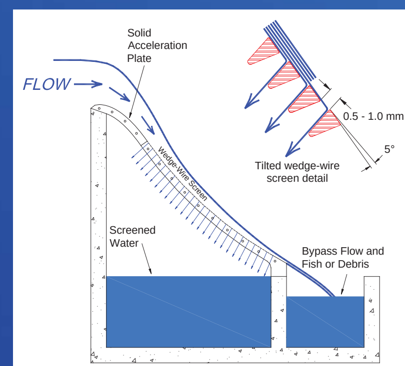
RECLAMATION

RECLAMATION

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





Features and Typical Arrangement of a Coanda-Effect Screen

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RECLAMATION

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

RECLAMATION

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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RECLAMATION

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

RECLAMATION

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

RECLAMATION

RECLAMATION

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

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RECLAMATION

Water Reuse: Detection and Impact of Pathogens and Chemicals

- **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 contaminates?
  - What are the best detection methods? Can the pathogens be detected by eDNA methods?

RECLAMATION

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

RECLAMATION

Water Reuse: Detection and Impact of Pathogens and Chemicals

- **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 contaminates analyzed in soil and plant samples?
  - Design field studies to measure the impact of reused water on agricultural products

RECLAMATION

Water Reuse: Detection and Impact of Pathogens and Chemicals

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

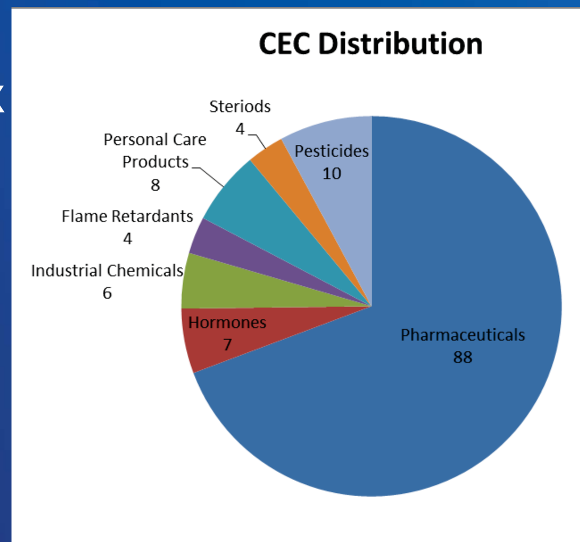
RECLAMATION

RECLAMATION

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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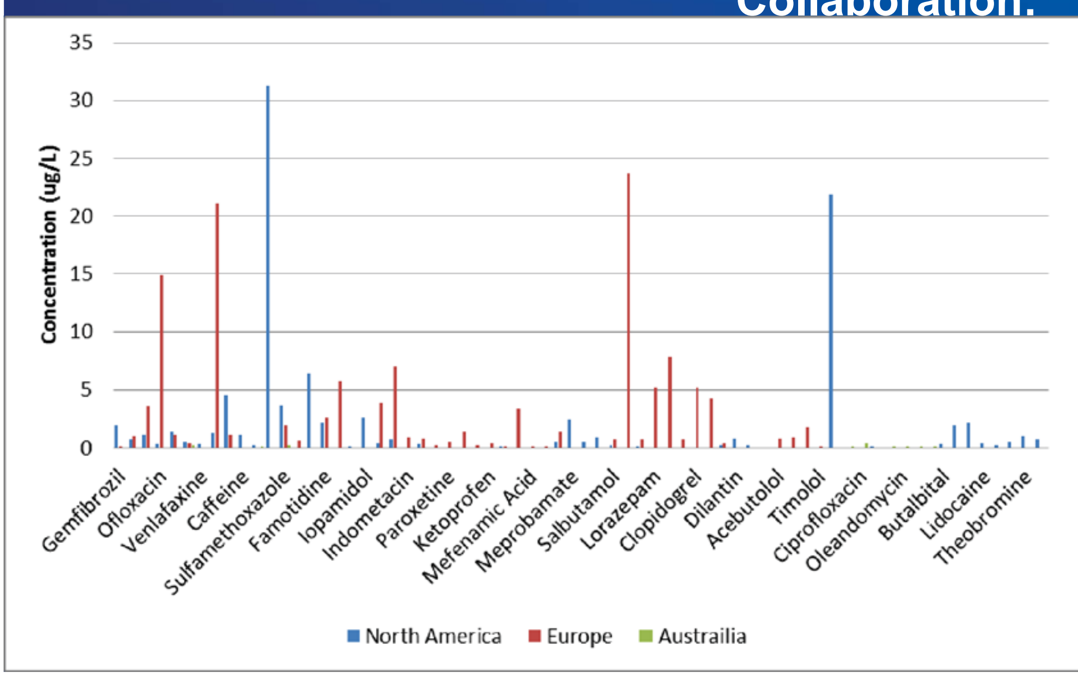
RECLAMATION

CECs

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

- **Results to Date**
  - **127 CECs – mainly pharma**
  - **UV/H_2O_2 - Ozonation**

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



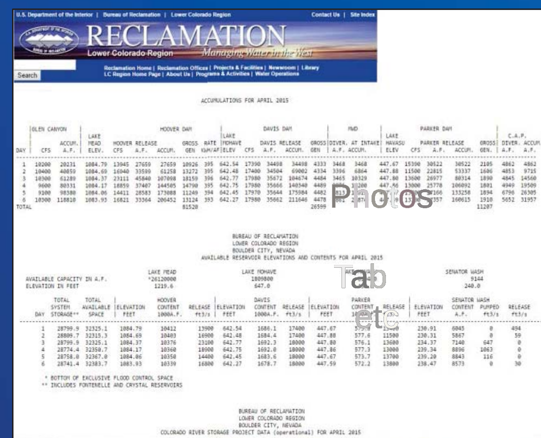
ATION

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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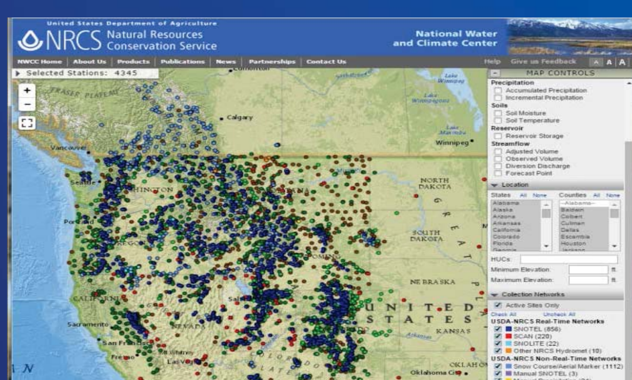
Improving Data Access

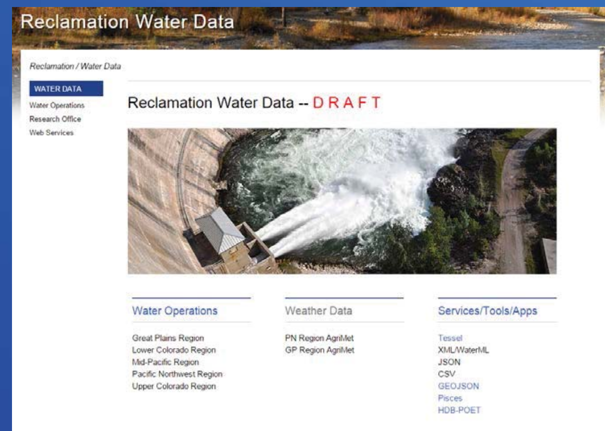
- *Expanded* Community of Practice for Water Data
- Poll community for the most widely accepted export format
- Learn and write the coding
- Create 'alternate' data export with new format standard
- Publish



RECLAMATION

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.**

RECLAMATION

RECLAMATION

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."*

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 = permeabiltiy
  - 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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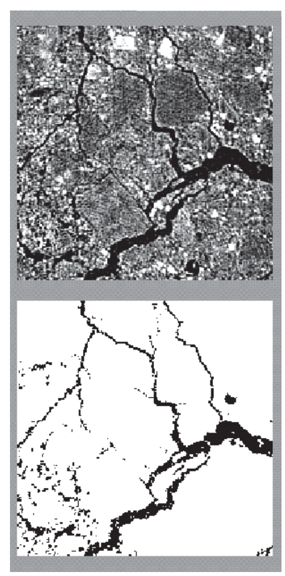
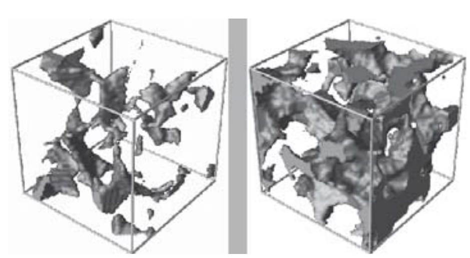
Pore structure and fluid flow in porous materials

- **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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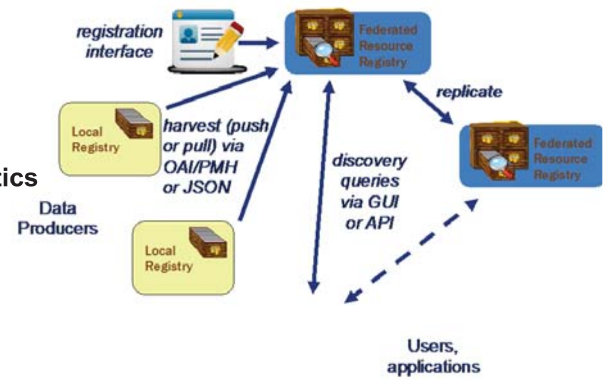
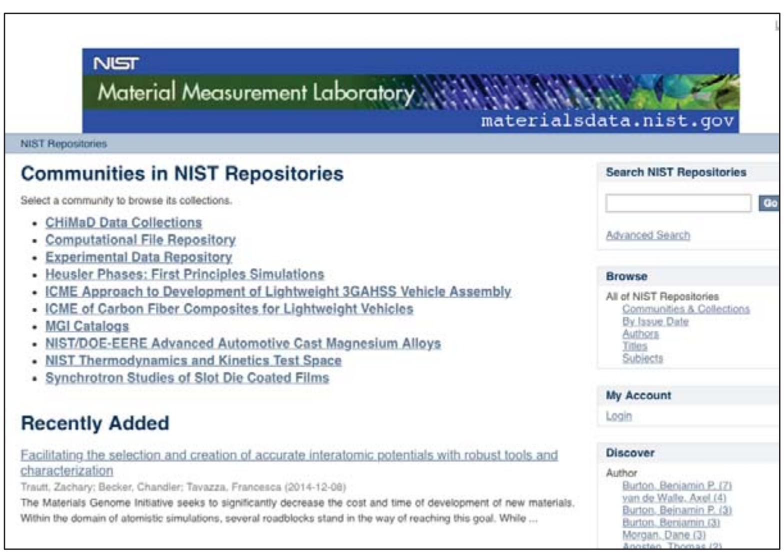


Example: MML DSpace Server

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.

H_2Omics: 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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from www.waterlog.com

H_2Omics: Comprehensive Contaminant Profiling to Guide Water Management in the Future

- **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)

from www.agilent.com

- **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

from www.illumina.com

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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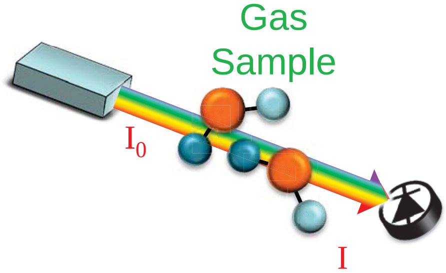
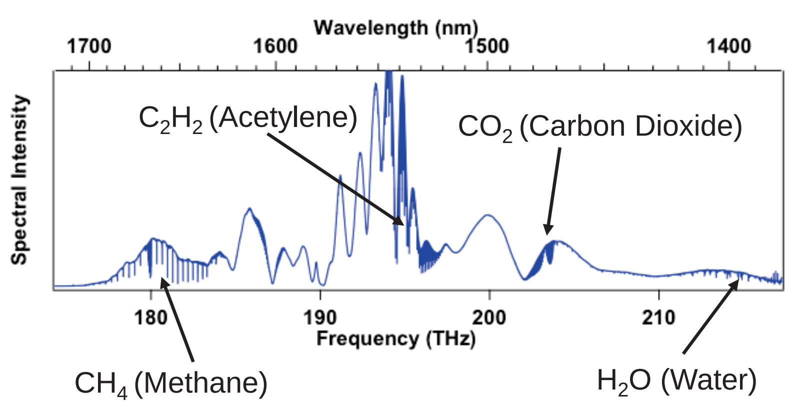
Dual Comb Spectroscopy

- **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**



$\ln(I/I_0) = A = \varepsilon l c$

measured known calculated



Nate Newbury
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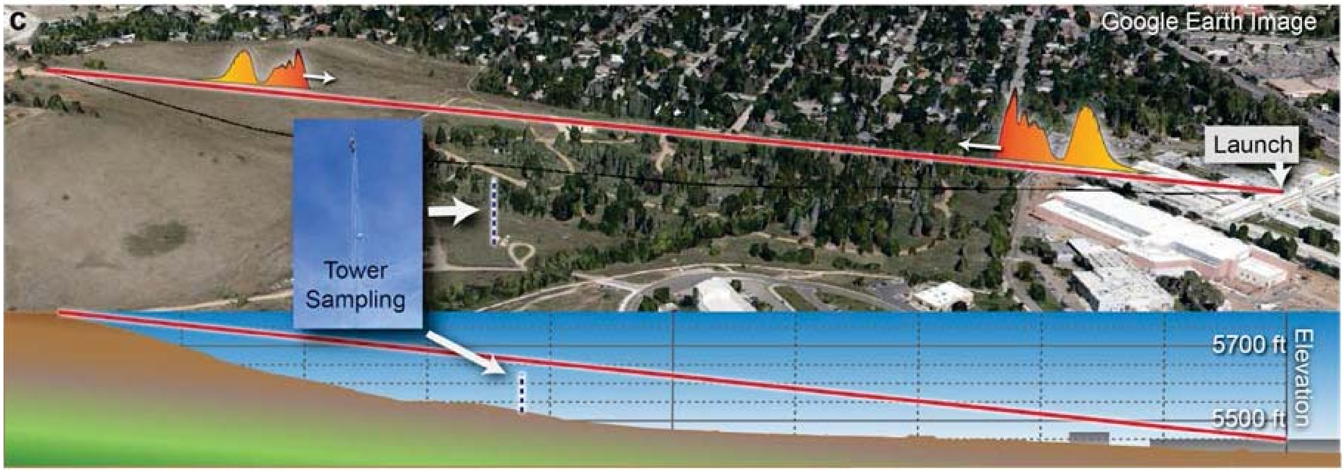
Trace Gas Measurements

- **Goals of Project:**
  - **Measure greenhouse gases (CO_2, water, CH_4, isotopes)**
  - **Measure VOCs in outdoor air**
  - **Measure gas emissions at gas/oil fields**

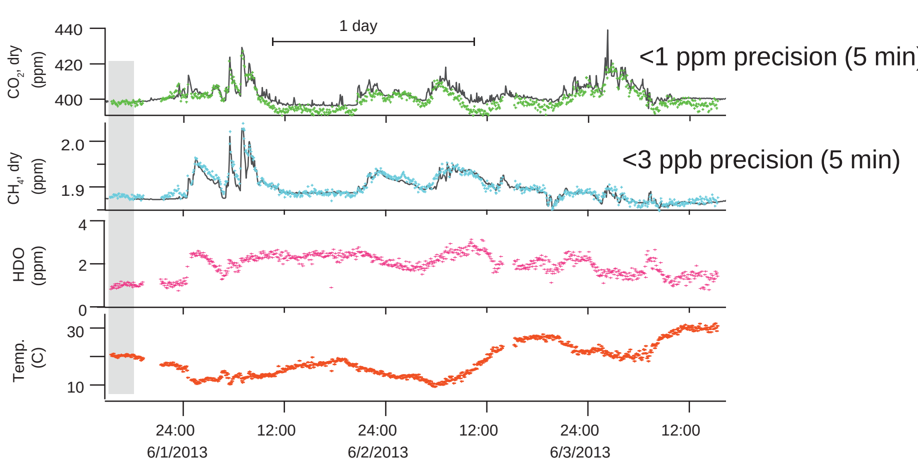


2 kilometer open path above NIST.
Lab-based test system; moving towards portable system.

Rieker et al. (2014) Optica

Trace Gas Measurements

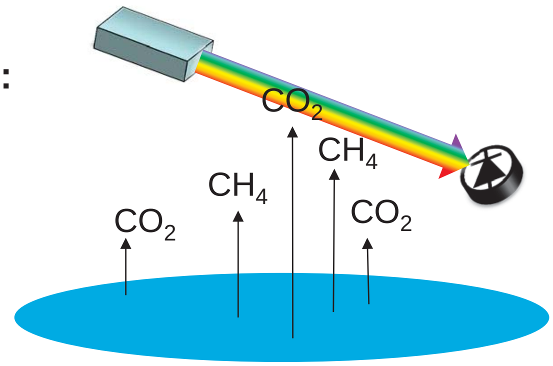
- **Results to Date**
  - **Measurements of CO_2, CH_4, and H_2O across outdoor, 2-km open-path measurements.**
  - **Currently developing portable system.**



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:**
    - **CO_2 (carbon dioxide)**
    - **CH_4 (methane)**
    - **C_2H_6 (ethane)**
    - **C_3H_8 (propane)**
    - **C_2H_4 (ethene)**
    - **C_3H_6 (propene)**
    - **C_2H_2 (acetylene)**
    - **CH_2O (formaldehyde)**
  - **We are currently evaluating system sensitivity for these species.**



Rieker et al. (2014) Optica

Reclamation-NIST Exploratory Research Symposium

Nanotechnology for Sustainable Water

Thomas Duster – NRC Postdoctoral Fellow
Material Measurement Laboratory
Applied Chemicals and Materials Division
Materials for Biological Environments Group
Engineered Nanoparticle Systems Project

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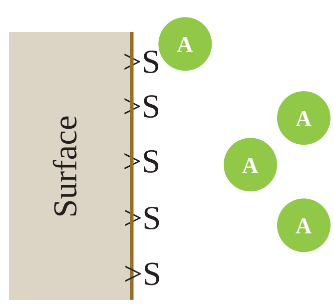
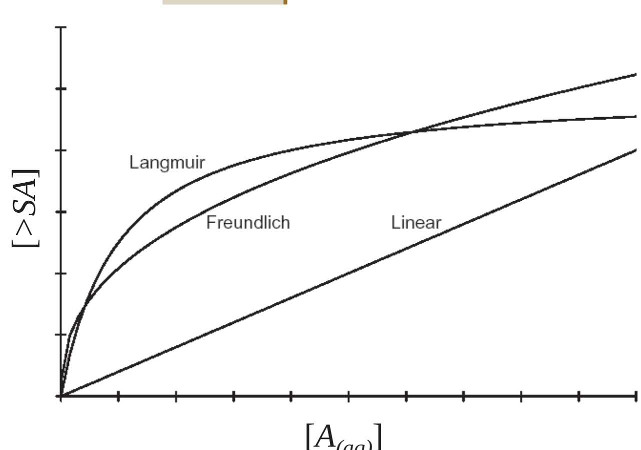
Nanotechnology for Sustainable Water

- Chemical Measurements for Nanomaterial Sorbents -



$$>S + A_{(aq)} \leftrightharpoons \; >SA$$

$$K = \frac{[>SA]}{[>S][A_{(aq)}]}$$

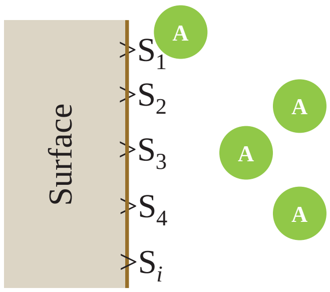


Problems

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 -



$$> S + A_{(aq)} \leftrightharpoons \; > SA$$

$$K = \frac{[> SA]}{[> S][A_{(aq)}]}$$

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

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

Model Types
Non-Electrostatic
Constant Capacitance
Diffuse Layer
Triple Layer

FITEQL 2.0 Modeling

$>S_iH^0 \leftrightarrow >S_i^- + H^+$

Known equilibrium constants

$[>S]_i$

$K_{(a)i}$

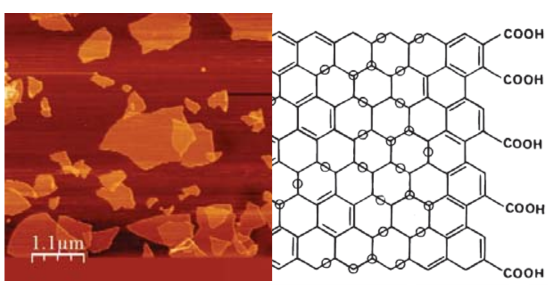
FITEQL 2.0 Modeling

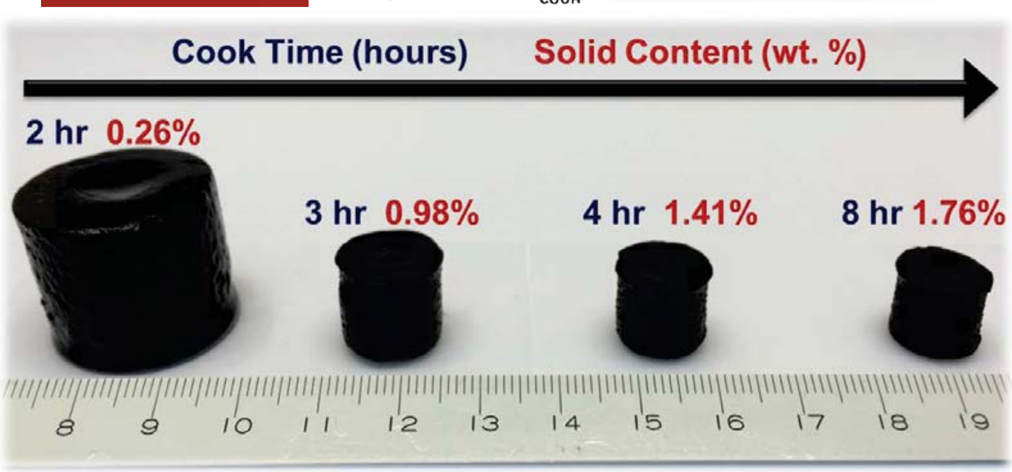
$>S_i^- + M^{2+} \leftrightarrow >S_iM^+$

$K_{(ads)i}$

Nanotechnology for Sustainable Water

- Chemical Measurements for Graphene Oxide Sorbents -





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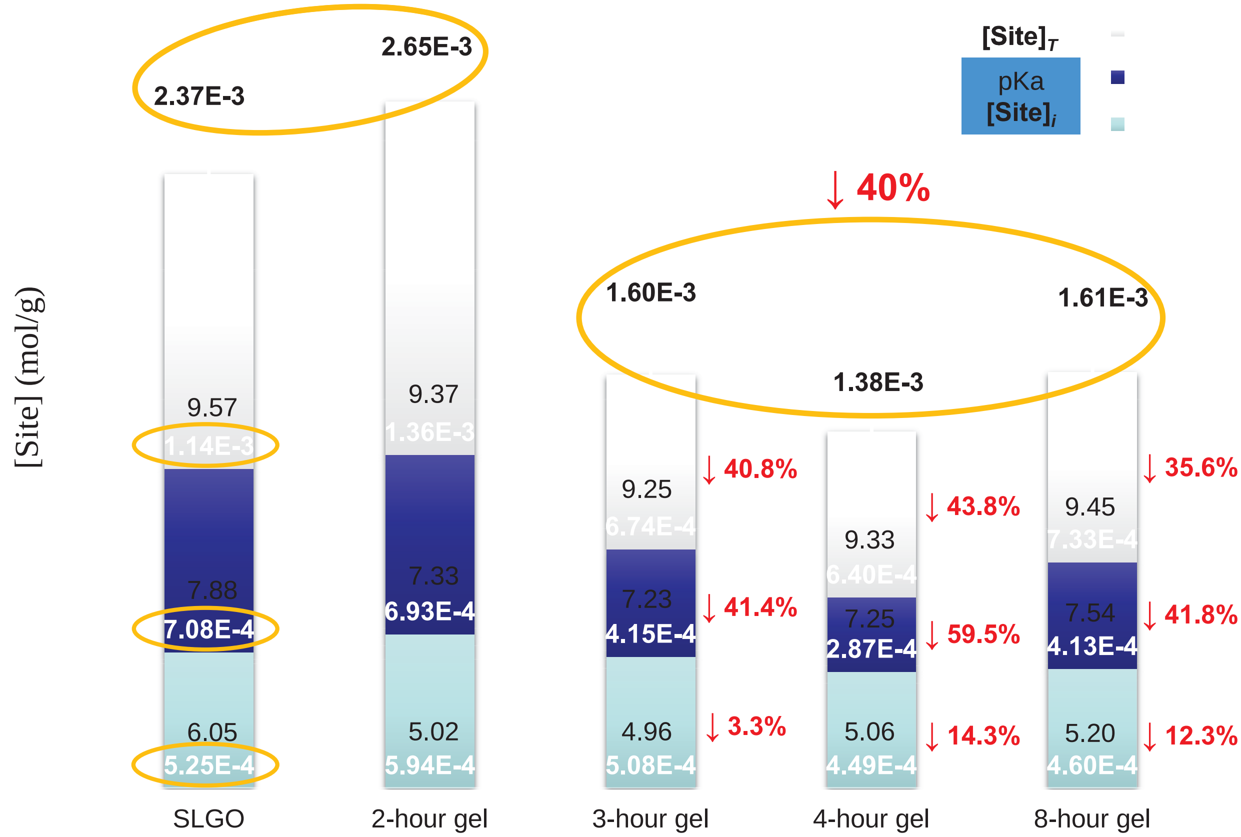
Nanotechnology for Sustainable Water

- Chemical Measurements for Graphene Oxide Sorbents -



Nanotechnology for Sustainable Water

- Chemical Measurements for Nanomaterial Sorbents -

Collaboration opportunities?

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

Contact Information

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Reclamation-NIST Exploratory Research Symposium

Relating structure and transport in polymeric thin film composite membranes

Presented by:

Christopher M. Stafford, Project Leader
Material Measurement Laboratory
Materials Science and Engineering Division
Functional Polymers Group

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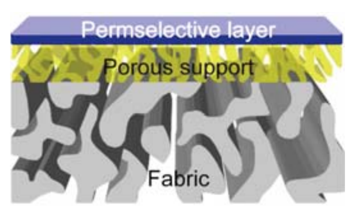
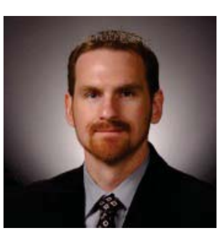
Problem Statement

- 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.



$$J_w \cong D_w \frac{\rho}{1-\phi_w} \frac{\Delta\phi_w}{h}$$

$$J_s \cong D_s \frac{\Delta c_s}{h}$$



Christopher M. Stafford
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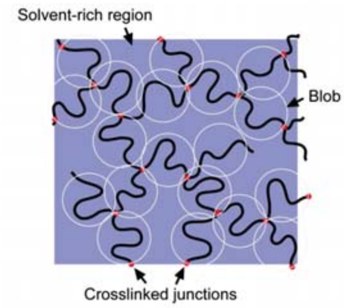
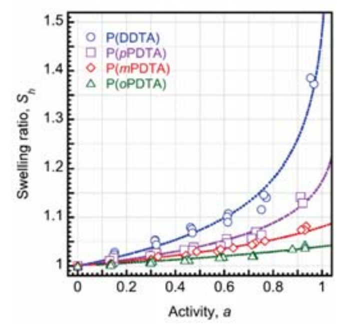
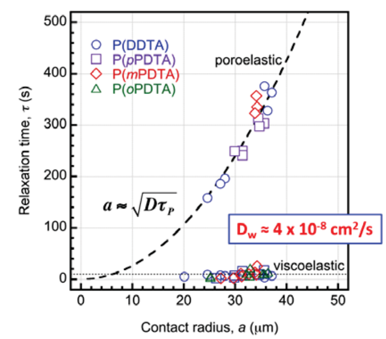
MSED, Functional Polymers Group
Gaithersburg, MD

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







Reclamation-NIST Exploratory Research Symposium

Laser-Induced Cavitation as a Hydro-Acoustic Source to Prevent Zebra Mussel Attachment in Water Cooling Infrastructure

Presented by:

Paul Williams, Physicist

Physical Measurements Laboratory

Quantum Electronics and Photonics Division

Sources and Detectors Group

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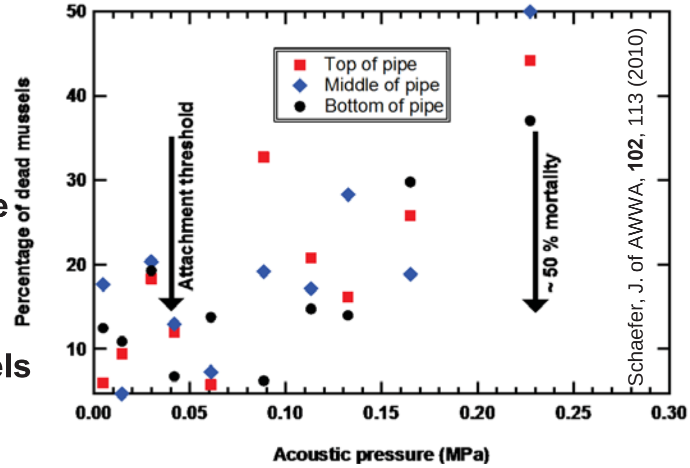
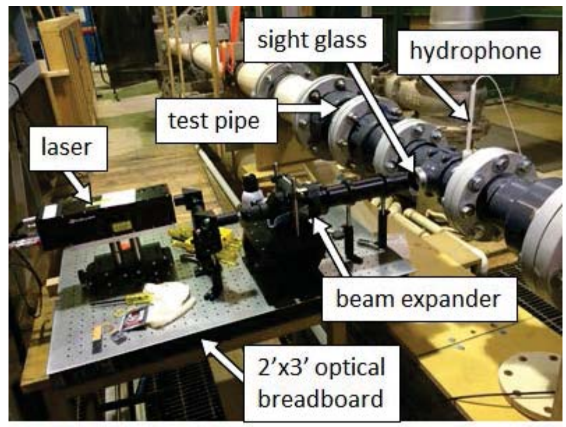
Physical Measurements Laboratory
Quantum Electronics & Photonics Division, Sources & Detectors Group – Bldg. 1-M3410

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





Reclamation-NIST Exploratory Research Symposium

Radiometric Modeling of Sub-Surface Vertical Profiles of Water-Penetrating Lidars for In-Situ Monitoring of Water Backscatter and Attenuation.

Presented by:

Michelle Stephens, Physicist
Physical Measurement Laboratory
Quantum Electronics and Photonics Division
Sources and Detectors Group

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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**

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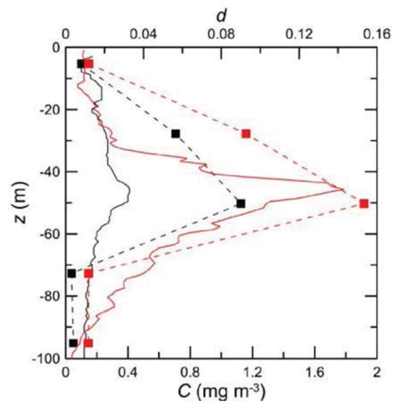
Quantum Electronics and Photonics Division,
Sources and Detectors Group- Bldg 1-3526

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**



Depth profiles of lidar depolarization, d, (squares connected by dashed line) and chlorophyll concentration, C, (lines) from May 2010 in the NW Atlantic Ocean (black) and July 2010 in the NE Pacific (red). *Rodier, S. et al, "CALIPSO Lidar Measurements for Ocean Sub-Surface Studies", Proc. 34th Intnl. Symp. On Remote Sensing Env. (2011).*

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**

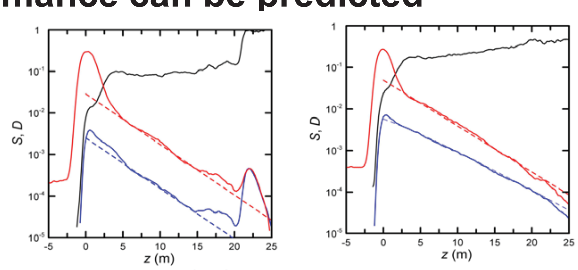


Fig.4. Typical depth profiles of the co-polarized return S_C (red), cross-polarized return S_X (blue), and depolarization D (black). The solid lines are measured values, and the dashed lines are the theoretical profiles from Eq. (8). The left panel is from the near-shore region. The large, unpolarized return at 22 m depth is the bottom of the ocean. The right panel is from the off-shore region.

Churnside, James H., "*Polarizaton effects on oceanographic lidar*" Opt. Express 16 (2008) 1196.

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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Applied Chemicals and
Materials Division
Boulder, CO

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

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