Emerging Water Reuse Frameworks for Military Sustainment and Resiliency

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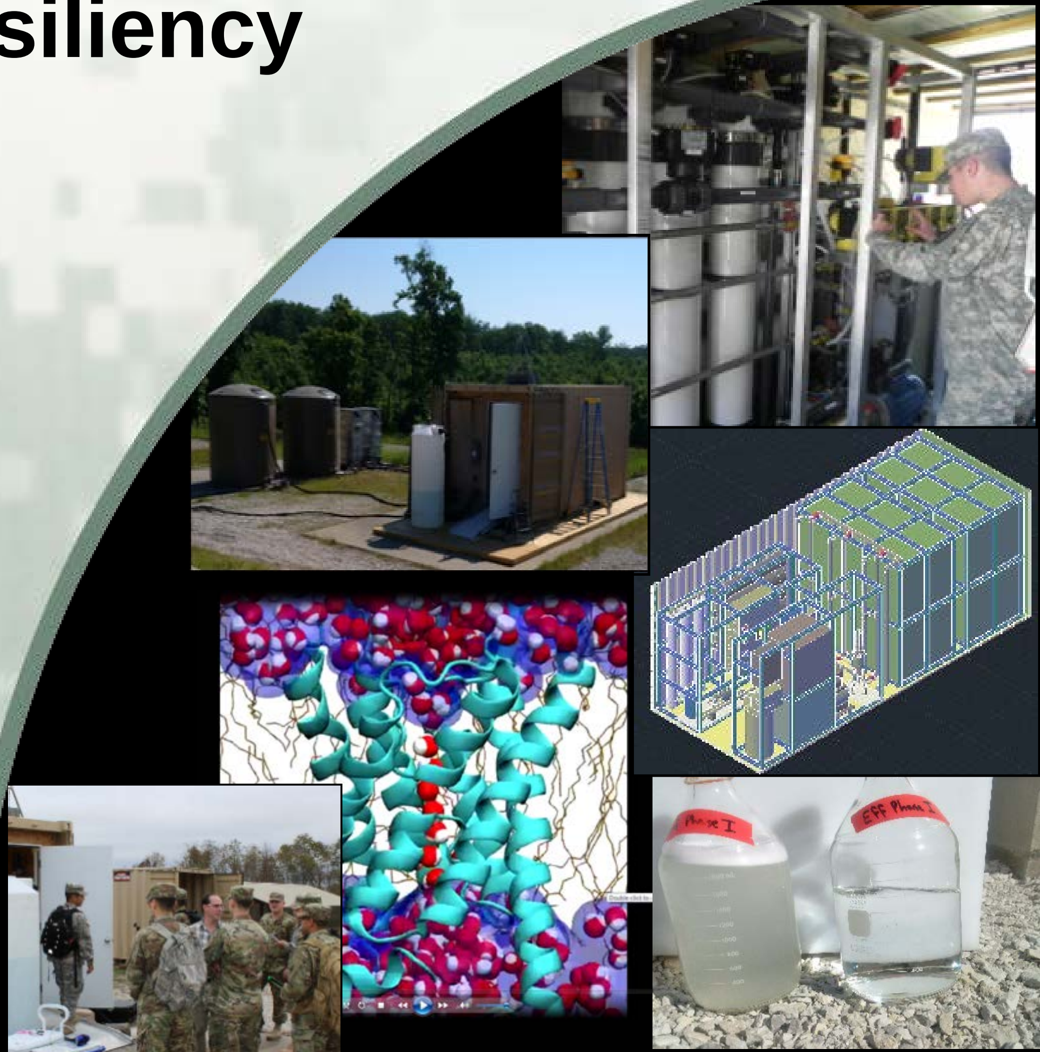


U.S.ARMY

US Army Corps of Engineers

ERDC Engineer Research and Development Center

Key Collaborators

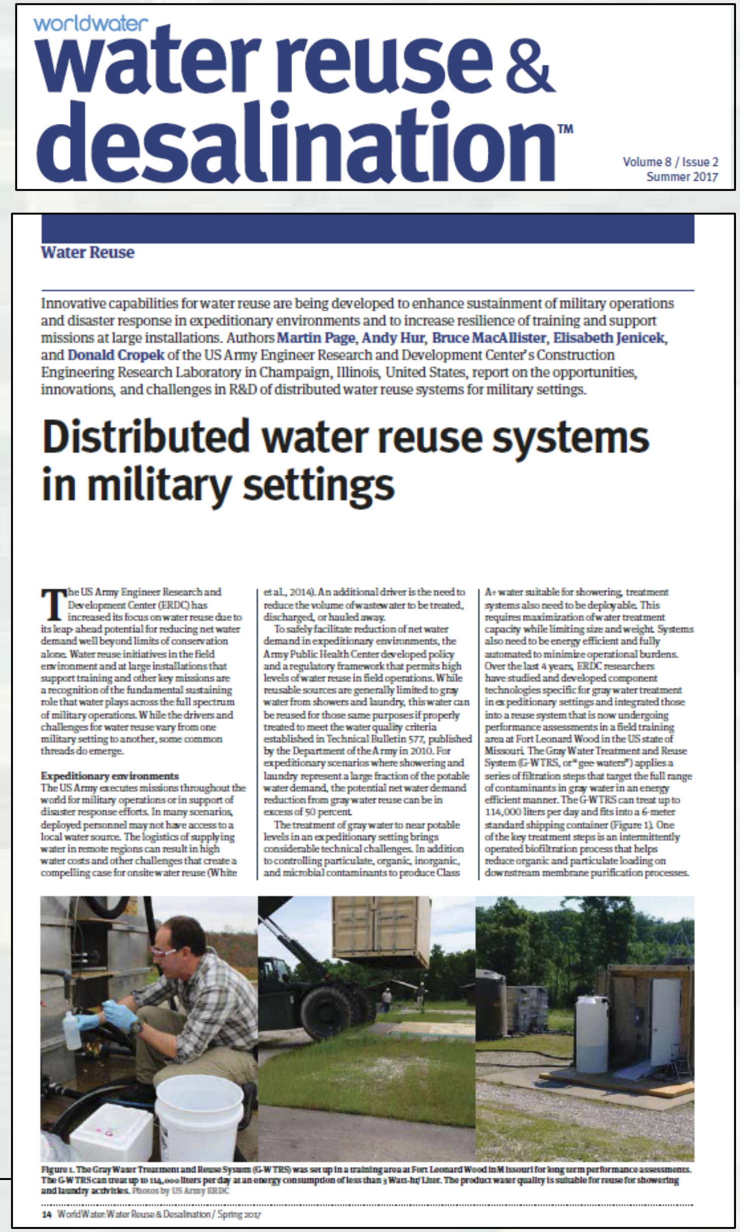
- ***Engineer Research and Development Center***
  - *Diana Kapanzhi, Bruce MacAllister, Ashley Boyd, and Dr. Chris Griggs (Gray Water Reuse); Dr. Kathryn Guy (Wastewater Treatment)*
  - *Dr. Don Cropek (Direct Potable Reuse)*
  - *Mr. Andy Hur (Life Cycle Cost Analysis)*
- ***Highland Engineering***
  - *John Boland, Engineer (Gray Water Pilot Controls)*
- ***GE Global Research and Suez***
  - *Paul Bandstra, Global Water Pilot Lead*
  - *Dr. David Moore, Materials R&D Lead*
- ***University of Illinois at Urbana Champaign***
  - *Dr. Michael Plewa (Toxicity Analysis)*

Water Reuse in Military Settings

- ***Challenges***
  - Water is often not readily available in field security or disaster response operations.
  - Water supply and wastewater treatment can be burdensome in field training areas as well.
  - At large permanent facilities, the Army alone uses about 45 billion gallons (175 Mm^3)of water per year.
- ***Opportunities***
  - Water reuse technologies to reduce net demand
  - Army policy and regulations allow for shower, laundry, latrine reuse in field settings.
  - Resiliency and emergency operations policies that promote water sustainment have been adopted at permanent facilities.

Distributed Water Reuse Systems

- ***Constraints/Challenges***
  - *Field settings:* Mobility; Climate
  - *Facility settings:* Cost; Infrastructure modifications
  - *All settings:* Training, Automation, Social, Regulatory, Cross-contamination
- ***Frameworks and Maturity***
  - Shower and laundry reuse in field settings (Prototypes available)
  - Direct potable reuse in field settings and fixed facilities (Under investigation)



worldwater
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Water Reuse

Innovative capabilities for water reuse are being developed to enhance sustainment of military operations and disaster response in expeditionary environments and to increase resilience of training and support missions at large installations. Authors **Martin Page**, **Andy Hur**, **Bruce MacAllister**, **Elisabeth Jenicek**, and **Donald Cropek** of the US Army Engineer Research and Development Center's Construction Engineering Research Laboratory in Champaign, Illinois, United States, report on the opportunities, innovations, and challenges in R&D of distributed water reuse systems for military settings.

Distributed water reuse systems in military settings

The US Army Engineer Research and Development Center (ERDC) has increased its focus on water reuse due to its leap-ahead potential for reducing net water demand well beyond limits of conservation alone. Water reuse initiatives in the field environment and at large installations that support training and other key missions are a recognition of the fundamental sustaining role that water plays across the full spectrum of military operations. While the drivers and challenges for water reuse vary from one military setting to another, some common threads do emerge.

Expeditionary environments

The US Army executes missions throughout the world for military operations or in support of disaster response efforts. In many scenarios, deployed personnel may not have access to a local water source. The logistics of supplying water in remote regions can result in high water costs and other challenges that create a compelling case for onsite water reuse (White et al., 2014). An additional driver is the need to reduce the volume of wastewater to be treated, discharged, or hauled away.

To safely facilitate reduction of net water demand in expeditionary environments, the Army Public Health Center developed policy and a regulatory framework that permits high levels of water reuse in field operations. While reusable sources are generally limited to gray water from showers and laundry, this water can be reused for those same purposes if properly treated to meet the water quality criteria established in Technical Bulletin 577, published by the Department of the Army in 2010. For expeditionary scenarios where showering and laundry represent a large fraction of the potable water demand, the potential net water demand reduction from gray water reuse can be in excess of 50 percent.

The treatment of gray water to near potable levels in an expeditionary setting brings considerable technical challenges. In addition to controlling particulate, organic, inorganic, and microbial contaminants to produce Class A+ water suitable for showering, treatment systems also need to be deployable. This requires maximization of water treatment capacity while limiting size and weight. Systems also need to be energy efficient and fully automated to minimize operational burdens. Over the last 4 years, ERDC researchers have studied and developed component technologies specific for gray water treatment in expeditionary settings and integrated those into a reuse system that is now undergoing performance assessments in a field training area at Fort Leonard Wood in the US state of Missouri. The Gray Water Treatment and Reuse System (G-WTRS, or "gee-waters") applies a series of filtration steps that target the full range of contaminants in gray water in an energy efficient manner. The G-WTRS can treat up to 114,000 liters per day and fits into a 6-meter standard shipping container (Figure 1). One of the key treatment steps is an intermittently operated biofiltration process that helps reduce organic and particulate loading on downstream membrane purification processes.

Figure 1. The Gray Water Treatment and Reuse System (G-WTRS) was set up in a training area at Fort Leonard Wood in Missouri for long term performance assessments. The G-WTRS can treat up to 114,000 liters per day at an energy consumption of less than 3 Watt-hr/Liter. The product water quality is suitable for reuse for showering and laundry activities. Photos by US Army ERDC

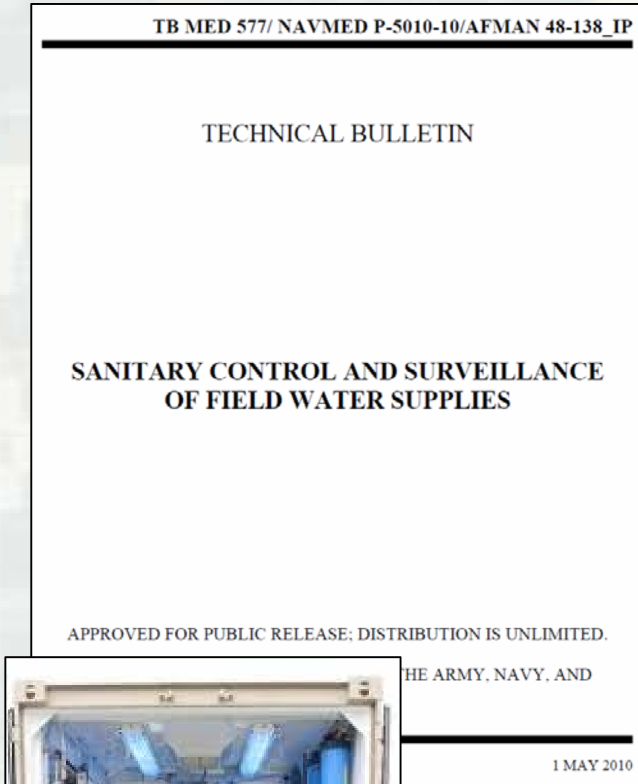
14 WorldWater: Water Reuse & Desalination / Spring 2017

TBMED 577, Chapter 9

Current Standards for Shower Water Recycling

1. Gray water source, no black water.
2. Non-potable use only.
3. Criteria:

Parameter	Metric
pH	5-9
Turbidity	< 1 NTU
Hardness	< 500 mg/L
TDS	< 1500 mg/L
Coliforms	Absent
Free chlorine residual	1-4 mg/L after 30 min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TECHNICAL BULLETIN

SANITARY CONTROL AND SURVEILLANCE OF FIELD WATER SUPPLIES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

HE ARMY, NAVY, AND

1 MAY 2010

Treatment Guidance

1. Best practical physical/chemical treatment processes that might include coagulation, sedimentation, filtration, activated carbon, and reverse osmosis treatment.
2. Primary and residual disinfection is required in all cases.

Army Force Provider Shower Water Recycling System (SWRS)

Reverse osmosis treatment is generally practiced.

ERDC

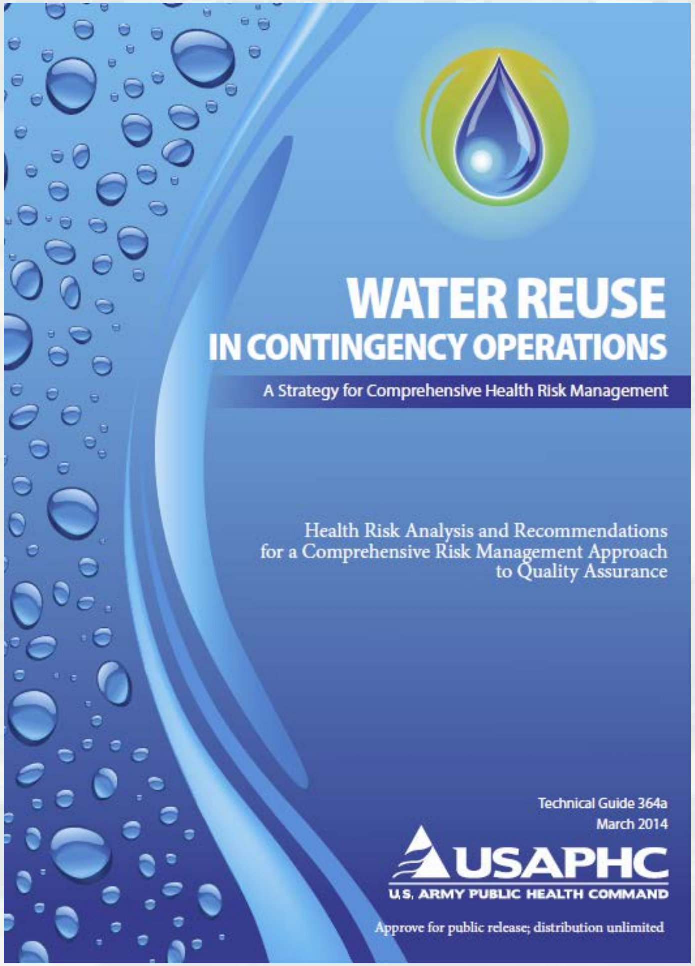
Strategy for Water Reuse Risk Management

Key Assumptions (summarized)

1. Best practices will be established in larger camps and pushed forward over time.
2. No natural buffers will be used.
3. Users are primarily healthy, fit adults.
4. Exposure pathways can be tailored to military operating environment.
5. Civilian regulatory codes as guidelines for best practices.

Limitations

1. No potable reuse, though high contact non-potable reuse such as showering allowed.
2. Health-based risks only (does not cover environmental)



Microbial Risk Assessment PHIP 39-01-0514

Table 21. Field Wastewater Unrestricted Risk-Based Concentrations

Daily Gastrointestinal Illness Rate[b] (Portion of showering population experiencing GI symptoms due to exposure to shower water)	Units[c]	*Escherichia coli* Water Concentration[a]				Confidence
		Two showers per day	One shower per day	One shower every 2 days (shower every other day)	One shower per week	
		Alternative A	Baseline	Alternative B	Alternative C	
1 in 100	CFU / 100 mL	5	10	30	100	
	CFU / 1 liter	50	100	300	1,000	
	CFU / 10 liters	500	1,000	3,000	10,000	
1 in 1,000	CFU / 100 mL	N/A[d]	1	3	10	
	CFU / 1 liter	5	10	30	100	Moderate
	CFU / 10 liters	50	100	300	1,000	
1 in 10,000	CFU / 100 mL	N/A[d]	N/A[d]	N/A[d]	1	
	CFU / 1 liter	N/A[d]	1	3	10	
	CFU / 10 liters	5	10	30	100	

Notes:
[a]Concentrations are rounded to one significant figure. See paragraphs 7.4.2, 7.5.1, 7.5.2, and 7.5.3 for the unrounded concentrations.
[b]Daly GI illness rate in the population. See appendix C for yearly risk analysis.
[c]Convention in water monitoring is to report microbial content in CFU per 100 mL of water. CFU per 1 liter and 10 liters are reported to show concentrations that are less than 1 CFU/100 mL.
[d] Not applicable, concentrations whose volumes lead to fractional CFU. A larger sampling volume results in a whole number CFU per volume concentration.

"This microbial risk assessment evaluates health risks associated with wastewater reuse in a deployment setting. It provides risk-based water concentrations (RBWCs) for treated wastewater unrestricted reuse scenarios. This document only provides RBWCs for *Escherichia coli*."

Microbial Risk Assessment for Unrestricted Wastewater Reuse During Army Deployments

Approved for public release, distribution unlimited

PHIP No. 39-01-0514

General Medicine: 500A

May 2014

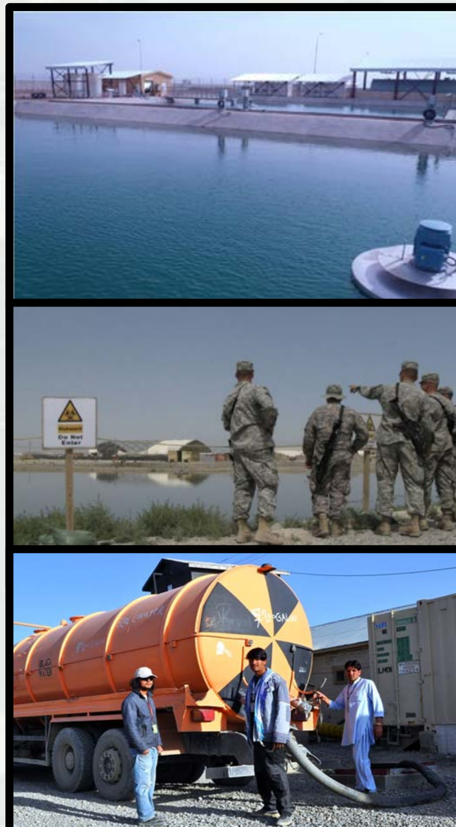
USAPHC

Conventional Field Framework

- Supply, Use Once, and Dispose (no reuse)

Supply*: 151 L/day (40 gpd) per Soldier

Use: 151 L/day (40 gpd) per Soldier



Waste: 151 L/day (40 gpd) per Soldier

*Water demand ranges from 30-40 gpd (114-151 Lpd) at expeditionary camps that provide hygiene, medical, and dining support capabilities.

Near Term Field Framework

- Gray Water Reuse and On-site Wastewater Treatment

Supply:
49 L/day
(13 gpd) per
Soldier

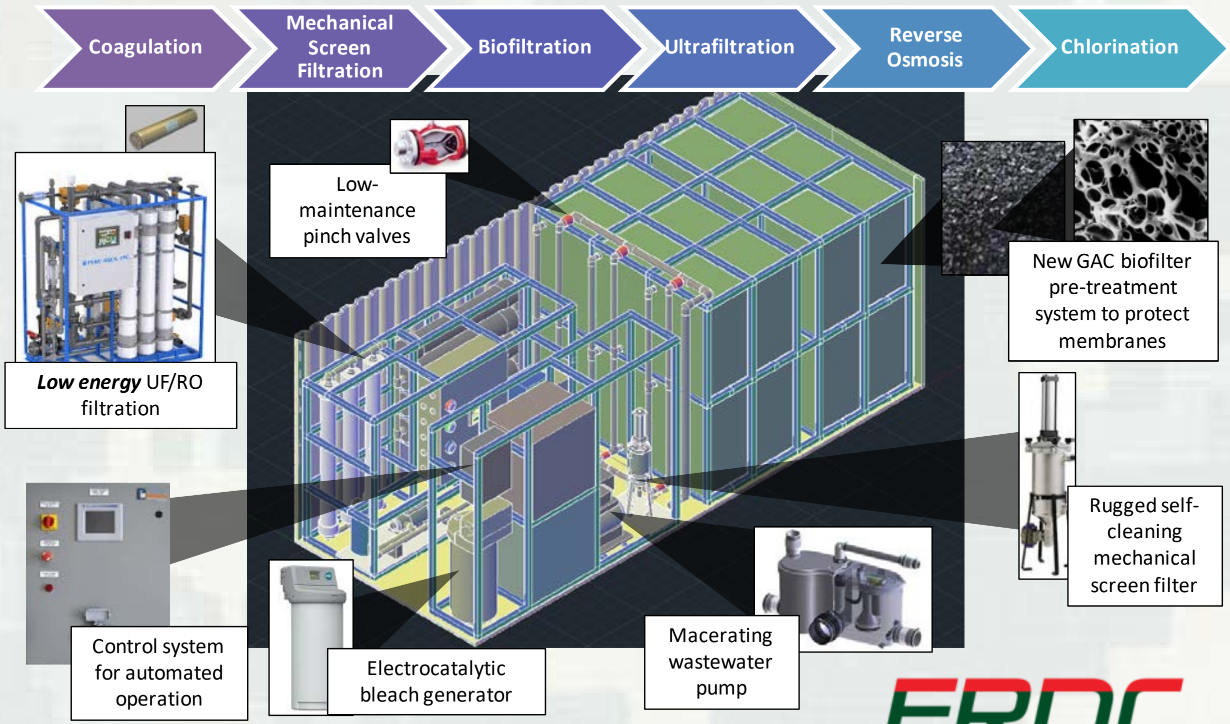
Use: 26 L/day (7 gpd) per Soldier

Use: 23 L/day (6 gpd) per Soldier
Reuse: 102 L/day (27 gpd) per Soldier

Waste:
49 L/day
(13 gpd) per
Soldier

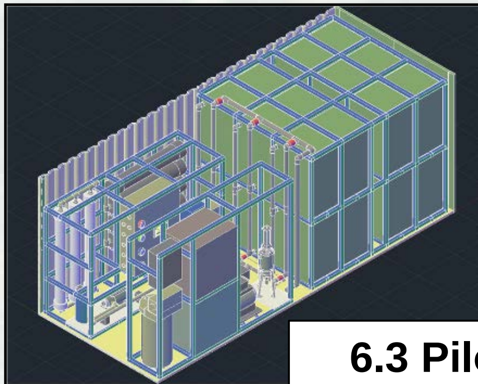
G-WTRS: Gray Water Treatment and Reuse System

- ***Objective.*** *Design, assemble, and evaluate a robust, operationally-efficient gray water reuse system that can reduce water demand for expeditionary environments.*
- ***Capability.*** The G-WTRS provides a 65% reduction in the base water supply by treating gray water from showers and laundry systems with 90% recovery for reuse.
- ***Benefit.*** The G-WTRS will reduce logistics and has an estimated payback period of 3 months.



ERDC

G-WTRS Development

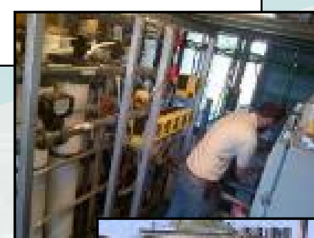


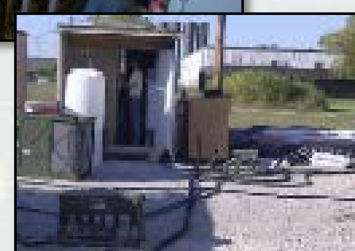
6.2 Bench Studies

- Patent-pending biofiltration pretreatment system
- Low energy reverse osmosis membranes and design
- FY13-14

6.3 Pilot Integration

- 80% water recovery
- < 10 Wh/gal
- Synthetic gray water → potable water quality
- TTA PdM-PAWS
- FY15-16

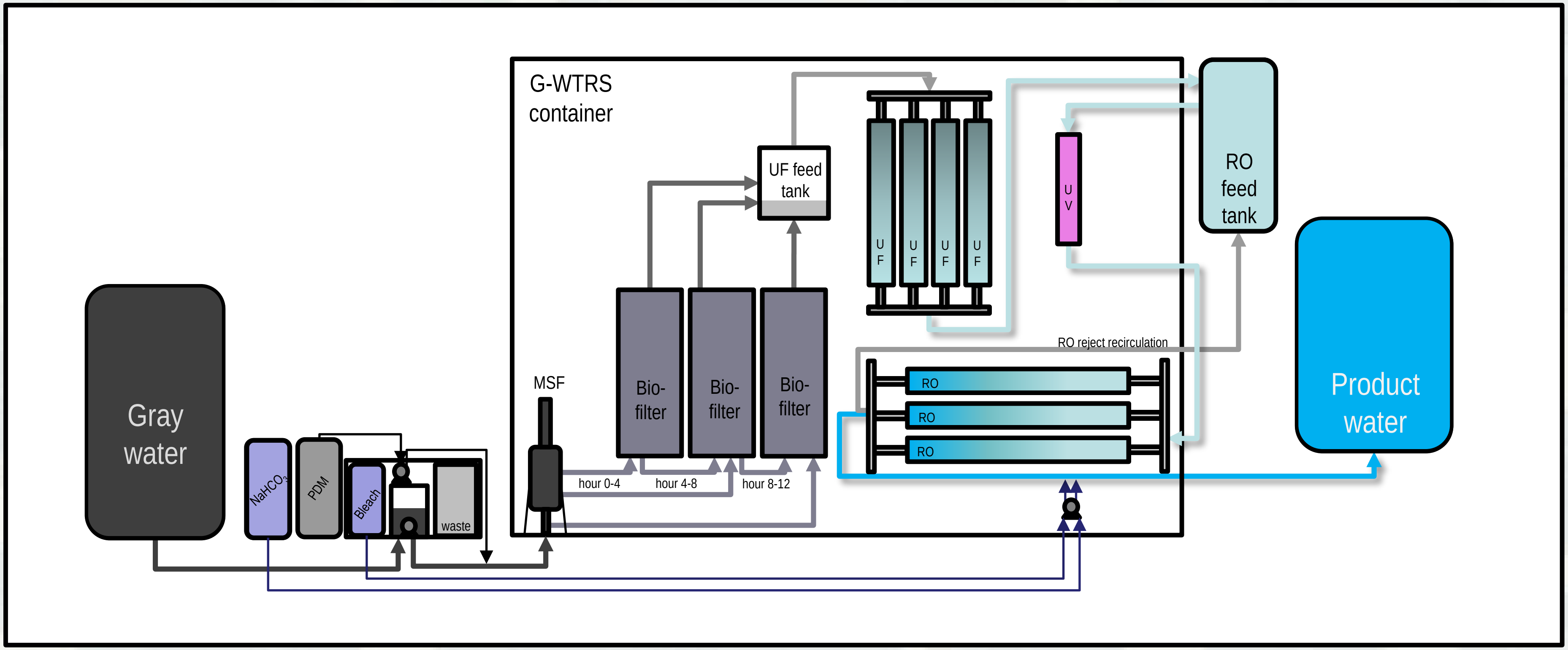




6.4 Field Assessments

- Long term performance in operational training area at Fort Leonard Wood
- Potable water quality
- FY17-19

G-WTRS Treatment Process Train



BUILDING STRONG®

Innovative solutions for a safer, better world

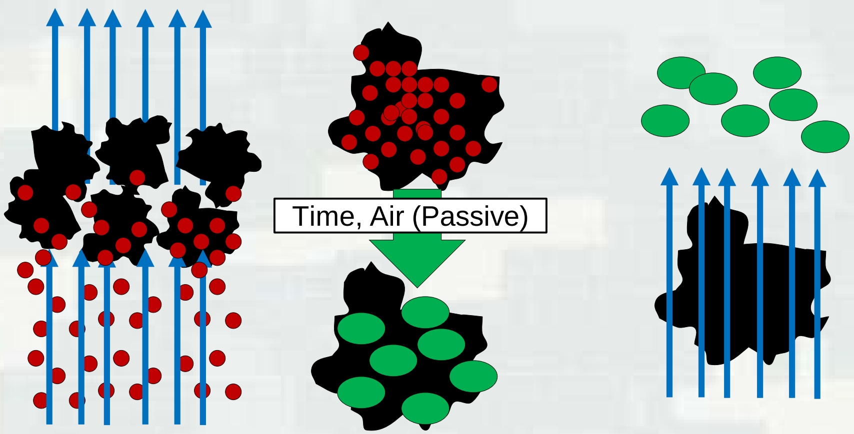
Intermittently-Operated Biologically Activated Carbon (IOBAC) Filtration

Cycling of adsorption and passive aerobic biodegradation has capability to remove high levels of organics

Step 1: Upflow GAC adsorption

Step 2: Drain filter and grow biomass, regenerating sites.

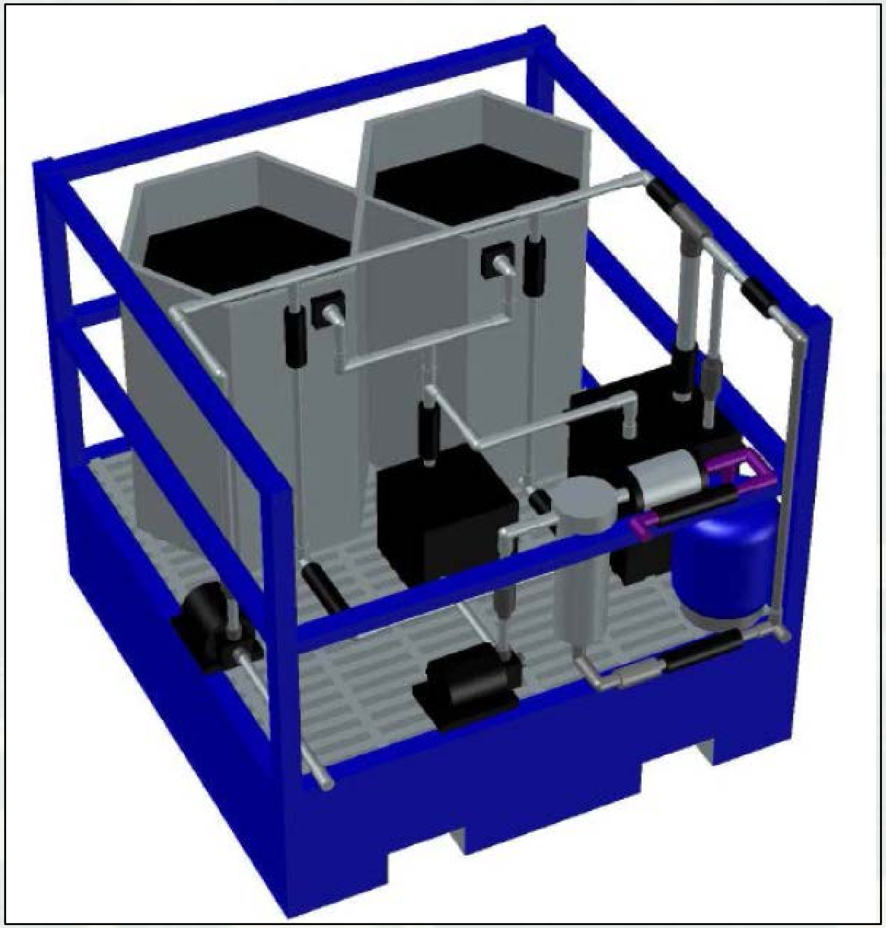
Step 3: Remove biomass & go back to Step 1.



Adsorb & Biodegrade

Bioregenerate

Wash/Scour



IOBAC Performance: Municipal Wastewater

Bioregen Temp	% COD Removal	Effluent COD Values
10°C	45-53%	70-85 mg/L
28°C	60-70%	52-61 mg/L

Notes:

- ***4-week continuous challenge test at 10°C***
- Influent COD was low (< 200 mg/L)
- Fraction COD removal similar to synthetic wastewater tests
- Performance will improve with greater bed depth

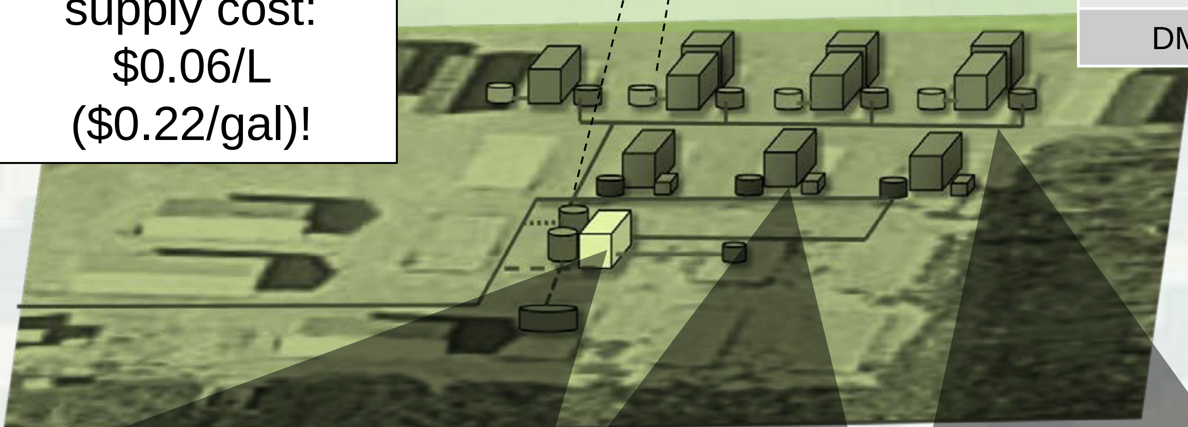
CBITEC Water Sustainment Test Bed

Real Time Monitoring

202 Goal: Integrate and demonstrate systems with capability for 90% reduction of net water demand in expeditionary settings.

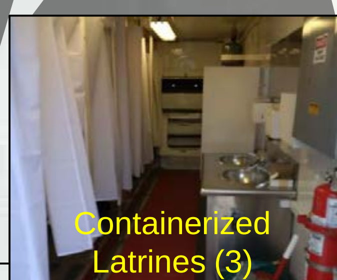
Current water supply cost: $0.06/L ($0.22/gal)!

Ongoing Demonstrations	FY 16	FY 17	FY 18	FY 19
Gray Water Reuse	***NDCEE funded***			
Shower Water Heat Recovery				
DMMS Water Metering				



Unique Site Capabilities:

1. Real gray and wastewater from > 300 personnel in training environment for system assessments
2. Continuous challenge test loop with synthetic gray/wastewater makeup capability to add load
3. Hot/cold climate testing (0-100ºF)
4. Approved leech field for local discharge
5. Generator power and DMMS integration



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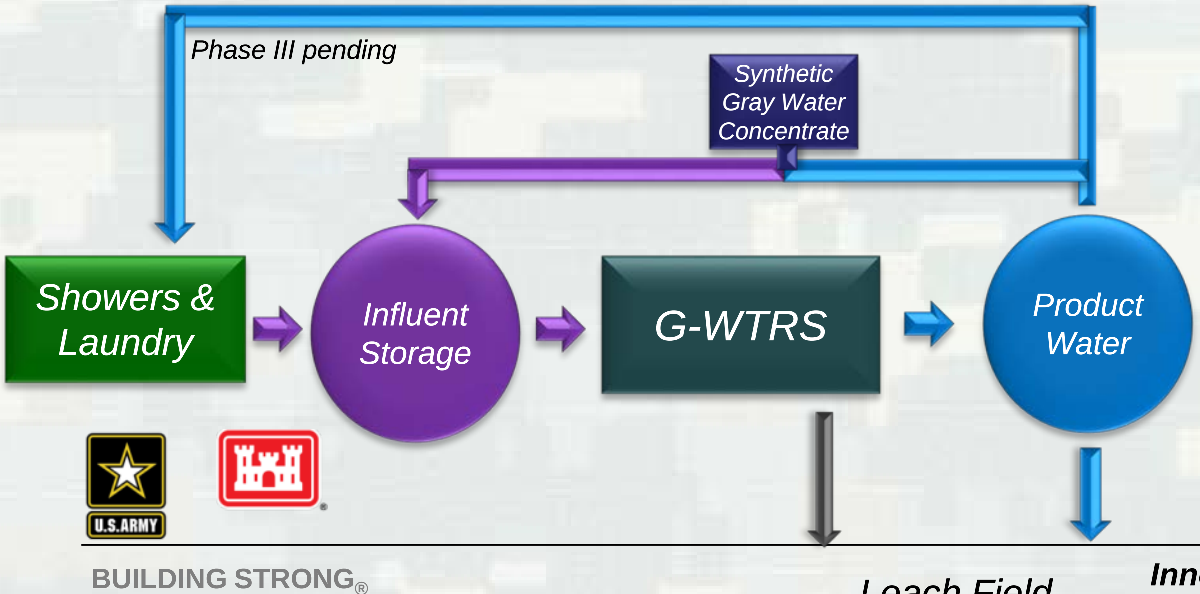
G-WTRS Validation Approach and Test Bed Setup

Phase I- Synthetic challenge with modified NSF 350 gray water at pilot scale (7500 gpd, 1 month).

Added: DEET, Permethrin, Sunscreen, Motor Oil, MS2 phage and F-pilus^{-} *E. coli*.

Phase II- Continuous flow challenge with Soldier-generated gray water plus recirculated product water spiked with modified NSF 350 concentrate formula (15,000 gpd, 3 months).

Phase III- Continuous flow challenge with Soldier-generated gray water and on-site reuse (7,500-15,000 gpd).

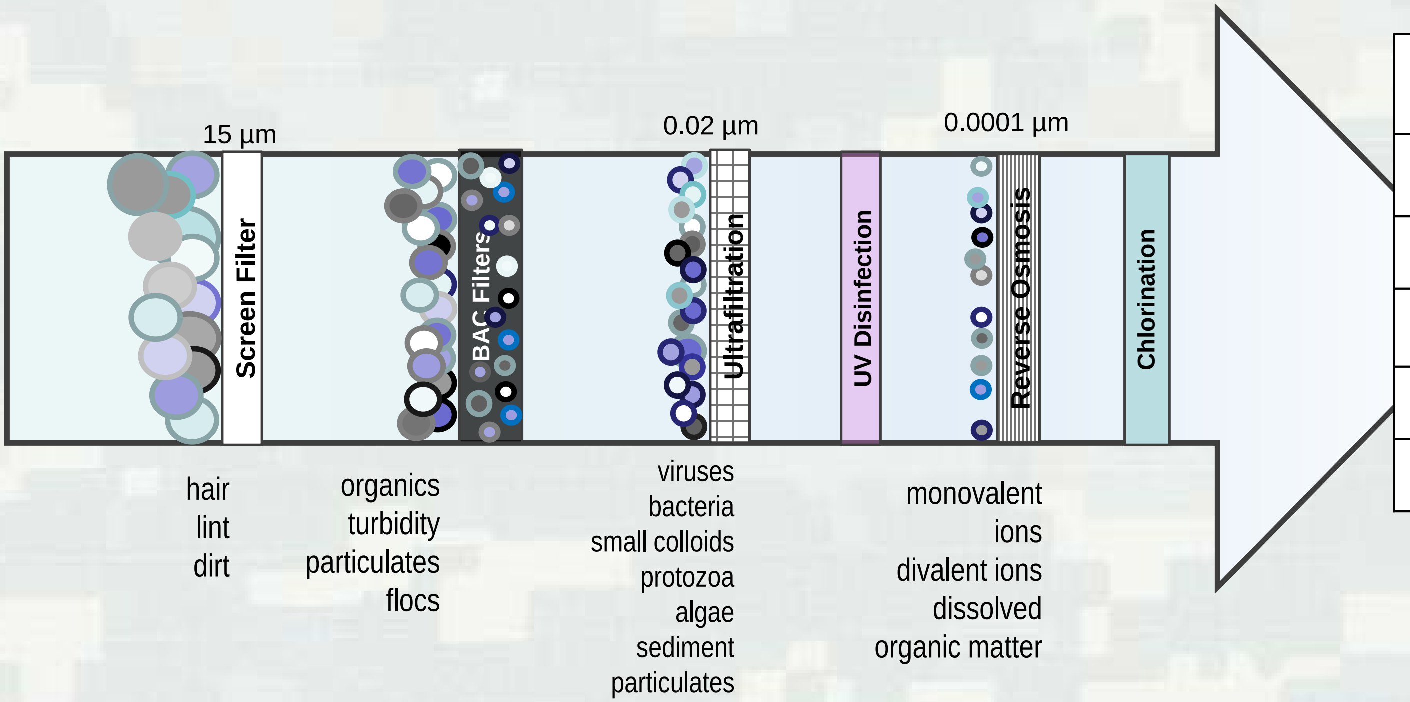


G-WTRS Field Water Treatment Performance Results:

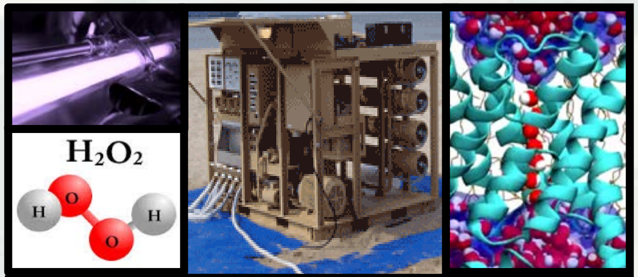
> 15 log removal of pathogen surrogates (99.9999999999999%)
> 99% removal of organics and particulates
> 99.9% removal of DEET; No detection of other micropollutants

Over 300 contaminants monitored during testing

Program Metric	Measured/ Observed Value
Treatment Capacity	Up to 30,000 gpd achievable
Gray Water Recovery	Up to 90% demonstrated
Energy Usage	4-8 Wh/gal at >15000 gpd
O&M Requirements	10 min/day (average)
Water Quality	Exceeds Army and EPA potable standards



ALL H2O Future Field Capability

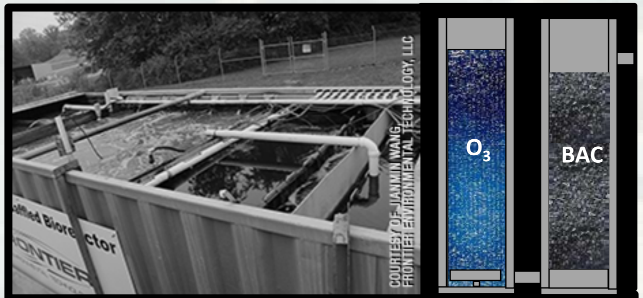


Advanced Water Purification

Potable Reuse: 26 L/day (7 gpd) per Soldier

Waste Heat Atmospheric Water Generator & Recovery

Class A and A[+] Reuse:
125 L/day (33 gpd) per Soldier



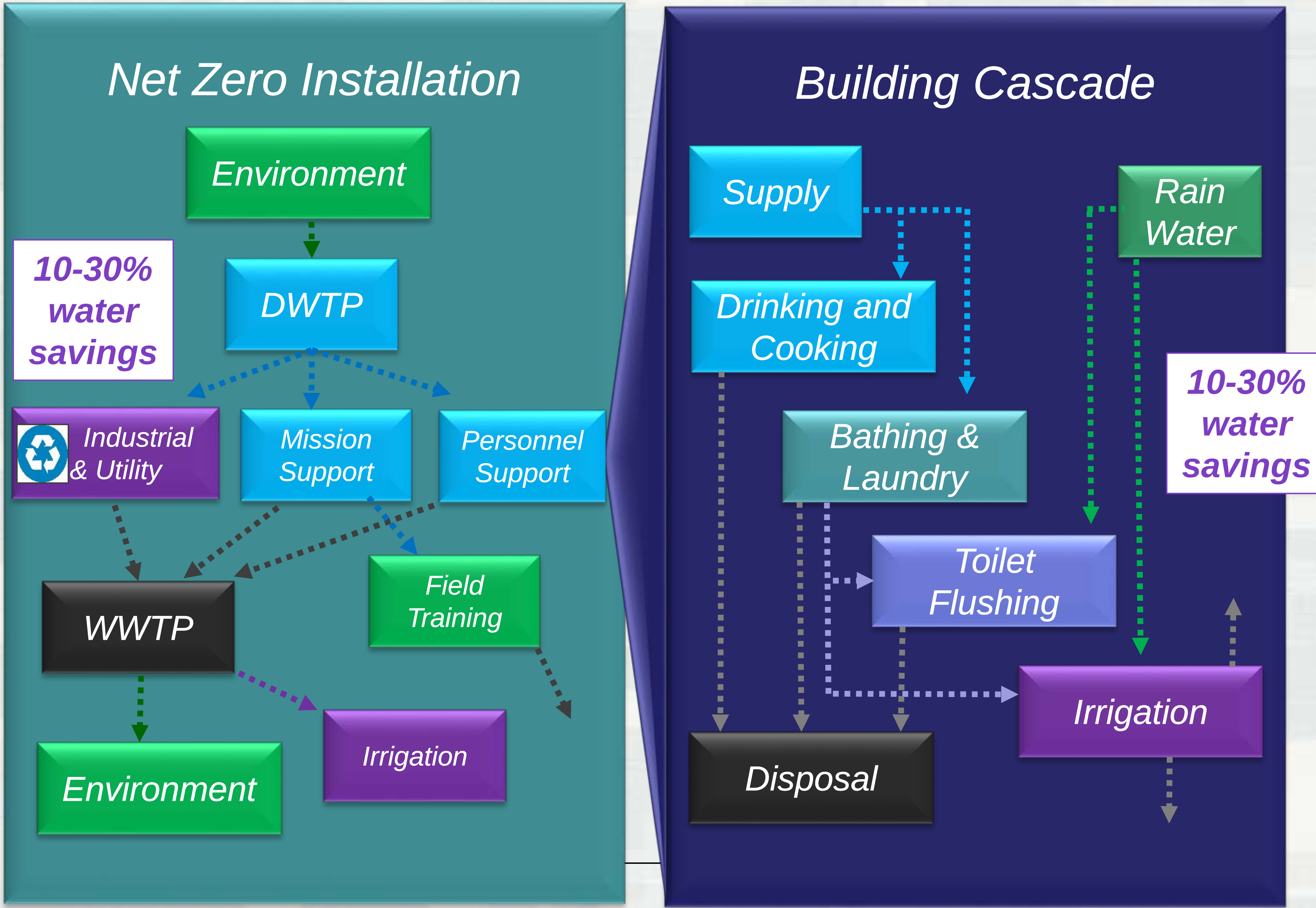
Advanced Wastewater Treatment

Note: Direct potable reuse is only being studied as a potential future capability. It is not currently approved by Army Public Health Center.

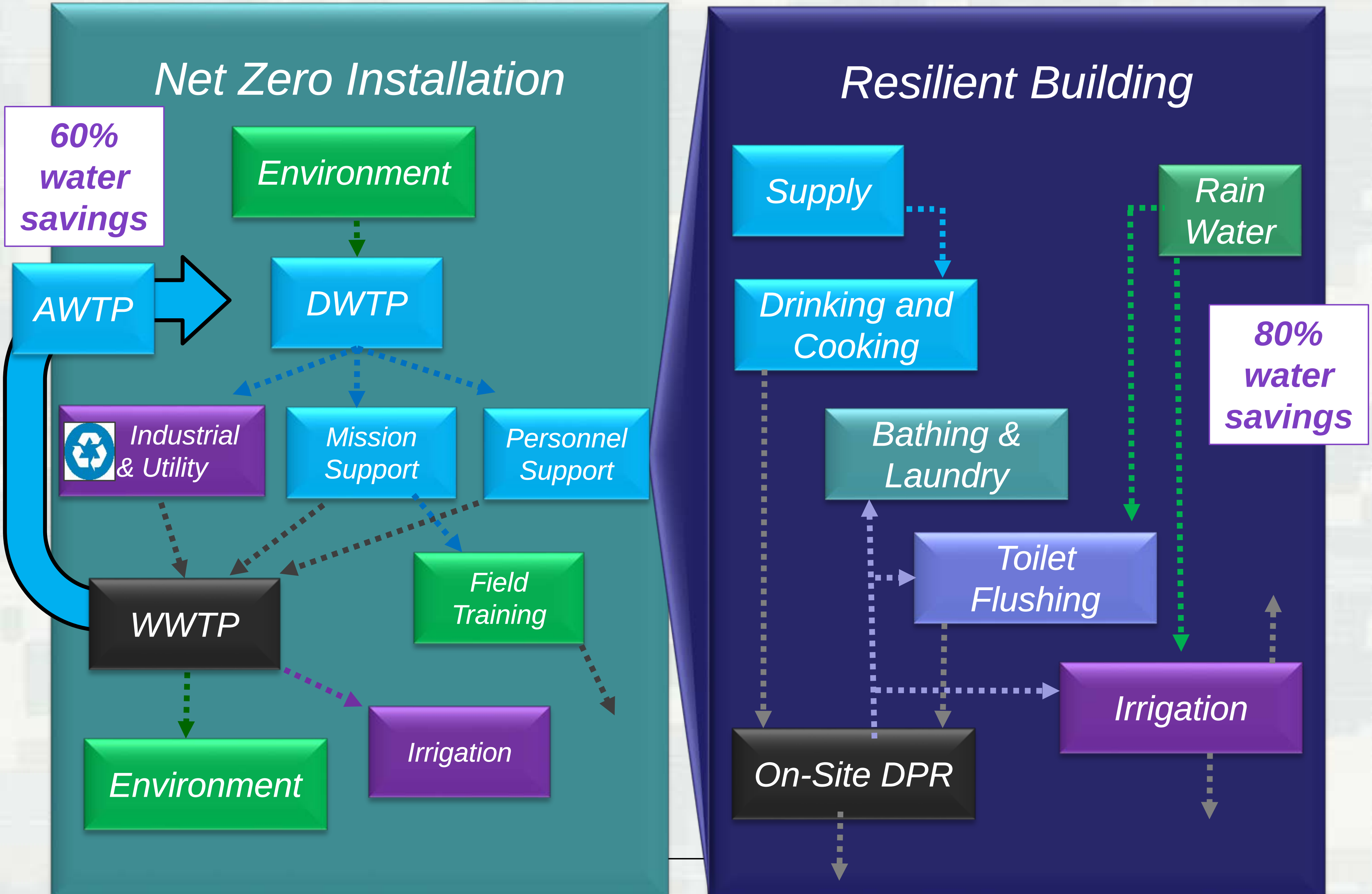
ERDC Water Engineering Testbed (ERDC-WET)

Assembly Ongoing

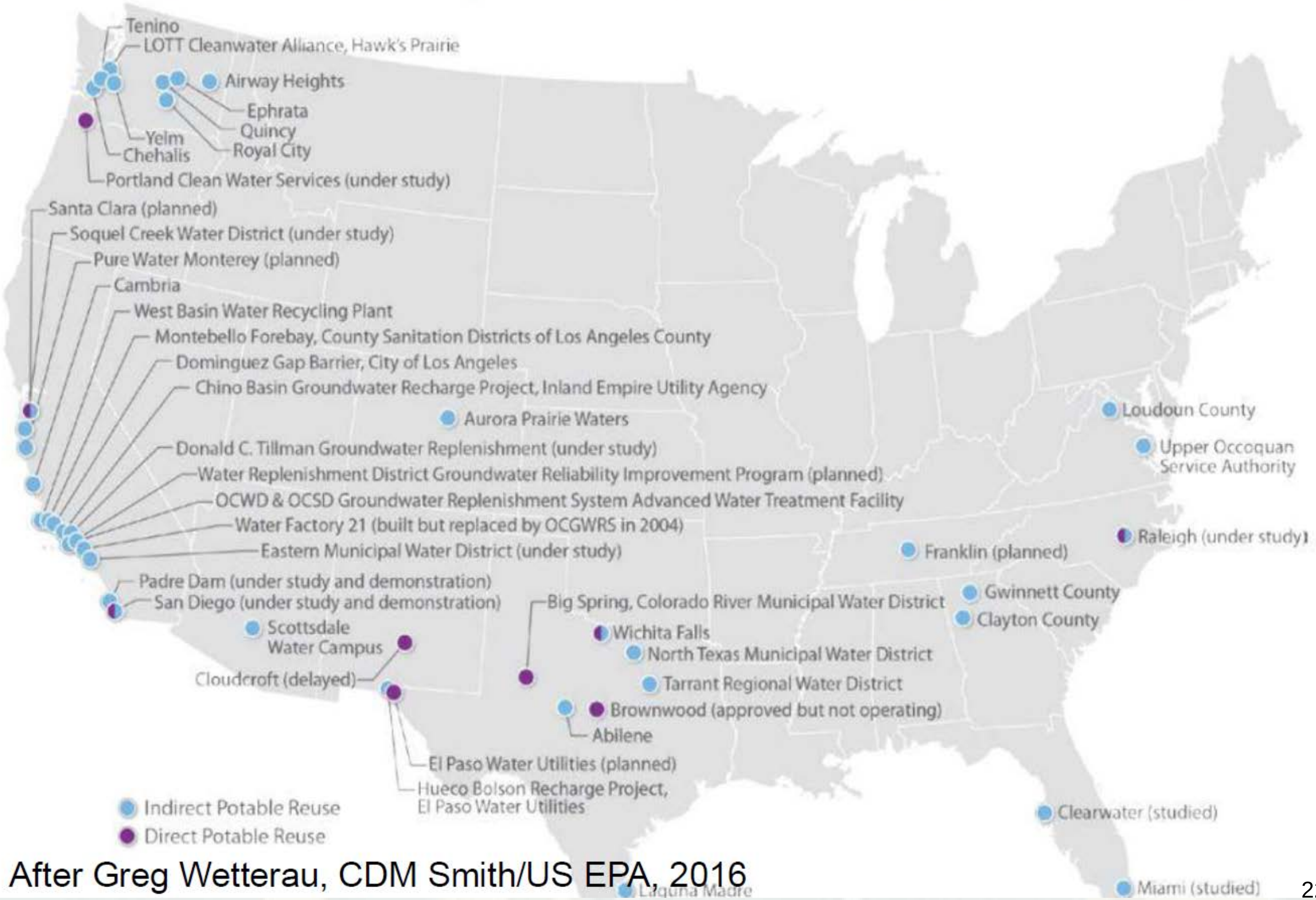
Current Installation Reuse Frameworks



Future Installation Reuse Frameworks



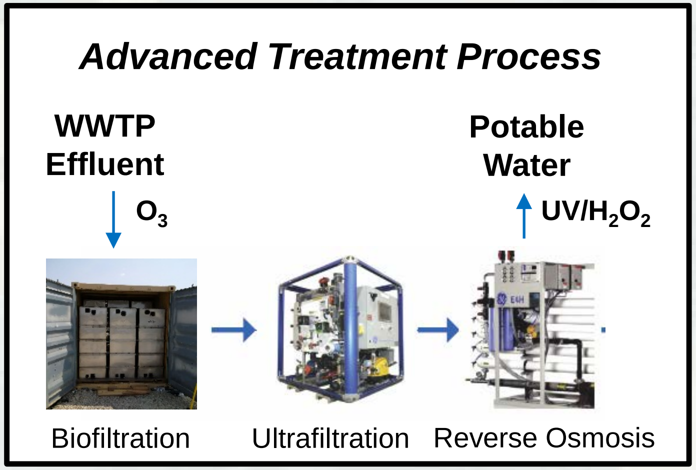
PLANNED potable reuse in U.S.



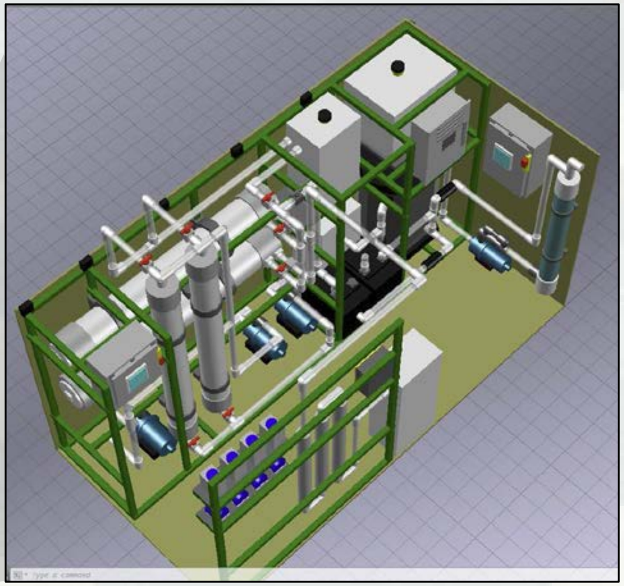
After Greg Wetterau, CDM Smith/US EPA, 2016

Direct Potable Reuse for Fixed Facilties

- **Issues**
  - Potential for unique contaminants or contaminant profiles
  - Advanced technologies need vetting
    - Contaminant permeation
    - Unknown trace hazardous byproducts and potential composite effects.
  - Small scale risk factors

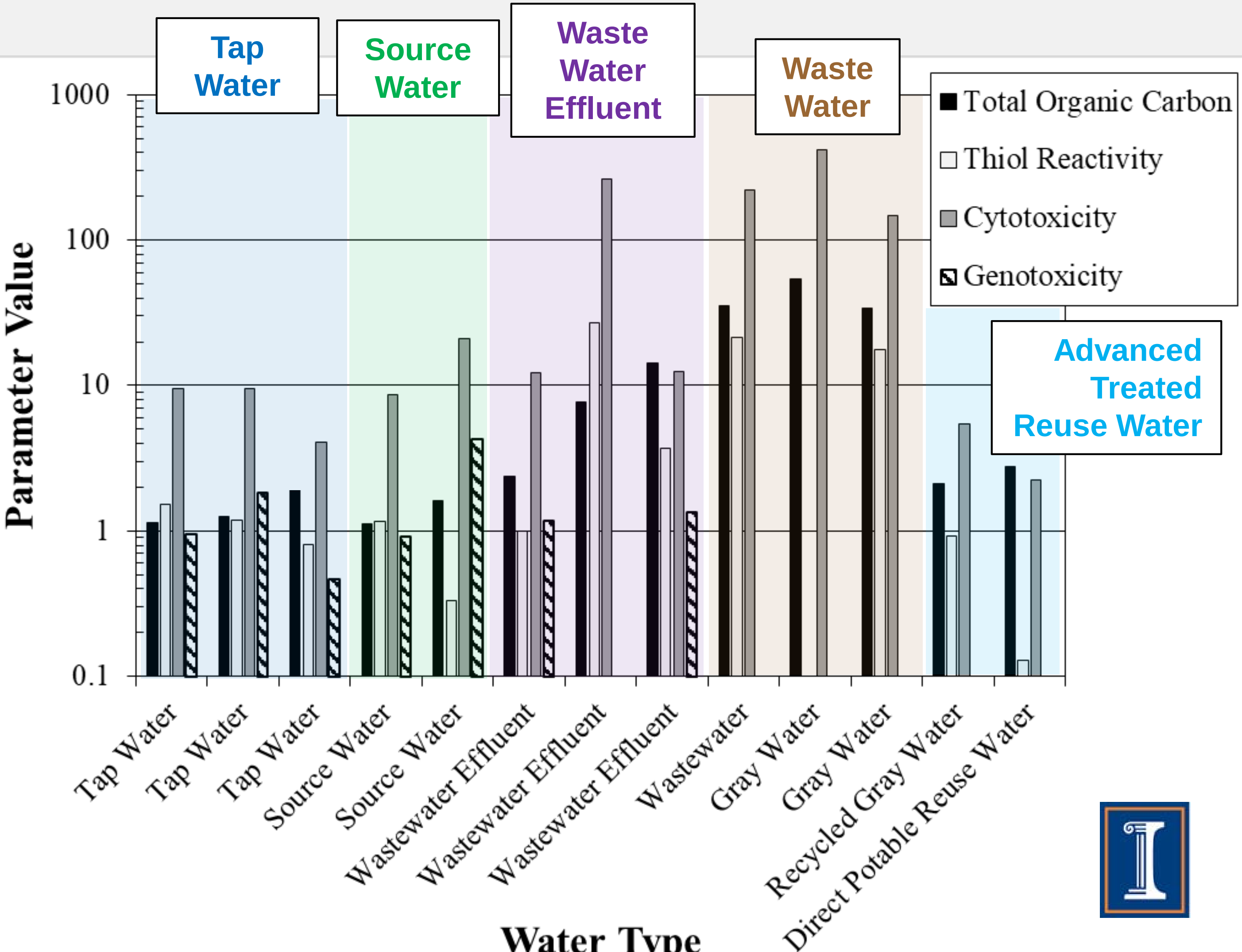


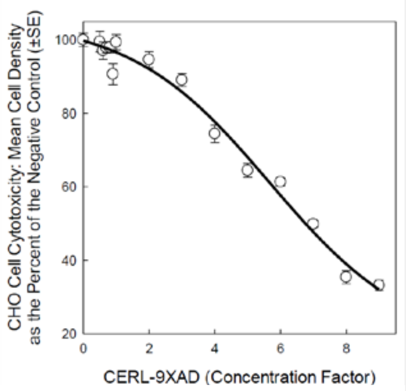
- **Ongoing R&D**
  - Pilot testing of advanced treatment processes for DPR
    - Assessing ultra low energy membranes.
  - Comparing water quality and composite toxicity of DPR system product water to current tap water at bases.



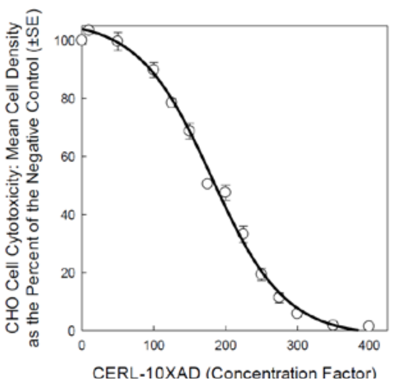
DPR Pilot Study Progress

- **Systems Evaluated**
  - G-WTRS; Tangent WaterCycle; Army Pilot Site samples





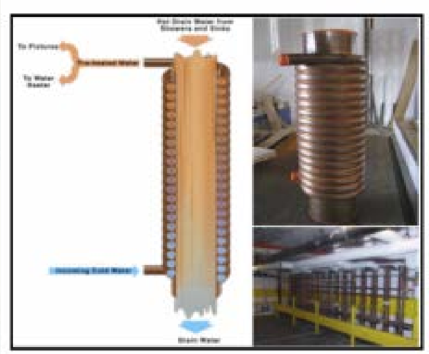
Gray water cytotoxicity



Recycled gray water cytotoxicity

Shower Water Recycling at Installations

Heat Exchanger



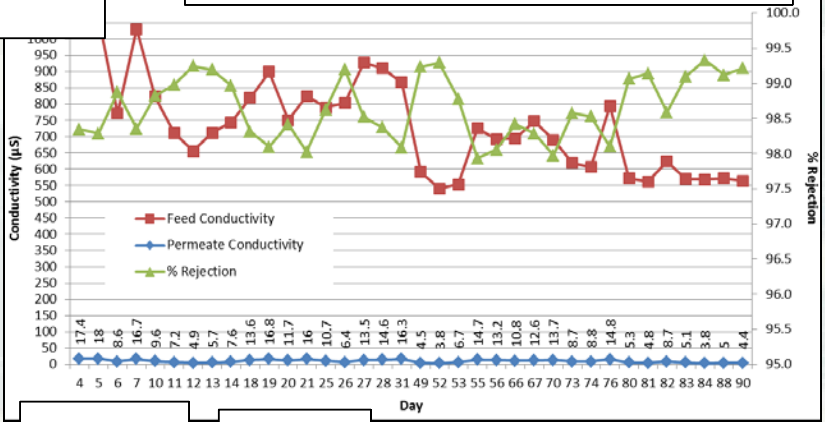
Goal: Reduce shower water heating requirement by 30%. Recycle 80% of shower water using < 5 Wh/gal.

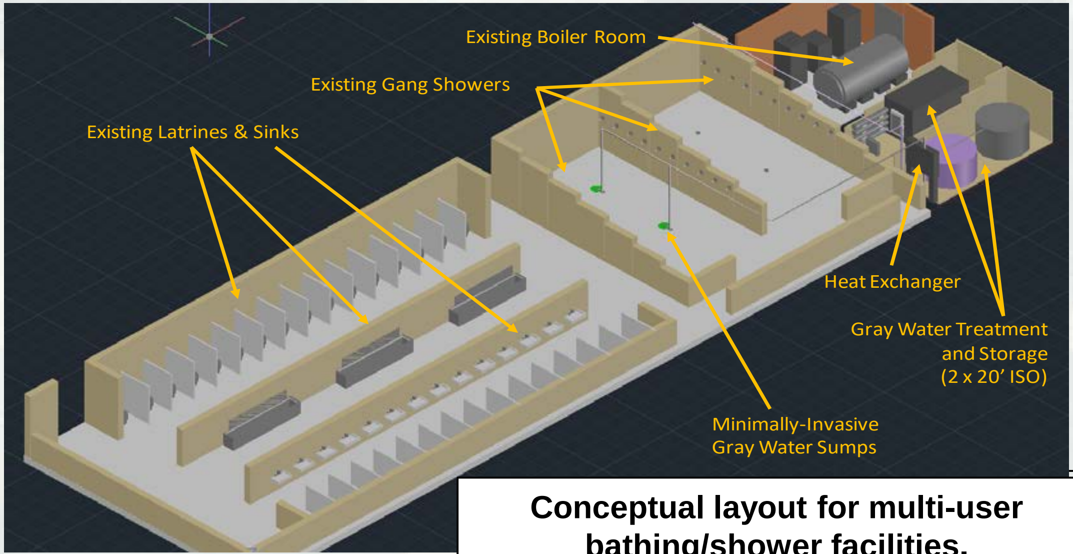
LEAP Membrane Bioreactor

MBR feed, reactor, and permeate water samples.

ULERO membrane technology

Ultra-Low-Energy RO membranes that can operate at 60 psi and reduce total dissolved solids by > 98%





Conceptual layout for multi-user bathing/shower facilities.

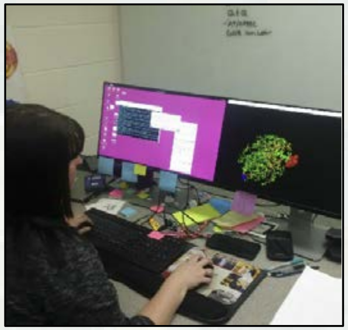
Innovative solutions for a safer, better world

Key Takeaways

- The military has very strong drivers for adopting water reuse- expeditionary logistics and resilient facilities.
- Innovative technologies and systems are being developed and validated for water reuse (including reuse in showers) at small scale.
- Even given the strong drivers, adoption rates have been limited due to challenges with training and automation.
- Associated health risk analyses may be a useful reference to states considering water reuse.
- Progressive regions with military facilities could be candidates for demonstration programs.

Acknowledgements

Research Staff and Support



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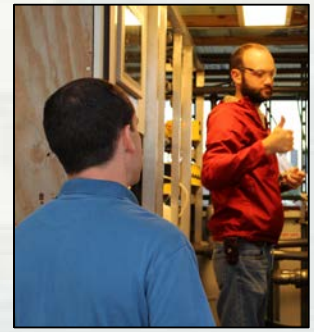

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