National Laboratories' Support to EM Cleanup

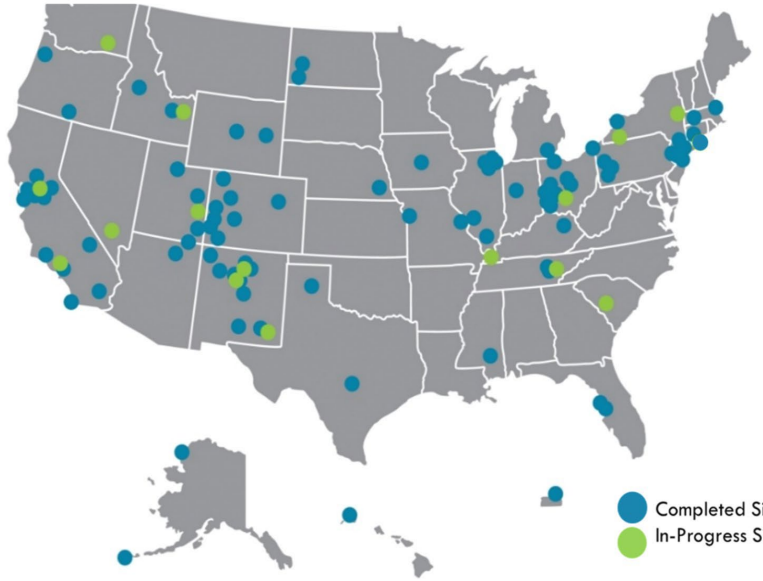
Ming Zhu, Ph.D., PE, PMP
EM Senior Advisor for Laboratory Policy

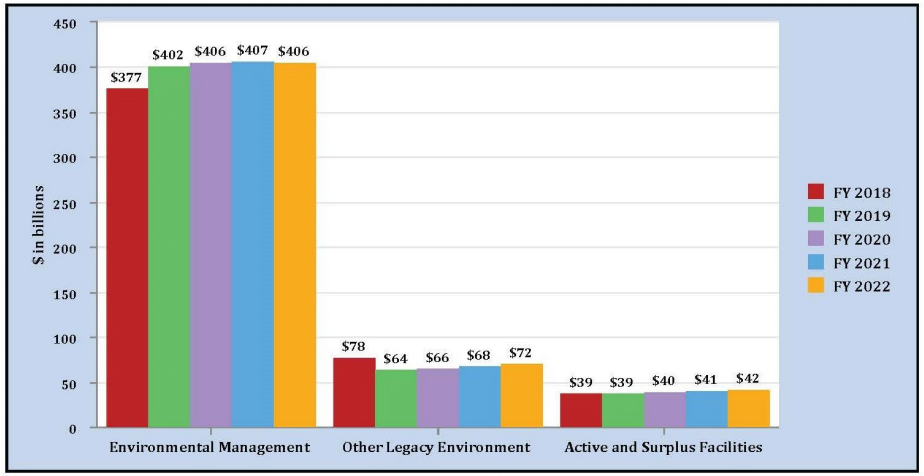
Presentation to EM SSAB Chairs Meeting

March 22, 2023

EM Mission Needs

- DOE's environmental cleanup and disposal liabilities are approximately $520B. Of that EM's portion is $406B.
- Tank waste is 60% of EM's environmental liability.
- Despite recent progress, EM's 15 remaining sites still face significant technical challenges.
- National Laboratories, as demonstrated over the last 34 years, provide critical expertise to tackle these challenges





EM National Laboratory Governance

Senior Advisor
EM-1
William "Ike" White

Chief Strategist
Vacant

Chief of Staff
EM-2.1
Cathy Tullis
Deputy Chief of Staff
John Howard

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Principal Deputy Assistant Secretary
EM-2
Jeffrey Avery

Correspondence Center

Office of Field Operations
EM-3
N. Nicole Nelson-Jean
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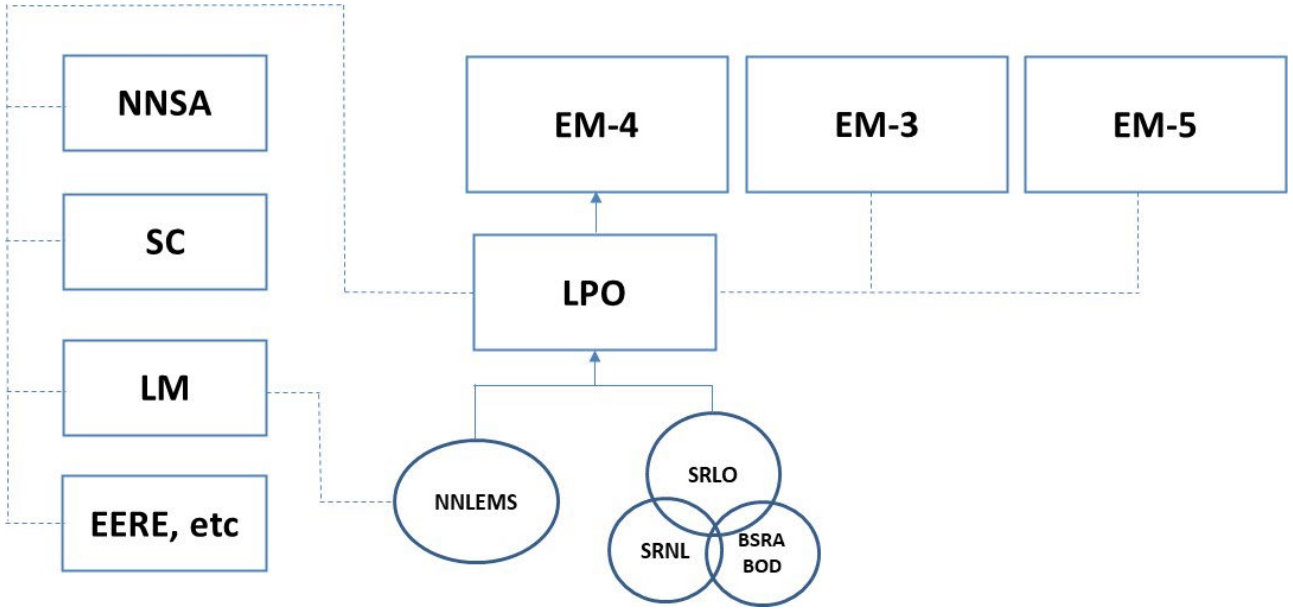
Office of Regulatory and Policy Affairs
EM-4
Randall Hendrickson
Acting Associate Principal Deputy Assistant Secretary

Office of Corporate Services
EM-5
Dae Chung
Associate Principal Deputy Assistant Secretary



Savannah River National Laboratory Updates

BATTELLE

LONGENECKER & ASSOCIATES

TECHSOURCE
A Science & Engineering Consultancy

- Battelle Savannah River Alliance, LLC M&O contract to position SRNL for enduring mission:
  - Cost Plus Award Fee
  - $3.8B over 10 years (5-year base with potential for up to 5 additional years)
- SRNL managed the EM MSIPP, which was expanded with $50M in FY22
- Advanced Manufacturing Collaborative (AMC) Facility being constructed at University of South Carolina Aiken
- State of South Carolina to build the $20M Workforce Development Center at Aiken
- Regulatory Center of Excellence (RCE) established in FY22
- Fusion Energy Research

Advanced Manufacturing Collaborative

- DOE reviews rated two-thirds of the SRNL facilities as substandard or inadequate for modern technology development.
- Secretary of Energy Advisory Board concluded in December 2014 that "*without the application of mature technologies from chemical and manufacturing industries, it is not clear that the cleanup can be completed satisfactorily or at any reasonable cost*".
- Congress appropriated $50M for design and construction of the AMC facility at University of South Carolina Aiken
- AMC
  - Provides much needed technology development collaborative space
  - Serves as an incubator for advanced manufacturing, fostering modern industrial practices, advancing new technologies
  - Strengthens the STEM pipeline in the SE region, developing next-generation workforce
- Schedule:
  - Broke ground in April 2022
  - CD-2/3 approved Q2 FY23
  - CD-4 Q3 FY25

Advanced Manufacturing Collaborative Facility

Regulatory Center of Excellence

- An expert resource charged with helping EM and others manage complex technical and regulatory issues involving science, government, and communications, by facilitating effective communications between DOE sites, stakeholders, regulators, and communities
- Draws upon the collective expertise of the SRNL, Longenecker and Associates and BSRA University Partners to provide innovative strategies that address mission-critical communication, regulatory compliance, and policy challenges at DOE sites
- Chartered by EM-4 in May 2022
- Currently supporting EM on national groundwater management strategy, and NE on consent-based siting program


NE Consent-Based Siting Comms and Outreach Workshop

Regulatory Center of Excellence
U.S. Department of Energy

Managed by
SAVANNAH RIVER NATIONAL LABORATORY

NNLEMS

- **In 2021 EM and LM expanded the EM National Laboratory Network to support both EM's legacy nuclear waste clean-up mission and LM's long-term stewardship missions.**
- **Leverage the combined knowledge base of the National Laboratories to advise DOE on policy decisions on environmental and legacy management and assist DOE in solving emerging or recalcitrant issues.**
- **Identifies/provides resources to support EM response, technical review, policy analysis, and strategic planning**

Core EMNLN Labs

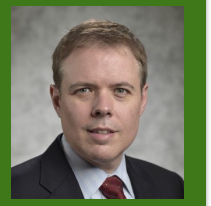
- Savannah River National Laboratory (SRNL)
- Idaho National Laboratory (INL)
- Los Alamos National Laboratory (LANL)
- Oak Ridge National Laboratory (ORNL)
- Pacific Northwest National Laboratory (PNNL)
- Sandia National Laboratories (SNL)

Added from LM Network

- Argonne National Laboratory (ANL)
- Brookhaven National Laboratory (BNL)
- Lawrence Berkeley National Laboratory (LBNL)
- National Energy Technology Laboratory (NETL)
- SLAC National Accelerator Laboratory

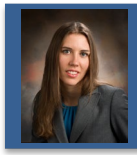
NNLEMS Organization

Ike White
DOE-EM Sponsor
Senior Advisor for Environmental Management
Office of Environmental Management



Ming Zhu
DOE-EM Liaison
Senior Advisor for Laboratory Policy

Vahid Majidi
Chair
Laboratory Director
Savannah River National Laboratory



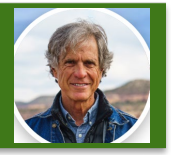
Kathryn Taylor-Pashow
NNLEMS Executive Director
EM Working Group Lead
Savannah River National Laboratory

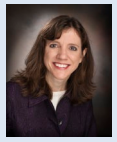
James Peery
Rotating Co-Chair
Laboratory Director
Sandia National Laboratory

Brian Looney
LM Working Group Lead
Savannah River National Laboratory

Carmelo Melendez
DOE-LM Sponsor
Director
Office of Legacy Management

Mark Kautsky
DOE-LM Liaison
UMTRCA Program Manager





Connie Herman
Savannah River National Laboratory

Eric Pierce
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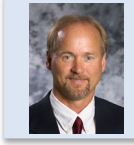
Alexandra Hakala
National Energy Technology Laboratory

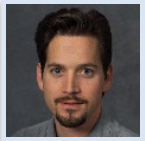
Vincent Noel
SLAC National Accelerator Laboratory

Tom Brouns
Pacific Northwest National Laboratory



Robert Miklos
Idaho National Laboratory

Julianna Fessenden
Los Alamos National Laboratory



Ken Williams
Lawrence Berkeley Laboratory

Eugene Yan
Argonne National Laboratory

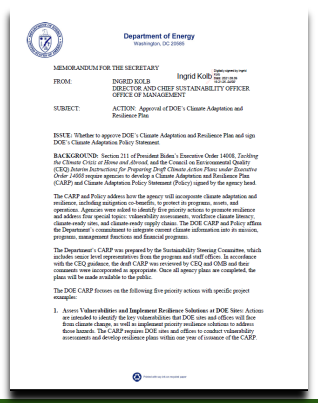
Mavrick Zavarin
Lawrence Livermore National Laboratory

NNLEMS Recent Accomplishments

- FY2017 NDAA Section 3134 Study of Supplemental Treatment of Hanford Low Activity Waste as well as the associated interactions with National Academies (Completed FY19)
- Provided a technical analysis supporting the revised interpretation of the HLW definition in an EMNLN Lab Directors' Letter to the Secretary of Energy (Completed FY19)
- Performed competency analyses for the participating National Laboratories against the needed EM competencies (Completed FY19)
- Completed analysis of the National TRU Program tools to coordinate and plan complex-wide packaging and shipping (Completed FY19)
- Conducted options analysis of treatment and disposition of LANL TRU waste drums at WCS using SRNL modular technology (Completed FY19)
- Independent Assessments for Risk Reduction of 5 LM Sites (Completed FY21)
- Independent Review of EM TD Programs for Alignment with EM Programmatic Priorities (FY21; completed)
- Technical Targets for Groundwater and Soil Remediation (Completed FY22)
- R&D Roadmap for Accelerating Hanford Tank Waste Cleanup (Completed 10/2022)
- FFRDC Report on NDAA Section 3125 Follow-on Study of Hanford Alternative Treatment of Supplemental Low Activity Waste (Completed 1/2023)
- Roadmap for characterization needs of spent columns of crystalline silicotitanate (CST) for disposition (Completed 2/2023)

NNLEMS Ongoing Initiatives

- Complete NDAA Section 3125 Follow-on Study of Hanford Supplemental Low Activity Waste (FY21-23) (**WM2023 Panel 139**)
- Start implementation of R&D Roadmap for Accelerating Hanford Tank Waste Cleanup (FY23-) (**WM2023 Panel 088**)
- Development of EM National Groundwater Management Strategy (**WM2023 Panel 124**)
- Independent Technical Review of the Groundwater Management Strategy for Cr(VI) and RDX Plumes at the LANL Site (**WM2023 Panel 124**)
- Technical Support to ETEC for development of soil and groundwater remediation strategy (**WM2023 Panel 124**)
- Technical Support to Development of Moab Groundwater Corrective Action Plan (**WM2023 Panel 124**)
- Technical Support to EM and LM Implementations of DOE Climate Action Plan (**WM2023 Panel 124**)
- Development and implementation of DOE PFAS Research Plan
- Independent Assessments for Risk Reduction of LM Sites (FY21-)


Department of Energy
Washington, DC 20585

MEMORANDUM FOR THE SECRETARY

FROM: INGRID KOLB
DIRECTOR AND CHIEF SUSTAINABILITY OFFICER
OFFICE OF MANAGEMENT

SUBJECT: ACTION: Approval of DOE's Climate Adaptation and Resilience Plan

ISSUE: Whether to approve DOE's Climate Adaptation and Resilience Plan and sign DOE's Climate Adaptation Policy Statement.

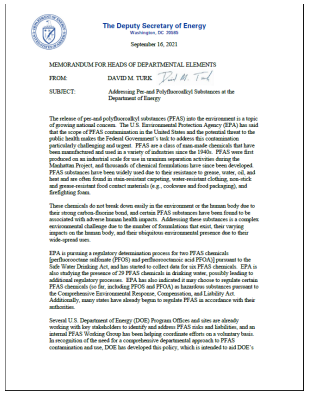
BACKGROUND: Section 211 of President Biden's Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, and the Council on Environmental Quality (CEQ) *Interim Instructions for Preparing Draft Climate Action Plans under Executive Order 14008* require agencies to develop a Climate Adaptation and Resilience Plan (CARP) and Climate Adaptation Policy Statement (Policy) signed by the agency head.

The CARP and Policy address how the agency will incorporate climate adaptation and resilience, including mitigation co-benefits, to protect its programs, assets, and operations. Agencies were asked to identify five priority actions to promote resilience and address four special topics: vulnerability assessments, workforce climate literacy, climate-ready sites, and climate-ready supply chains. The DOE CARP and Policy affirm the Department's commitment to integrate current climate information into its mission, programs, management functions and financial programs.

The Department's CARP was prepared by the Sustainability Steering Committee, which includes senior level representatives from the programs and staff offices. In accordance with the CEQ guidance, the draft CARP was reviewed by CEQ and OMB and their comments were incorporated as appropriate. Once all agency plans are completed, the plans will be made available to the public.

The DOE CARP focuses on the following five priority actions with specific project examples:

1. Assess Vulnerabilities and Implement Resilience Solutions at DOE Sites: Actions are intended to identify the key vulnerabilities that DOE sites and offices will face from climate change, as well as implement priority resilience solutions to address those hazards. The CARP requires DOE sites and offices to conduct vulnerability assessments and develop resilience plans within one year of issuance of the CARP.


The Deputy Secretary of Energy
Washington, DC 20585

September 16, 2021

MEMORANDUM FOR HEADS OF DEPARTMENTAL ELEMENTS

FROM: DAVID M. TURK

SUBJECT: Addressing Per-and Polyfluoroalkyl Substances at the Department of Energy

The release of per-and polyfluoroalkyl substances (PFAS) into the environment is a topic of growing national concern. The U.S. Environmental Protection Agency (EPA) has said that the scope of PFAS contamination in the United States and the potential threat to the public health makes the Federal Government's task to address this contamination particularly challenging and urgent. PFAS are a class of man-made chemicals that have been manufactured and used in a variety of industries since the 1940s. PFAS were first produced on an industrial scale for use in uranium separation activities during the Manhattan Project, and thousands of chemical formulations have since been developed. PFAS substances have been widely used due to their resistance to grease, water, oil, and heat and are often found in stain-resistant carpeting, water-resistant clothing, non-stick and grease-resistant food contact materials (e.g., cookware and food packaging), and firefighting foam.

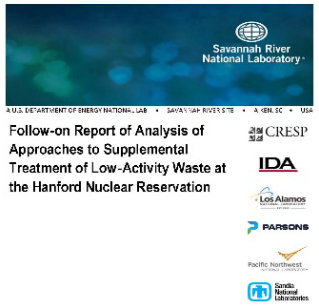
These chemicals do not break down easily in the environment or the human body due to their strong carbon-fluorine bond, and certain PFAS substances have been found to be associated with adverse human health impacts. Addressing these substances is a complex environmental challenge due to the number of formulations that exist, their varying impacts on the human body, and their ubiquitous environmental presence due to their wide-spread uses.

EPA is overseeing a regulatory determination process for two PFAS chemicals [perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA)] pursuant to the Safe Water Drinking Act, and has started to collect data for non-PFAS chemicals. EPA is also studying the presence of 29 PFAS chemicals in drinking water, possibly leading to additional regulatory processes. EPA has also indicated it may choose to regulate certain PFAS chemicals (or the, including PFOS and PFOA) as hazardous substances pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act. Additionally, many states have already begun to regulate PFAS in accordance with their authorities.

Several U.S. Department of Energy (DOE) Program Offices and sites are already working with key stakeholders to identify and address PFAS risks and liabilities, and an internal PFAS Working Group has been helping coordinate efforts on a voluntary basis. In recognition of the need for a comprehensive departmental approach to PFAS contamination and use, DOE has developed this policy, which is intended to aid DOE's

NDAA Section 3125 Study on Hanford SLAW

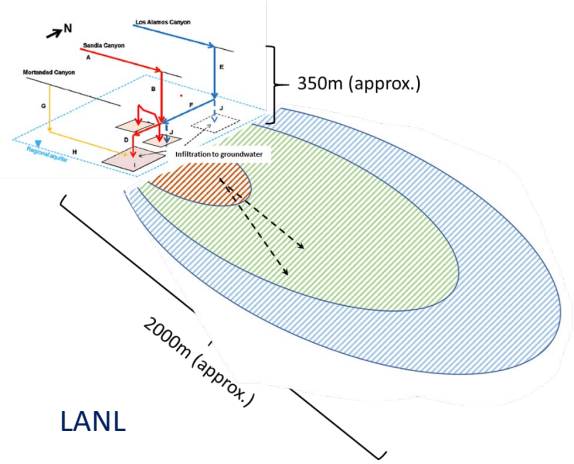
- NDAA Section 3125 for FY21 mandated FFRDC and NAS to conduct a follow-on study of alternative treatment of supplemental low-activity waste at Hanford, with an emphasis on grouting
- The FFRDC team, led by SRNL, issued its final report on Jan. 16, 2023, with the following recommendation: "*DOE should expeditiously secure and implement multiple pathways for off-site grout solidification/immobilization and disposal of LAW in parallel with the DFLAW vitrification process*."
- WA and OR States, Tribes, and communities have responded positively to the FFRDC report
- NAS is expected to issue its final report in the end of April or early May



Vitrification 1: Disposal onsite at Hanford	FBSR 1A: Solid monolith product disposal onsite at Hanford	Grout 4B: Off-site grouting/disposal	Grout 6: Phased Approach Off-site grouting/disposal, then on-site grouting/disposal
Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)			
Highly effective for primary waste; moderately effective for secondary waste. Medium confidence in the assessment.	Effective. Medium confidence in the assessment, due to technology immaturity.	Highly effective. High confidence in the assessment.	Highly effective. Good to high confidence in the assessment.
Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by waste tank storage duration)			
High risk due to significant cost-based startup delays and operations limits. Moderate technical implementation risk. Construction finishes and treatment starts in 2047, mission does not complete without significant additional annual budget.	High risk due to construction time required and technical execution risk. Construction finishes and treatment starts in 2039; mission completes 2070.	Low risk due to earliest potential start of treatment in 2027, minimal construction, low-temperature process, likely capacity, and modest transportation and operations costs. Limited facilities (e.g., evaporator and load-out station) needed; mission completes 2066.	Very low risk due to earliest potential start of treatment in 2027, flexible timing of conversion to on-site low-temperature process, and inexpensive operations. Grout plant construction finishes 2039; mission completes 2066.
Criterion 3: **Likelihood of successful mission completion** (including technical, engineering, and resource-related risks)			
Very low probability of successful completion due to resource intensity.	Low probability of successful completion due to technical risk.	Very high likelihood of successful completion.	High likelihood of successful completion.
Criterion 4: Lifecycle cost (discounted lifecycle costs)			
$7.6B construction; $5.1B operations (total operations costs exceed benchmark budget by $1.2B)	$3.4B construction; $2.2B operations	$0.4B construction; $3.4B operations	$1.4B construction; $2.7B operations

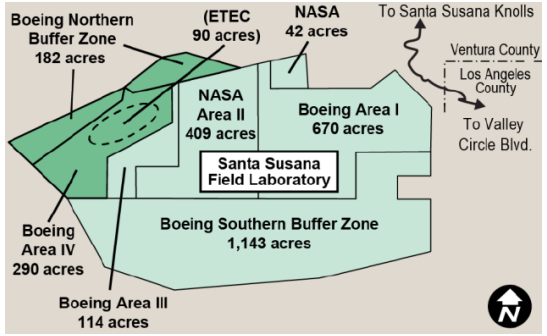
Reviews of Groundwater Strategies for LANL, Moab and ETEC

- At the request of EM sites, NNLMES has reviewed the groundwater management strategies for Cr(VI) and RDX plumes at LANL; development of Groundwater Corrective Action Plan (GCAP) for Moab, and soil and groundwater remediation at ETEC
- For the LANL Site:
  - NNLEMS has recommended adaptive management approach for the complex site
  - EM-LA plans to use the NNLEMS report to inform the site's regulatory negotiations and management decisions
- For the Moab Site:
  - NNLEMS has developed time staged GCAP strategies, each with a set of defined risk management objective(s)
  - The Moab Site plans to use the NNLEMS report to develop the GCAP
- For ETEC:
  - NNLEMS has analyzed the Look-Up Table Values for soil remediation and backfill availability, and recommended a risk-based approach
  - The ETEC Site plans to use the NNLEMS report to inform regulatory interactions in ROD development



LANL

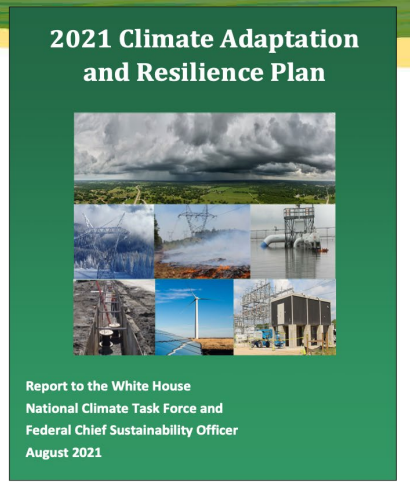
Moab

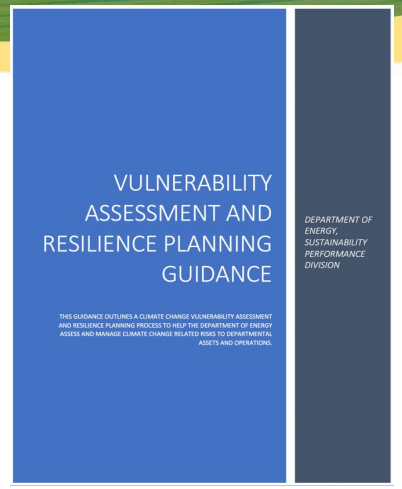


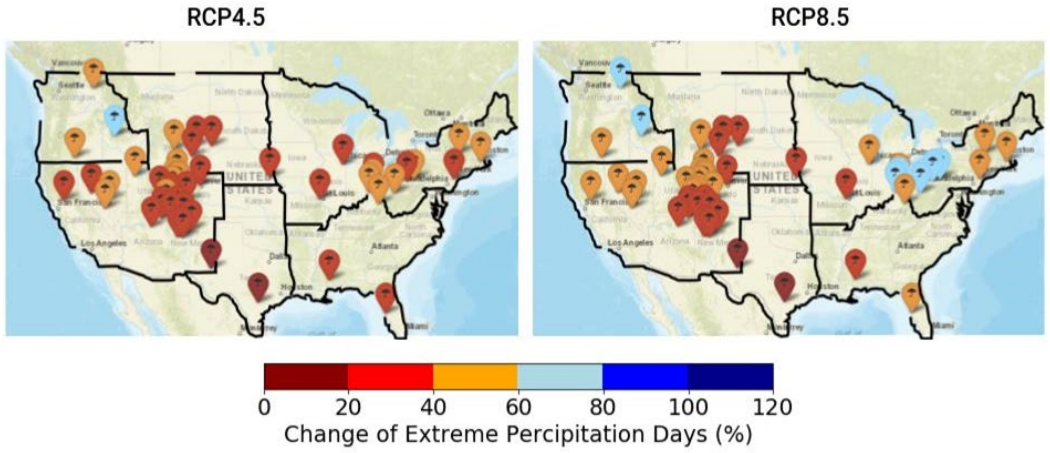
ETEC

Climate Vulnerability and Resilience Assessments

- DOE 2021 Climate Adaptation and Resilience Plan requires sites to develop vulnerability assessment and resilience planning
- GAO recommended that DOE develop plans to assess effects of climate changes on LM's sites and to mitigate any significant impacts
- NNLEMS (LBNL and SRNL) supported EM sites for developing VARP, and LM sites for addressing GAO reports
- Phase II work underway







	ETTP	Hanford	Moab	Paducah	Portsmouth	SRS	WIPP	WVDP
Cold Wave	N/A	N/A	N/A	Unlikely	Unlikely	Unlikely	N/A	Relatively moderate
Drought	N/A	None to low	Increased severity	Anticipated	Anticipated	Anticipated	N/A	No rating
Heat Wave	Almost Certain	Medium to high	N/A	Likely	Likely	Likely	Very likely	No rating
Winter Weather	Likely	N/A	N/A	Anticipated	Anticipated	Unlikely	Somewhat likely	Very low
Precipitation	Almost Certain	Low	Less precipitation overall	Anticipated	Anticipated	Anticipated		N/A
Ice Storm	N/A	N/A	N/A	Anticipated	Anticipated	Unlikely		Relatively low
Lightning	Almost Certain	N/A	N/A	Almost certain	Almost certain	Almost certain	N/A	Relatively low
Riverine Flooding	N/A	Low	N/A	N/A	N/A	N/A	N/A	Relatively moderate
Tornado	N/A	N/A	N/A	Extremely unlikely	Extremely unlikely	Extremely unlikely	N/A	Relatively moderate
Wildfire	N/A	Medium to high	Increased risk with drought	Anticipated	Anticipated	Anticipated	N/A	Very low

EM National Groundwater Management Strategy

- Historically EM program has focused on tank waste cleanup. However, stakeholder concerns are focused on off-site migration of groundwater contamination
- A significant portion of EM's environmental liability is associated with remediation of complex groundwater plumes and long term monitoring is a large component of liability
- NNLEMS is developing a National Strategy to expedite closure at EM's groundwater plumes at complex sites, in 3 phases

Phase 1: Technical Targets Document

(November 2021)

- Updated 2002 document to reflect current needs

Phase 2: Site Interviews

(August 31, 2022)

- Interviews with 9 DOE-EM sites
- Identification of high priority site-specific challenges for each site
- Develop recommendations to expedite closure.

Phase 3: Expedited Site Closure Strategy Document

(Ongoing)

- HQ plan for development of end-sate vision to expedite closure at each site
- Recommendations for improving stakeholder interactions
- Technology development and test bed recommendations

R&D Roadmap for Accelerating Hanford Tank Waste Mission

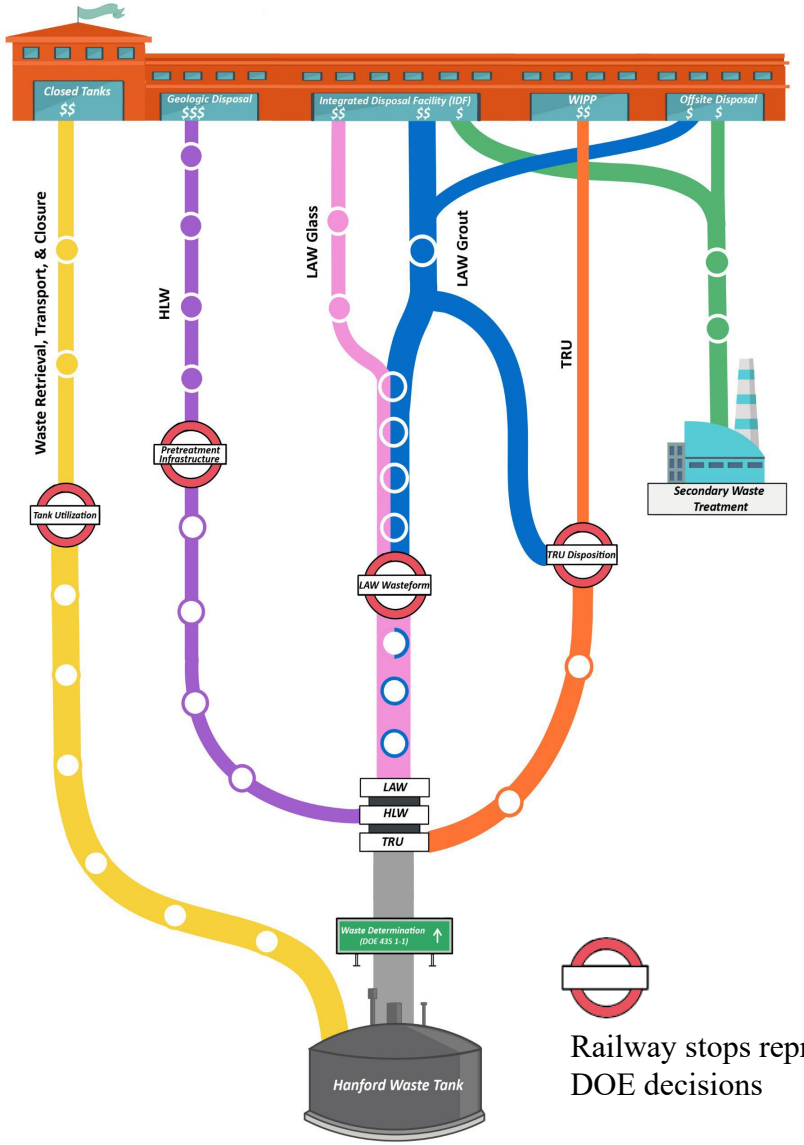
Charter for Hanford Tank Waste R&D Roadmap

- **The retrieval, treatment, and disposal of Hanford tank waste is the largest portion of EM's environmental liabilities.**

- **EM-1 chartered NNLEMS to develop the R&D Roadmap to continually identify research and development (R&D) opportunities to provide cutting-edge technologies that can be used for improving efficiency, along with reducing costs and accelerating the schedule for the Hanford tank waste cleanup program.**

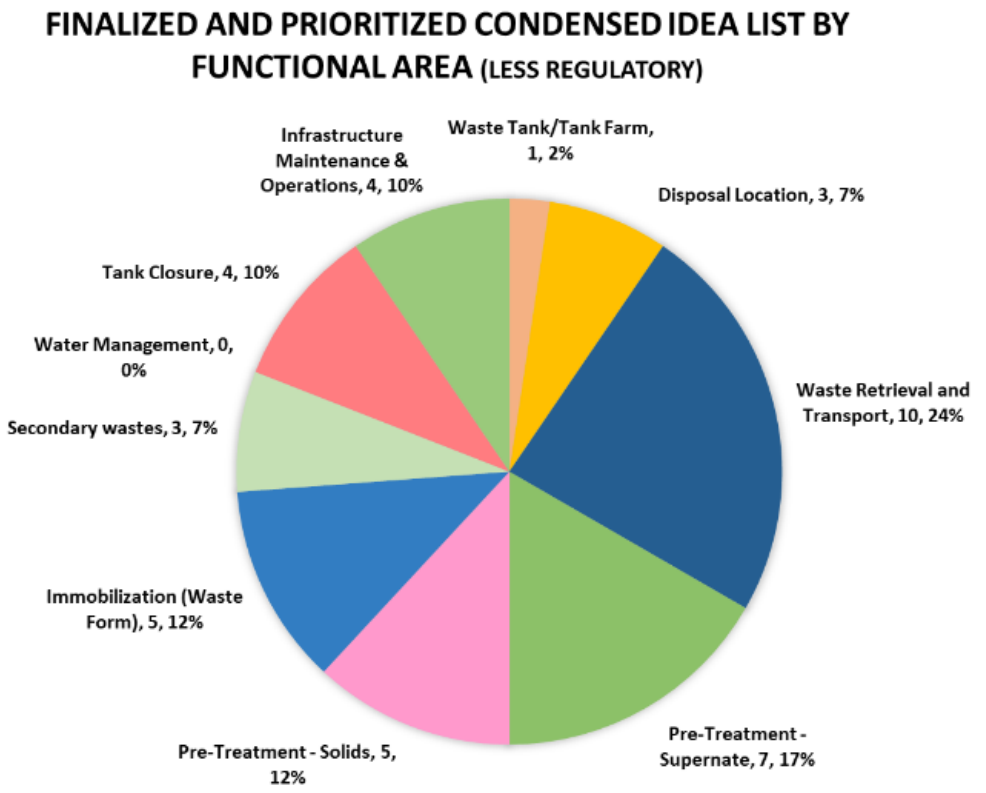
- **R&D Roadmap managed, approved and maintained by a Federal Steering Committee that reports to EM-1:**
  - Ming Zhu, EM Senior Advisor for Laboratory Policy (Lead)
  - Delmar Noyes, Assistant Manager of the Tank Farm Project
  - Kurt Gerdes, Director of the EM Technology Development Office
  - Steve Trischman, Director of Office of Budget and Planning

NNLEMS Recommended R&D Roadmap



Railway stops represent key DOE decisions

- A recommended portfolio of R&D investments: 35 areas
- Five quick win ideas
- A competitive process for R&D investments
- A communication/engagement strategy



NNLEMS "Quick Win" Ideas

NNLEMS identified "quick win" ideas that could help advance the near-term Hanford mission:

- **LDR Organics Characterization and Removal/Destruction to enable waste form alternatives**
  - Continue evaluation of organic removal/destruction methods
- **Development of Sludge Preparation Tanks At or In-Tank**
  - Evaluate and test technologies for HLW sludge preparation to meet HLW vitrification goals
- **Tank Life Extension to Support Mission Acceleration and Completion**
  - Evaluate technologies to repair or allow interim use of DSTs with potential leak sites; enhance existing tank integrity program with new inspection technologies
- **SST Retrieval Infrastructure to Enable Flexible, Timely Waste Mobilization**
  - Provide technologies or at-tank equipment for emergency leaks to repair, transfer, and/or immobilize retrieved waste
- **Sample Reduction using Material Balance and Real-Time, In-Line Monitoring Approaches for HLW Applications**
  - Expand on existing DFLAW real-time, in-line monitoring program to meet the needs of HLW vitrification

NNLEMS Prioritized R&D Areas for HLW Applications

- **Develop system model for infrastructure & technology cost evaluation**
  - Multi-lab effort combining code development and process modeling to assess the impacts of changes to the flowsheet including technology insertion
- **Cementitious material development to improve long-term performance**
  - Work with WRPS program to advance the R&D needed to allow cementitious waste forms to be accepted for disposal on-site or offsite
- **Improve transport models/performance assessments for waste forms**
  - Evaluate existing performance assessment inputs to determine where areas of conservatism might exist in the assumptions on waste form performance and/or where disposal contaminant migration assumptions may be conservative
- **Improved equipment decontamination/disposal options**
  - As tank farm and facility operations become more routine, the need for more robust methods to decontaminate equipment will be important to minimize the disposal volume
- **Alternative disposal options for CST ion exchange media**
  - Further the NNLEMS study to consider disposal locations which may entail additional characterization of spent CST
- **Remote/Automated systems**
  - Continue to evaluate means for removing the worker from the hazards

NNLEMS Recommended R&D Portfolio

Priority Ranking (*Color of the symbol(s) denotes the "railway route"*)
- ✪= **Top**
- ●= **High**
- ◎= **Medium**

Research Area	R&D Investment			Estimated Savings	
	Tech. Type	*Timeframe (years)*	*Total Cost*		
Waste Retrieval, Transport, & Closure					
✪ Increase volume available for tank storage (WR&T-14)	Transformational	0-5	$0-10M	$10-25B	7-10 yrs.
● Dry waste characterization, monitoring, & retrieval technologies (WR&T-3b & 10a)	Incremental	0-5	$10-50M	>$25B	7-10 yrs.
● Process automation & feedback of monitoring and retrieval technologies (WR&T-7b)	Incremental	0-10	$50-100M	>$25B	>10 yrs.
● Advanced in-situ characterization methods coupled with improved performance assessment models (TC-4, TC-5, WR&T-8)	Transformational	0-15	$10-50M	$1-10B	5-7 yrs.
● Formulate & install barriers targeted for constituents of concern at tanks or disposal site with active monitoring (TC-7, WR&T-2b, DL-1)	Incremental	0-15	$50-100M	$1-10B	5-7 yrs.
● Improved sampling methods for double shell tanks (WT-9)	Incremental	0-10	$100-300M	$1-10B	5-7 yrs.
● Improved methods to detect/ repair leaks for storage tanks (IF-2, WR&T-2a & b)	Risk Mitigation	0-10	$100-300M	$1-10B	5-7 yrs.
● Risk-based waste retrieval sequencing (TC-3)	Incremental	0-10	$0-10M	$1-10B	3-5 yrs.
Waste Pretreatment					
✪ In-tank pretreatment of HLW sludge (PS-4)	Transformational	0-5	$10-50M	>$25B	>10 yrs.
✪ At-tank pretreatment of HLW sludge (PS-2)	Transformational	0-5	$100-300M	>$25B	>10 yrs.
● RCRA organics removal from tank supernate (PL-5)	Transformational	0-10	$10-50M	>$25B	>10 yrs.
● Increased solids concentration during waste processing with water management (PS-6)	Transformational	0-5	$100-300M	>$25B	>10 yrs.
● Improved understanding of aluminum chemistry to optimize sludge processing (PS-3)	Long-range	0-5	$0-10M	$250M-1B	>10 yrs.
◎◎ Improved supernate filtration processes (PL-1)	Risk Mitigation	0-5	$0-10M	$0-250M	0-3 yrs.
◎◎ Additives to optimize filtration (PL-2)	Incremental	0-10.	$0-10M	$0-250M	0-3 yrs.
◎◎ Sodium nitrate separation or destruction technologies (PL-8)	Transformational	0-10	$10-50M	$0-250M	0-3 yrs.
◎ Plutonium/actinide removal from supernate (PL-10)	Transformational	0-5	$50-100M	$0-250M	0-3 yrs.

Research Area	R&D Investment			Estimated Savings	
	Tech. Type	*Timeframe (years)*	*Total Cost*		
Waste Immobilization & Disposal					
✪ Cementitious materials development to improve long-term performance (IM-13)	Transformational	0-10	$10-50M	>25B	>10 yrs.
✪ Improved high level waste glass formulations (IM-1b)	Incremental	0-5	$10-50M	>$25B	>10 yrs.
✪ NOX management through sludge washing or offgas abatement (IM-4)	Incremental	0-10	$50-100M	$1-10B	5-7 yrs.
✪✪ Improved transport models/performance assessments for waste forms (DL-3)	Transformational	0-10	$0-10M	$250M-1B	3-5 yrs.
● Improvement to high level waste glass melter design & throughput (IM-2c)	Incremental	0-10	$100-300M	>$25B	>10 yrs.
◎◎ Waste dewatering/dried waste form (IM-12)	Transformational	0-10	$300-600M	$10-25B	>10 yrs.
Secondary Waste Treatment					
● Improved grout waste forms (SW-1)	Incremental	0-5	$10-50M	$0-250M	0-3 yrs.
◎ Iodine separation in liquid phase (PL-6)	Risk Mitigation	0-5	$0-10M	$0-250M	0-3 yrs.
◎ Iodine separation in gas phase (SW-9)	Risk Mitigation	0-10	$0-10M	$0-250M	0-3 yrs.
◎ Technetium separation technologies (SW-10)	Incremental	0-10	$10-50M	$0-250M	0-3 yrs.
◎ Process intensification/automation of Effluent Treatment Facility (IF-7 & 12)	Incremental	0-10	$100-300M	$0-250M	0-3 yrs.
Mission Enablers					
✪ Improved equipment decontamination/ disposal options (WR&T-9)	Incremental	0-5	$0-10M	>$25B	7-10 yrs.
✪ Real time monitoring for liquid process feeds (WR&T-10b)	Incremental	0-5	$0-10M	$250M-1B	5-7 yrs.
● Develop system model for infrastructure & technology cost evaluation (Hanford-1)	Transformational	0-5	$10-50M	$0-250M	0-3 yrs.
◎ Optimize cesium loading on crystalline silicotitanate ion exchange media (PL-3)	Incremental	0-10	$0-10M	$250M-1B	3-5 yrs.
◎ Improved offgas treatment/abatement for key air toxics (PS-9)	Incremental	0-5	$10-50M	$0-250M	0-3 yrs.
◎ Alternative disposal options for crystalline silicotitanate ion exchange media (DL-6)	Transformational	0-10	$10-50M	$0-250M	0-3 yrs.
◎ Remote/automated systems (IF-14)	Incremental	0-5	$100-300M	$0-250M	0-3 yrs.

DOE Implementation of the Roadmap

- **EM-1 has requested feedback**
  - EMAB review
- **Advisory Subcommittee (EM, SC, and ARPA-E)**
  - Develop the competitive process
  - Organize and conduct proposal reviews
- **Funding**
  - EM plans to use $50M of the FY23 appropriations for the implementation of the Roadmap
- **Scope**
  - Under development
- **Schedule**
  - To initiate projects in late FY23