Office of Research and Development

Safe and Sustainable Water Resources Research Program

Water Systems

Project 3: Transformative Approaches and Technologies

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Director, National Exposure Research Laboratory-Systems Exposure Division

Board of Scientific Counselors-SSWR Subcommittee Meeting

Hyatt Regency, Cincinnati, OH

August 24 – 25, 2015

Task 3A – System Approaches for Assessment of Transformative Fit-for-Purpose and Resource Recovery-Based Water Systems

Water Systems

1. Development of a transformative technology toolkit library

2. Metrics, tools improvement, and expansion

3. System analyses comparing conventional and transformative community water systems and applications in community-based case studies

Task Lead: Cissy Ma

1. Development of a Transformative Technology Toolkit Library

Water Systems

FY16 Key Activities/Products/Impacts

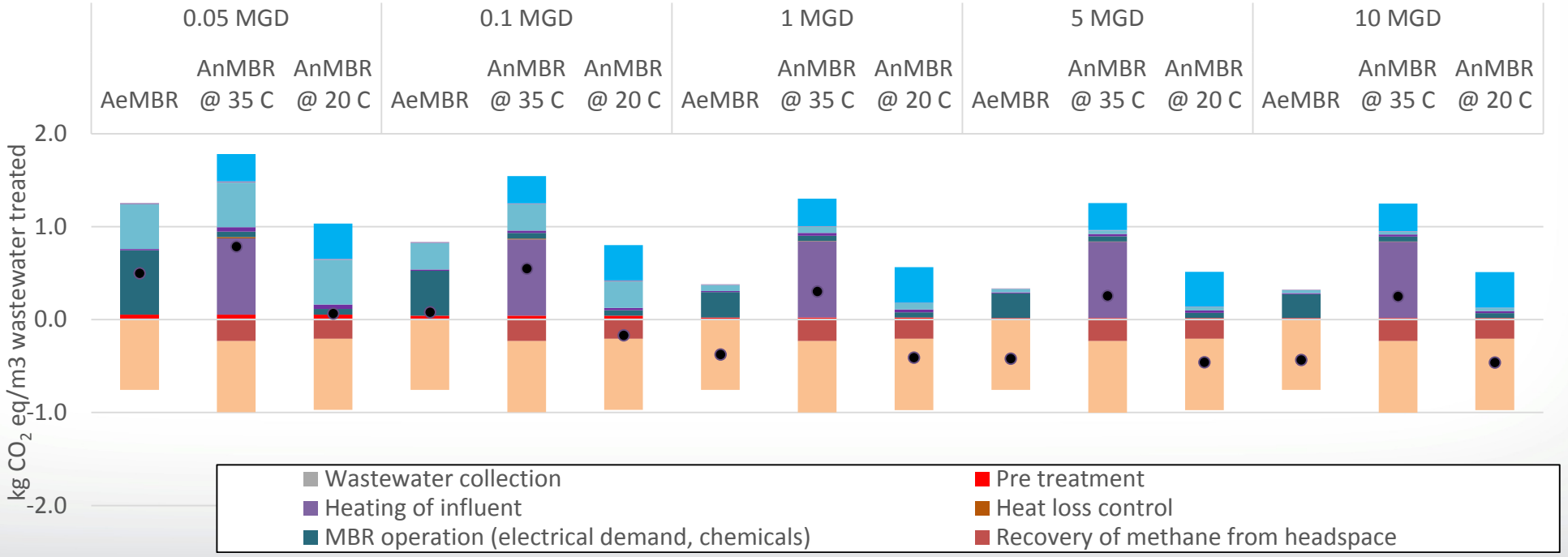
- Aerobic Membrane Digestor (AeMBR)
- Anaerobic Membrane Digestor (AnMBR)
- Anaerobic Digestion
- Constructed Wetland
- Struvite
- 5-level Nutrient Removal Treatment Train

1. Development of a Transformative Technology Toolkit Library

Water Systems

FY16 Key Activities/Products/Impacts

- Aerobic Membrane Digestor (AeMBR)
- Anaerobic Membrane Digestor (AnMBR)



1. Development of a Transformative Technology Toolkit Library

Water Systems

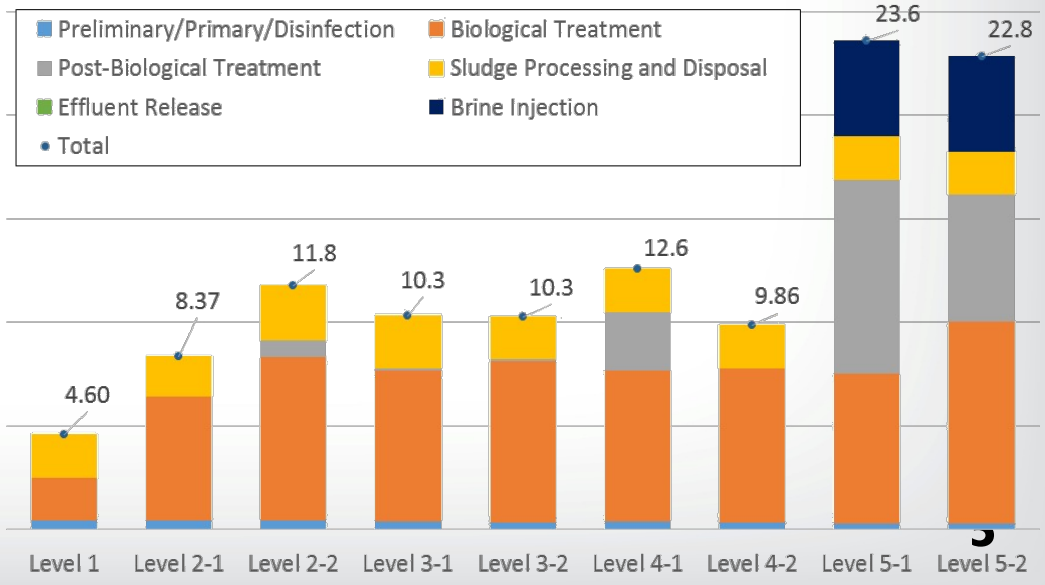
5-Level Nutrient Removal Treatment Train

Level	Type of Biological Treatment	Phosphorus Precipitation	Fermenter	Sand Filter	Other
1	Plug Flow Activated Sludge				
2	Anaerobic/ Anoxic/Oxic				
2	Activated Sludge, 3-Sludge System	√			
3	5-Stage Bardenpho	√	√	√	
3	University of Cape Town Town Process, Modified Modified	√	√	√	
4	5-stage Bardenpho	√	√	√	Denitrification Filter (100%) (100%)
4	4-stage Bardenpho Membrane Bioreactor Bioreactor	√			
5	5-Stage Bardenpho	√	√	√	Denitrification Filter (10%) Ultrafiltration And Reverse Osmosis (90%)
5	5-stage Bardenpho Membrane Bioreactor	√	√		Reverse Osmosis (85%)

Target Effluent Nutrient Concentrations by Level

Level	Total Nitrogen, mg/l	Total Phosphorus, mg/l
1	*	*
2	8	1
3	4-8	0.1-0.3
4	3	0.1
5	<2	<0.02

Cumulative Energy Demand



2. Metrics, Tools Improvement, and Expansion

FY16 Key Activities/Products/Impacts

- **Methodology improvement**
  - Risk assessment (Log Reduction Targets for non-potable water reuse)
  - Life Cycle Assessment (Water Scarcity Index)
  - Emergy (Loop and Recycling Pathway)

3. System Analyses Comparing Conventional and Transformative Community Water Systems and Applications in Community-Based Case Studies

FY16 Key Activities/Products/Impacts

- **Energy footprints for current centralized water and wastewater systems**
  - Greater Cincinnati region (GCWW and MSD, stormwater).
- **Evaluation of alternative scenarios for decentralized non-potable water systems (scale, source separation of wastes, treatment approach)**
  - San Francisco, CA and other stakeholders (from knowledge to application)
- **Resource recovery based small community system**
  - Bath, NY (energy recovery, water reuse, nutrient recovery)

3. System Analyses Comparing Conventional and Transformative Community Water Systems and Applications in Community-Based Case Studies

FY16 Key Activities/Products/Impacts

- **Energy footprints for current centralized water and wastewater systems**
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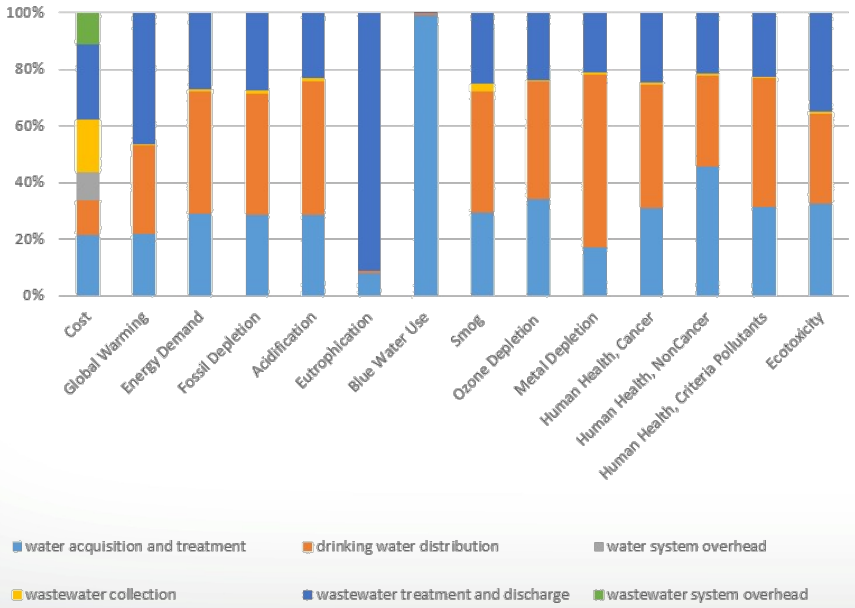
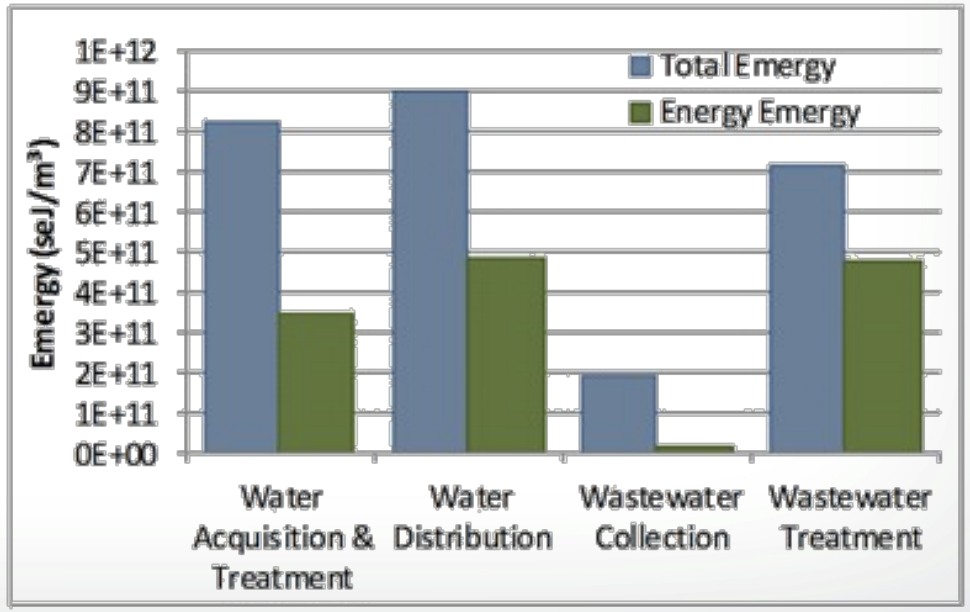




Task 3B – Novel Detection Tools for Systems Applications

Water Systems

1. Development of a knowledgebase and proof-of concept for AOPs and biosensor technology to capture the presence of major classes of contaminants that pose a risk to human health

2. Design and development of an AOP targeting biosensor, which will provide guidance for evaluating the methods employed for water quality characterization and provide information for risk and exposure assessment

Task Lead: Eunice Varughese

1. Development of a Knowledgebase and Proof-of Concept for AOPs and Biosensor Technology

Water Systems

FY16 Key Activities/Products/Impacts

- **Initiated discussions within EPA and outside of EPA**
  - Will help to develop the knowledgebase and better understand how to implement AOPs in biosensor technology.
  - Partners inside EPA include individuals from ORD and OW. Partners recruited outside of EPA include individuals from USGS, NOAA, US Army, WEF, and Greater Cincinnati Water Works.
- **Weekly meetings**
  - On-going to develop the knowledgebase as to which toxicity pathways and AOPs should be targeted for biosensor technology.
- **Discussions and findings being captured in a review document**
  - Will be beneficial to OW in determining some of the priority toxicity pathways and using that information to develop tools to better gauge the safety of drinking water.

2. Design and Development of an AOP Targeting Biosensor

Water Systems

FY16 Key Activities/Products/Impacts

- **Partnership with the EPA Innovation Team**
  - Established to initiate a three phase challenge grant to develop a water biosensor that detects the presence of chemicals that activate various toxicity or AOP pathways.
- **Phase I challenge**
  - Weekly meetings with EPA and external partners
  - In the process of putting together a draft for Phase I, as an Ideation/Theoretical Challenge.
  - Weekly calls are defining needs in order to leverage the design of the biosensor.
- **Phase II and III challenges**
  - Following Phase I, there will be a Phase II challenge to develop a prototype.
  - Contingent on funding, Phase III will be the development of a field-deployable sensor.
- **Real-world use of toxicity water sensor**
  - Will give OW and Regions a tool to better characterize water quality by providing input on exposure assessment.
  - Can be used in water reclamation efforts to mitigate treatment procedures for water reuse.

Task 1C – Case Studies & Demonstrations of Transformative Approaches for Water Systems & Water Reuse

Water Systems

1. Demonstration and evaluation of decentralized wastewater treatment for water reuse

2. Development of improved guidance for non-potable water reuse

3. Application and evaluation of integrated approaches for sustainable water resource management

Task Lead: Ardra Morgan

1. Demonstration and Evaluation of Decentralized Wastewater Treatment for Water Reuse

Water Systems

FY16 Key Activities/Products/Impacts

- **Part of DoD's Environmental Security Technology Certification Program (ESTCP) that seeks to demonstrate and validate innovative environmental technologies**
  - A joint EPA-DoD ESTCP solicitation was issued for innovative, energy-efficient, low maintenance systems for decentralized treatment and recycling of wastewater, or sewer mining, on military installations
  - CDM Smith was awarded the contract for their AnMBR design
- **Trailer with the anaerobic membrane bioreactor (AnMBR) was installed in Fort Riley, Kansas in June 2016**

1. Demonstration and Evaluation of Decentralized Wastewater Treatment for Water Reuse

Water Systems

FY16 Key Activities/Products/Impacts

Status: AnMBR has been running since mid-July.

Objective: To provide an assessment of pilot-scale AnMBR technology, operated at ambient temperature, including methane gas removal from the permeate using hollow fiber membrane modules and zeolite removal of nutrients from effluent.

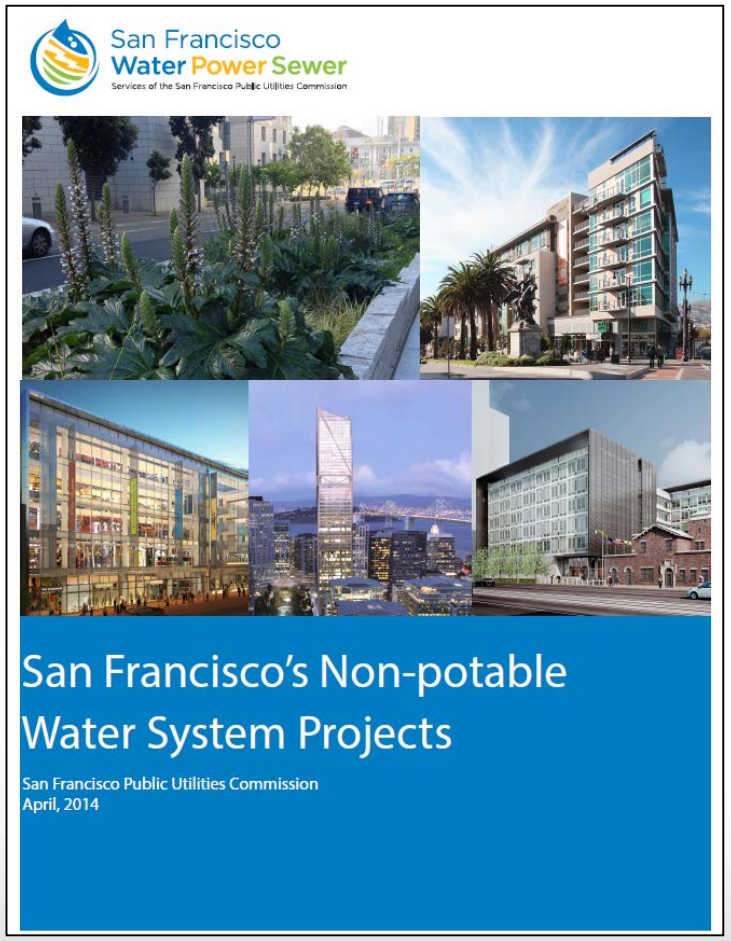
Data: Field performance data from the AnMBR will be evaluated during ~18 months of operation (through end of CY 2018).

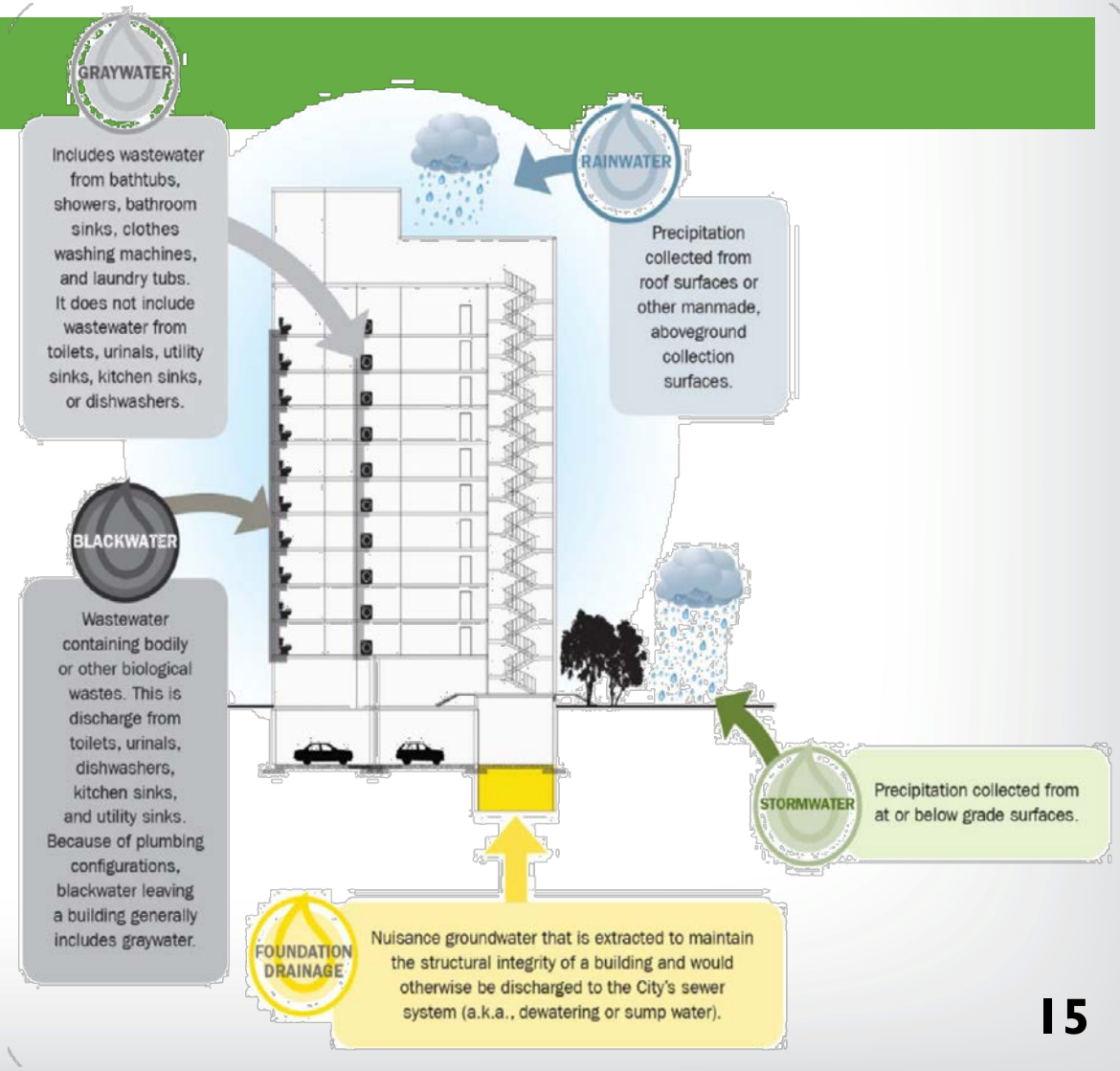
Impacts: Provides real-world data to assess an advanced, energy-efficient resource recovery based treatment of wastewater.

- *Near Term (FY 16 Product):* Life Cycle assessment of sewer mining using different treatment technologies at different scales and populations densities
- *Mid Term (FY18 projected):* Summary report of AnMBR performance

2. Development of Improved Guidance for Non-Potable Water Reuse

FY16 Key Activities/Products/Impacts





2. Development of Improved Guidance for Non-Potable Water Reuse

FY16 Key Activities/Products/Impacts

- **Partnership with NWRI panel to develop a framework for decentralized non-potable water systems**
  - Provide additional information and guidance to state and local health departments. Allows these agencies to consider development of a DNWS program that adequately protects public health.
    - Source waters: blackwater, graywater, domestic wastewater, roof runoff, stormwater, condensate, foundation water
    - Nonpotable end uses: toilet flushing, clothes washing, cooling tower, unrestricted-access municipal irrigation
    - Oriented towards non-single residence applications: multi-user buildings and district/ neighborhood scale
  - Adopted a Risk-Based Approach to Defining Pathogen Log Reduction Targets (LRTs)

2. Development of Improved Guidance for Non-Potable Water Reuse

	Norovirus (gc)[a]	*Adenovirus* (TCID50)	*Rotavirus* (FFU)	*Cryptosporidium* (oocysts)[b]	*Giardia* (cysts)	*Campylobacter* (CFU)	*Salmonella* (CFU)
Municipal Wastewater							
Municipal	9.0/8.7/6.2	5.6	-	6.4/6.3/5.5	-	5.1	1.1
Home use	9.3/8.9/6.4	6.7	-	7.7/7.4/6.8	-	6.1	3.3
Drinking	13.1/12.8/10.2	9.7	-	10.5/10.4/9.6	-	9.2	5.2
Greywater 1000-person collection							
Municipal	8.4/8.1/5.6	-	6.4	4.5/4.2/3.6	3.4	3.7	1.2
Home use	8.8/8.5/6.0	-	6.4	4.5/4.2/3.6	3.8	3.7	1.6
Drinking	12.6/12.3/9.8	-	10.6	8.8/8.5/7.9	7.6	8.0	5.4
Greywater 5-person collection[c]							
Municipal	7.7/7.4/4.9	-	5.9	0/0/0	0	0	0
Home use	7.8/7.8/5.0	-	6.3	0/0/0	0	0	0
Drinking	12.4/12.0/9.5	-	10.5	0/0/0	0	0	0
Stormwater – 10^{-1}							
Municipal	8.0/7.7/5.1	4.6	-	5.4/5.3/4.5	-	4.1	0.1
Home use	8.3/7.9/5.4	5.7	-	6.6/6.4/5.8	-	5.1	3.3
Drinking	12.1/11.7/9.3	8.7	-	9.5/9.4/8.6	-	8.2	4.2
Stormwater – 10^{-3}							
Municipal	6.0/5.7/3.2	2.6	-	3.4/3.3/2.5	-	2.1	0
Home use	6.2/5.9/3.4	3.7	-	4.7/4.4/3.8	-	3.1	1.2
Drinking	10.1/9.8/7.3	6.7	-	7.5/7.4/6.6	-	6.2	2.2
Rainwater							
Municipal	-	-	-	-	-	3.1	3.5
Home use	-	-	-	-	-	3.3	3.5
Drinking	-	-	-	-	-	7.3	7.7

[a]Hypergeometric model/Averaged results/Fractional Poisson

[b]Fractional Poisson/Averaged results/Exponential model

[c]99th%ile for protozoans and bacteria is approx. equal to the 95th%ile of the 1000-person system

2. Development of Improved Guidance for Non-Potable Water Reuse

Water Systems

FY16 Key Activities/Products/Impacts

- **NWRI recommended approach to monitoring**
  - Routine monitoring of indicator organisms does not provide real time information required for operation of DNWS.
  - New monitoring approach: Operational Monitoring
    - Ongoing verification of system performance
    - Continuous observations
    - Surrogate parameters correlated with LRTs
  - New monitoring approach: Start-up and Commissioning
    - Validation monitoring - Performance target confirmation via challenge testing (or endogenous organisms?)

2. Development of Improved Guidance for Non-Potable Water Reuse

FY16 Key Activities/Products/Impacts

❖ **Biological organisms to confirm log reduction targets**

- Measurement of pathogens difficult.
  - Hundreds of potential pathogens, sporadic occurrence, expensive, low concentrations
- Measure biological surrogates that represent pathogens?
  - Typical surrogates (fecal indicator organisms) too dilute
  - Spike with surrogate, calculate reduction (challenge to spike large systems)
  - Endogenous microbes as alternative biological surrogate
    - ✓ *What microbes are present in the DNWS?*
    - ✓ *How abundant are the candidate surrogates?*
    - ✓ *Are the candidate surrogates consistently present in the influent of the DNWS?*
    - ✓ *Compare log reduction profiles of alternative biological surrogates top those of pathogens during various treatment processes.*

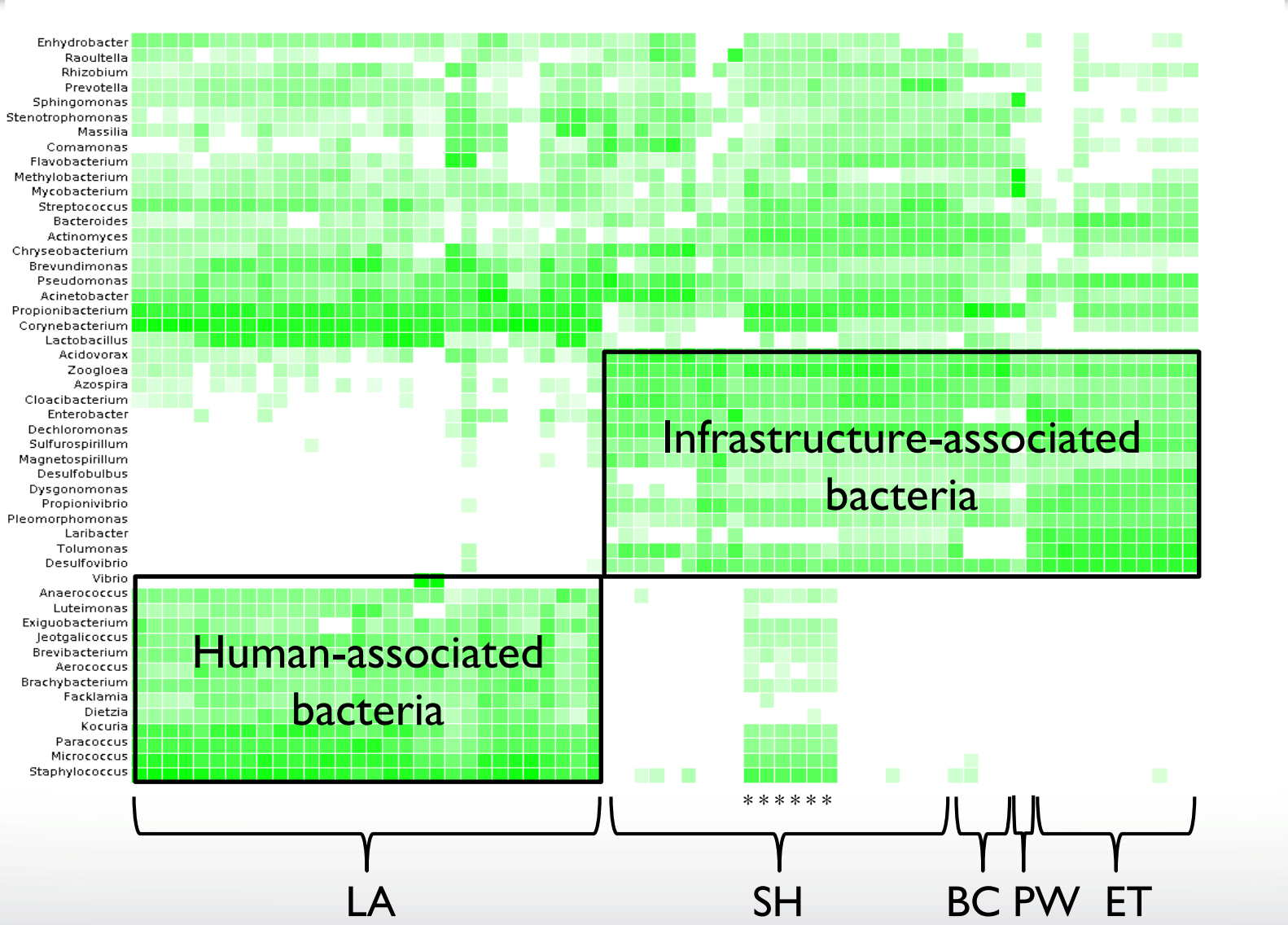
2. Development of Improved Guidance for Non-Potable Water Reuse

Water Systems

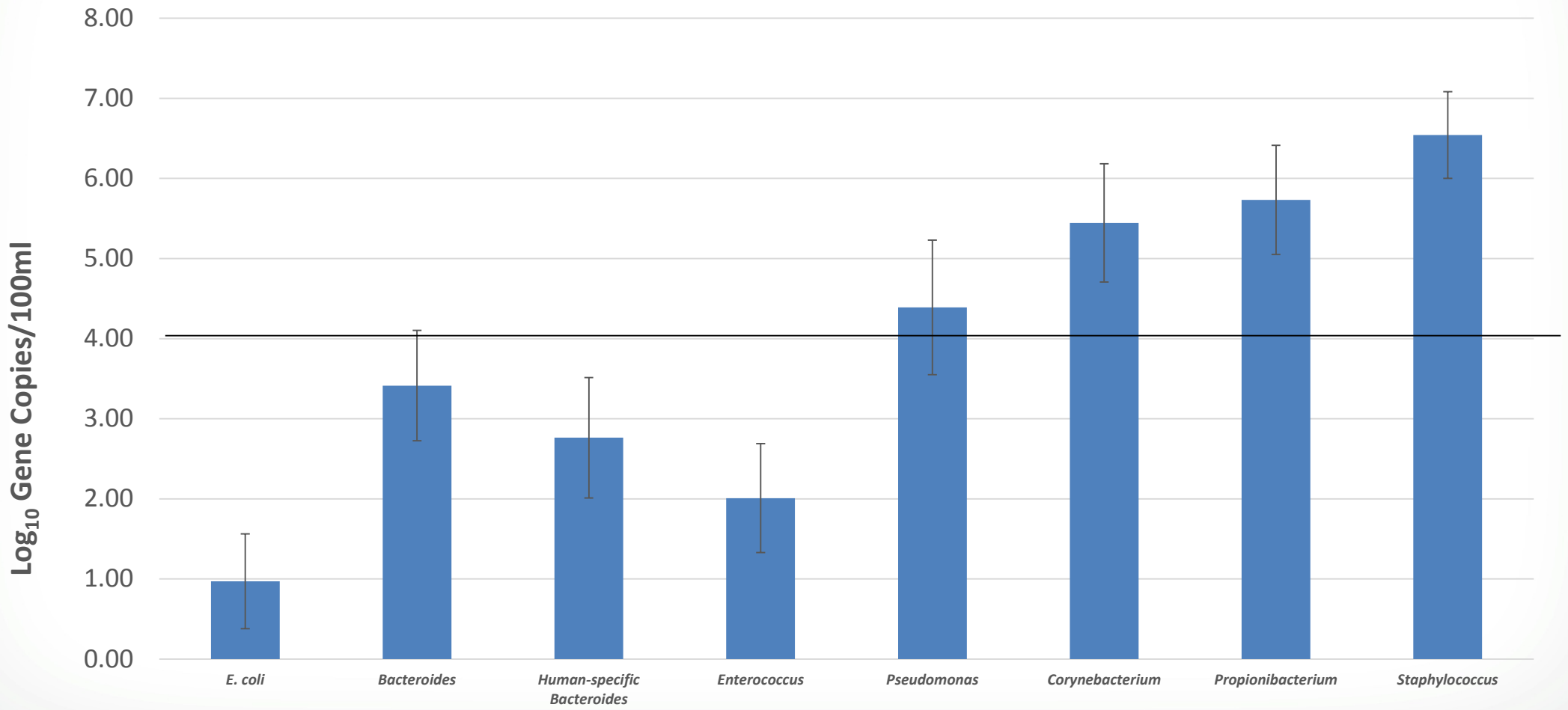
FY16 Key Activities/Products/Impacts

- **Work approach to alternative surrogates**
  - Previously published work found alternative potential bacterial surrogates (either human skin-associated and infrastructure related in graywater recycling systems
  - On-going work focused on collaborative sampling of source separated graywater and combined flows from partners in San Francisco (and Colorado) with assistance from EPA Regional staff
  - Continue analysis of surrogates for representative pathogen groups: bacteria, virus, and protozoa

Log_{10}-scale Heat Map of Top 50 Genera Detected in Graywater



Quantification of Candidate Bacterial Surrogates in Laundry Graywater



2. Development of Improved Guidance for Non-Potable Water Reuse

Water Systems

FY16 Key Activities/Products/Impacts

Summary

- Two detailed EPA-ORD publications will be submitted for peer review journal shortly
  - NWRI panel will use as part of their framework document to be published at the end of summer
  - Publications are FY17 APR (Develop of Risk-Based Pathogen Reduction Targets for Non-Potable Use of Locally Collected Waters)
- Continued involvement with stakeholders (National Blue Ribbon Commission to Accelerate Adoption of On-Site Water Reuse – US Water alliance and SFPUC)
  - Continued work of alternative monitoring approaches
  - Define/share integrated sustainability assessment of different scenarios (overlap with Task 3A)

2. Case Studies and Demonstrations of Transformative Approaches for Water Systems and Water Reuse

FY16 Key Activities/Products/Impacts

- **Application and evaluation of integrated approaches for sustainable water resource management**

  Objective: Evaluate the effectiveness of innovative low-impact development (LID) infrastructure and best management practices (BMPs) for wet weather capture and aquifer recharge in the arid southwestern US.

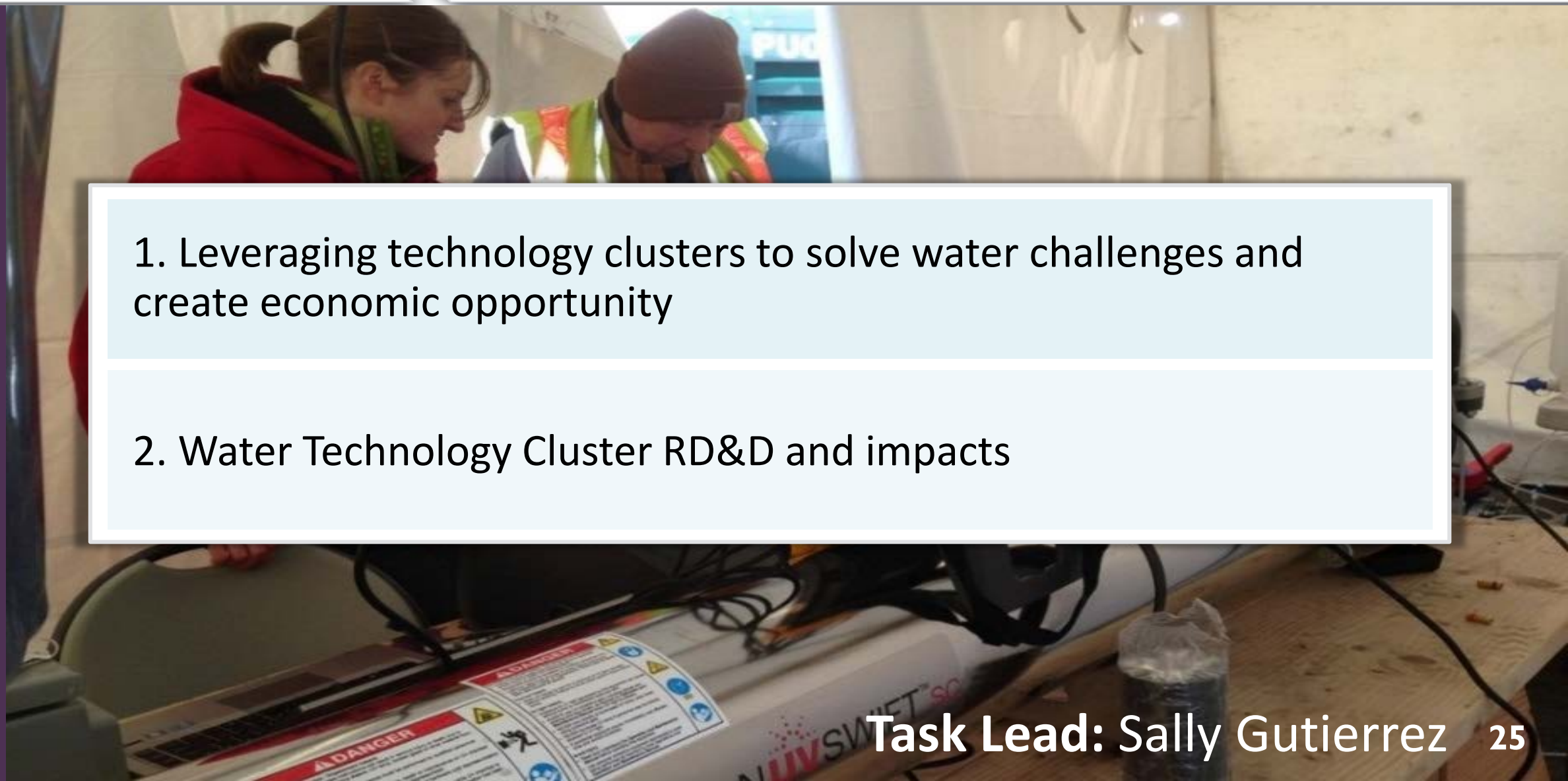
  - Design, build, and monitor BMP performance for diversion of wash flow, urban/rooftop runoff, and recycled wastewater for focused recharge of aquifers through infiltration galleries and dry wells in arid areas.
  - Collaborate with the Army to build and test a prototype aquifer recharge technology at Fort Irwin, CA in the Mojave Desert.

  Status: Project is currently in the planning stages

  Impacts: Prototype would be transferable to large urban areas, such as Los Angeles, and works toward Net Zero water goals. Evaluates and assesses BMP options for natural and artificial aquifer recharge to improve sustainable water management and resilience in drought-stressed municipalities.

Task 3D – Water Technology Innovation Clusters

Water Systems



1. Leveraging technology clusters to solve water challenges and create economic opportunity

2. Water Technology Cluster RD&D and impacts

Task Lead: Sally Gutierrez

FY16 Key Activities/Products/Impacts

❖ **Leveraging technology clusters to solve water challenges and create economic opportunity**

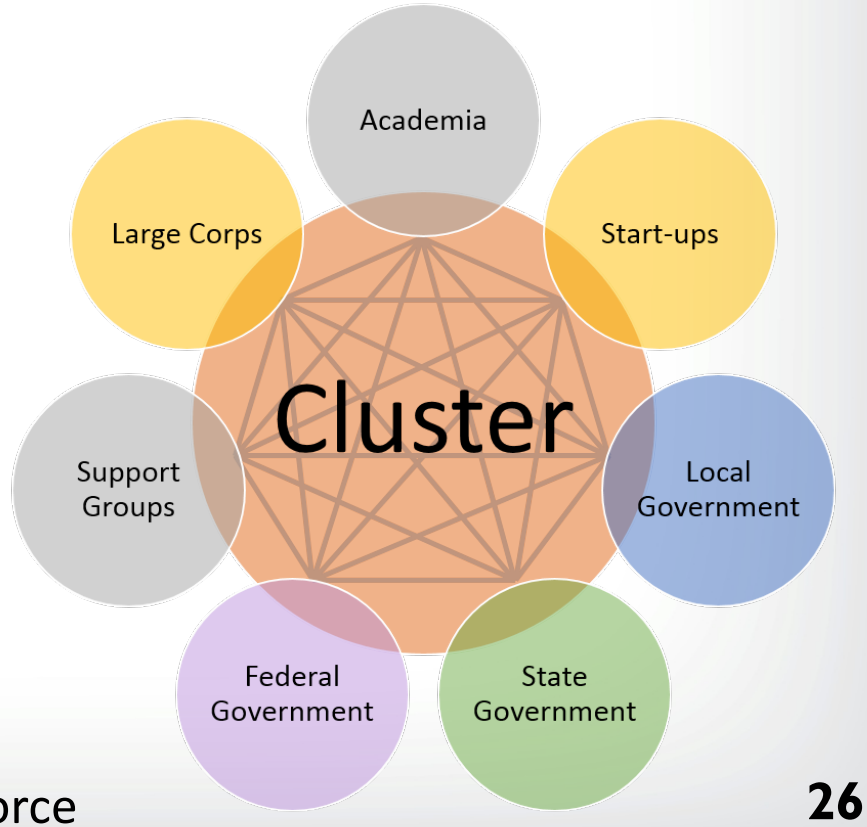
Greater Cincinnati area water cluster

Program Goals:

- Leverage community assets
- Increase water technology innovation
- Accelerate adoption of innovative water technologies

Research Project Selection Criteria:

- Stimulates collaboration with partners
- Addresses EPA research priorities
- Ready or nearly ready for commercialization
- Provides education or training to develop regional workforce



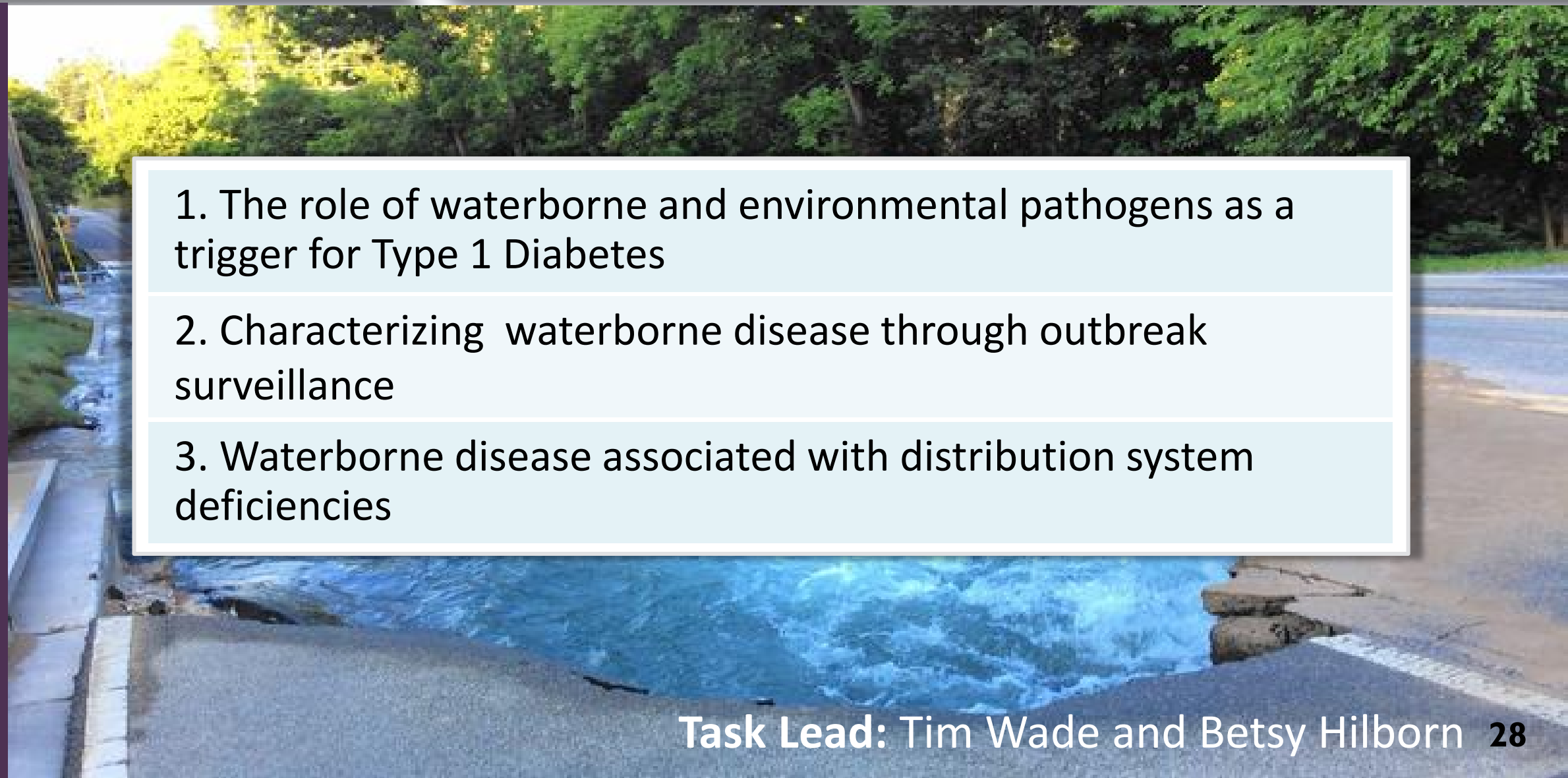
2. Case Studies and Demonstrations of Transformative Approaches for Water Systems and Water Reuse

❖ Water Technology Cluster RD&D and impacts

Current Projects	OW Blueprint Priority
Commercialization of detention pond water quality improvement system	Improving and Greening of the Water Infrastructure
Energy-efficient water and salt recovery from brine concentrates	Conserving and Reusing Water
Expanding water utility access to CANARY – Event detection software	Reducing Costs and Improving Techniques for Monitoring
Real-time analytics for water quality management in small water systems	Improving Performance of Small Drinking Water Systems
Implementing Ultraviolet (UV) Disinfection Systems for Treatment of Groundwater for Small-Medium Sized Utilities	
Commercialization of human fecal source identification technologies	Improving Access to Safe Drinking Water and Sanitation
Commercialization of affordable data loggers for citizen scientists to improve stream origin databases	Improving Water Quality of Oceans, Estuaries, and Watersheds

Task 3E – Approaches to Assess the Overall Health of a Community

Water Systems



1. The role of waterborne and environmental pathogens as a trigger for Type 1 Diabetes
2. Characterizing waterborne disease through outbreak surveillance
3. Waterborne disease associated with distribution system deficiencies

Task Lead: Tim Wade and Betsy Hilborn

1. The Role of Waterborne and Environmental Pathogens as a Trigger for Type I Diabetes

Water Systems

FY16 Key Activities/Products/Impacts

- Formed collaboration with University of Colorado Medical School and obtained access to plasma and saliva samples from cohort of T1D patients (The Diabetes and Autoimmunity Study in the Young -DAISY).
- Developing multiplex methods to detect antibodies to waterborne viruses in saliva and serum that may "trigger" T1D.
- A larger sample of serum and saliva specimens from the DAISY cohort are currently being analyzed.
- Two manuscripts are in preparation describing the assay methodology.
- Search for additional cohorts to evaluate associations with waterborne exposures is underway.

2. Characterizing Waterborne Disease through Outbreak Surveillance

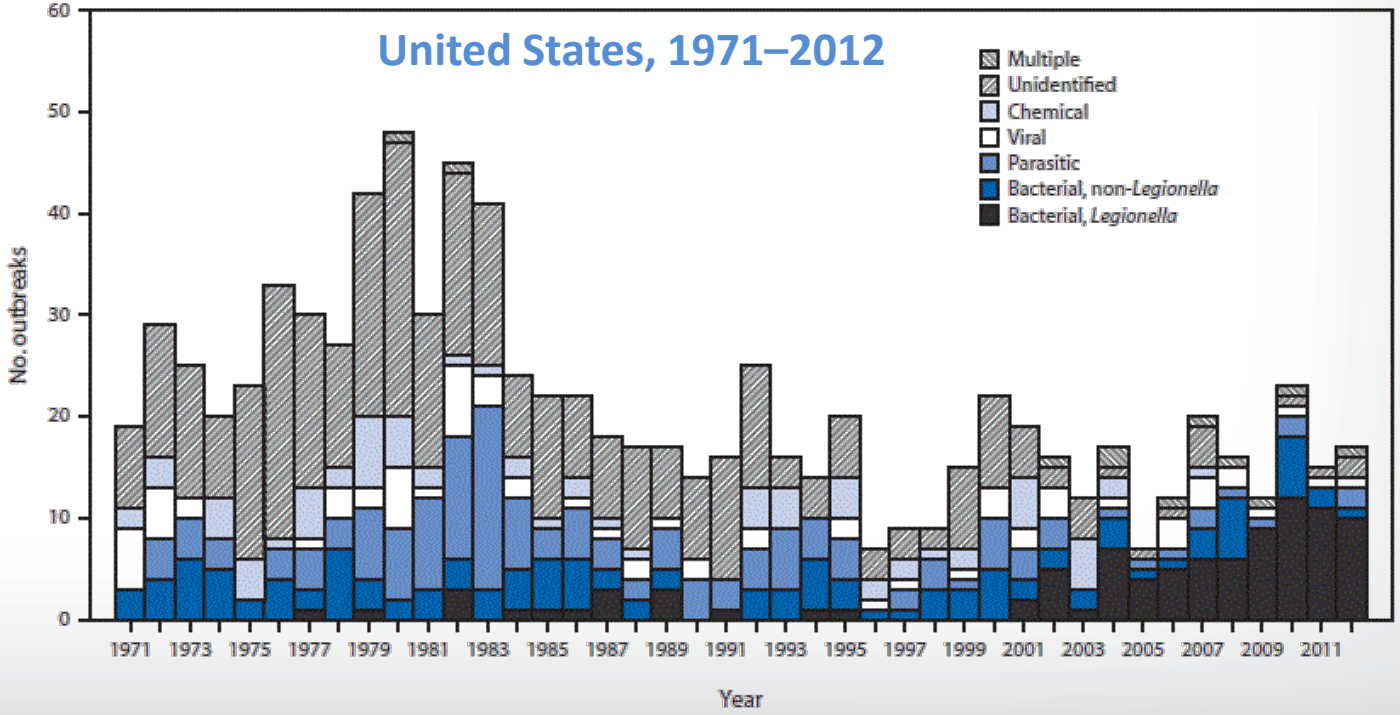
Water Systems

FY16 Key Activities/Products/Impacts

- Currently working with Centers for Disease Control and Prevention to summarize 2013-2014 waterborne disease outbreaks (On track for publication in FY 2017).

- Past reports have contributed to OW's regulatory activities related to emerging waterborne contaminants, such as *Legionella*.

Etiology of 885 drinking water–associated outbreaks, by year United States, 1971–2012



3. Waterborne Disease Associated with Distribution System Deficiencies

Water Systems

FY16 Key Activities/Products/Impacts

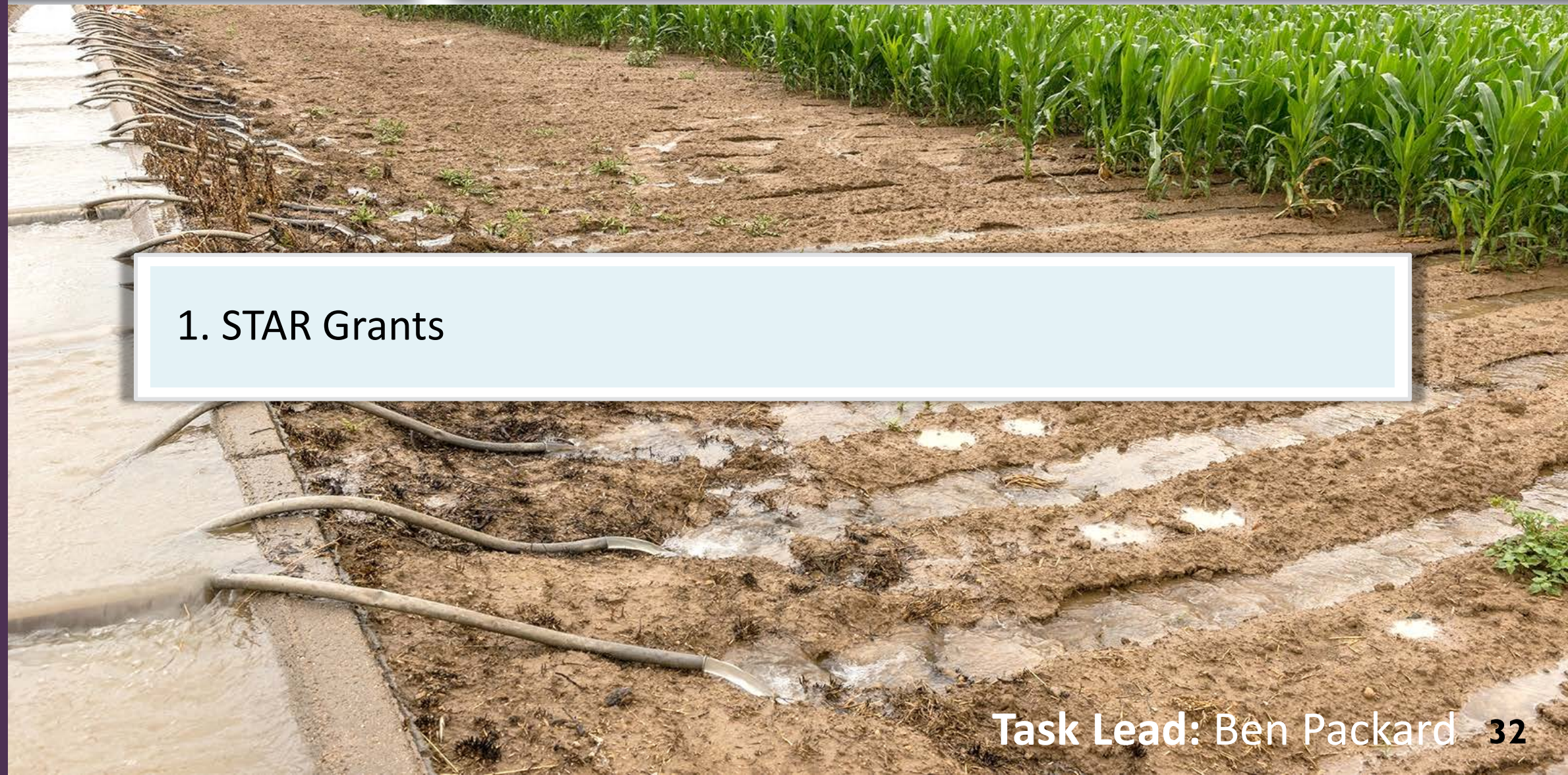
❖**Product on track**

- Identified sources of data: type I diabetes mellitus, waterborne disease and distribution deficiency data.
- Developing Interagency Agreement with CDC to enhance study of health effects associated with low pressure events, repairs and breaks.

- Will provide information for OW and Regions to assess health impacts associated with aging infrastructure.

Task 3F - Human & Ecological Health Impacts Associated with Water Reuse & Conservation Practices

Water Systems



1. STAR Grants

Task Lead: Ben Packard

1. STAR Grants

FY16 Key Activities/Products/Impacts

- Grants will evaluate water conservation practices that promote reuse such as aquafer recharge, potable reuse, and agricultural reuse.
- Grants are in Year 1 (awarded Fall 2015)
- Grant Kickoff meeting scheduled for October 26-27 in Washington D.C.
- Daniel Gerrity – University of Nevada - Las Vegas
- Early Career Award: *Framework for Quantifying Microbial Risk and Sustainability of Potable Reuse Systems in the United States*
- Ryan Dupont – Utah State University: *Assessment of Stormwater Harvesting via Managed Aquifer Recharge to Develop New Water Supplies in the Arid West: the Salt Lake Valley Example*

1. STAR Grants

FY16 Key Activities/Products/Impacts

- Amit Pramanik – WE&RF
  - *Improving Water Reuse for a Much Healthier Potomac Watershed*
- Helen Nguyen – University of Illinois at Urbana-Champaign
  - *Enabling Adaptive UV and Solar-Based Disinfection Systems to Reduce the Persistence of Viral Pathogens in Wastewater for Sustainable Reuse*
- Jay Gan – University of California - Riverside
  - *Reclaimed Water Irrigation: Plant Accumulation and Risks of Contaminants of Emerging Concern (CECs).*

Project Summary

Task 3A-RW	• Toolkit for transformative water systems • Metrics (e.g. log reduction targets for non-potable reuse, LCAs) • Conventional vs. transformative water systems
Task 3B-Monitoring and Analytical Methods	• Proof-of-concept/Identification of potential technologies • Sensor challenge-detect contaminants that trigger adverse outcomes (e.g. cell-based sensors used for screening)
Task 3C-Treatment	• Decentralized reuse • Non-potable reuse • Integrated approaches for sustainable water management • WTIC-Innovative Technologies
Task 3D-Health Effects	• Waterborne pathogens as triggers for Type 1 diabetes • Outbreak surveillance • Diseases associated with distribution systems