PORTSMOUTH EM
SITE SPECIFIC ADVISORY BOARD

•OSU Endeavor Center• 1862 Shyville Road • Piketon, Ohio 45661 • (740) 289-5249 •

Proposed Agenda for the June 6, 2019 Board Meeting

6 p.m.

Call to Order, Introductions
Review of Agenda
Approval of April Minutes

DDFO Comments **--15 minutes**

Federal Coordinator Comments **--10 minutes**

Liaison Comments **-- 5 minutes**

Administrative Issues **--20 minutes**

- **DRAFT Recommendation 19-03- Request Regarding Existing Landfills and Plumes Outside Perimeter Road** **--15 minutes**
  - Public Comments on Recommendation
  - Board Comments on Recommendation

- **DRAFT Recommendation 19-04- Recommendation to Re-open the Records of Decision (ROD)** **--15 minutes**
  - Public Comments on Recommendation
  - Board Comments on Recommendation

- **EM SSAB Chairs Draft Recommendations- EM's Review of Cleanup Milestones** **--5 minutes**
  - Public Comments on Recommendation
  - Board Comments on Recommendation

  Improving EM's Science and Technology Program **--5 minutes**
  - Public Comments on Recommendation
  - Board Comments on Recommendation

Subcommittee Updates **--10 minutes**

Public Comments **--15 minutes**

Final Comments from the Board **--15 minutes**

Support Services
EHI Consultants, Inc.
1862 Shyville Road
Piketon, OH 45661
Phone 740.289.5249
Fax 740.289.1578

PORTSMOUTH EM
SITE SPECIFIC ADVISORY BOARD

MINUTES OF THE THURSDAY, JUNE 6, 2019, SSAB MEETING • 6:00 P.M.

Location: The Ohio State University Endeavor Center, Room 160, Piketon, Ohio

Site Specific Advisory Board (SSAB) Members Present: Chair, Bob Berry; Vice-Chair, Carlton Cave; Dr. Todd Burkitt, Brad Burns, Dennis Foreman, Rick Fraley, Turman Helton, Jimmy Smalley, Judy Vollrath, Carol Caudill, Jody Crabtree, Cynthia Quillen

SSAB Members Absent: Lisa Bennett, Beckie Thomas-Kent

U.S. Department of Energy (DOE) and Contractors: Greg Simonton, Johnny Reising, DOE; Rick Greene, Joe Moore, RSI EnTech; Julie Galloway, Cindy Lewis, EHI Consultants (EHI); Jack Williams, Fluor-BWXT Portsmouth (FBP); Damon Detillion, PMA, Mark Johnson, Tri-State Building Trades; John Knauff United Steel Workers (USW); Lee McGetick, Leslie Price (AECOM)

Liaisons: Sean Kubera, Ohio Department of Health (ODH); Amy Tegethoff, Tom Schneider, Ohio Environmental Protection Agency (EPA)

Facilitator: Eric Roberts, EHI

Public: Matt Brewster, Pike County Health Dept.; Lee Blackburn, Sierra Club; Geoffrey Sea (SONG); Vina Colley (PRESS/NNWS); Megan Williams, Scioto Valley Schools; Stephanie Howe, Ohio University (OU); Robert Tomlison, Connie Entler, Dawn Entler, Josh Blevins, Kim Blevins, Josh Lamerson, Jack Shepherd, Nancy Shepherd, Frank Zultz, Michael Mays, Victor Brushart, Bruce Overly, Cheryl Overly, Minnie Jones, Paul Montgomery, Patty Montgomery, Susan Jane Montgomery, Marilyn Ison, Gina Doyle, Lori Barker, Lisa Davis

Approved by Bob Berry, Board Chair

Bob Berry

Call to Order:

Berry: I would like to call the meeting to order.

Roberts: I would like to welcome everyone, and I will be facilitating the meeting. There will be a public comment period after the presentations. The board should stay within its defined scope and follow the meeting ground rules adopted.

June Agenda:
Roberts: I would like to move the EM SSAB chairs Draft Recommendations above the Board draft recommendations. They should be in the order we received them. With your permission I would like to make that switch. Are there any other modifications or proposed changes to the June agenda?

March Minutes:
Roberts: Are there any modifications or proposed changes to the April minutes?

> ***Foreman:*** On page three the first section where I asked EPA about contamination found off-site. During the back and forth I looked down and asked Ms. Tegethoff when she heard about the fire, she said it was the first she was hearing about it and I also asked Mr. Sean Kubera, ODH and I don't see that in the minutes.

- ***Cave:*** I make a motion to approve the April minutes after amended.
- ***Burkitt:*** I second the motion.
    - ***Motion carried, minutes approved***

DDFO comments provided by Greg Simonton, Federal Project Coordinator:

- **D&D Progress-X-326 Deactivation**
- **D&D Progress -X-333 Deactivation**
- **D&D Progress-X-705**
- **OSWDF Construction**
- **Groundwater Cleanup**
- **Conversion Plant Update**
- **Environmental Monitoring Program**
    - **Annual Site Environmental Report (ASER)**
    - **Air Monitoring Locations/2017 Air Monitor Detects**
- **Radiation Dose from Common Sources**
- **DOE Community Open Houses**
- **Economic Outreach**
- **Local Procurement**
- **Educational Outreach – Interns**
- **Charitable Outreach**
- **Upcoming Outreach Events**

Question/Comment:	***Answer:***
Smalley: Is it true you are having outside contractors to do the asbestos removal? Is there any trouble they are having removing the asbestos discovering it in other piping?	***Simonton:*** Yes, I believe so. Not that I know of, I will have to check on that.
Foreman: Last meeting I asked what is the protocol in alerting the community on emergencies. Is that going to be talked about tonight? Have the issue of the JIC not having a backup generator been addressed yet? I am very concerned that they don't have backup generator.	***Simonton:*** We are not having a presentation on that, but we will have a presentation in a future meeting.
Mr. Snyder can you address the green stuff on the concrete from the DUF6. It was in the Columbus Dispatch about a leak.	***Snyder:*** I think the details of it is better answered from DOE. ***Simonton:*** I will have to find the answer from someone else that can explain it better than me.
The EIC is right upstairs here and copies of the ASER is up there correct?	Yes.
With the Village of Piketon, we must send out water quality (your drinking water). Do other sites across the complex, do we send out air quality information. I know residents who live in the camp creek area that are freaking out, my nephew keeps asking me I don't know the answer. It would be nice if we could send out air quality testing to the residents.	I can get a list of the reports that are submitted. I feel the ASER has all the summaries of the testing results in it.
Are all the air monitors a property of DOE or are they the mix of DOE and OEPA?	All DOE owned.
Mr. Snyder are you going to put in some of your own OEPA air monitoring?	***Snyder:*** It is being discussed.
Do we know where all three air monitors are that detected contamination?	***Simonton:*** One was the school, one was in Otway about 13 miles away from the site, I don't recall the other one.

Are neptunium or americium hypheted by-products of enriched uranium?	They would be part of the program where they re-fed some of the material to be enriched. That happened over several years I believe in the 70's or 80's.
Question on the testing. I saw them during the weekend. Since the NAU report shown there was high levels in the water, did they do any testing at the Little Beaver Creek?	Only testing they did over the weekend was in the school and the air outside the school. What you are talking about will be the broader independent analysis that will be led by the locals. I believe the health department will be the lead on that. I am not part of those discussions, but I do know the department is working with them to make sure they have resources. I am referring to the school on getting the tests result back. This was specifically for the school.
I talked to the guys who were doing the testing at the local restaurants, they were from Savannah River, Hanford and Oak Ridge. I wish they would have done some testing on the water while they were here since they are supposed to be the bes. That was my only concern since the water was an issue, too.	
Is this shared by sixteen other sites?	Yes, it is not for EM but all of DOE.
The local people we have had some water issues lately because of the sliding hillsides. Can the public entities and government entities be part of this? This would be great for little governments to be a part of this I know we can't do it all over United States. It would be great if we could be community partners or buying partners just for infrastructure.	I don't know the answer to that.
Burkitt: Who sets the regulatory limits on the air monitoring?	***Simonton:*** I don't know the answer to that.
Helton: What does the ASER stand for? Is this reported to the EPA?	***Simonton:*** Annual Site Environmental Report. It is part of a comprehensive evaluation from all the sampling we do from the water to the soil, air, animals, plants, throughout the year. It goes out not only to the regulatory entities, but to

	the local elected officials, schools, health departments, and the members of the public can get copies of it too.

A copy of the DDFO presentation is available on the SSAB web site (www.ports-ssab.energy.gov)

Federal Project Coordinator comments provided by Greg Simonton, Federal Project Coordinator:

Question/Comment:	***Answer:***
Foreman: I just met Mr. Bettinger at the open house in Jackson. I didn't know he existed until the Jackson meeting. Is he going to be the new site lead?	***Simonton:*** Yes, we have a new site lead. He replaces Joel who got appointed to the new deputy to Robert Edwards in Lexington. His name is Jeff Bettinger, He is out of town this week. Joel will still be the DDFO.

Liaison comments provided by Sean Kubera, ODH:
Kubera: None at this time.

Liaison comments provided by Amy Tegethoff, OEPA:
Tegethoff: None at this time.

Question/Comment:	***Answer:***
Foreman: Mr. Snyder, Ms. Tegethoff, and Mr. Kubera, since the last meeting we found out there were fires. How many fires have been since then?	***Tegethoff*** (OEPA): One fire they did let me know about.

Administrative Issues:

EM SSAB Chairs Draft Recommendation-EM's Review of Cleanup Milestones:

Question/Comment:	***Answer:***
Vollrath: Are we considered a small site?	***Berry***: I don't think we are considered a small site, I think a medium site.
Burkitt: What is the entire site budget?	***Berry:*** I think the entire site budget is approximately 430 million dollars that includes DUF6, disposal cell and D&D. I would think ours would be around 370.
Helton: What is the rationale of putting us back on barter?	***Berry:*** It worked. There is an open market. It is hard to plan what you are going to get, how much money you are going to get from barter.

	Simonton: Just for reference the president's budget request is in February. Typically the president's budget comes out and there is a slight cut in the EM budget, but in our case some of the offset would be covered by barter. That was some of the thinking. It is much harder to plan a budget with barter fluctuating.
Foreman: The old website you guys use to have was amazing. You had all the minutes, all the recommendations. I had to message them today, I couldn't find recommendation 19-01. The old site was just amazing, you could find everything that was ever done by this board. I would like to go back to that because it would make it easier. Then you could have a tab for milestones you could click it and it could explain things to the general public. Mr. Berry what is their interpretation of timely manner? When you use a word like that you leave a lot of leeway to DOE. Do they have a database I can go search like Google?	***Roberts:*** They don't know the exact amount of times to update this database, so they use the term timely manner. Maybe not actually what you are asking, but the GSA does have a database that we are required to provide information to every year, meetings attended, recommendations, etc. This is funded by the federal government and we want to make sure we are being accountable.

Cave: I would like to make a motion that we proceed with a vote.
Helton: I would like to second the motion.

Public Comment on Recommendation:

Sea: I am disappointed that this recommendation includes nothing about community involvement in the process. For those of you who don't know, all superfund sites and CERLA includes a vision that communities do their own studies, including hiring their own experts. This community could have desperately used in the current situation of what is happening in the Zahn's school and elsewhere. The DOE because it is a federal agency doesn't have to comply with EPA regulations. DOE has its own program of empowerment over its communities, but only two communities have not been given technology systems grants, those communities are this community and Paducah. That situation has to be rectified.

Lamerson: I agree with everything Mr. Sea just said. Why hasn't this community been funded federally like all the other sites were. The public here in Pike County has grown in population of those opposing the five-year plan, including me. Things are not being communicated with us. A lot of people in this community don't have internet access they can't get on and read about the SSAB board meeting. It needs to be put in the newspaper and made public to the people in this county.

Knauff: We get 90 minutes a year to come speak, seven minutes a month or 15 minutes every other month. There is no community involvement in this process. 90 minutes a year is not enough.

Ison: I agree with Mr. Sea, Mr. Lamerson and Mr. Knauff. We don't know enough. We are left out in the dark. Many people don't have internet and we are important. Our families are important and what we have to say is important and you are going to hear it today.

Colley: When our representatives come and meet on-site with closed doors with the health department and everyone else a lot of decisions are being made for this community. We have been left out now for 35 years. It is time the government opens the door and lets us in. I want to talk about trace amounts of transuranics. The trace amounts need to be put in your minutes, because that is a secret code. Trace amount of neptunium, the closed door must be stopped.

Doyle: I agree with everyone that has spoken. There are so many people in our community that have spoken up just to each other and they have something to say, they have voices. They have property all around here that they are worried about, they have children that they worry about. Everybody that lives in this community has something to lose if this isn't taken care of the right way. Everybody here that has spoken, I agree with, because we need to be heard and we are going to be heard. We are sending our letters out and doing everything we can. I have a list started Matt Brewster, and over 477 comments of people with cancer in our community. The cancer cluster that is where it started from. Something needs to be done, you guys need to let us be heard.

Motion approved *(12 approved, 0 o*pposed*, 0 abstained, 0 recused)*

EM SSAB Chairs Draft Recommendation-Improving EM's Science and Technology Program:

Question/Comment:	***Answer:***
Foreman: Mr. Berry or Mr. Cave have you been telling them what we have been asking for like we want robotics partially funded or implemented. We could have a training facility here a robotics lab here right in Pike County,	***Roberts:*** No response yet. Carlton, Bob obviously, you have discussed the robotics, anything else you would like to add.

Ohio. Have we gotten a response back from 19-01?	***Cave:*** I would like to say Dennis, Mr. Berry has put it on the table for the last three years.

Cave: I would like to make a motion that we proceed with a vote on this recommendation.
Crabtree: I would like to second the motion.

Public Comment on Recommendation:

Sea: I would like to know why we don't hear about the other hazardous waste materials at Piketon, we only hear about radiation. Well, I have been studying this plant for 40 years. I can tell you there are at least four different toxic materials that probably have caused more health effects in this community than radiation. When they find cancer clusters it is very likely that they are not caused by radiation, but by the toxic materials released from this facility. The four leading ones are nickel, PCBs, TCEs and fluoride. We need a lot more discussion on these other toxic materials besides radiation.

Knauff: These words reduction of radiological and other hazardous waste material, wonderful words, I do not see it being applied here at all. I see it going in the opposite direction. I don't see any current decision from you or anybody else, contractors as long as you can't use a word that is in a contract between DOE and FBP. We deactivated a long time ago. Decontamination is a word and it is nonexistent in the work out there. That is why we have more of this waste than less.

Colley: I am going to disagree about the toxic chemicals. I think they need to be added too, but we cannot let the radiation part go. We need the DOE and Department of Labor, Department of Defense to step up and tell us exactly what we have on this site. We have plutonium, we have neptunium, so our representatives know, and they are not getting involved in the issue.

Ison: Can we have testing include exposure to lithium? We have reported cases of workers trying to move the rusty barrels of lithium and the existing dust was stirred up where they were trying to work. lithium is very light and would most likely travel some distance on wind currents. I want to know where all the materials are moved to and the route it took. Is the JVS going to be tested and if anyone there is against it on their board and on this board? I am waiting the results of my thyroid test to see if I have thyroid cancer, so I want some of these questions answered for my reassurance.

Motion approved *(11 approved, 0 o*pposed*, 1 abstained, 0 recused)*

Draft Recommendation 19-03:

Question/Comment:	***Answer:***
Vollrath: Correct me if I am wrong. 19-01 was that kind of our budget recommendation? Did we mention the closure fund? I am not sure if I like in addition to the closure fund, should we mention 19-01?	***Roberts:*** OK, that also gets your point of reference. Bob are you open to us adding a line? ***Berry:*** Yes, absolutely. ***Roberts:*** Is everyone OK with adding this line?
Foreman: What are the contaminants of concern in these? From what I heard those two are the worst contaminated. Are these considered closed landfills? DOE, do you have a characterization on what is in them at this time? Since it is a closed landfill, does the OEPA have the final say?	***Simonton:*** Yes, we can provide the characterization on the records of the landfills. ***Roberts:*** I believe the most current presentation was given by J.D. Chiou at a subcommittee on the feasibility of the landfills. This is a recommendation DOE can accept or not. If they chose to accept, this doesn't allow them to decide because they do have regulators.
Smalley: The cell must be absolutely ready, correct, before anything goes in there?	***Simonton*:** We won't need fill until the material is ready to go in the cell.
Cave: If something is dug up out of a landfill and it didn't reach the regulatory limit or it was to high, it would be shipped off?	***Simonton:*** It must meet the Waste Acceptance Criteria.
Burkitt: Who assesses that? Is it the contractor, DOE, who?	***Simonton:*** I don't know the answer to that. It is a contractor, but I don't know who does the overall assessment.

Cave: I would like to make a motion that we proceed with a vote on Recommendation 19-03
Burns: I would like to second the motion.

Public Comment on Recommendation:

Blackburn: I would first like to commend the board for finally making a recommendation to clean up toxic landfills outside of Perimeter Road. There is one issue I have with it, which is it is basically saying that if there is room. If you remember this is very much like the wording of cleanup of landfills and plumes inside Perimeter Road and it took congressional action for DOE to finally agree to do it. So, if you want them to clean it up, you must tell them you want it cleaned up. It is their mess. They need to clean it up.

Williams: We have been told for years that the landfills and plumes would only be cleaned up if they have the disposal cell and now what I am hearing is you do not know if you will have room inside the cell. Have the permits been granted to dig up the landfills and plume because the previous meetings that I have heard the permits have not been granted for such activities? And do the contents go under the WAC and is the WAC still under development or did I misunderstand that? So how could you possibly make a recommendation to dig up 734 A and B without having a characterization of what is in those landfills and without having a Waste Acceptance Criteria?

Zultz: Does this simply apply for the PORTS site or does it go to all sites? I am hearing that in South Carolina they are in the process of getting their radioactive material changed to a lower class to be able to get it out of state. Can we get something in the recommendation that we are not accepting out of state waste no matter what level it is? We do not want waste outside our state coming into our onsite cell.

Ison: The Portsmouth plant which is in Piketon, Ohio, shuld be called the Piketon Plant because we are suffering all the consequences. I don't want this stuff dumped in Piketon period. I think you could move it carefully, safely, out of here. I drive right by it, my family lives by it. I raised my kids right by it. Over thirty some years, my kids swam in the creek, they played in the creek, they played in the yard, they played on the farmland around there. The farmers plowed the fields and disk them and stuff keeps coming over in my yard, and on my house. We drive in that dust. Don't tell me it is not contaminated by that dump. I want the stuff moved. I want it moved to a desert. Our rainfall is abundant.

Tomlison: I live about a mile from the school. I would request that you would simplify your stuff so the general public can understand.

Sea: First, Not only have these plumes not been characterized, but there has never been a risk study done to determine whether digging them up would expose the community to more hazard than leaving them in the ground. I suspect that it will expose the community to more hazard by digging them up and moving them over and reburying them. All that work taking them up and exposing the material to the environment, it would expose the wildlife and expose the material to be carried by

the wind. Second, where are you folks even coming from to even suggest this, you have not been listening to this community. This community has been telling you, we do not want the waste cell. We intend to stop the waste cell, there is not going to be a waste cell. If there is not going to be a waste cell, to pass a resolution like this, encourages DOE to think the community somehow in some way supports a waste cell.

Colley: We have been fighting this waste since about 86-87. I would like to know how you could even consider putting waste in it when we told you back in '95, '96, '97 that the bedrock was cracked under the site, which is sitting on top of the largest aquafeed in the mid-west. Why are we still considering putting waste in a space out there? My other question is do you have a license to store waste out there? I know back in 1986 you guys did not have a license for all the waste and you got in trouble because of all the waste on-site.

Knauff: As we know every meeting starts with those words and I am going to harp on them until I can't any longer. Deactivation instead of decontamination is limiting your mission. And you should be asking the same question, who is the verifier about what is coming out of the X-326 building. I assure you there isn't anything in those landfills worse than what is left in the S-326 building now. And I am telling you now that the verifier is going to be FBP, a DOE contractor and a lot of stuff still in the X-326 building needs to be removed and not placed in the cell.

Montgomery: I would like to ask, if you guys are so good at landfill work why do you have to dig this crap up and fill another landfill? And if it is no good, then how do we know that this new one will be? You can't fix the ones you put out around the place that is leaking, but you are going to dig them all up put them in this other one, in about 10 years it will be.

Paul Overly: I would just ask the board to pause and give thought to passing this before you approve digging up landfills that are going to stir up toxins that we will breath. I would just ask first of all you don't know that the contaminants in full. You don't know the monitoring system out there, Mr. Simonton showed us, an in-depth study of where these monitors are at. I recommend that you get your money back, the wind in Pike County is not blowing northeast to southwest, and it is hitting Otway 13 miles to the southwest. We have no monitors, so you do not know the extent of the contaminants that have went on past. You know that the two monitors that were hit are the farthest away from the facility. So, it could be in Jackson by now, we do not know, you do not know. That is the first step before you approve anything.

Cheryl Overly: This is confusing to me. How can you make 19-03 when your next recommendation is 19-04 to re-open the record of decision and reevaluate the waste acceptance criteria? Based on a community input? Unless I am thinking about this wrong, I am not sure why 19-03 is a recommendation with 19-04 being one?

Barker: This WAC, correct me if I am wrong, at a meeting we had in Piketon, with Joel there was no cap on the level of radiation put in that site, based on what we learned in that meeting. They couldn't give us a level and open to anything out of state. We don't even want our stuff in it, we want it gone. I have a grandchild that was born with disabilities. They live within walking distance of Zahn's Corner School, she is a year old and has leg braces that she just got, has a catheter and bowel issues. She is trying to learn how to walk in a little walker that to me is unacceptable. Something like this when none of us want it here? We don't want any of it, so it should just be moved and hauled off.

Davis: What happens when you open the plumes and landfills when the air catches all the radioactivity that is buried out there? Then it is too late to do anything about it, it is already airborne. This shouldn't even be voted on. If you can guarantee me that the air quality will be good from doing that then I might say it would be OK. Are there any guarantees with no cotainants floating in our community when all this takes place? This shouldn't even be voted on today.

Ison: Like I said, I live close to the plant on Dutch Run. We had straight line winds that were the strength of a tornado, come straight through the A-plant right up the road from me. That wind was so strong that it tore up the electric lines. We couldn't get back home, no phone service and we couldn't get home. It uprooted a huge apple tree in our yard. You can't tell me that the wind didn't pick up the dust and dirt and contaminants from your plant and from that dump, you can't. You guys have covered up too much, we don't believe anything you say anymore. The board, I thank you for all your recommendation and all your help. But DOE, we are not going to take it anymore, we do not believe you. We do not want this dump. It is dangerous and we want to see our grandchildren live healthy lifes.

Board Comments on Recommendation:

Fraley: I do not want to vote on this until we get the facts.

Roberts: Is this a suggestion to table this?

Board: Yes

Roberts: OK. Let's open that up for discussion. Is there anyone else?

Helton: I agree with Rick, I was under the assumption that the plumes would be explained what was in them prior to being dug on. If they don't meet the criteria they wouldn't be dug on. I agree with Rick. Now I learn that the WAC is not completed. I think we need to table this recommendation. I would like to see the plumes gone, but if the WAC can't cover that criteria at this point, that is crazy.

Smalley: I have a problem with this too.

Burkitt: I would like to make a motion that we table Recommendation 19-03.
Helton: I would like to second the motion.
Roberts: Does anyone oppose tabling Recommendation 19-03?

Motion to table Recommendation 19-03 *(11 approved, 0 o*pposed*, 0 abstained, 0 recused)*

Draft Recommendation 19-04:

Question/Comment:	***Answer:***
Foreman: What is the difference between an open house and a public comment period? Open house is something you just show up and nothing is put on record. So, to be transparent let's have a public comment period. What you all commented tonight will go on record. People need a voice. I just want to try to explain to the community, what this means is the recommendation to reopen the ROD does not stop the progress of work, Mr. Berry. The public, when they speak at the open houses, that is not documented, it is not reported. Mr. Crabtree said there was a process. If you remember Councilmen Brushart went through it as well as myself, when we paid for the 3rd party assessment we got no money from DOE, talk about spinning their wheels, it took them nine months to tell us no. We went ahead and pulled the trigger and paid for it out of our tax dollars, the small town of Piketon. We give up our money for you. Not because it is a bad thing, because it is the right thing. We paid for the third-party assessment and we didn't dig one hole, we went through the four thousand plus documents and what did they find? Misrepresentation of where the fractures are, I am not making any misrepresentations it is right in the ROD. When you mistate things then I am going to have a little bit of a problem. When you reopen the ROD then you can say I think there should be more	

sampling. 19-04, I wrote it, I support it whole-heartedly. I support you the community to have the work, it doesn't stop with this thing. But guess what, what if you find something you don't like on there and you don't want in this community, shouldn't you have the right to say? That is why I wrote this recommendation, that is why I feel strongly about it. I do not know how else I can put this. It gives the community a choice and let me ask you, Mr. Simonton, open houses are not a regulatory document. But a public comment period is. That is what I am saying, and I feel now with what is going on the people need to have a voice. I am not ready to make a decision for all these people's families for a thousand years unless I let them have more than a voice, because of the misrepresentations of DOE and they admit they messed up. These misrepresentations need to be amended and the community needs to have a voice. Right now we are involved, so, here is the deal, several people on this board have written recommendations, Mr. Berry has written several. I am an elected official and I filled out my paperwork for SSAB, I didn't lie to you Mr. Simonton, DOE, I told you who I am, I speak for the community. I live in an affected area. If one of those cylinders break, Mr. Bulter, Mr. Schneider, Ms. Tegethoff, Mr. Kubera, ODH have to alert everyone. I have an 83-year-old up the hill I need to take care of, to make sure everyone is taken care of, so the board is involved, if you want to adjust something then speak up and say it. Here is the deal, the community is sitting here, they are listening. This is the way to open the ROD to have a discussion. This board is	***Simonton***: Public comment is formal, yes.

not the only entity attending this meeting. DOE says we need to be more transparent and people need to have a better role in the community. What better way to have a role in the community than to open the ROD and have these people be able to speak and say what they have on their mind? We are just a small representation of the people. 19-04 is a simple recommendation to open the ROD to understand what is in the WAC. I think we should go ahead and vote right here. I want to vote.	
Burns: I have been listening to a lot of things tonight also listening to people in the past since they found the neptunium in Zahn's Corner. It says it is a thousand times below looking at the graph that Greg presented tonight shows it one thousand times below the risk level. A lot of the things coming up tonight and a lot of your concern, which is my concern. As a resident of Pike County, if DOE would just step up. DOE seems to think if they do not say anything it will go away. People are tired of them not saying anything and it is not going to go away. I think that all of this scare going on in the community could have been smashed right away if DOE would have made an announcement the day following they found this, stating here is what the levels are these levels cannot hurt you. If they would have just came up with something and said something. Me as a member of this board, I am for the community. It's my responsible to look out for this county and residents in other counties and I definitely would like to see DOE make a public statement sometime. The SSAB board is also here to help DOE, to help them figure out problems. We cannot go to war without weapons. DOE help us out if you want the SSAB board	

to help this war we have going on. Let's just call it a concern, then say something, make a public announcement. These people have a legitimate concern as do I. Thank you Eric. Mr. Foreman, I like what you have done here, but at the same time, it is your recommendation, not the board's recommendation. I would like to see the board get involved in this recommendation. I would in no way, shape or vote on this recommendation tonight. I am not saying it is bad, but I am saying that we as a board need to be together and go through a recommendation and agree on a recommendation. I don't have a problem with you writing a recommendation or any member of this board writing a recommendation, but I do with the board not being involved in it.	
***Smalley*:** This whole thing is the health and safety of our citizens first. I have six grandchildren and one great grandchild. I knew when I went to work at the A-plant back in 1989 when they were still processing, I had all the training, it was dangerous, I knew all about it. I saw releases. I worked in the 705, I was janitor all over that place. My dad five years ago died of fast acting lung cancer. First thing his company asked me was did he smoke, Yes, he did 50 years ago, that had nothing to do with this. It is a concern for me. Like I said, I accept that because it was a good job and good wages. One time I got exposed, I had to clean my hands. It scared me. I have had health problems, thank God since 2012, no cancer. It is unacceptable that it was in this school. It should not be in that school period. I don't know where it came from or how it got there, but we want a future for our children. I have three kids that are RNs. I am proud of	

them. My youngest daughter told me, Dad from what you have told me about the A-plant, I have no desire to work there. I don't want to be an operator, I don't want to be a nurse, I don't want to be 10 miles of that place. Another thing that concerns me is back about 2010 right before Fluor started, I saw people walking out of there in their work clothes. 40-50 years they had a regimen where you didn't wear your badges, you didn't wear your work clothes outside of the plant. I have seen them do it, and I do not like it. I have seen people at Wal-Mart and other places, they have their vest on, they have their badges on. They do not even have laundry on plant site anymore. When you got done at the end of the day, you went in there and showered, took off your work clothes put them in a hamper, and they washed them. You got in your street clothes and walked off plant site. Nobody should be leaving that plant with work clothes on. You do not want that out in the public. The health and safety of our citizens is the number one priority.	
Burkitt: I just want to comment on what Mr. Burns and Mr. Smalley said, and I agree with them. But the problem I have and the problem that has existed with this issue, when you talk about neptunium that was in 2017 and I have been coming to these meetings. Someone could have told me, even if it is hey, we got an air hit at your school. I am the school superintendent there. We should not have to dig through a report to get that information. That is frustrating. I would like better communication with the department. Honest communication is non-existent.	
Berry: I fully support trying to keep the communication going. I support more monitoring stations. But I do not support shutting down the on-site waste cell.	

Neptunium was detected four times since 2003, which means it was detected before that cell was developed, now you want to blame it all on the cell and shut it down. If you are that concerned, then the whole plant should be shut down. I do not think it is coming from the on-site cell and the amount detected is a thousand times lower than the acceptable level. The ROD was a long time developing, people stated what they wanted, it was passed and moved forward.	
Crabtree: First I want to support what Bob said. I went to lots of public comment sessions and the ROD that was developed took years to try to develop this site, so our future generations have a chance of living here. I support sampling, but I think this is a backwards approach. There is a lot more work going on that plant site than the disposal cell. I agree we need to find the source, but let's not just pick out the first thing and shut it down. That will create the loss of local jobs. Hundreds of them. I will not support this recommendation. My point is this will affect a lot of people. I feel this is a backwards approach.	
Cave: I pretty much agree with Mr. Brad Burns in that we were not involved in the thought process of this recommendation. I believe everybody here knows that most of our recommendations come from our subcommittee meetings where we have sat around the table and had open discussions on the recommendation unless I was absent from that meeting. I didn't have the opportunity to have a discussion with this topic.	***Roberts:*** So, Carlton it is your preference that we role this recommendation back to committee?

Roberts: Dennis has asked to role this forward for a vote. Does anyone want to second it? Then we would open it up for comment. It is still a board document so

you can choose to do what you want. Dennis put a motion on the board to call for a vote, does anyone to second it?
Smalley: I would like to second the motion.

Public Comment on Recommendation 19-04:

Paul Overly: I would like to mention that even though I live over toward Beaver and not in Scioto Valley School District that all three of our children are in the Tag Program in Pike County and this Tag program is at Zahn's so it does affect me directly. I would like to say again that there is a division with one side aligning with the community the other side is more about jobs. I respect that, but I would rather have healthy, poor children than dead children. In all respect to Mr. Crabtree, the analogy you gave if there is a very serious accident on 32 that involves life you better believe I would shut that road down until I could figure out how it happened. That's all we are asking that they shut down everything.

Tomlison: I just have to say what was in the schools was less than you are exposed to in an x-ray, but the thing is even in a hospital when you are sick there is not going to be x-rays every day. They don't do that to expose you to it. Even though it might be less than an x-ray, you will be exposed to it every day.

Sea: Mr. Berry said the ROD was a long time in coming and everyone had their say. That is a direct quote, that is a false statement. I was involved in the formation of the ROD and public comments on it. There was a single public hearing. That public hearing was held on the night of the worse blizzard in Pike County in the last 10 years. All the schools in Ross, Pike and Scioto counties were closed that day, we demanded that the DOE cancel that hearing, DOE would not do it, they held it anyway and almost no one showed up. I would say that 95% of people in this room did not know about the ROD and did not have the opportunity to comment on it. Our group asked for the formation of this SSAB. If this SSAB does not pass this resolution, we will petition for the dissolution of this SSAB.

Roberts: I am going to ask that you address the board not individuals on the board. We are trying to work through this together for what is best for the community.

Brewster Health Commissioner: As the ROD was being developed the sign off no one at least no one in the public, recognized that DOE activities would be contaminating outside locations. Normally when this happens, a contaminant leaves a site and a responsible party would stop these outside impacts. Since the ROD has been approved and you have been implementing your project according to the ROD and since you have also been contaminating the lands, water, homes and schools of our community, it would seem to me that you do not have adequate controls in place. It is reasonable for the public to expect and leaders to demand that you do the responsible thing and stop the very acts that is causing this unacceptable condition, which is contamination we are talking about. The ROD should be opened

to allow for a development of a path forward with the public support and you can execute without contaminating our community.

Williams: There is no other logical conclusion than that PORTS is the source of offsite contamination. I heard people behind me mentioning STAR, stop think act review, that is a common practice when there is a problem that is what this resolution asks for. The responsible decision is to stop, and reopen the ROD. If you represent this community you want to address the lack of trust in this community and facility, reopen the ROD. If the ROD has accurate information that should not take long to confirm. The difference between 19-03 and 19-04 is 19-03 could have additional contamination of our community and 19-04 would result in additional caution and information for our community and reopening the ROD gives information that was requested by Mr. Burns and be provided by DOE. Please consider voting on this resolution tonight and approving it by doing what the community wants by reopening and determining the source of the contamination.

Colley: I want to say that we need to decide on this tonight. We can't wait any longer, there has been a lawsuit filed in the community already and we need to look at this waste in Piketon one more time. We have recycled fuel, reprocessing it here at Piketon. Piketon is a uranium enrichment facility. We were not supposed to be reprocessing plutonium and neptunium. We got it sent in here from New York in 1953. This is how long they have kept this a secret. Not only that, but in 1990 Paducah started shipping stuff to Piketon that came from Russia. None of these workers have been told, they are sick, now we have this stuff, and everyone is saying where did it come from? It came from recycled reactor fuel that we were not supposed to have and that makes our waste the high-level waste.

Davis: I just ask the board to really think hard on the ROD and open it back up. The community didn't even know that that was being made. The community has been left in the dark about everything. I didn't even know there was going to be a waste facility here until a few years ago. I have lived here my whole life, why haven't I been told that? Why didn't I know there were any meetings? It sure wasn't publicized very well. So I ask the board to reconsider the community, what we want and we want the ROD to be opened back up and reviewed and looked at with greater details.

Ison: Have any of you had children with cancer and pass away with it? Have you gone to Children's Hospital every day for their treatment? Have you been on the phone with them for their final wish? They all went to Zahn's Corner, two went to Zahn's, one lived right down the street. They all three died from cancer. They all three got cancer. But I am not going to be quiet. I watched those little boys die. One of them didn't even get his wish, he couldn't even stand up to do karate, but he could lay on the floor and do it. There are three boys buried out there at Mound Cemetery together and you can't tell me that it wasn't something from Zahn's Corner School. There is also many more. Many.

Knauff: As Brother Smalley said, we have and are signed up to do the job at the site to finish the job cleaning it up, so it doesn't get spread out anymore. We can do that if we want to do it correctly. What is interesting to me is the threat of losing a lot of jobs. I talked to a commissioner the other day that said, " John they told us if we didn't agree to that that they would just put a fence around it. What are we going to say to that?" I said let me ask you a question, which is worse, putting a fence up now and let it stand for a while or let them put everything in it under the sun into that waste cell and put a fence around it and we have a grass field with nothing there. If we do not do this correctly, this community is going to pay the price forever. I have been concerned and have been concerned ever since I have been back. Let me tell you what the project director said when I went to the executive director safety meeting this month. He characterized this as being in a war and we have a fake news thing going on with this thing. Also, your slide should have all the exposures on top of each other. These kids didn't sign up for the extra.

Lamerson: I would like to thank Mr. Foreman for his resolution. I would like to say to this board you are appointed to represent the people of southern Ohio, not DOE or Fluor. Many of you that I see sitting around the table, I saw working at the plant, or have a relative working there or husband or wife is at the plant. I do not agree with your membership of this board. I think it should be broader. Mr. Crabtree your intimidating statement about jobs is a bunch of hogwash. The federal government must clean up that site no matter what. He attacked us. I don't like to be put on a stopwatch. Whose decision was it to give us 60 seconds? But you gentlemen can speak, however, long as you want and do whatever you want. You need a resolution to give us more time to talk and be heard.

Barker: The meeting that you had for the public to decide on the ROD, I have lived here all my life, went to school with Greg, I didn't know anything about those meetings. My kids both went to Piketon, Zahn's Corner. When you watch your grandchild go through the things mind did, I don't care who loses their job, I don't care how much it cost them. They can get other jobs and relocate. Most of them aren't from here anyway, they came here to work. My dad worked there and retired from there. That is what fed us, but my dad would never ever put one child, let alone thousands of kids' lives on the line for his job. He would walk away, if he knew that stuff was going on. I think it is ridiculous that you are trying to throw money at kids and people's lives. My son had three kids die from cancer from his class. It is ridiculous.

Cheryl Overly: I would just like to ask the board to consider passing this tonight. I know a couple of you have said you didn't have the input, or the subcommittee didn't meet. I think this might have been brought up at a prior meeting, I could be incorrect on that. But I don't think it is going to go away. I guess I don't understand what you have to lose by passing this. If you reopen the ROD and nothing comes from it, then what have you lost? But if you reopen it and you find things the public wasn't aware of, then look what we gained. So, I would ask that you really consider it, don't just pass it off because you didn't know this was coming. It is a difficult

situation that you are in to have to vote in front of people, I understand that, but you are on the board for a reason, so I ask that you strongly consider this.

Doyle: I would just like to say; I would hope you would vote for this recommendation. I can't believe that the greatest minds that we have in the field and this is what they come up with for us, this is it. Kids going to school being contaminated, people losing their homes because of it, that is what they are going to face. They are going to lose their homes because there is nothing left here. This nuclear energy industry already has blemishes all over it. You can look it up anywhere, every place in this United States and other places have blemishes so why do you guys want to be the next one? Why can't you tell us that this can be safe, why can't you take this stuff and send it out to the desert? Why can't you help us be safe in our own homes and help our children have a future here?

Myers: I would like to encourage this board to really consider this recommendation. I think it is a good thought to table this and really think about this contamination in our community and I think our eyes would really be opened to what we find. I know everybody spoke about cancer. Myself, I have had 13 brain surgeries. You are going to tell me that does not have some correlation to the contamination? Is the CTC going to be checked and the MRDD building behind it checked as well?

Johnson: I am the business manager from Tri-state building construction trades, and I represent the construction workforce out at the plant. We currently have about 120 people out there. This resolution just singles out the disposal cell work and I think everybody in the room knows that there is much more contamination at the process buildings, which we are just fine with moving forward with that, but in my option the disposal cell work is the cleanest work out there. I believe we moved 2.2 million cubic yards of dirt out there in the last couple of years, but it is no different then if we moved 20 cubic yards of dirt in the last couple of years for the Portsmouth by-pass. But anyway, by singling this out, I fear it is going to be a negative on trying to get funding for the project. I have had this job for 10 years and I go to Washington every year to fight for funding, our congressional people are rock stars at getting funding every year and shutting this down is properly a negative.

Board Comments on Recommendation:

Foreman: People in the community, I got one and the board got one, too. Estimated 80 thousand flyers went out for your Open Houses. I got one at my house, I am sure everyone in this room got one, but I didn't get a flyer when you had all these public comments. It gives the community the chance to know what was in those buildings. It just says open the ROD to have a discussion about the WAC, which we started a long time ago and Mr. Snyder says they are still implementing the plan. If we are still implementing the plan, now is the time, people want to have a say. This time send out 80 thousand flyers and see if they show up.

Caudill: I am retired from USEC and I have children and grandchildren and we had this vote once before and it didn't pass and I voted for it and I intend to vote for it today because I don't want my grandchildren to say their grandma was on that board and didn't do a thing to stop it. That is my reason. I appreciate everyone that has been here and told the stories of their family and friends.

Foreman: One more thing, people recuse themselves if it is a conflict of interest. Just want to make that point.

Motion not passed *(5 approved, 6 o*pposed*, 0 abstained, 0 recused)*

Roberts: Dennis recommendation 18-02, we voted on it last May, it did not pass. 18-02 recommended DOE open the waste disposal Record of Decision and open public comment. That recommendation did not pass so Dennis asked about submitting a majority report. He has provided to us a cover letter and asked that be done. So, we are going to run it though the office to DOE.

Subcommittee Updates:
Budget and Lifecycle Planning Subcommittee Update by Cindy Quillen:
Quillen: The Budget and Lifecycle Planning Subcommittee met on April 9. The purpose of the meeting was to present an update on the President's FY 2020 Budget Request presented by Bob Smith, Fluor-BWXT.

D&D/Remediation Subcommittee Update by Brad Burns:
Burns: The D&D/Remediation and Future Use Subcommittee met on April 9. The purpose of the meeting was to present a Non-Destructive Assay Update presented by Ricky Walls.

Future Use and Infrastructure Coordination Subcommittee Update by Brad Burns:
Burns: The Future Use and Infrastructure Coordination Subcommittee met on April 9. The purpose of the meeting was to have an update on Landfill Consolidation/Redevelopment Planning Update by J. D. Chiou.

Workforce Development, Education Outreach and Worker Training Subcommittee Update by Dennis Foreman:
Foreman: The Historic Legacy & Community Engagement Subcommittee met on April 9. The purpose of the meeting was to discuss Traveling Displays presented by Jack Williams.

Public Comments:

Ison: I want you to remember three things, Aaron Ross, Luke Kitt, Auston Rhoden, Zach Farmer, Kathlyn Smith, Terry Jordan, Shayna D, Josh Snail, Sandy Richards (my children's grandmother), Connie Rider my very good friend that grew up right there beside the plant, the day she died was hard, she fought very hard for nine years, six

surgeries, the day she died another good friend called me, messaged me on my phone and said I wanted you to know I went for a scan today and my cancer has spread. Her name was Becky Peters Bolt she worked at the A-plant too. In one day, I was losing two friends. When you look at this and you voted against Dennis recommendation, how can you sleep at night? How can you sleep at night because I watch my little grandchildren out in the yard, and it scares the daylights out of me now more than it did when my kids were young. And I know when we had these rallies we had retirees tell us all the papers that DOE fudged. They told us about their badges that were hot, then the person would take them and throw them in the trash and give them another badge. I believe them, nobody can tell me they were lying. They won't say that, they were mad. They know that things were covered up and you expect us to trust you and trust you about this dump and you guys voted no on this man who has worked for this trying to help people. He isn't trying to hurt people, he is trying to help them, why won't you? Why won't DOE? You help everybody else in this country. It's time Piketon gets it. Piketon. We want help, we deserve help. I want the truth. I am getting mad, I am furious because I have lost, I have lost greatly in my lifetime from all of this. I've got the rest of my life and I will fight it.

Frank: Local resident. The re-opening of ROD is nothing that should cause you guys any concern. It is just a roadblock if you mention that you want one. That is the only thing that is stopping it. So when you are involved in all this contamination and kids are involved and pregnant women that's the community. The health of the community, we need jobs, yes jobs are important, people need income, but people need to be able to breath clean air, drink clean water. Livelihoods are at state, not bank accounts, but lives.

Sea: Maybe you have never heard of our group, we started in 2006 as a neighborhood organization, people living around the fenceline to oppose the plan at that time which was the real plan by the Bush administration to store all of the country's high nuclear waste at Piketon. They were a few months away from implementing that plan. We stopped them. We stopped them by getting petitions filled out not on-line but door to door in this community of over 5,000 people opposed to that plan. At that time Piketon was the only DOE site in the country that didn't have a SSAB or community advisory board. It was our group that included the petitions calling on DOE to create an SSAB for Piketon. It was in response to our petition that DOE created your body. The reason you are sitting there, but they did not fulfill our requirements for the creation of a community advisory board. They put contractor representatives on the board. We asked for a community advisory board. We didn't get what we asked for, and tonight you proved to this community that you do not represent this community and don't ever claim that you did, because you did not. You failed that job and because you did that, we tonight are initiating to get a petition drive to disenfranchise this body and to replace it with a true community advisory board that includes no contractor personnel, no conflicts of interest on the board, so you go screw yourselves. We are going to stop that waste cell. OK? This community is.

Williams: I just wanted to point out, I want Congressman Wenstrup's representative to make note of this. I believe there were six votes against the 19-04 recommendation tonight. I know Mr. Fraley has a contract at the plant. It is my understanding that Mr. Crabtree works for somebody out there, I don't honestly know. I am curious of the representation of the members of this board, who is employed by or retired from or the contractors of or has a spouse that works out there that might have a conflict of interest? I think that if you look and see who voted against, you will find that there really are conflicts of interest. How many seats on the SSAB total? Give me a break, these are valued questions, I think. How many are vacant Dennis? How are the appointments made to the SSAB? Who picks them DOE or Fluor puts who they want on the SSAB? Write it down, shout it from the rooftops. How many Pike County people are on the SSAB? How many of these seats have not been filled for this amount of time? It is a site-specific advisory board, site specific to Pike County, we deserve better than what is happening here. This is ridiculous.

Knauff: We have about a thousand members working on the plant site and we know how to do the job correctly and we know when it is not going correctly. I wish the X-326 building was in the condition that you think it is. I think you are disinformed about that as you were about the fire that was going on. It's just not the way you are having it painted. There is still a lot of product, a lot of equipment still in the 26 building. When I went to the executive safety meeting after the Zahn's Corner incident the director Bob Smith tells me he is in a war with the community and fighting fake news. Tells me that we not only have a problem with how we handle the decontamination, that is a problem when we can't even use that word, decontamination and decommissioning that site if we don't focus on that, we have a PR problem. If you do not take these people and their kids concerns seriously and if you don't treat them with proper respect, how do you expect them to trust you with anything? I said this at the very beginning when I came to these site advisory boards, it is not enough time for public comment. We are down now to 90 minutes a year total public comment at these sessions, back then we had 15 minutes every month for 12 months, what's that? An hour 20 minutes, it is not enough time for these people to have input. It is an insult to anybody's intelligence to compare those exposures up there. These kids, us live in a post nuclear war era and all that stuff is out there that is normal exposer. We can't eliminate that. But these kids did not sign up for anything extra, anything that we can prevent coming off that plant site we should do. So those exposers rates up there on that chart, you should stack them on top of each other then put this newest exposure on top because that collectively is what they are getting. There is no guarantee that if you stay under the action level that you are not going to get anything, but I say I hope those air monitors are not out there to tell us when to go out and scoop up the dirt, they are out there to tell us something is not going correctly. We are getting a hit now and we didn't use to get them, we need to figure out where that is coming from and cease that activity and clean it up.

Colley: Thank you for writing that resolution and hopefully you write up another one. Maybe if you will work with them, they will come back and do what is right for the community. I want to remind the board, you are liable for what you do and your decisions in the community, you are contractors, there can be a lawsuit against this board for making decisions that is not a way for the community. I am going to tell you one more time, we have highly radioactive waste at this site. They started shipping reprocessing reactor fuel at this site since 1953 it started showing up on the equipment inside the site. We have a real serious problem out here. How many times have I talked to this board about the problem and they just laugh it off? Maybe not you guys, but there have been more in the past. If you go back and look at some of the past boards that were here, they found plutonium that was here and it is written up in your documents. There are written documents about plutonium. We have ignored the real problems here with neptunium that has now gone off site to the school. How much is it to ask you to quit digging right now until we find out? DOE needs to tell everyone where the neptunium comes from. We need those records released. I understand they can't release them while processing, but we want them released now with a full investigation. I think the union in 1979 went to Washington D.C. they asked for an investigation and all they got was harassment. So, I am begging you and the community is begging you to stop this mess until we find out what is going on. Dennis, I hope you write up another resolution and come back to the next one and see where it goes from there. Thank you, Dennis.

Barker: The 16 air monitors, one that is not enough, if it made it to Otway then it made it to Jasper Elementary and Piketon High School. Face it, it is at my house, at my son's house, which is very close to the school. Somebody mentioned pregnancy. My daughter-in-law got pregnant right after they brought the house, the beautiful green house with the rocks on the front of it on Zahn's Corner Road, almost on the corner. They worked, my husband worked, and I worked on that house for months. She got pregnant, has fertility problems so she did vitro, this was her last egg. Three eggs, we have a set of twins that are three and this one year old. This baby, which was exposed to all that crap, look how she was born. You people that turned down Dennis. My granddaughter is worth way more than anything at that plant. And the dirt work, my son that lives there works for an excavation company out of Columbus and makes a lot of money. They can't keep enough dirt workers. Send your workers up there, I promise you he will put them to work. And you are saying trace amounts and I remember; I do think that the representative has there, and the question was asked what the dangerous level and safe level is. The answer was oh we don't know; we haven't done studies on that off-site contamination. These kids are getting exposed to it every day and who knows what else. And who knows what hasn't been detected because there are not air monitors in other areas. How can I get my son's property and my son's kids, my kids and property tested? The testing should go as far distance from the plant until you can get a clean test. I have a feeling you would be shocked at how far it has gone over the years. The plant is called the Portsmouth plant when it is something good, when it is something bad it is called the Piketon plant. That is how it has been for years, that's been the joke of the community. CTC

or all the schools you pick out should be tested in this county. Eastern, Western, it might be there too.

Doyle: I would just like to say first of all when we speak, we are not used to speaking in front of people. When we speak, we want to be taken seriously. When we get upset or get excited it is not directed at everybody in this room, but toward what is happening in our neighborhood, what is happening to our families. I saw whole families with all different kinds of cancer, didn't just have one, it wasn't hereditary, all different kinds of cancer. When you don't listen to what we are saying, when you tell us we don't have a voice, it tells us you don't care about us and about our children. That is not acceptable. It's just not acceptable anymore. You know when you have kids and there's not just cancer but so many cases of autoimmune diseases. There are so many MS, ALS, deformities so many in this area. I don't know how anybody can say it is not from the plant. Is money more important to you guys than life's? That is what we want to know, is it more important to you than lives? Because to us, it is not. My kids all went to school at Zahn's, all three of my girls have health issues. One is on thyroid medicine the rest of her life, another one is watching her thyroid, the other has an adrenaline problem with her only one kidney. So why woundn't we be concerned? Why wouldn't we take this serious and why won't you?

Final Comments from the board:

Foreman: I would like to thank the community for coming out and speaking. Come often and let every member on this board how you feel. We serve on this board and have broad shoulders. I have them, I will take what you have to say whether you like me or not, it doesn't matter. So, I will tell you what, keep coming to the meetings be involved. I want the board to recognize that the health commissioner did get up and speak, you need to pay attention, we are supposed to be representatives of the community. Right now, in this time of history, there is no wrong time to do the right thing. Tonight, was the right time. It was the right time to do the right thing. We could have done it tonight. There is nothing wrong with discussion, open and transparent discussion. Congressman Wenstrup's said, and I will hammer him until the day I die, he did say transparency. The government has lost its way with transparency. I am being transparent, 19-04 will have another number now. I will write another one, then I will write another one, then another one. These people and you as well, a lot of people say it cost jobs, to do it the right way some of those jobs might last a little longer. You don't need to hurry this thing up, I heard a ten-year plan, slow your roll and relax and do this the right way. We only have one chance to do this the right way. This is our community, these are my people, your people and I love this area, so for me, yes, I wrote this recommendation, and I am not going to apologize for it. Thank you.

Burns: I first want to address Mr. Foreman, let me tell you this, I admire you for writing this, I really do and with a few changes on it, I would probably vote for it. I should have abstained myself, instead of voting against it, my mistake. But I will tell

you this, most of what you had in there, I do agree with. And I do agree that if the people want the ROD opened back up then it should be. But if you want to do it with the board and let me go over a few things that I have questions about, I would be happy to do that. I would like to see you present it again. I really, really would. And to some of you folks in the audience, let me set the record straight, I have never worked out there a day in my life. My wife does as a lot of your family has, too. She is retiring in a few months, so I have no monkey in the show, it doesn't matter to me whether the ROD opens or not except for my conscience. I am a Shriner and carry children to the hospitals two or three times a week. I take children that is club footed, children that don't have legs, children with no arms. I have seen what diseases and things can do to children. I have a bond with these children when I take them because I take them week after week after month. I am proud of doing that because God wants me to do that. It's a God-given right to do what he wants me to do and help children. To answer your question about children and money, there is not enough money in this whole world for one child. I have a heart for children, so it wasn't anything to do anything or anybody, there are just a few things in the reading of this proposal that I would like to talk about. My only reason, and again I wish I had abstained instead of voting against. So, we will have this again. Dennis, I admire you for writing this, I really do.

Quillen: I like the fact that Dennis took it on himself to write that, but my reasoning is actually what Brad said it should have included a whole committee not just one person. And me as far as not having a conflict of interest, I was fortunate enough to find work out at the A-plant back in 1977 and I am a proud employee of over 42 years. I have seen the plant come and go as far as safety rules. And I have seen a lot of people violated because they thought they could keep stuff. I have seen a lot of changes both negative and positive at the plant and I got to retire last year after 36 years, because I wanted to. I wanted to spend more time on this board to help make an example and to try to make improvements. I am as upset as you are that they found contamination in the school. I know what it is like to be scared, not understanding or knowing what they are doing. It is so technical up here and they need to bring it down for the common person to understand it. The public needs to understand everything from us. You are thinking, exposure, exposure oh my God when in reality we are all running scared. The employees at the plant are upset because they are wondering how it got in the school as well as you all because you have kids and grandkids, so I sympathize with you. I understand your fears. When we are out there asking you to join, don't slap us away. Join, fill out the application. Information is what you need. Don't take it because Vina says so or Joe Blow says so. I just want you to understand where we are at. I want to look at the ROD again and see if we are missing something. I agree with what Brad said. Thanks everyone for coming.

Foreman: DOE needs to speed the membership up and get some more members, because like tonight we were lucky to get quorum to be able to vote. Before you leave tonight, Julie or Cindy can get you an application and you can fill it out to sign up. I have the Scioto Valley Schools superintendent and treasurer here, if I apply at

least tell me I didn't get hired, say thank you for your interest in our school and so on. DOE takes time and they don't tell you that, if you didn't get picked. They don't tell you anything. I want to see that changed. These good people here take the time to fill out an application to get on this board that you do send a letter that says at this time we are not picking you, but we will keep you on file. I am just saying right now we have six positions to be filled and I get with the interest in the community, we need to fill those positions, it would be a good thing.

Roberts: We will let Greg close it up.

Simonton: Thank you for everything, I know it was a long meeting. A lot of recommendations. I do want to say, because of the one thing said, there is no liability, you are a volunteer. Recommendations do not open you up to any liabilities, I want to make sure you know that. I want to thank you for the discussion, it is emotional with the conflict right now. It is emotional for everyone involved. It is not easy. Thank you very much for taking the time and consider all sides. Thank you, guys, so much.

Berry: I want to say that to those of you interested, I got an e-mail today that the DOE published an interpretation of radioactive waste. If any of you are interested, it is on their web site. Thank you very much, thanks for coming, please be safe on the way home. Adjourned.

Next Meeting: TBA

Action Items:

- EHI switch the National Chairs recommendations and the local recommendations on the agenda.
- DOE to find out if there is any trouble removing the asbestos discovered in other piping.
- DOE to schedule a presentation on the protocol to alerting the community on emergencies.
- DOE to find out about the green stuff on the concrete from the DUF6 from a leak.
- DOE to find out the regulatory limits on the air monitoring.
- DOE to get a list of air quality testing that are submitted.
- DOE to provide the characterization on the records of the landfills.
- DOE to find out who assesses the Waste Acceptance Criteria.

U.S. DEPARTMENT OF ENERGY

Deputy Designated Federal Official Presentation
Portsmouth Site Specific Advisory Board

June 6, 2019

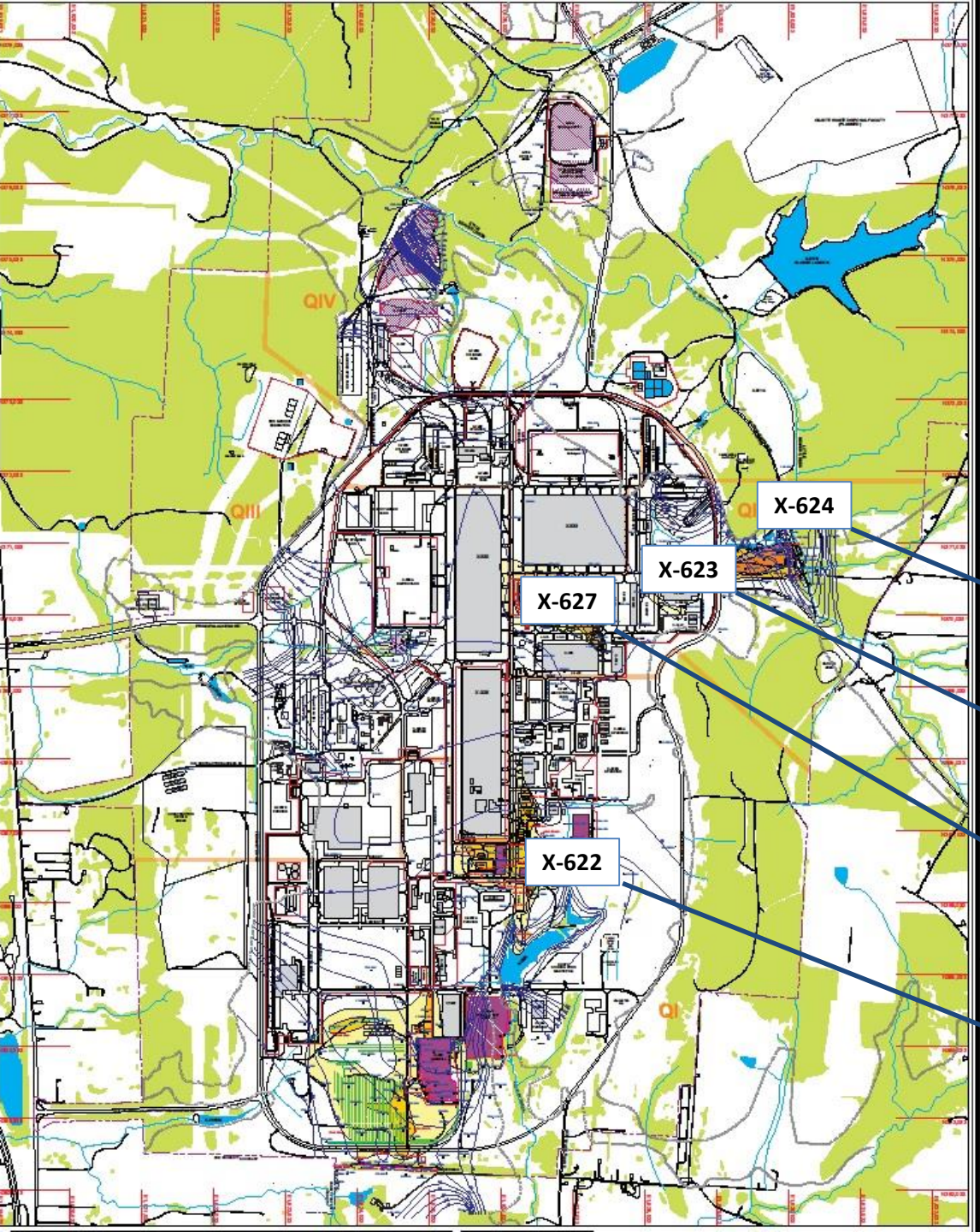
D&D Progress – X-326 Deactivation

D&D Progress-X-333 Deactivation

D&D Progress- X-705

OSWDF CONSTRUCTION

Groundwater Cleanup



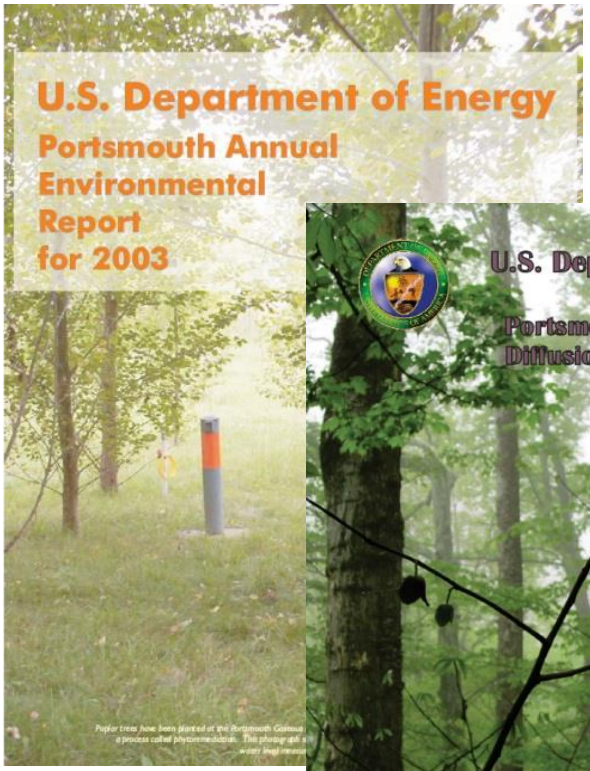
Groundwater Treated FY19 through April 2019	Groundwater Source	TCE Removed FY19 through April 2019 lbs.
Gallons 172,200	X-701B Plume	1.89
Gallons 15,040	Misc. Site	0.00
Gallons 6,316,600	7-Unit Plume	75.60
Gallons 12,847,800	5-Unit & X-749/ X-120 Plumes & PK Drainage	18.73

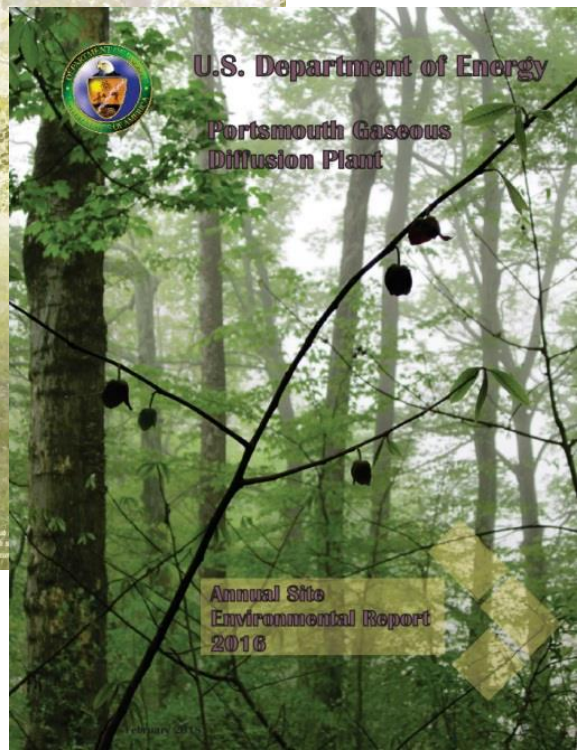
Conversion Plant Update

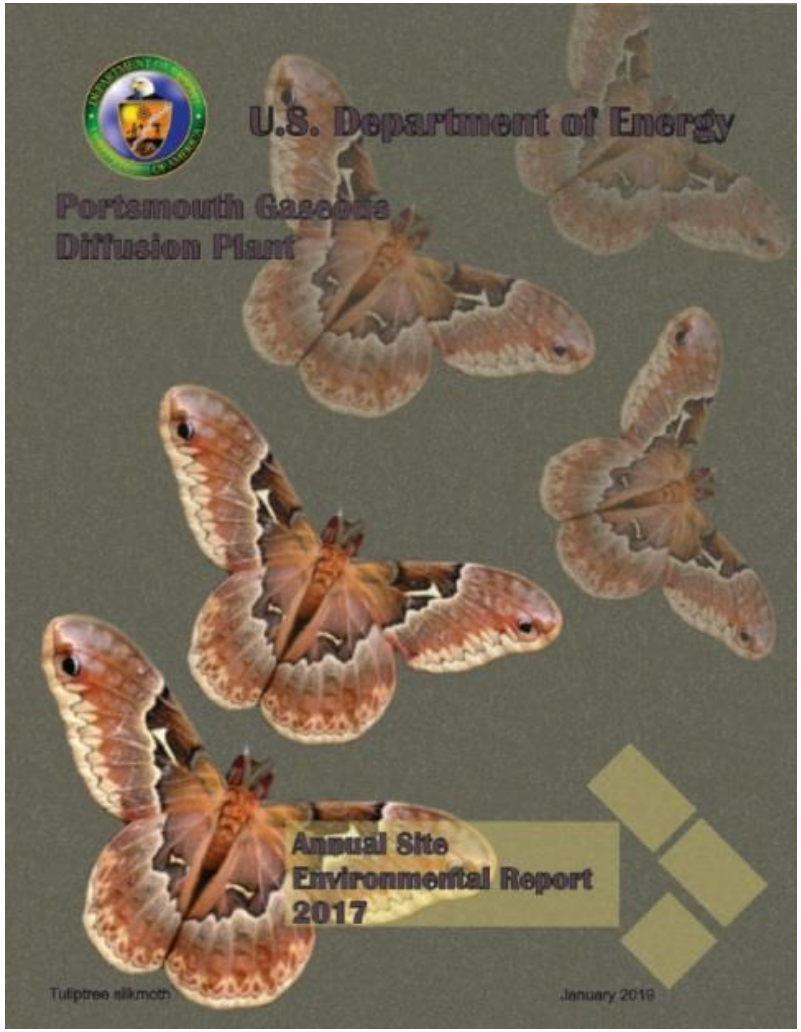
Portsmouth and Paducah - Depleted Uranium Hexafluoride (DUF6)

Environmental Monitoring Program

Annual Site Environmental Report (ASER)

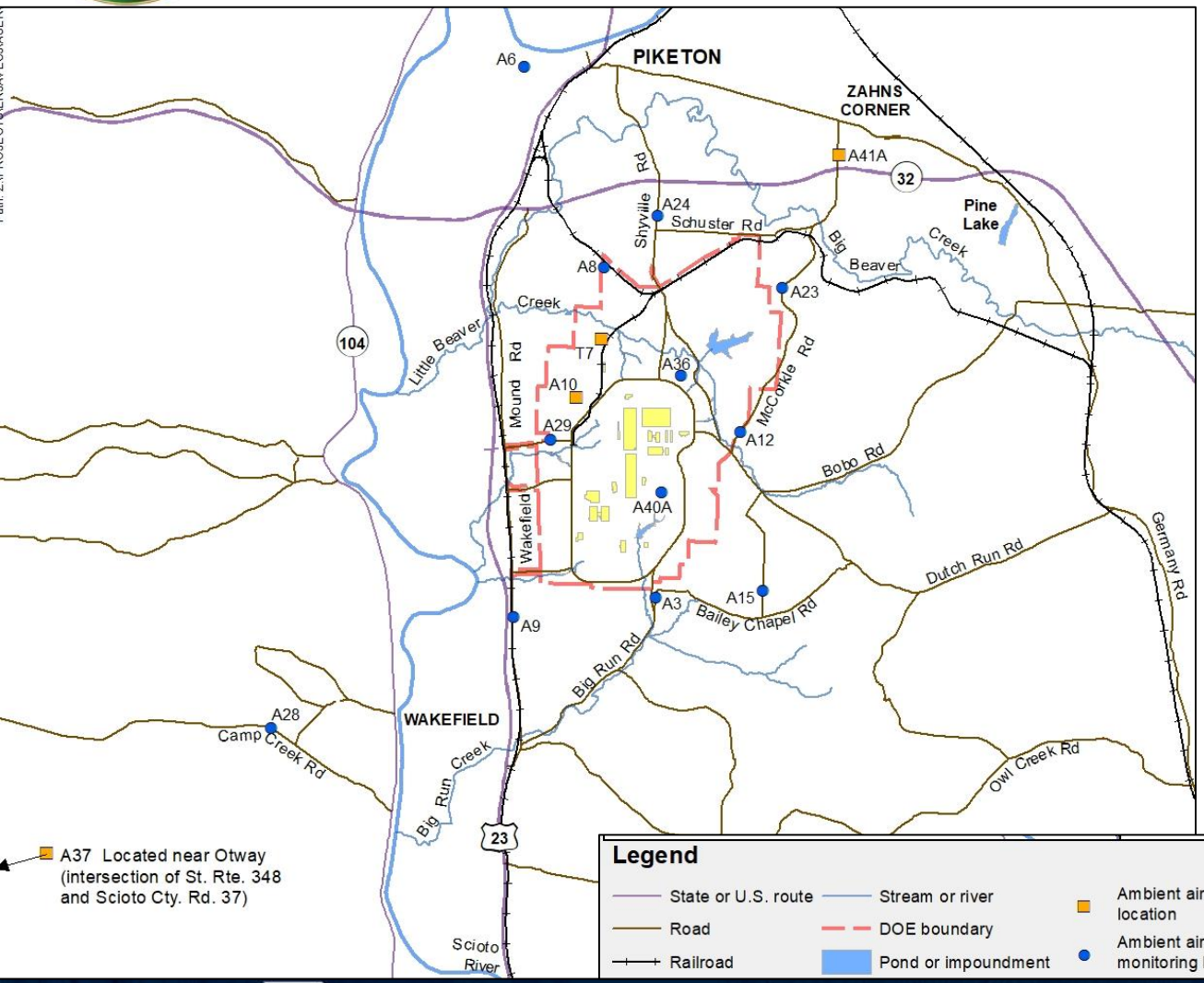




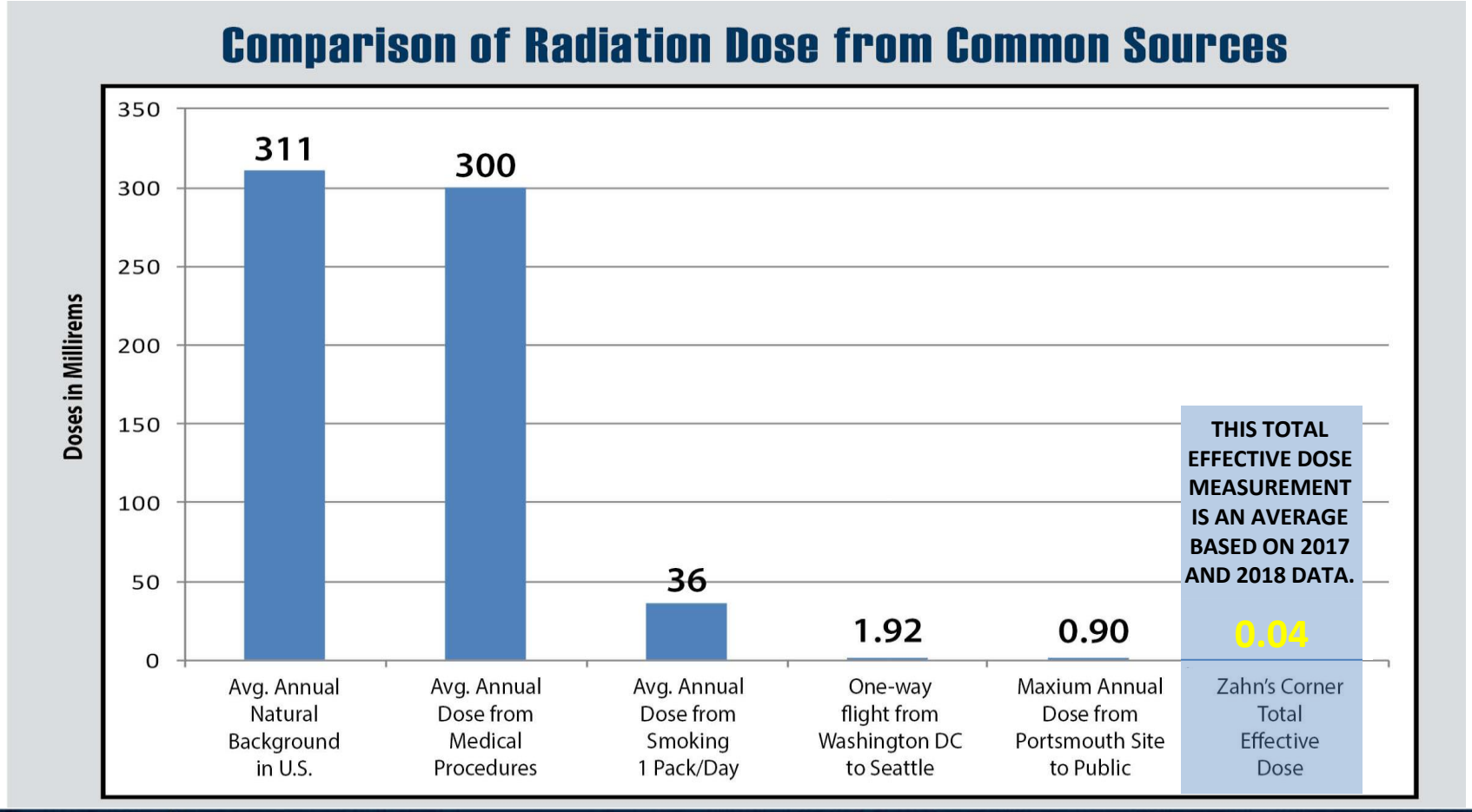


Environmental Monitoring Program

Air Monitoring Locations/2017 Air Monitor Detects



Radiation Dose from Common Sources



DOE Community Open Houses

Economic Outreach

Fluor-BWXT Supports Portsmouth Airport Business Park Development

Local Procurement

Educational Outreach - Interns

Charitable Outreach

Upcoming Outreach Events

SSAB Fall Retreat
Date TBD

DOE Public Tours:
Saturday - June 15, 2019
Saturday - July 20, 2019
Saturday - August 17, 2019
Saturday - September 21, 2019
Saturday - October 19, 2019

To register for the public tours go to: www.fbportsmouth.com

PREPARING THE FUTURE
PORTS D&D PROJECT

For a full list of SSAB activities, check out the website at ***http://www.ports-ssab.energy.gov***

ENVIRONMENTAL MANAGEMENT SITE-SPECIFIC ADVISORY BOARD

CHAIRS MEETING RECOMMENDATION

May 9, 2019 - Augusta, Georgia

Recommendation #1 – EM's Review of Cleanup Milestones

Background:

On February 14, 2019, the U.S. Government Accountability Office (GAO) published "DOE Should Take Actions to Improve Oversight of Cleanup Milestones" (GAO-19-207). The report found that DOE did not accurately track or report whether milestones were met, missed, or postponed. It also found that sites continually renegotiate milestones they are at risk of missing.

GAO recommended the Office of Environmental Management (EM) should update its policies and procedures to establish a standard definition of milestones, track original milestone dates as well as changes to its cleanup milestones, report annually to Congress on the status of its cleanup milestones, and conduct root cause analyses of missed or postponed milestones.

One of the ways that the local boards that make up the Environmental Management Site-Specific Advisory Board (EM SSAB) become informed about cleanup actions at their sites is tracking cleanup milestones. Milestone achievement, delays and change information should be shared with the local boards on a regular basis.

Recommendations:

1. The EM SSAB Chairs recommend EM create a complex-wide, consistently applied data dictionary for milestones terminology. The inconsistency in not applying the same criteria in DOE tracking of milestones results in confusion for the local boards and the EM SSAB Chairs as they meet to discuss cleanup issues and contemplate recommendations.

2. Local boards and the public should be able to access site-specific milestone information in a timely manner. Milestone information should contain the

rationale for identifying the type based on the data dictionary of milestones and detailed information about why a milestone will be advanced/delayed/postponed.

Who We Are

The EM SSAB is the DOE-EM's most effective vehicle for fostering two-way communication between DOE-EM and the communities it serves. The EM program is the world's largest environmental cleanup program, and the EM SSAB its only citizen advisory board. For more than 20 years, the volunteer citizens of the EM SSAB have partnered with EM officials at both the local and national levels to ensure that the public has a meaningful voice in cleanup decisions.

Public participation is required/recommended as part of a number of environmental regulations. It is also good business practice, resulting in better decisions that often result in improved cleanup. Over the past two decades, EM SSAB members have volunteered over 48,000 hours of their time and submitted to EM officials over 1500 recommendations, 88% of which have been fully or partially implemented, resulting in improved cleanup decisions.

The EM SSAB comprises approximately 200 people from communities in Georgia, Idaho, Kentucky, Nevada, New Mexico, Ohio, Oregon, South Carolina, Tennessee and Washington. The Board is cumulatively representative of a stakeholder population totaling millions of people who are affected by generator sites, transportation routes and disposal sites. As we move forward, the EM SSAB welcomes the opportunity to highlight the value of this unique volunteer board and discuss its priorities during the months and years ahead.

ENVIRONMENTAL MANAGEMENT SITE-SPECIFIC ADVISORY BOARD

CHAIRS MEETING RECOMMENDATION

May 9, 2019 - Augusta, Georgia

Recommendation #2 – Improving EM's Science and Technology Program

Background:

The Environmental Management Site-Specific Advisory Board (EM SSAB) Chairs wish to respond to the National Academies of Sciences' (NAS) report, "Independent Assessment of Science and Technology for the Department of Energy's Defense Environmental Cleanup Program" (2019) which assesses the success of the EM Science and Technology (S&T) program; a program that defines needs for near-term and out-year cleanup of radioactive material. As Advisory Boards to DOE-EM, the EM SSAB Chairs collectively seek a continued EM focus on permanent reduction of risk to future human generations and the environment.

The EM SSAB Chairs agree to the need for a formal, open, transparent, quantifiable and integrated S&T program that is accessible, by everyone – scientists, regulators and the public. We also agree on the need for an aggressive, cohesive S&T program that can verify the success of selected remediation pathways by utilizing hard data in defense of chosen risk-informed cleanup decisions. We also see the need for a data-rich, user friendly and publicly accessible digital platform that is easily accessed and navigated by everyone.

Recommendations:

1. **The EM SSAB Chairs support the development of a programmatically integrated, (under one identified EM government program) robust S&T effort that is fully funded in order to: a) identify and pursue development of the technologies necessary to successfully achieve risk based reduction of radiological and other hazardous waste material; b) to integrate decisions that are common between sites with similar remediation needs; c) to identify scientific challenges common to sites.**

Deferring cleanup to the future (by relying on the myth that there will be more money or other, cheaper remediation solutions) has never driven down cost of remediation, to date.

2. **A portion of the technology development effort for the DOE-EM cleanup program should focus on breakthrough solutions and technologies that can substantially reduce cleanup costs, schedules and uncertainties as stated in the NAS report.**

3. **The EM SSAB Chairs recommend exploring already developed, usable computer platforms to see if they are flexible enough to systematize verification of Best Practices decisions.**

At Hanford Nuclear Reservation, the PHOENIX Computer Platform has been in development both for the Richland side of the site (soil and groundwater remediation) and for the DOE Office of River Protection (in support of the safe configuration of the Tank Farms and building of the Waste Treatment Plant).

In development for eight years now, the Phoenix Platform is a data-rich base of maps, waste-site definition, characterization data and more. We wonder if a platform, such as this one, might not be adapted as a solution, programmatically, to address the need to define S&T needs and validate decisions.

It is clear that piecemeal, undocumented and scattered S&T efforts to date, have not served EM well, leaving the DOE-EM department potentially destined to not be able to identify common remediation needs from site to site, or worse, repeat testing of already pursued technologies that could not reach maturity.

4. **The EM SSAB Chairs recommend EM explore the path of working with the Advanced Research Projects Agency-Energy (ARPA-E) office, coupled with public outreach and transparency to implement a directional shift towards better control.**

The culture and process of contracting must be changed. The reins of scientific need and technology development should reside in a government-identified and controlled structure of discipline that manages budgetary resources, delivery time expectations and mission scope. ARPA-E might be the solution to manage a breakthrough S&T development program for EM. ARPA-E focuses on technologies too early for private-sector investment. ARPA-E awardees are unique because they are developing entirely new ways to generate, store, and use energy.

Who We Are

The EM SSAB is the DOE-EM's most effective vehicle for fostering two-way communication between DOE-EM and the communities it serves. The EM program is the world's largest environmental cleanup program, and the EM SSAB its only citizen advisory board. For more than 20 years, the volunteer citizens of the EM SSAB have partnered with EM officials at both the local and national levels to ensure that the public has a meaningful voice in cleanup decisions.

Public participation is required/recommended as part of a number of environmental regulations. It is also good business practice, resulting in better decisions that often result in improved cleanup. Over the past two decades, EM SSAB members have volunteered over 48,000 hours of their time and submitted to EM officials over 1500 recommendations, 88% of which have been fully or partially implemented, resulting in improved cleanup decisions.

The EM SSAB comprises approximately 200 people from communities in Georgia, Idaho, Kentucky, Nevada, New Mexico, Ohio, Oregon, South Carolina, Tennessee and Washington. The Board is cumulatively representative of a stakeholder population totaling millions of people who are affected by generator sites, transportation routes and disposal sites. As we move forward the EM SSAB welcomes the opportunity to highlight the value of this unique volunteer board and discuss its priorities during the months and years ahead.

United States Government Accountability Office

Report to the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate

February 2019

NUCLEAR WASTE

DOE Should Take Actions to Improve Oversight of Cleanup Milestones

GAO-19-207

February 2019

NUCLEAR WASTE

DOE Should Take Actions to Improve Oversight of Cleanup Milestones

GAO Highlights

Highlights of GAO-19-207, a report to the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate

Why GAO Did This Study

EM manages DOE's radioactive and hazardous waste cleanup program using compliance agreements negotiated between DOE and other federal and state agencies. Within the agreements, milestones outline cleanup work to be accomplished by specific deadlines. EM's cleanup program faces nearly $500 billion in future environmental liability, which has grown substantially.

GAO was asked to review DOE's cleanup agreements. This report examines the extent to which EM (1) tracks the milestones in cleanup agreements for EM's cleanup sites; (2) has met, missed, or postponed cleanup-related milestones at selected sites and how EM reports information; and (3) has analyzed why milestones are missed or postponed and how EM considers those reasons when renegotiating milestones.

GAO reviewed agreements and milestones at EM's 16 cleanup sites and compared information tracked by EM headquarters and these sites; interviewed officials from four selected sites (chosen for variation in location and scope of cleanup, among other factors); and reviewed EM guidance related to milestone negotiations.

What GAO Recommends

GAO is making four recommendations, including that EM establish a standard definition of milestones across the cleanup sites, track and report original and renegotiated milestone dates, and identify the root causes of why milestones are missed or postponed. In commenting on a draft of this report, DOE agreed with three of the recommendations and partially agreed with a fourth.

View GAO-19-207. For more information, contact David C. Trimble at (202) 512-3841 or TrimbleD@gao.gov.

What GAO Found

The cleanup process at the 16 sites overseen by the Department of Energy's (DOE) Office of Environmental Management (EM) is governed by 72 agreements and hundreds of milestones specifying actions EM is to take as it carries out its cleanup work. However, EM headquarters and site officials do not consistently track data on the milestones. EM headquarters and site officials provided GAO with different totals on the number of milestones in place at the four sites GAO selected for review. These discrepancies result from how headquarters and selected sites define and track milestones. First, not all sites make the same distinction between major (i.e., related to on-the-ground cleanup) and non-major milestones and, as a result, are not consistently reporting the same milestones to EM headquarters. Second, sites do not consistently provide EM headquarters with the most up-to-date information on the status of milestones at each site. These inconsistencies limit EM's ability to use milestones to manage the cleanup mission and monitor its progress.

EM does not accurately track met, missed, or postponed cleanup-related milestones at the four selected sites, and EM's milestone reporting to Congress is incomplete. EM sites renegotiate milestone dates before they are missed, and EM does not track the history of these changes. This is because once milestones change, sites are not required to maintain or track the original milestone dates. GAO has previously found that without a documented and consistently-applied schedule change control process, program staff may continually revise the schedule to match performance, hindering management's insight into the true performance of the project. Further, since 2011, EM has not consistently reported to Congress on the status of the milestones each year, as required, and the information it has reported is incomplete. EM reports the most recently renegotiated milestone dates with no indication of whether or how often those milestones have been missed or postponed. Since neither EM headquarters nor the sites track renegotiated milestones and their baseline dates at the sites, milestones do not provide a reliable measure of program performance.

EM officials at headquarters and selected sites have not conducted root cause analyses on missed or postponed milestones; thus, such analyses are not part of milestone negotiations. Specifically, EM has not done a complex-wide analysis of the reasons for missed or postponed milestones. Similarly, officials GAO interviewed at the four selected sites said that they were not aware of any site-wide review of why milestones were missed or postponed. Best practices for project and program management outlined in GAO's Cost Estimating and Assessment Guide note the importance of identifying root causes of problems that lead to schedule delays. Additionally, in a 2015 directive, DOE emphasized the importance of conducting such analysis. Analyzing the root causes of missed or postponed milestones would better position EM to address systemic problems and consider those problems when renegotiating milestones with regulators. Without such analysis, EM and its cleanup regulators lack information to set more realistic and achievable milestones and, as a result, future milestones are likely to continue to be pushed back, further delaying the cleanup work. As GAO has reported previously, these delays lead to increases in the overall cost of the cleanup.

Contents

Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	Department of Energy
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
RCRA	Resource Conservation and Recovery Act of 1976

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

February 14, 2019

The Honorable Deb Fischer
Chairman
The Honorable Martin Heinrich
Ranking Member
Subcommittee on Strategic Forces
Committee on Armed Services
United States Senate

The Department of Energy (DOE) faces nearly $500 billion in future environmental liabilities related to the cleanup of nuclear and hazardous waste at its 16 sites around the country. These liabilities have grown substantially despite DOE spending roughly $6 billion annually on its cleanup program.[1] The waste is primarily a result of decades of producing material for the nation's nuclear weapons program and can pose risks to human health and the environment. The waste consists of millions of gallons of radioactive waste in underground storage tanks, thousands of tons of spent (used) nuclear fuel and special nuclear material, large volumes of transuranic and mixed low level waste, and huge quantities of contaminated soil and water. At many of its sites, DOE has had difficulty making significant progress on the cleanup, particularly for the most dangerous wastes and at sites with the most challenging cleanup work. Because of the large and expanding estimated costs of cleaning up these sites, in 2017, we designated the federal government's environmental liabilities—more than 80 percent of which pertain to DOE—as a new high-risk area.[2] In January 2019, we noted that the estimated cost to complete the cleanup was likely to increase.[3]

[1]The federal government is financially liable for cleaning up areas where federal activities have contaminated the environment. Various federal and state laws, agreements with states, and court decisions require the federal government to clean up environmental hazards at federal sites and facilities—such as nuclear weapons production facilities and military installations. Federal accounting standards require agencies responsible for cleaning up contamination to estimate future cleanup and waste disposal costs and to report such costs as environmental liabilities in their annual financial statements.

[2]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others,* GAO-17-317 (Washington, D.C.: Feb. 15, 2017).

[3]GAO, *Department of Energy: A Program-Wide Strategy and Better Reporting Needed to Address Growing Environmental Cleanup Liability*, GAO-19-28 (Washington, D.C.: Jan. 29 2019).

DOE's Office of Environmental Management (EM) is responsible for managing DOE's cleanup program and overseeing the contractors that carry out the cleanup work at EM's sites. Federal laws—including the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA); the Resource Conservation and Recovery Act of 1976, as amended (RCRA); and the Atomic Energy Act of 1954, as amended—govern cleanup at these sites. EM's cleanup work has been implemented under cleanup agreements negotiated between DOE sites and federal and state regulatory agencies, such as the U.S. Environmental Protection Agency (EPA) and state environmental protection agencies.[4] EM uses milestones—dates by which certain tasks are to be completed—as a tool for managing and tracking progress on site cleanup, along with earned value management systems and performance metrics.[5] EM also reports to Congress on the status of these milestones and bases its annual request for cleanup funding in part on the need to meet site milestones. However, in 1995 and 2002, for example, we reported that milestones, as developed and used by DOE, were not a good measure of EM's cleanup progress and recommended that DOE set national cleanup priorities and renegotiate milestones based on those priorities.[6] In 2015, an independent review found that the use of cleanup agreements negotiated by individual EM sites, rather than a more centralized approach, sometimes caused EM to focus its scarce resources on outdated milestones and lower-priority risks to human health and the environment.[7]

[4]We use the term agreements in this report to refer to all enforceable documents governing the cleanup even though not all of the documents that contain milestones are agreements. For example, the March 2016 Amended Consent Decree at the Hanford Site was issued by a court and the milestones were established by the court, not by agreement of the parties.

[5]Earned value management systems measure the value of work accomplished in a given period and compare it to the planned value of work scheduled for that period and the actual cost of work accomplished. Performance metrics include such things as the number of radioactive liquid waste tanks that are closed. See Department of Energy, Office of Environmental Management, O*perations Activities Protocol* (February 28, 2012).

[6]GAO, *Department of Energy: National Priorities Needed for Meeting Environmental Agreements*, RCED-95-1 (Washington, D.C.: Mar. 3, 1995); and *Waste Cleanup: Status and Implications of DOE's Compliance Agreements,* GAO-02-567 (Washington, D.C.: May 30, 2002).

[7]DOE requested the Consortium for Risk Evaluation with Stakeholder Participation, an independent multidisciplinary consortium of universities led by Vanderbilt University, to organize a review in response to congressional direction accompanying the Consolidated Appropriations Act, 2014.

You asked us to review EM's cleanup agreements that set requirements and milestones for EM's cleanup approach at its 16 sites and how EM has performed in meeting those milestones historically. This report examines the extent to which EM (1) tracks the milestones in cleanup agreements in place at EM's cleanup sites; (2) has met, missed, or postponed cleanup-related milestones at selected sites and how EM reports that information; and (3) has analyzed why milestones are missed or postponed and how, if at all, EM considers those reasons when renegotiating milestones with regulators.

To review and summarize the number of cleanup agreements and corresponding milestones in place at EM's cleanup sites, we collected and examined all of the cleanup agreements for EM's 16 active cleanup sites. We also collected EM's publicly reported lists of cleanup milestones—as found in DOE's Future-Years Plans submitted to Congress in 2012 and 2017—as well as updated lists that we obtained from EM headquarters.[8] In addition, we gathered lists of milestones from some of the sites, as described below. We compared information provided by EM headquarters and the sites to identify discrepancies, if any, regarding the number and status of the milestones. We also compared EM's approach to tracking milestones against GAO's standards for internal control in the federal government.[9]

To analyze the extent to which EM has met, missed, or postponed cleanup-related milestones at selected sites and how EM reports that information, we selected a nongeneralizable sample of four sites—Idaho National Laboratory in Idaho; Savannah River Site in South Carolina; Los Alamos National Laboratory in New Mexico; and the Hanford Site in Washington—for in-depth review. We selected these sites to ensure diversity in (1) geographic location, (2) the responsible DOE agency (EM is responsible for the cleanup at the 16 sites, but the National Nuclear Security Administration oversees five of the sites), (3) the size of the annual cleanup budget (selecting both large and small budgets), and (4) the size of the total environmental liability (selecting both large and small liabilities). Findings from these sites cannot be generalized to sites that we did not include in our review. From each of the selected sites, we

[8]Department of Energy, *Future-Years Defense Environmental Management Plan*, (Washington, D.C.: September 2012); and *Future-Years Defense Environmental Management Plan: FY 2018 to FY 2070*, (Washington, D.C.: August 2017).

[9]GAO, *Standards for Internal Control in the Federal Government,* GAO-14-704G (Washington, D.C.: September 2014).

collected EM's public reports on historical and current data on the number and status of milestones and reviewed, analyzed, and summarized this information. We reviewed DOE's 2017 cleanup policy and associated policies and procedures and met with officials from each of the sites in the sample to find out more about site efforts to track how often milestones had been met, missed, or postponed.[10] To evaluate how EM reported this information, we compared DOE's 2012 and 2017 reports to Congress and EM's internal milestone reporting systems at headquarters and the sites. We also compared EM's reporting against the requirement to report to Congress and best practices for project schedules.[11]

To evaluate the extent to which EM has analyzed why milestones are missed or postponed, we interviewed EM headquarters and site officials. To analyze the extent to which EM considers those reasons when renegotiating milestones, we reviewed EM's orders and guidance that govern the process of negotiating cleanup milestones with regulators. We compared this guidance against best practices in project and program management.[12]

We conducted this performance audit from May 2017 to February 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

EM oversees a nationwide complex of 16 sites. A majority of the sites were created during World War II and the Cold War to research, produce, and test nuclear weapons (see figure 1).[13] Much of the complex is no longer in productive use but still contains vast quantities of radioactive

[10]Department of Energy, *Requirements for Management of the Office of Environmental Management's Cleanup Program*, (Washington, D.C.: July 2017).

[11]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules,* GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

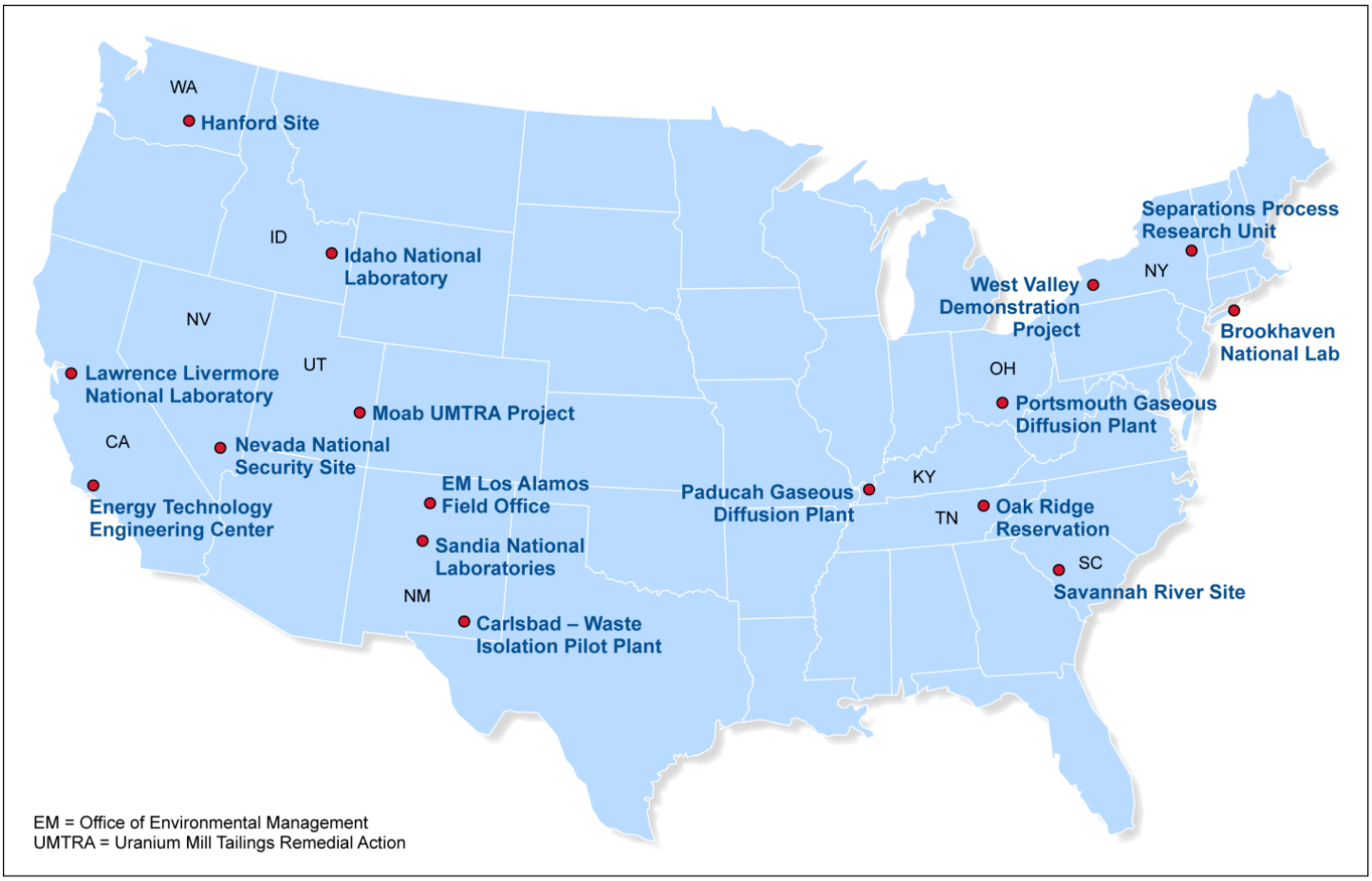
[12]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs,* GAO-09-3SP (Washington, D.C.: March 2009).

[13]For a detailed list of the cleanup activities at the sites we examined for this review, see appendix I.

and hazardous materials related to the production of nuclear weapons. In 1989, EM began carrying out activities around the complex to clean up, contain, safely store, and dispose of these materials.[14] Starting at about the same time, DOE documents indicate that EM and state and federal regulators entered into numerous cleanup agreements that defined the scope of cleanup work and established dates for coming into compliance with applicable environmental laws. EM has spent more than $170 billion since it began its cleanup program, but its most challenging and costly cleanup work remains, according to EM documents.

[14]In the fall of 1989, DOE established the Office of Environmental Restoration and Waste Management, which was later renamed the Office of Environmental Management.

Figure 1: Department of Energy Office of Environmental Management Sites Where Cleanup Remains



Sources: GAO analysis of Department of Energy information; Map Resources (map). | GAO-19-207

The processes that govern the cleanup at EM's nuclear waste sites are complicated, involving multiple laws, agencies, and administrative steps. EM's cleanup responsibilities derive from different laws, including CERCLA, RCRA, the Atomic Energy Act, and state hazardous waste laws. Federal facility agreements, compliance orders, and other compliance agreements also govern this cleanup.

Federal facility agreements are generally enforceable agreements that DOE enters into with EPA and affected states under CERCLA and applicable state laws. For each federal facility listed on the National Priorities List, EPA's list of seriously contaminated sites, section 120 of

CERCLA requires the relevant federal agency to enter into an interagency agreement with EPA for the completion of all necessary cleanup actions at the facility. The interagency agreement must include, among other things, the selection of the cleanup action and schedule for its completion. Interagency agreement provisions can be renegotiated, as necessary, to incorporate new information, adjust schedules, and address changing conditions.[15]

States generally issue federal facility compliance orders to DOE under RCRA and the Federal Facilities Compliance Act. RCRA prohibits the treatment, storage or disposal of hazardous waste without a permit from EPA or a state that EPA has authorized to implement and enforce a hazardous waste management program. Under the Federal Facilities Compliance Act, federal agencies are subject to state hazardous waste laws and state enforcement actions, including compliance orders. RCRA regulations establish detailed and often waste-specific requirements for the management and disposal of hazardous wastes, including the hazardous waste component of mixed waste.[16] Tri-party agreements among DOE, EPA, and the relevant state often serve as both a federal facility agreement and a compliance order.

In addition to federal facility agreements, other types of agreements governing cleanup at specific sites may also be in place, including administrative compliance orders, court-ordered agreements, and settlement agreements. Administrative compliance orders are orders from state agencies enforcing state hazardous waste management laws. Court-ordered agreements result from lawsuits initiated primarily by states. Settlement agreements are agreements between parties that end a legal dispute.

[15]CERCLA does not itself establish regulatory standards for the cleanup of specific substances, but it requires that remedial actions—which are long-term cleanups—comply with "applicable or relevant and appropriate requirements." Applicable or relevant and appropriate requirements include standards promulgated under any federal environmental law, in addition to standards promulgated under certain state laws or regulations that are more stringent than corresponding federal law and are identified to the entity leading the cleanup in a timely manner. 42 U.S.C. § 9621(d)(1). The federal agency must afford to relevant state and local officials the opportunity to participate in the planning and selection of the remedial action. 42 U.S.C. § 9620(f).

[16]The term "mixed waste" means waste that contains both (1) hazardous waste subject to the Resource Conservation and Recovery Act or authorized state programs that operate in lieu of the federal program; and (2) radioactive waste subject to the Atomic Energy Act of 1954. Under RCRA or authorized state hazardous waste programs, a state does not have authority over the radioactive waste component of the mixed waste.

These agreements may include milestones—dates by which DOE commits to plan and carry out its cleanup work at the sites. DOE has identified two different types of milestones: enforceable and planning milestones. Generally, an enforceable milestone has a fixed, mandatory due date, subject to the availability of appropriated funds, whereas a planning milestone is not enforceable and usually represents a placeholder or shorter term of work. In this report, we are examining any enforceable milestone that derives from either federal facility agreements or other compliance agreements.

EM manages its cleanup program based on internal guidance, on milestone commitments to regulators, and in consultation with a variety of stakeholders. First, according to EM officials, EM manages cleanup activities based on requirements listed in a cleanup policy that it issued in July 2017 along with guidance listed in standard operating policies and procedures associated with this policy. The 2017 cleanup policy states that EM will apply DOE's project management principles described in Order 413.3B to its operations activities in a tailored way.[17] Second, EM's budget requests are explicit regarding the role the milestones play in the cleanup effort. For example, in its fiscal year 2019 request to Congress, EM stated that the request addresses cleanup "governed through enforceable regulatory milestones."[18] Third, in addition to the milestone commitments to EPA and state environmental agencies, other stakeholders involved include county and local governmental agencies, citizen groups, and other organizations. These stakeholders advocate their views through various public involvement processes, including site-specific advisory boards.

[17]Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Washington, D.C.: April 12, 2018). GAO has ongoing work examining DOE's implementation of the 2017 cleanup policy.

[18]Department of Energy, *Department of Energy FY 2019 Congressional Budget Request, Volume 5, Environmental Management* (Washington, D.C.: March 2018).

At EM's 16 Cleanup Sites, Cleanup Is Governed by 72 Agreements, but EM Headquarters and Sites Do Not Consistently Define or Track Milestones

At EM's 16 cleanup sites, cleanup is governed by 72 agreements and hundreds of cleanup milestones. These agreements include federal facility agreements generally negotiated between DOE, the state, and EPA, and compliance orders from state regulators. These agreements may impose penalties for missing milestones and may amend or modify earlier agreements, including extending or eliminating milestone dates. Within the agreements, hundreds of milestones outline deadlines for specific actions to be taken by EM as it carries out its cleanup work. However, because EM lacks a standard definition of milestones, some sites track milestones differently than EM headquarters, limiting EM's ability to monitor performance.

At EM's 16 Cleanup Sites, Cleanup Is Governed by 72 Agreements, Most of Which Include Cleanup Milestones

In total, DOE has entered into 72 cleanup agreements at EM's 16 cleanup sites. The agreements were initially signed between 1985 and 2009 (see table 1). With the exception of the Moab Uranium Mill Tailings Remedial Action Project in Utah and the Waste Isolation Pilot Plant in New Mexico, each site is governed by at least one cleanup agreement. Twelve are governed by multiple agreements (up to as many as 17 at the Savannah River Site, for example).

Table 1: Cleanup Agreements at 16 Environmental Management (EM) Cleanup Sites

EM cleanup site	Total number of agreements	Year first agreement was signed
Brookhaven National Laboratory, NY	1	1992
Energy Technology Engineering Center, CA	3	1995[a]
Hanford Site, WA	6	1989
Idaho National Laboratory, ID	8	1991
Lawrence Livermore National Laboratory, CA	3	1988
Los Alamos National Laboratory, NM	4	1993
Moab Uranium Mill Tailings Remedial Action Project, UT	0	N/A[b]
Nevada National Security Site, NV	4	1992
Oak Ridge Reservation, TN	4	1991[c]
Paducah Gaseous Diffusion Plant, KY	5	1992
Portsmouth Gaseous Diffusion Plant, OH	9	1989
Sandia National Laboratories, NM	2	2004
Savannah River Site, SC	17	1985
Separations Process Research Unit, NY	3	2009
Waste Isolation Pilot Plant, NM	0	N/A[d]

EM cleanup site	Total number of agreements	Year first agreement was signed
West Valley Demonstration Project, NY	3	1992
	72	

Source: GAO analysis of Department of Energy (DOE) agreements. | GAO-19-207

[a]California's Department of Toxic Substances Control issued a consent order to DOE in 1995 that governed the operation and closure of approximately 10 cubic meters of mixed waste at the site.

[b]Cleanup at the Moab Project is governed by the Uranium Mill Tailings Radiation Control Act, which does not require a federal facility agreement.

[c]According to DOE officials, the Oak Ridge agreement was signed in 1991 but became effective upon the Environmental Protection Agency's notification to the parties, which occurred in 1992.

[d]Any necessary cleanup activities at the Waste Isolation Pilot Plant are governed primarily by the Waste Isolation Pilot Plant Land Withdrawal Act and the Resource Conservation and Recovery Act of 1976, as amended, permit issued by the state.

Twelve sites are governed by federal facility agreements, generally with the relevant state and EPA. These agreements generally set out a sequence for accomplishing the work, tend to cover a relatively large number of cleanup activities, and include milestones that DOE must meet. All of the 12 sites with federal facility agreements are also governed by additional compliance agreements that have been negotiated at each site subsequent to the initial federal facility agreement or other agreement with the state. These agreements may impose penalties for missing milestones and may amend or modify earlier agreements, including extending or eliminating milestone dates. For example, the Hanford Site is subject to three consent decrees that resulted from litigation in which the state of Washington sued DOE for failing to meet certain cleanup milestones.

EM Headquarters and Selected Cleanup Sites Do Not Consistently Define or Track Milestones

EM headquarters and cleanup site officials provided us with different totals on the number of milestones in place at the four sites we selected for further review. Both federal facility agreements and other compliance agreements contain milestones with which EM must comply and, according to EM officials and our review of the agreements, these agreements collectively contain hundreds of milestones.[19] However, milestone information that EM headquarters and site officials shared with us was not consistent. For example, for milestones due in fiscal years 2018 through 2020, officials at EM headquarters identified 135

[19]Several factors can influence the number of milestones in an agreement, including the extent of environmental contamination and the preferences of the regulators.

enforceable cleanup milestones at the four selected sites, which was less than half of the number of such milestones officials at those sites reported to us (see table 2).

Table 2: Number of Enforceable[a] Cleanup Milestones Due in Fiscal Years 2018 through 2020 at Selected Environmental Management (EM) Sites

Selected Site	Total milestones reported by EM headquarters	Total milestones according to sites
Hanford Site	57	178
Idaho National Laboratory	11	12
Los Alamos National Laboratory	24	38
Savannah River Site	43	79
Total	**135**	**307**

Source: GAO analysis of Department of Energy milestone information. | GAO-19-207

[a]Generally, an enforceable milestone has a fixed, mandatory due date, subject to the availability of appropriated funds.

These discrepancies result from how headquarters and selected sites define and track milestones.

- **Milestone definitions.** EM headquarters officials said that they are primarily concerned with milestones related to on-the-ground cleanup; that is, cleanup activities that actually result in waste being removed, treated, or disposed of. EM officials said they consider these to be major milestones. However, not all sites make the same distinction between major and non-major milestones and, as a result, are not consistently reporting the same types of milestones to EM headquarters. For example, officials at the Savannah River Site track milestones in a federal facility agreement that lists 79 milestones due in fiscal years 2018 through 2020. This agreement makes no distinction between major and non-major milestones and includes administrative activities, such as revisions to cleanup reports, in its milestone totals. EM headquarters officials, on the other hand, do not include these activities as major milestones and list only 43 milestones due in the same time frame. Similarly, Hanford officials do not distinguish between major or other milestones in their internal tracking. As a result, Hanford officials are tracking 178 milestones due in fiscal years 2018 through 2020, whereas EM headquarters officials are tracking 57 for the same time frame at Hanford.
- **Requirements for updating milestones.** Sites do not consistently provide EM headquarters with the most up-to-date information on the status of milestones at each site. This is because EM requirements

governing the submission of milestone information do not specify when or how often sites are to update this information, so sites have the discretion to choose when to send updated milestone data to headquarters. As a result, the information on the list of milestones used to track cleanup performance by EM headquarters may differ from the more up-to-date information kept by the sites. For example, officials at each of the four sites we examined stated that they try to send updated information on the status of milestones to headquarters on an annual basis, though they sometimes send it less frequently. Officials at EM headquarters acknowledged that their list of milestones is not always up-to-date because of the lag between when a milestone changes at the site and when sites update that information in the EM headquarters' database.

In addition to inconsistencies in tracking and defining milestones, lists of milestones maintained by EM headquarters and the four selected sites may not include all cleanup milestones governing the cleanup work at the site. We found two cases in which permits at two sites included milestones that neither EM headquarters nor site officials included in their list of sites' cleanup milestones. For example, milestones related to a major construction project at one of the selected sites we reviewed—Savannah River—are not listed in either EM headquarters' or the Savannah River Site's list of enforceable milestones. According to South Carolina state environmental officials, milestones associated with this project are part of a separate permit and dispute resolution agreement not connected to the federal facility agreement or one of the sites' compliance agreements. Recently, DOE acknowledged in its fiscal year 2019 budget request that this project has faced technical challenges, and officials noted that the previously agreed-upon start date for operating this project would be delayed. However, this milestone and its delay are not included in either EM headquarters' or Savannah River's list of milestones. Similarly, officials at the Hanford Site said that some milestones governing Hanford's cleanup are part of the site wide RCRA permit issued by the state, which is separate from its federal facility agreement, and, as a result, officials do not track this information in the same Hanford milestone tracking system and do not report it to EM headquarters.

EM does not have a standard definition of milestones for either sites or headquarters to use for reporting and monitoring cleanup milestones or guidance on how often sites should update the status of milestones. EM headquarters officials cited guidance that sites can refer to when entering their milestone data into the headquarters-managed database. This guidance addresses how to submit milestone data but does not include a definition of milestones or specify how often sites should update the

information.[20] EM headquarters officials noted that sites have the discretion to input milestones as they choose. EM's lack of a standard definition of milestones limits management's ability to use milestones to manage EM's cleanup mission and monitor its progress. We have previously found that poorly defined, incomplete, or missing requirements make it difficult to hold projects accountable, result in programs or projects that do not meet user needs, and can result in cost and schedule growth.[21] In addition, according to Standards for Internal Control in the Federal Government, information and communication are vital for an entity to achieve its objectives. [22] According to these standards, the first principle of information and communication is that management should define the information requirements at the relevant level and the requisite specificity for appropriate personnel. Without this, EM's ability to use milestones for managing and measuring the performance of its cleanup program is limited.

EM Does Not Track Sites' Renegotiated Milestone Dates and Has Not Consistently Reported Milestone Information to Congress as Required

EM relies on cleanup milestones, among other metrics, to measure the overall performance of its operations activities. However, sites regularly renegotiate milestones they are at risk of missing, and EM does not track data on the history of postponed milestones. As a result, EM cannot accurately track the progress of cleanup activities to meet these milestones. Additionally, EM has not consistently reported required information to Congress, and the information it has reported is incomplete. For example, in its report to Congress on the status of the enforceable milestones, EM includes the latest (meaning the most recently renegotiated) milestone dates with no indication of whether or how often those milestones have been missed or postponed.

[20]Department of Energy, *Milestones Module Guidance* (March 2016).

[21]See, for example: GAO, *DOE Project Management: NNSA Needs to Clarify Requirements for Its Plutonium Analysis Project at Los Alamos,*GAO-16-585 (Washington, D.C.: Aug. 9, 2016); *Defense Acquisition Process: Military Service Chiefs' Concerns Reflect Need to Better Define Requirements before Programs Start*, GAO-15-469 (Washington, D.C.: June 11, 2015); *Defense Acquisitions: Managing Risk to Achieve Better Outcomes*, GAO-10-374T (Washington, D.C.: Jan. 20, 2010); and *United States Coast Guard: Improvements Needed in Management and Oversight of Rescue System Acquisition*, GAO-06-623 (Washington, D.C.: May 31, 2006).

[22]GAO, *Standards for Internal Control in the Federal Government,* GAO-14-704G (Washington, D.C.: September 2014).

Sites Renegotiate Milestone Dates Before They Are Missed, and EM Does Not Track How Often This Occurs

Site officials typically renegotiate enforceable milestones they are at risk of missing with their regulators, in accordance with the modification procedures established in federal facility agreements. EM officials said that sites have the ability to renegotiate milestones before they are missed. For example, the Hanford Site Federal Facility Agreement allows DOE to request an extension of any milestone; the request must include, among other things, DOE's explanation of the good cause for the extension. As long as there is consensus among EM and its regulators, the milestone is changed. Similarly, the Los Alamos Federal Facility Agreement requires site officials to negotiate cleanup milestones each fiscal year.[23] Because renegotiated milestones are not technically missed, EM avoids any fines or penalties associated with missed milestones.

Site officials we interviewed at the four selected sites stated that it is common for regulators and sites to renegotiate milestones before sites miss them. For example, at the Savannah River Site, both DOE and South Carolina officials said they could not recall any missed milestones among the thousands of milestones completed since the cleanup began. Similarly, Hanford officials told us that since the beginning of the cleanup effort in 1989, more than 1,300 milestones had been completed and only 62 had actually been missed because, in most cases, whenever milestones were at risk of being missed, they were renegotiated. However, officials at these sites could not provide us with the exact number of times milestones had been renegotiated. This is because once milestones are changed, sites are not required to maintain or track the original milestones. As a result, the new milestones become the new agreed-upon time frame, essentially resetting the deadline.

Because EM does not track the original baseline schedule for renegotiated milestone dates, milestones do not provide a reliable measure of program performance. According to best practices identified in GAO's schedule assessment guide, agencies should formally establish a baseline schedule against which performance can be measured.[24] In particular, we have previously found that management does not have the ability to identify and mitigate the effects of unfavorable performance without a formally established baseline schedule against which it can

[23]According to Los Alamos site officials, a 2016 Consent Order includes a single-year milestone table established on DOE's ability to fund cleanup work at the site and targets to lay out plans for the following 2 fiscal years.

[24]GAO-16-89G.

measure performance. We have also found that, without a documented and consistently-applied schedule change control process, program staff may continually revise the schedule to match performance, hindering management's insight into the true performance of the project. In addition, DOE's internal project management policies call for steps to maintain a change control process, including setting a baseline schedule for completing certain activities and maintaining a record of any subsequent deviations from that baseline.[25] EM uses milestones as one of its metrics for measuring the performance of its cleanup efforts, since the milestones are effectively schedule targets. However, since neither EM headquarters nor the sites track renegotiated milestones and their baseline dates at the sites, EM cannot accurately use milestones for managing and measuring the performance of its cleanup program.

EM Has Not Consistently Reported Required Information to Congress, and the Information It Has Reported Is Incomplete

EM has not consistently reported required information to Congress on the status of its milestones. The National Defense Authorization Act for Fiscal Year 2011 established a requirement for EM to annually provide Congress with a future-years defense environmental cleanup plan. This plan is to contain, among other things, information on the current dates for enforceable milestones at specified cleanup sites, including whether each milestone will be met and, if not, an explanation as to why and when it will be met.[26] However, since 2011, EM has only provided Congress with the required annual plan in 2 years—2012 and 2017—and EM officials told us in September 2018 that they were unsure when EM would release the next future-years plan.[27] EM officials said that, instead of the annual plan, they have provided oral briefings to Congressional staff during the 4 years when a formal report was not produced.

[25]Department of Energy, *Requirements for Management of the Office of Environmental Management's Cleanup Program* (Washington, D.C.: July 2017).

[26]Pub. L. No. 111-383, § 3116(a), 124 Stat. 4512 (codified as amended at 50 U.S.C. § 2582a (2018)). The National Defense Authorization Act for Fiscal Year 2011 required that milestone information from the following sites be included in the annual future-years defense environmental cleanup plans: (1) Idaho National Laboratory; (2) Waste Isolation Pilot Plant; (3) Savannah River Site; (4) Oak Ridge National Laboratory; (5) Hanford Site; (6) any defense closure site of the Department of Energy; and (7) any site of the National Nuclear Security Administration.

[27]Department of Energy, *Future-Years Defense Environmental Management Plan* (Washington, D.C.: September 2012), and *Future-Years Defense Environmental Management Plan: FY 2018 to FY 2070* (Washington, D.C.: August 2017).

In addition, our analysis of the 2012 and 2017 plans EM submitted to Congress identified three ways in which the plans provide inaccurate or incomplete information on EM's enforceable milestones.

- **No historical record.** First, the plans contain no indication of whether each milestone date reported is the original date for that milestone or whether or how many times the milestones listed have been missed or postponed. Instead, the plans report the latest (and most recently renegotiated) dates for the milestones without listing the original dates or acknowledging that some of the milestones have been delayed, in some cases by several years, beyond their original agreed-upon completion dates. For example, we found that at least 14 milestones from the 2012 plan were repeated in the 2017 plan with new forecasted completion dates, but the 2017 plan gave no indication that these milestones had been postponed (see table 3).[28] The milestones' due dates had been pushed back by as many as 6 years without any indication in the 2017 report that they were delayed. As noted above, EM headquarters does not track changes to milestones and EM officials at both headquarters and the sites said that they have not historically kept a record of the original baseline dates for renegotiated milestones they change. As a result, EM officials could not readily provide information on whether the other milestones listed in the 2012 report met their listed due date or whether they were postponed. Headquarters officials stated that to gather this information they would need to survey officials at each site.

Table 3: Examples of Changed Milestone Dates in Environmental Management's (EM) 2012 and 2017 Future-Years Defense Environmental Cleanup Plans[a]

Site	Milestone name	Due date listed in EM's 2012 plan	Due date listed in EM's 2017 plan
Hanford Site	Barrier 3 Construction Complete	10/31/2014	10/31/2019
	Barrier 3 Design/Monitoring Approval From Ecology	6/30/2013	9/30/2018
	Barrier 4 Construction Complete	10/31/2015	10/31/2020
	Barrier 4 Design/Monitoring Approval From Ecology	6/30/2014	9/30/2019
	Complete Disposition Of 300 Area Surplus Facilities	9/30/2015	9/30/2018
	LAW Facility Construction Substantially Complete	12/31/2014	12/31/2020

[28]We were able to match the names of 14 milestones in the 2012 report to those in the 2017 report, but there may be other milestones that represent the same cleanup work but whose names changed in the intervening 5 years.

Site	Milestone name	Due date listed in EM's 2012 plan	Due date listed in EM's 2017 plan
	M-015-21A Submit 200-BP-5 and 200-PO- 1 Operable Unit Feasibility Study Report and Proposed Plan(s) to Ecology	6/30/2015	6/30/2018
	M-016-175, Begin sludge removal from 105-KW Fuel Storage Basin	9/30/2014	9/30/2018
	M-016-176, Complete sludge removal from 105-KW Fuel Storage Basin	9/30/2015	12/31/2019
	M-016-178, Initiate deactivation of 105-KW Fuel Storage Basin	12/31/2015	12/31/2019
	M-024-58F, Initiate Discussions of Well Commitments	6/1/2013	6/1/2018
Idaho National Laboratory	Cease use of tank farm	12/31/2012	12/31/2018
Oak Ridge Reservation	Submit to TDEC a draft plan for disposition of the transuranic waste remaining in Solid Waste Storage Area 5 North-Trench 13	8/1/2014	6/30/2019
Savannah River Site	Issue Record of Decision for D-Area Operable Unit (Includes 10 sub-units with 10 associated milestones)	12/6/2016	6/30/2019

Source: GAO analysis of Department of Energy data. | GAO-19-207

[a]Department of Energy, *Future-Years Defense Environmental Management Plan* (Washington, D.C.: September 2012); and *Future-Years Defense Environmental Management Plan: FY 2018 to FY 2070* (Washington, D.C.: August 2017).

- **Inaccurate forecast.** Second, the forecast completion dates for milestones listed in the 2012 and 2017 plans may not present an accurate picture of the status of the milestones and EM's cleanup efforts. For example, in the 2012 plan, DOE reported that four out of 218 milestones were at risk of missing their planned completion date, while the rest were on schedule. As discussed above, we found 14 of the milestones in the 2012 plan had been postponed and listed again in the 2017 plan.[29] Similarly, the 2017 plan listed only one milestone out of 154 as forecasted to miss its due date. However, because EM does not have a historical record of the changes made to the milestones, it is unclear how many of these milestones represented their original due dates.
- **Incomplete list.** Third, the plans did not include milestones from all of the 10 DOE cleanup sites that EM is required to report on.[30] In 2012, EM did not report milestone information for two of the 10 sites that

[29]This does not include milestones that may have been delayed but did not appear in the 2017 plan.

[30]The act does not require EM to report on six cleanup sites: Brookhaven National Laboratory, Energy Technology Engineering Center, Moab Uranium Mill Tailings Project, Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, and West Valley Demonstration Project.

were required to be included in the plan. In the 2017 plan, information was missing for one of the 10 required sites. EM headquarters officials said that this could be because some sites did not update their milestone information or some sites may still be renegotiating new milestones. However, neither report indicated that data were missing for these sites.

As a result of these issues, DOE's future-years defense environmental cleanup plans provide only a partial picture of the milestones and overall cleanup progress made across the cleanup complex, and actual progress made in cleanup is not transparent to Congress. The absence of reliable and complete information on the progress of EM's cleanup mission limits EM's ability to manage its mission and complicates Congress's ability to oversee the cleanup work.

EM Does Not Analyze the Root Causes of Missed or Postponed Milestones and Does Not Have Guidelines for Considering Root Causes When Renegotiating New Milestones

Best practices and DOE requirements for project management call for a root cause analysis when problems lead to schedule delays, but EM officials at both headquarters and selected sites have not analyzed reasons why milestones are missed or postponed. According to best practices identified in GAO's cost estimating guide, agencies should identify root causes of problems that lead to schedule delays and renegotiated milestones.[31] Specifically, when risks materialize (i.e., when milestones are missed or delayed), risk management should provide a structure for identifying and analyzing root causes. The benefits of doing so include developing a better understanding of the factors that caused milestones to be missed and providing agencies with information to more effectively address those factors in the future. In addition, DOE has recently emphasized the importance of doing this kind of analysis. In 2015, DOE issued a directive requiring sites to do a root cause analysis when the project team, program office, or independent oversight offices determine that a project has breached its cost or schedule thresholds.[32] This directive, which applies to all programs and projects within DOE, calls for "an independent and objective root cause analysis to determine

[31]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs,* GAO-09-3SP (Washington, D.C.: Mar. 2, 2009).

[32]Department of Energy, *Memorandum for Heads of All Department Elements: Project Management Policies and Principles* (Washington, D.C.: June 8, 2015). This language is mirrored in DOE's order that outlines guidance for managing capital asset projects. See Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, Order 413.3B, Chg. 5 (Washington, D.C.: April 12, 2018).

the underlying contributing causes of cost overruns, schedule delays, and performance shortcomings," such as missed or postponed milestones.

However, EM has not done a complex-wide analysis of the reasons for missed or postponed milestones. Similarly, officials we interviewed at the four selected sites said that they were not aware of any site-wide review of why milestones were missed or postponed. According to headquarters officials, this analysis has not been done because EM has determined that DOE requirements governing this type of analysis apply only to contract schedules, not regulatory milestones, and that missed or postponed milestones are not necessarily an indication of cleanup performance shortcomings. However, as previously noted in this report, missing or postponing milestones is a systemic problem across the cleanup complex that makes it difficult for DOE to accurately identify cleanup performance shortcomings. Because EM has not analyzed why it has missed or postponed milestones, EM cannot address these systemic problems and consider those problems when renegotiating milestones with regulators.[33] Without such analysis, EM and its cleanup regulators lack information to set more realistic and achievable milestones and, as a result, future milestones are likely to continue to be pushed back, further delaying the cleanup work. As we have reported previously, these delays lead to increases in the overall cost of the cleanup.[34]

Conclusions

The federal government faces a large and growing future environmental liability, the vast majority of which is related to the cleanup of radioactive and hazardous waste at DOE's 16 sites around the country. EM has responsibility for addressing the human health and environmental risks presented by this contamination in the most cost-effective way. However, most of EM's largest projects are significantly delayed and over budget, and state regulators for nearly all of EM's cleanup sites have responded by initiating enforcement actions, often leading to additional agreements,

[33]EM issued standard operating procedures for negotiating milestones in 2013. This document specifies such things as which milestone changes require headquarters approval and when sites must prepare a negotiating strategy before meeting with regulators to make changes. See Department of Energy, *Review and Approval of Regulatory Agreements, Milestones and Decision Document: U.S. Department of Energy Office of Environmental Management Standing Operating Policies and Procedures (SOPP)* (Washington, D.C.: April 2013).

[34]GAO-19-28.

including administrative orders and court settlements, in addition to initial federal facility agreements to ensure those risks are addressed.

EM relies on cleanup milestones, among other metrics, to measure the overall performance of its operations activities, and EM reports that very few of its cleanup milestones over the past 2 decades have been missed. However, EM's self-reported performance in achieving milestones does not provide an accurate view of actual progress in cleaning up sites. EM has not established clear definitions for tracking and reporting milestones and does not have any requirements governing the way sites are to update milestone information. As a result, EM's internal tracking of these milestones has inconsistencies. Additionally, since the requirement to annually report on the status of milestones was set in 2011, EM has produced only two reports to Congress, and these were inaccurate and incomplete. Without a clear and consistent approach to collecting and reporting this data, including the history of milestone changes, EM cannot accurately use milestones for managing and measuring the performance of its cleanup program. The absence of reliable and complete information on the progress of EM's cleanup mission also limits EM's and Congress's ability to oversee the cleanup work. In addition, without a root cause analysis of why milestones are missed or postponed, EM and its cleanup regulators lack information to set more realistic and achievable milestones. As a result, future milestones are likely to continue to be pushed back, further delaying the cleanup work, which will likely increase cleanup costs and risks to human health and the environment.

Recommendations for Executive Action

We are making the following four recommendations to DOE:

The Assistant Secretary of DOE's Office of Environmental Management should update EM's policies and procedures to establish a standard definition of milestones and specify requirements for both including and updating information on milestones across the complex. (Recommendation 1)

The Assistant Secretary of DOE's Office of Environmental Management should track original milestone dates as well as changes to its cleanup milestones. (Recommendation 2)

The Assistant Secretary of DOE's Office of Environmental Management should comply with the requirements in the National Defense Authorization Act by reporting annually to Congress on the status of its cleanup milestones and including a complete list of cleanup milestones

for all sites required by the act. The annual reports should also include, for each milestone, the original date along with the currently negotiated date. (Recommendation 3)

The Assistant Secretary of DOE's Office of Environmental Management should conduct root cause analyses of missed or postponed milestones. (Recommendation 4)

Agency Comments and Our Evaluation

We provided a draft of this report to DOE for review and comment. DOE provided written comments, which are reproduced in appendix II; the agency also provided technical comments that we incorporated in the report as appropriate. Of the four recommendations in the report, DOE agreed with three, and partially agreed with one.

- Regarding the recommendation that DOE update EM's policies and procedures to establish a standard definition of milestones and specify requirements for both including and updating information on milestones across the complex, the agency agreed with the recommendation. DOE stated that these policy-driven reforms can improve the efficiency of milestone tracking.
- Regarding the recommendation that DOE track changes to cleanup milestones, the agency agreed with the recommendation. DOE stated that EM currently monitors milestone status, including changes as the need for changes are identified and as part of its ongoing communication with field offices, and therefore DOE considers the recommendation to be closed. However, as we noted in the report, neither EM headquarters nor the sites track the original baseline schedule for renegotiated milestone dates. We adjusted the language of the recommendation to make clear that the EM Assistant Secretary should track original milestone dates as well as changes to cleanup milestones. DOE stated in its written comments that EM does not believe that tracking original and changed milestones will strengthen EM's ability to use milestones to manage and measure the performance of its cleanup program. However, as we noted in this report, according to best practices identified in GAO's schedule assessment guide, agencies should formally establish a baseline schedule against which performance can be measured. We have found that, without a documented and consistently-applied schedule change control process, program staff may continually revise the schedule to match performance, hindering management's insight into the true performance of the project. In addition, DOE's internal project management policies call for steps to maintain a change control

process, including setting a baseline schedule for completing certain activities and maintaining a record of any subsequent deviations from that baseline.

- Regarding our recommendation that DOE comply with the requirements in the National Defense Authorization Act by reporting annually to Congress on the status of its cleanup milestones and including a complete list of cleanup milestones for all sites required by the act, the agency partially agreed with the recommendation. DOE stated that additional budget and clarification of purpose and scope would be required to fulfill this recommendation. As we point out in our report, DOE has not fully complied with requirements established by the act, including not submitting all required annual reports and, even when DOE did submit these reports, its reporting omitted information about some sites. DOE stated that EM is reviewing options to address this recommendation.
- Regarding our recommendation that DOE conduct root cause analyses of performance shortcomings that lead to missed or postponed milestones, the agency agreed with the recommendation and stated that EM is evaluating options to implement it. However, DOE stated that there may be multiple reasons why milestones are changed, and not all of the changes are due to DOE performance. To acknowledge the uncertainty in the causes of missed or postponed milestones, we adjusted the language of the recommendation to clarify that the EM Assistant Secretary should conduct root cause analyses of missed or postponed milestones.

In addition, in its written comments, DOE disagreed with the draft report's description of the process and authorities related to renegotiating compliance milestones, stating that EM cannot and does not unilaterally delay/postpone milestones and that EPA and state regulator approval of milestone changes is required. We agree, and the report states that it is common for regulators and sites to renegotiate milestones before sites miss them. DOE also disagreed with the draft report’s characterization of the coordination between EM sites and headquarters in tracking milestones. In particular, DOE’s written comments state that site-specific databases include all regulatory compliance milestones drawn from applicable agreements, while the headquarters database tracks major enforceable milestones. However, as our report notes, because not all sites make the same distinction between major and non-major milestones, sites are not consistently reporting the same types of milestones to EM headquarters. In addition, DOE’s written comments state that EM sites and headquarters routinely collaborate and discuss the status of milestones via meetings and EM periodically requests that

sites verify the data in the EM headquarters database. Nevertheless, as our report notes, EM requirements governing the submission of milestone information do not specify when or how often sites are to update this information.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, and other interested parties. In addition, this report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or trimbled@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made significant contributions to this report are listed in appendix III.

David C. Trimble
Director, Natural Resources and Environment

Appendix I: Department of Energy (DOE) Cleanup Sites

Brookhaven National Laboratory

The Brookhaven National Laboratory was established in 1947 by the Atomic Energy Commission. Formerly Camp Upton, a U.S. Army installation site, Brookhaven is located on a 5,263-acre site on Long Island in Upton, NY, approximately 60 miles east of New York City. Historically, Brookhaven was involved in the construction of accelerators and research reactors such as the Cosmotron, the High Flux Beam Reactor, and the Brookhaven Graphite Research Reactor. These accelerators and reactors led the way in high-energy physics experiments and subsequent discoveries but also resulted in radioactive waste. To complete the cleanup mission, DOE is working to build and operate groundwater treatment plants, decontaminate and decommission the High Flux Beam Reactor and the Brookhaven Graphite Research Reactor, and dispose of some wastes off-site.

Energy Technology Engineering Center

The Energy Technology Engineering Center occupies 90 acres within the 290 acre Santa Susana Field Laboratory 30 miles north of Los Angeles, California. The area was primarily used for DOE research and development activities. In the mid-1950s, part of the area was set aside for nuclear reactor development and testing, primarily related to the development of nuclear power plants and space power systems, using sodium and potassium as coolants. In the mid-1960s, the Energy Technology Engineering Center was established as a DOE laboratory for the development of liquid metal heat transfer systems to support the Office of Nuclear Energy Liquid Metal Fast Breeder Reactor program. DOE is now involved in the deactivation, decommissioning, and dismantlement of contaminated facilities on the site.

Hanford Site

DOE is responsible for one of the world's largest environmental cleanup projects: the treatment and disposal of millions of gallons of radioactive and hazardous waste at its 586 square mile Hanford Site in southeastern Washington State. Hanford facilities produced more than 20 million pieces of uranium metal fuel for nine nuclear reactors along the Columbia River. Five plants in the center of the Hanford Site processed 110,000 tons of fuel from the reactors, discharging an estimated 450 billion gallons of liquids to soil disposal sites and 53 million gallons of radioactive waste to 177 large underground tanks. Plutonium production ended in the late 1980s. Hanford cleanup began in 1989 and now involves (1) groundwater monitoring and treatment, (2) deactivation and decommissioning of contaminated facilities, and (3) the construction of the waste treatment

and immobilization plant intended, when complete, to treat the waste in the underground tanks.

Idaho National Laboratory

DOE's Idaho Site is an 890-square-mile federal reserve, situated in the Arco Desert over the Snake River Plain Aquifer in central Idaho. The Idaho Cleanup Project involves the environmental cleanup of the Idaho Site, contaminated with legacy wastes generated from World War II-era conventional weapons testing, government-owned research and defense reactors, spent nuclear fuel reprocessing, laboratory research, and defense missions at other DOE sites.

Lawrence Livermore National Laboratory

The 1-square-mile Lawrence Livermore National Laboratory site is an active, multi-program DOE research laboratory about 45 miles east of San Francisco. A number of research and support operations at Lawrence Livermore handle, generate, or manage hazardous materials that include radioactive wastes. The site first was used as a Naval Air Station in the 1940s. In 1951, it was transferred to the U.S. Atomic Energy Commission and was established as a nuclear weapons and magnetic fusion energy research facility. Over the past several years, Lawrence Livermore constructed several treatment plants for groundwater pumping and treatment and for soil vapor extraction. These systems will continue to operate until cleanup standards are achieved.

Los Alamos National Laboratory

Los Alamos National Laboratory is located in Los Alamos County in north central New Mexico. The laboratory, founded in 1943 during World War II, served as a secret facility for research and development of the first nuclear weapon. The site was chosen because the area provided controlled access, steep canyons for testing high explosives, and existing infrastructure. The Manhattan Project's research and development efforts that were previously spread throughout the nation became centralized at Los Alamos and left a legacy of contamination. Today, the Los Alamos National Laboratory Cleanup Project is responsible for the treatment, storage, and disposition of a variety of radioactive and hazardous waste streams; removal and disposition of buried waste; protection of the regional aquifer; and removal or deactivation of unneeded facilities.

Moab Uranium Mill Tailings Project

The Moab Site is located about 3 miles northwest of the city of Moab in Grand County, Utah. The former mill site encompasses approximately 435 acres, of which about 130 acres is covered by the uranium mill

tailings pile. Uranium concentrate (called yellowcake), the milling product, was sold to the U.S. Atomic Energy Commission through December 1970 for use in national defense programs. After 1970, production was primarily for commercial sales to nuclear power plants. During its years of operation, the mill processed an average of about 1,400 tons of ore a day. The milling operations created process-related wastes and tailings, a radioactive sand-like material. The tailings were pumped to an unlined impoundment in the western portion of the Moab Site property that accumulated over time, forming a pile more than 80 feet thick. The tailings, particularly in the center of the pile, have a high water content. Excess water in the pile drains into underlying soils, contaminating the ground water.

Nevada National Security Site

In 1950, President Truman established what is now known as the Nevada National Security Site in Mercury, Nevada, to perform nuclear weapons testing activities. In support of national defense initiatives, a total of 928 atmospheric and underground nuclear weapons tests were conducted at the site between 1951 and 1992, when a moratorium on nuclear testing went into effect. Today, the site is a large, geographically-diverse research, evaluation, and development complex that supports homeland security, national defense, and nuclear nonproliferation. In Nevada, DOE activities focus on groundwater, soil, and on-site facilities; radioactive, hazardous, and sanitary waste management and disposal; and environmental planning.

Oak Ridge Reservation

DOE's Oak Ridge Reservation is located on approximately 33,500 acres in eastern Tennessee. The reservation was established in the early 1940s by the Manhattan Engineer District of the U. S. Army Corps of Engineers and played a role in the production of enriched uranium during the Manhattan Project and the Cold War. DOE is now working to address excess and contaminated facilities, remove soil and groundwater contamination, and enable modernization that allows the National Nuclear Security Administration to continue its national security and nuclear nonproliferation responsibilities and the Oak Ridge National Laboratory to continue its mission for advancing technology and science.

Paducah Gaseous Diffusion Plant

The Paducah Gaseous Diffusion Plant, located within an approximately 650-acre fenced security area in in McCracken County in western Kentucky, opened in 1952 and played a role in the production of enriched uranium during and after the Cold War until ceasing production for

commercial reactor fuel purposes in 2013. Decades of uranium enrichment and support activities required the use of a number of typical and special industrial chemicals and materials. Plant operations generated hazardous, radioactive, mixed (both hazardous and radioactive), and nonchemical (sanitary) wastes. Past operations also resulted in soil, groundwater, and surface water contamination at several sites located within plant boundaries.

Portsmouth Gaseous Diffusion Plant

The Portsmouth Gaseous Diffusion Plant is located in Pike County, Ohio, in southern central Ohio, approximately 20 miles north of the city of Portsmouth, Ohio. Like the Paducah Plant, this facility was also initially constructed to produce enriched uranium to support the nation's nuclear weapons program and was later used by commercial nuclear reactors. Cleanup activities here are similar to those at the Paducah Plant.

Sandia National Laboratories

The Sandia National Laboratories comprises 2,820 acres within the boundaries of the 118 square miles of Kirtland Air Force Base and is located about 6 miles east of downtown Albuquerque, New Mexico. It is managed by the National Nuclear Security Administration. Sandia National Laboratories was established in 1945 for nuclear weapons development, testing, and assembly for the Manhattan Engineering District. Beginning in 1980, the mission shifted toward research and development for nonnuclear components of nuclear weapons. Subsequently, the mission was expanded to research and development on nuclear safeguards and security and multiple areas in science and technology.

Savannah River Site

The Savannah River Site complex covers 198,344 acres, or 310 square miles, encompassing parts of Aiken, Barnwell, and Allendale counties in South Carolina, bordering the Savannah River. The site is a key DOE industrial complex responsible for environmental stewardship, environmental cleanup, waste management, and disposition of nuclear materials. During the early 1950s, the site began to produce materials used in nuclear weapons, primarily tritium and plutonium-239. Five reactors were built to produce nuclear materials and resulted in unusable by-products, such as radioactive waste. About 35 million gallons of radioactive liquid waste are stored in 43 underground tanks. The Defense Waste Processing Facility is processing the high-activity waste, encapsulating radioactive elements in borosilicate glass, a stable storage form. Since the facility began operations in March 1996, it has produced

more than 4,000 canisters (more than 16 million pounds) of radioactive glass.

Separations Process Research Unit

The Separations Process Research Unit is an inactive facility located at the Knolls Atomic Power Laboratory in Niskayuna, New York, near Schenectady. The Mohawk River forms the northern boundary of this site. Built in the late 1940s, its mission was to research the chemical process to extract plutonium from irradiated materials. Equipment was flushed and drained, and bulk waste was removed following the shutdown of the facilities in 1953. Today, process vessels and piping have been removed from all the research unit's facilities. In 2010, cleanup of radioactivity and chemical contamination in the Lower Level Railroad Staging Area, Lower Level Parking Lot, and North Field areas was completed.

Waste Isolation Pilot Plant

The Waste Isolation Pilot Plant is an underground repository located near Carlsbad, New Mexico, that is used for disposing of defense transuranic waste. The plant is managed by DOE's Office of Environmental Management and is the only deep geological repository for the permanent disposal of defense generated transuranic waste.

West Valley Demonstration Project

The West Valley Demonstration Project occupies approximately 200 acres within the 3,345 acres of land called the Western New York Nuclear Service Center. The project is located approximately 40 miles south of Buffalo, New York. The West Valley Demonstration Project Act of 1980 established the project. The act directed DOE to solidify and dispose of the high-level waste and decontaminate and decommission the facilities used in the process. The land and facilities are not owned by DOE. Rather, the project premises are the property of the New York State Energy Research and Development Authority. DOE does not have access to the entire 3,345 acres of property.

Appendix II: Comments from the Department of Energy

Department of Energy
Washington, DC 20585

JAN 2 4 2019

Mr. David Trimble
Director
Natural Resources and Environment
U.S. Government Accountability Office
Washington, DC 20548

Dear Mr. Trimble:

This letter provides the Department of Energy (DOE) Office of Environmental Management's (EM) response to the draft Government Accountability Office (GAO) report, "DOE Should Take Actions to Improve Oversight of Cleanup Milestones" (GAO-19-207) ("draft report"). EM requests this letter be incorporated into the final report.

EM appreciates the GAO assessment of regulatory compliance milestones related to the cleanup and management of DOE defense nuclear facilities, and provides in this letter clarifications and responses to the recommendations made in the draft report. While EM does not believe a milestone tracking system can drive cleanup performance by itself, EM agrees that tracking milestones is an important tool. EM plans to make the milestone tracking system a more effective and efficient tool. More importantly, EM believes its recent initiatives to include end-state contracting, a new fee advisory board, and enhancements to Performance Evaluation and Management Plans (PEMPs) will drive significant improvements in cleanup performance.

Points of Clarification

EM Coordination on Milestone Tracking. EM disagrees with the draft report's characterization of the coordination between EM sites and headquarters in tracking milestones. Specifically, EM disagrees that maintaining EM headquarters and site milestone datasets causes inconsistencies in the milestone data. By design, site-specific and EM headquarters databases serve different purposes. Site-specific databases include all regulatory compliance milestones drawn from applicable agreements, decrees, and other sources. Sites use these comprehensive datasets to facilitate routine engagements with regulators. For example, a given site may use the dataset for prioritization planning, a necessary and fundamental activity given ongoing cleanup data analysis and single year budget outlays. The EM headquarters database tracks major enforceable milestones such as activities that include important decisions and on-the-ground cleanup work. EM uses this focused dataset to address complex-wide questions.

EM disagrees with the draft report's claim that "sites do not consistently provide EM headquarters with the most up-to-date information on the status of milestones at each site." EM sites and headquarters routinely collaborate and discuss the status of milestones in monthly site briefings, annual budget preparation meetings, and annual

agreements, milestones, and decision documents (AMDD) reporting. EM also periodically requests that sites verify the data in the EM headquarters database to support up-to-date completeness and accuracy.

Causes of and Process for Renegotiating Milestones. EM disagrees with the draft report's limited description of the drivers for renegotiating milestones and does not believe the draft report accurately describes the drivers and authorities related to milestone renegotiation. There may be multiple reasons why milestones are changed, and not all of the changes are due to DOE performance. For example, some of the milestones require regulator action (e, g., timely review of a DOE document). The draft report also asserts that EM "performance shortcomings" lead to "missed milestones." This is not always true. Regulatory compliance milestone performance is the product of several interrelated, dynamic factors. The fact that EM routinely renegotiates milestones with regulators does not automatically signal an EM deficiency that requires analysis and reform.[1] In most instances, milestones are renegotiated according to established processes to address technical, regulatory, or financial challenges, that the parties to the cleanup agreements agree are appropriate to support a revised milestone date. For example, milestones may be renegotiated to limit liabilities, fines, and/or penalties. In other cases, routine renegotiations are built into the cleanup agreements. Rolling milestone arrangements, for example, include annual renegotiations of outyear milestones to proactively overcome cleanup uncertainties, inconsistent budgets, and enable adjustments to priorities by design (e.g., Los Alamos).

EM also disagrees with the draft report's description of the process and authorities related to renegotiating compliance milestones. EM cannot and does not unilaterally delay/postpone milestones. EPA and state regulator approval of milestone changes is required. EPA and state regulators, rather than EM, often drive renegotiation. For example, GAO listed the Oak Ridge Trench 13 milestone as an example of a changed milestone. In that case, EM submitted the required plan well ahead of the milestone date in the enforceable order. However, upon receipt and review, the Tennessee Department of Environment & Conservation (TDEC) non-concurred on the preferred option. EM and TDEC ultimately agreed to defer the milestone and provide TDEC additional information supporting the options. Therefore, the State regulator drove and approved the milestone change.

Utility and Costs of Tracking Historical Original and Changed Milestones. The draft report does not clearly explain or acknowledge the foreseeable expenditure of resources that would be required to expand the EM milestone dataset to include milestone dates since their inception. EM does not agree with the draft report's position that tracking original and changed milestones will strengthen EM's ability to use milestones to manage and measure the performance of its cleanup program. Original milestone dates have limited utility once changed because EM does not have sole authority over the milestone

[1] At Hanford, the parties have often used the existing provisions of the Tri-Party Agreement (e.g., Modification of Agreement, Good Cause for Extensions, Resolution of Disputes) to address regulatory compliance milestone issues. The administrative record for the Tri-Party Agreement, while voluminous, is available online at the following link: https://pdw.hanford.gov/arpir/

tracking and renegotiation process. Regulators, and their distinct discretionary preferences, are significant drivers in how milestones should be set, tracked, enforced, prioritized, implemented, and renegotiated in federal facility and other environmental compliance agreements.

Responses to Recommendations

Recommendation 1: The EM Assistant Secretary should update EM's policies and procedures to establish a standard definition of milestones and specify requirements for both including and updating information on milestones across the complex.

Management Response: Concur. EM supports the recommendation to develop written definitions and guidance to strengthen consistency with respect to approaching corporate-level data entry for regulatory compliance milestones. EM agrees that policy driven reforms can improve the efficiency of milestone tracking.

Estimated completion date: September 30, 2019.

Recommendation 2: The EM Assistant Secretary should track changes to cleanup milestones.

Management Response: Concur. EM currently monitors milestone status, including changes as the need for changes are identified and as part of its ongoing communication with field offices.

Estimated completion date: EM considers this recommendation closed.

Recommendation 3: The EM Assistant Secretary should comply with the requirements in the National Defense Authorization Act by reporting annually to Congress on the status of its cleanup milestones and including a complete list of cleanup milestones for all sites required by the Act. The annual reports should also include, for each milestone, the original date along with the currently negotiated date.

Management Response: Partially Concur. EM is reviewing options to address this recommendation. However, additional budget and clarification of purpose and scope would be required to fulfill this recommendation.

Estimated completion date: December 31, 2019.

Recommendation 4: The EM Assistant Secretary should conduct root cause analyses of performance shortcomings that lead to missed or postponed milestones.

Management Response: Concur. EM is evaluating options to address this recommendation, including the possibility of elaborating on milestone performance in other, conventional root cause analyses of cleanup activities. For example, a more accurate view of actual progress in cleaning up sites might be found in EM's site "key

performance goals," in accordance with the GPRA [Government Performance and Results Act] Modernization Act of 2010.

Estimated completion date: September 30, 2019.

If there are questions, please contact me or Ms. Elizabeth A. Connell, Acting Associate Principal Deputy Assistant Secretary for Regulatory and Policy Affairs, at (202) 586-0637.

Sincerely,

Anne Marie White
Assistant Secretary
for Environmental Management

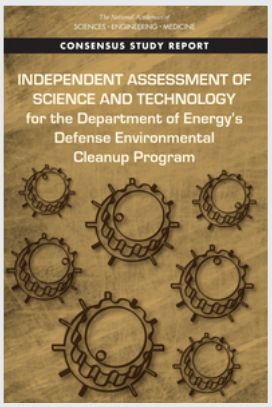
Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

David C. Trimble, (202) 512-3841 or trimbled@gao.gov

Staff Acknowledgments

In addition to the contact named above, Nico Sloss (Assistant Director), Jeffrey T. Larson (Analyst in Charge), Natalie M. Block, Antoinette C. Capaccio, R. Scott Fletcher, Cindy K. Gilbert, Richard P. Johnson, Jeffrey R. Rueckhaus, Ilga Semeiks, Sheryl E. Stein, and Joshua G. Wiener made key contributions to this report.



Independent Assessment of Science and Technology for the Department of Energy's Defense Environmental Cleanup Program (2019)

DETAILS

122 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-48775-7 | DOI 10.17226/25338

CONTRIBUTORS

Committee on Independent Assessment of Science and Technology for the Department of Energy s Defense Environmental Cleanup Program; Nuclear and Radiation Studies Board; Division on Earth and Life Studies; National Academies of Sciences, Engineering, and Medicine

SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2019. *Independent Assessment of Science and Technology for the Department of Energy's Defense Environmental Cleanup Program*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25338.

INDEPENDENT ASSESSMENT OF SCIENCE AND TECHNOLOGY for the Department of Energy's Defense Environmental Cleanup Program

Committee on Independent Assessment of Science and Technology for the Department of Energy's Defense Environmental Cleanup Program

Nuclear and Radiation Studies Board

Division on Earth and Life Studies

A Consensus Study Report of

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

This activity was supported by award DE-EM0001172/NAS Proposal Number 10003493 between the National Academy of Sciences and the Department of Energy's Office of Environmental Management. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

International Standard Book Number-13: 978-0-309-48775-7
International Standard Book Number-10: 0-309-48775-7
Digital Object Identifier: https://doi.org/10.17226/25338

Cover: This report identifies seven types of technologies and alternative approaches that have the potential to substantially reduce long-term cleanup costs; accelerate cleanup schedules; and mitigate uncertainties, vulnerabilities, or risks, or otherwise significantly improve the Department of Energy's Defense Environmental Cleanup Program for former nuclear weapons sites. These technologies and alternative approaches are posed as "knobs" that can be "turned" through a properly organized and focused science and technology development and deployment effort.

Additional copies of this publication are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2019. *Independent Assessment of Science and Technology for the Department of Energy's Defense Environmental Cleanup Program*. Washington, DC: The National Academies Press. doi: https://doi.org/10.17226/25338.

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. C. D. Mote, Jr., is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.nationalacademies.org**.

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

Consensus Study Reports published by the National Academies of Sciences, Engineering, and Medicine document the evidence-based consensus on the study's statement of task by an authoring committee of experts. Reports typically include findings, conclusions, and recommendations based on information gathered by the committee and the committee's deliberations. Each report has been subjected to a rigorous and independent peer-review process and it represents the position of the National Academies on the statement of task.

Proceedings published by the National Academies of Sciences, Engineering, and Medicine chronicle the presentations and discussions at a workshop, symposium, or other event convened by the National Academies. The statements and opinions contained in proceedings are those of the participants and are not endorsed by other participants, the planning committee, or the National Academies.

For information about other products and activities of the National Academies, please visit www.nationalacademies.org/about/whatwedo.

COMMITTEE ON INDEPENDENT ASSESSMENT OF SCIENCE AND TECHNOLOGY FOR THE DEPARTMENT OF ENERGY'S DEFENSE ENVIRONMENTAL CLEANUP PROGRAM

PATRICIA J. CULLIGAN (*Chair*), Columbia University, New York, New York
M. JOHN PLODINEC (*Vice Chair*), Community and Regional Resilience Institute, Aiken, South Carolina
SUE B. CLARK, Washington State University/Pacific Northwest National Laboratory, Richland, Washington
PAUL T. DICKMAN, Argonne National Laboratories, Washington, DC
BARBARA L. HAMRICK, University of California, Irvine
ROBERT T. JUBIN, Oak Ridge National Laboratories, Oak Ridge, Tennessee
WILLIAM LEE, Imperial College London/Bangor University, Gwynedd, United Kingdom
ALEXANDRA NAVROTSKY, University of California, Davis
JAMES A. RISPOLI, North Carolina State University, Raleigh
REBECCA A. ROBBINS, International Atomic Energy Agency, Vienna, Austria
ROBIN D. ROGERS, University of Alabama, Tuscaloosa
POL D. SPANOS, Rice University, Houston, Texas

Staff

OURANIA KOSTI, Study Director
KEVIN D. CROWLEY, Senior Advisor
TONI GREENLEAF, Administrative and Financial Associate
MICHAEL B. HUDSON, Senior Program Assistant
JORGE MENDOZA-TORRES, Senior Research Librarian

NUCLEAR AND RADIATION STUDIES BOARD

Staff

Acknowledgments

The successful completion of this study would not have been possible without the cooperation and assistance of many organizations and individuals. The committee would especially like to acknowledge and thank the following organizations and individuals for their support:

Department of Energy's Office of Environmental Management (DOE-EM), which sponsored the study and provided information on the office's activities in support of technology development for the cleanup program. Ms. Beth Moore served ably as the agency's liaison to the committee and was effective in coordinating, together with Mr. Rodrigo V. Rimando, Jr., the committee's visits to DOE sites. Mr. Rimando also responded to the committee's numerous requests for information related to the DOE-EM Technology Development Office's processes for selecting and prioritizing technologies for development and deployment. He remained flexible and available to assist the committee with information gathering and fact checking despite his transfer to another position within DOE-EM in October 2018. The committee and staff applaud his professionalism and commitment during the study process.

DOE's Hanford, Idaho, Oak Ridge, Portsmouth, and Savannah River sites for hosting the committee's visits and for providing information on the sites' cleanup work and associated challenges, science and technology applications and needs, and available resources. Special thanks are given to the following individuals for organizing the committee's site visits and for lining up the experts to brief the committee: Ms. Elaine Diaz, Dr. Vicky Freedman, Ms. Naomi Jaschke, and Ms. Karen Sinclair for the site visit to Hanford and Pacific Northwest National Laboratory; Mr. Joel Case and Ms. Danielle

Miller for the site visit to Idaho; Ms. Staci Monroe, Ms. Elizabeth Phillips, and Dr. Eric Pierce for the site visit to Oak Ridge; Ms. Elizabeth Scott for the site visit to Portsmouth; and Mr. Andrew Fellinger and Mr. Tony Polk for the site visit to Savannah River. The committee also thanks the site DOE representatives, contractors, and other support staff listed in Appendix D, who briefed the committee.

Stakeholders of the Hanford, Idaho, Oak Ridge, Portsmouth, and Savannah River sites who provided presentations or comments on their role in selecting technologies considered for development or deployment at the sites.

Other individuals and invited participants who provided information and support for this study. Their names are listed in Appendix D.

The committee also thanks staff at the Nuclear and Radiation Studies Board (NRSB) of the National Academies of Sciences, Engineering, and Medicine (the National Academies) for organizing and facilitating this study. Study director Dr. Ourania Kosti organized the committee meetings and site visits and assisted the committee with collecting the information it needed to write its report. Ms. Toni Greenleaf and Mr. Michael Hudson managed the logistics of the meetings, report review, and publication. NRSB director Dr. Charles Ferguson escorted a small group of committee members during the site visit to Portsmouth Gaseous Diffusion Plant.

The committee and the study director are indebted to Dr. Kevin Crowley, advisor to the NRSB (and former NRSB director), who provided valuable technical and policy insights throughout the study as well as valuable historical perspectives on the DOE-EM science and technology program and the National Academies' work to advise DOE-EM. Dr. Crowley was also instrumental in assisting the committee with report writing and review.

Acknowledgment of Reviewers

This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

Gordon E. Brown, Jr., Stanford University
Melanie Brownridge, Nuclear Decommissioning Authority, United Kingdom
Glen T. Daigger, University of Michigan
Steven L. Krahn, Vanderbilt University
M. David Maloney, Jacobs Engineering Group
Raymond L. Orbach, The University of Texas at Austin

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by Drs. **George Hornberger,** Vanderbilt University, and **Cindy Atkins-Duffin,** Lawrence Livermore National Laboratory. They were responsible for making certain that an independent examination of this report was carried out in accordance with the

standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

Contents

APPENDIXES

List of Common Acronyms

AI	artificial intelligence
ARPA-E	Advanced Research Projects Agency–Energy
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRESP	Consortium for Risk Evaluation with Stakeholder Participation
D&D	decontamination and demolition (DOE-EM usage) or decontamination and decommissioning (general usage)
DOE	Department of Energy
DOE-EM	Department of Energy's Office of Environmental Management
DWPF	Defense Waste Processing Facility
EFCOG	Energy Facility Contractors Group
EMAB	Environmental Management Advisory Board
EPA	U.S. Environmental Protection Agency
FY	fiscal year
GAO	U.S. Government Accountability Office
HLW	high-level radioactive waste

INTEC	Idaho Nuclear Technology and Engineering Center
IPABS-IS	Integrated Planning, Accountability, and Budgeting System–Information System
IWTU	Integrated Waste Treatment Unit
LCC	lifecycle cost
LLW	low-level waste
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NRSB	Nuclear and Radiation Studies Board
NSF	National Science Foundation
ORP	Office of River Protection
PNNL	Pacific Northwest National Laboratory
R&D	research and development
RL	Richland Operations Office
S&T	science and technology
SEAB	Secretary of Energy Advisory Board
SRS	Savannah River Site
SSAB	Site-Specific Advisory Board
TCCR	Tank Closure Cesium Removal
TRU	Transuranic
VOC	volatile organic compound

Synopsis

The National Defense Authorization Act (P.L. 114-328) for fiscal year 2017 contained a request (see Appendix A) for a National Academies of Sciences, Engineering, and Medicine (the National Academies) review and assessment of science and technology (S&T) development efforts within the U.S. Department of Energy's Office of Environmental Management (DOE-EM). The National Academies appointed an expert committee to carry out this review and assessment and prepare a technical report. The committee found that DOE-EM's management of S&T development is ad hoc and uncoordinated and thus less effective than it should be.

DOE-EM relies on site contractors to identify S&T development needs and make S&T development investments focused on *near-term* cleanup needs, although the program's S&T needs are primarily *long term*. Headquarters-directed S&T investments are small in comparison to the size of the annual DOE-EM budget for cleanup and they are not geared toward finding breakthrough solutions and technologies that have the potential to substantially reduce cleanup lifecycle costs and schedules, currently reported—and likely underestimated—to be $377 billion and 50-plus years.[1]

The committee recommends that several actions be taken to improve DOE-EM's S&T development program:

- DOE-EM should obtain an independent assessment of the cleanup program's lifecycle costs and schedules from a government engineering organization that is specifically focused on identifying key

[1] See discussion on DOE-EM lifecycle costs and schedules in Section 1.1 of Chapter 1.

remaining technical risks and uncertainties. DOE-EM should use this assessment to reevaluate the adequacy of its S&T development investments to address the identified risks and uncertainties and make any necessary adjustments.

- DOE-EM should implement a formal S&T management process to successfully use S&T to complete its cleanup mission. Peer review needs to be infused throughout this process.
- A portion of the technology development effort for the DOE-EM cleanup program should focus on breakthrough solutions and technologies that can substantially reduce cleanup lifecycle costs, schedules, risks, and uncertainties. This technology development effort should be managed by the Advanced Research Projects Agency–Energy (ARPA-E), a division within DOE with a record of investing in innovative solutions for complex technical challenges. Such a program would require substantial new funding *separate* from the DOE-EM budget.

The committee identified several technologies and alternative approaches that might be explored by an ARPA-E-managed breakthrough S&T development program. These involve changes to the following:

1. Waste chemistry at bulk and interfacial scales to facilitate treatment and disposal.
2. Nuclear properties of waste to facilitate treatment and disposal.
3. Human involvement in cleanup activities to increase cleanup efficiencies and reduce worker risks.
4. Interrogation approaches to characterize wastes and monitor cleanup remedies and environmental impacts.
5. Modeling and visualization approaches to manage large cleanup-related data sets and improve predictive capabilities.
6. Disposal pathways to increase waste disposition options.
7. Decision-making approaches to improve the quality and durability of cleanup decisions.

Executive Summary

The National Defense Authorization Act for fiscal year 2017 (P.L. 114-328) contained a request (see Appendix A) for a National Academies of Sciences, Engineering, and Medicine (the National Academies) review and assessment of science and technology (S&T) development efforts within the Department of Energy's Office of Environmental Management (DOE-EM). The National Academies appointed an expert committee to carry out the study and prepare a technical report. This executive summary contains the complete list of the committee's findings and recommendations.

Study Charge 1: Provide a review of DOE-EM's technology development efforts, including an assessment of the processes by which technologies are identified and selected for development.

This study charge is addressed in Chapter 2 of this report.

Finding 1: DOE-EM projects that it will spend at least another 50 years and $377 billion to complete its cleanup of the nuclear weapons complex. These time and cost estimates are highly uncertain—and probably low—because of (1) substantial remaining uncertainties in the cleanup program's lifecycle costs, schedules, and risks; and (2) the possible future inclusion of additional DOE sites and facilities into the DOE-EM cleanup program.

Recommendation A: DOE-EM should obtain an independent assessment of the cleanup program's lifecycle costs and schedules from a government engineering organization—for example, the U.S. Army Corps of Engineers—that is specifically focused on identifying key remaining technical risks and uncertainties. DOE-EM should use this assessment to reevaluate the major cleanup challenges it faces, including the timeline and costs associated with addressing them with current S&T investments, and make any necessary adjustments to its S&T development program.

Finding 2: Most DOE-EM-related S&T activities are site based, contractor driven and managed, and have a *short-term* focus on addressing technical challenges in existing cleanup projects. DOE-EM headquarters has a limited role in selecting, managing, and coordinating this site-based S&T to ensure that it meets the cleanup program's needs, particularly over the long term and across different sites.

Finding 3: DOE-EM's management of S&T is ad hoc and uncoordinated and thus less effective than it should be. DOE-EM lacks formal, documented processes for (1) managing the technology lifecycle—from basic research through technology deployment—and (2) sharing lessons learned, including failures, successes, and good practices, from its technology development and deployment efforts both within and outside of DOE-EM.

Recommendation B: DOE-EM should design and implement an *S&T management process* for identifying, prioritizing, selecting, developing, and deploying the new knowledge and technologies needed to address its cleanup challenges, including the technical risks and uncertainties identified from the assessment in Recommendation A. Independent peer review should be used to evaluate (1) the S&T management process before it is implemented, (2) S&T projects before they are funded, and (3) the overall effectiveness and impact of DOE-EM's S&T efforts.

Finding 4: DOE-EM has substantially reduced investments in S&T development over the past 15 years and has focused instead on technology deployment in current cleanup projects. In particular, DOE-EM has demonstrated little to no interest in investing in S&T development that might lead to breakthrough solutions and technologies that can substantially reduce cleanup lifecycle costs, schedules, risks, and uncertainties.

Recommendation C: A portion of the technology development effort for the DOE-EM cleanup program should focus on breakthrough solutions and technologies that can substantially reduce cleanup lifecycle

costs, schedules, risks, and uncertainties. Such a program would require substantial new funding *separate from* the DOE-EM budget and a different model for managing research and stimulating innovation. This technology development effort should be

- **Managed by the Advanced Research Projects Agency–Energy (ARPA-E), a division within DOE with a record of investing in innovative solutions for complex technical challenges.**
- **Informed by the independent assessment of the cleanup program's key remaining risks and uncertainties called for in Recommendation A and the S&T management process for identifying, prioritizing, selecting, developing, and deploying the new knowledge and technologies called for in Recommendation B.**
- **Be independently peer reviewed to evaluate its impact on the cleanup program.**

DOE-EM should work cooperatively with ARPA-E to identify and implement these breakthrough technologies and solutions into the cleanup program.

Study Charge 2: Provide a review and assessment of the types of technologies and/or alternative approaches for the DOE-EM cleanup program that could

a. Reduce long-term costs,
b. Accelerate schedules, and
c. Mitigate uncertainties, vulnerabilities, and/or risks, or otherwise significantly improve the cleanup program.

This study charge is addressed in Chapter 3 of this report.

Finding 5: The committee identified seven technologies and alternative approaches that could substantially reduce long-term cleanup costs; accelerate cleanup schedules; and mitigate uncertainties, vulnerabilities, or risks, or otherwise significantly improve the cleanup program. These involve changes to the following:

1. **Waste chemistry at bulk and interfacial scales to facilitate treatment and disposal.**
2. **Nuclear properties of waste to facilitate treatment and disposal.**

3. **Human involvement in cleanup activities to increase cleanup efficiencies and reduce worker risks.**
4. **Interrogation approaches to characterize wastes and monitor cleanup remedies and environmental impacts.**
5. **Modeling and visualization approaches to manage large cleanup-related data sets and improve predictive capabilities.**
6. **Disposal pathways to increase waste disposition options.**
7. **Decision-making approaches to improve the quality and durability of cleanup decisions.**

1

Background and Study Task

The National Defense Authorization Act for fiscal year (FY) 2017 (P.L. 114-328) contained a request for a National Academies of Sciences, Engineering, and Medicine (the National Academies) review and assessment of science and technology (S&T) development[1] efforts within the Department of Energy's Office of Environmental Management (DOE-EM).[2] The congressional request is shown in Appendix A. The National Academies appointed an expert committee to carry out this review and assessment and prepare a technical report with findings and recommendations. The committee did not consider nontechnical factors, for example political and regulatory constraints or public acceptance in its report, although it recognizes that they affect the development and application of new technologies and alternative approaches in the cleanup program.

This chapter provides background information on DOE-EM's mission, the role of S&T development in advancing that mission, and the committee's approach to responding to the congressional request.

1.1 DOE-EM MISSION

DOE-EM is responsible for cleaning up 107 sites in 31 states and 1 territory that were utilized for nuclear weapons development, testing,

[1] The committee defines S&T as the scientific and engineering activities leading to the development and deployment of new approaches and technologies in the DOE-EM cleanup program to increase efficacy and safety and/or reduce costs and schedules.

[2] DOE-EM refers collectively to headquarters and the site offices that oversee the implementation of cleanup projects.

and related activities during the Manhattan Project (1942–1946) and the Cold War (1947–1991). The DOE-EM cleanup program began in 1989 and has, over the past three decades, cleaned up 91 sites at a cost of about $170 billion (GAO, 2019). DOE projects that cleanup of the remaining 16 sites will continue for at least another 50 years (until 2070 or beyond) at an estimated cost of $377 billion.[3,4] These cost and schedule projections do not account for the possible future expansion of the cleanup mission to sites now managed by other DOE offices. Such expansion could extend the timeline by several decades and add to the cost of the remaining cleanup work.[5]

It is important for the purposes of the present study to recognize two facts about the DOE-EM cleanup program:

1. The cleanup program has not yet reached its halfway point from either a cost or a schedule standpoint; and
2. The largest and most complex sites in DOE-EM's remaining portfolio—the Hanford Site in Washington, the Savannah River Site in South Carolina, the Oak Ridge Reservation in Tennessee, and the Idaho Site—still have to be cleaned up. As shown in Figure 1.1, DOE-EM projects that tank waste remediation alongside facility decontamination and demolition (D&D) are the costliest remaining cleanup activities.

[3] This environmental liability estimate is based on DOE's FY 2018 financial statements which are developed in accordance with federal accounting standards. A much lower lifecycle cost estimate for the cleanup program was provided to the committee by DOE-EM (communication with Rodrigo V. Rimando, Jr., Director, Technology Development Office, October 19, 2018): $232 to $274 billion. This lower estimate was generated by the Integrated Planning, Accountability, and Budgeting System (IPABS) [Life-Cycle Cost (LCC)-01c Report dated September 17, 2018] and was used by DOE-EM to communicate with Congress about its FY2019 budget request. During the briefing to the committee on October 19, 2018, Mr. Rimando noted that there was high uncertainty in the IPABS estimates. See discussion in Chapter 2 on the discrepancy between DOE and DOE-EM remaining cleanup cost estimates.

[4] As the committee was finalizing its report for publication, DOE issued an update on the Hanford Site's cleanup lifecycle cost and schedule (DOE-RL, 2019). That update estimates that Hanford's lifecycle cleanup costs are approximately $323 to $677 billion, about three to six times larger than the 2016 estimate of about $108 billion. The low-range cost estimate of $323 billion reflects the "baseline planning case," whereas the high-range cost estimate of about $677 billion "fully incorporates the realization of risks associated with uncertainty in discrete elements of work." The 2019 DOE update also extends the cleanup timeline by 10 to 30 years, that is, through 2080 to 2102. The committee did not have the opportunity to be briefed on the DOE reports' findings. However, this update for Hanford suggests that DOE's current $377 billion/50-year-plus estimate for complex-wide cleanup costs and timelines could be low by hundreds of billions of dollars and several decades.

[5] The U.S. Government Accountability Office (GAO) estimates that DOE-EM's current environmental liability "does not include more than $2.3 billion in costs associated with 45 contaminated facilities that will likely be transferred to EM from other DOE programs in the future" (GAO, 2019).

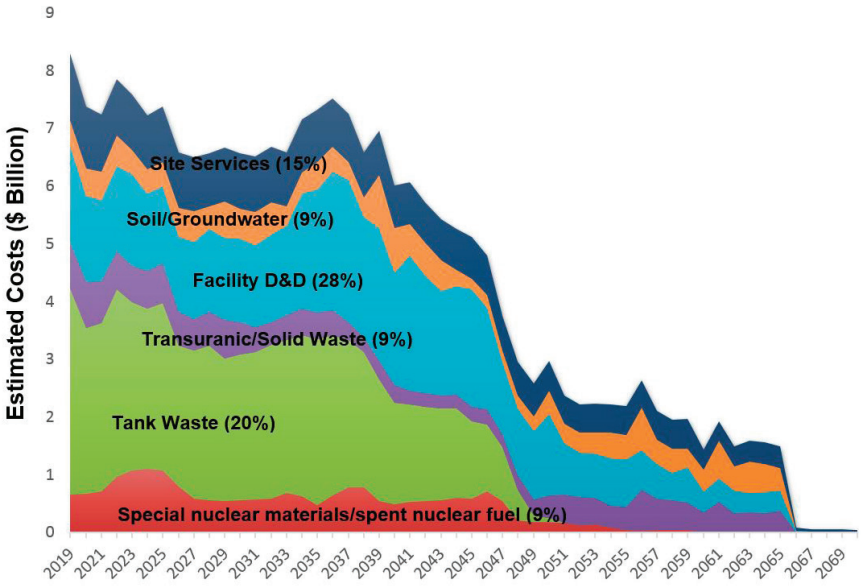


FIGURE 1.1 Projected lifecycle costs and schedules for the DOE-EM cleanup program. The DOE-EM cleanup effort is projected to continue for at least another 50 years (until 2070 or beyond) and cost $377 billion. The majority of the funds are projected to be expended in the next 30 years or sooner. Tank waste remediation activities account for about 20 percent of the lifecycle costs and facility decontamination and demolition for about 28 percent.
SOURCES: Integrated Planning, Accountability, and Budgeting System–Information System (IPABS), September 17, 2018. Provided by Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM.

The long estimated remaining life of the cleanup program provides ample time for new cleanup approaches and technologies to be developed and deployed to reduce cleanup costs and schedules and to mitigate cleanup risks and uncertainties. DOE-EM does not hold a comprehensive list of the technologies it has deployed; therefore, it is difficult to link technology advancements with cost and schedule savings. However, the experience from cleaning up large and complex sites, for example Rocky Flats near Denver, Colorado, showed that new technology development can have major impacts in accelerating schedules and reducing costs.[6] The

[6] Cleanup of Rocky Flats was completed in 2005. The site cleanup was accelerated by nearly 60 years and was completed at about a $30 billion lower cost than DOE-EM's 1995 plan (communication between David Maloney, Technology Fellow [Emeritus], Jacobs Engineering Group, and Ourania Kosti, the National Academies, on February 25, 2019). GAO identified implementation of new technology that significantly accelerated schedules and reduced total costs to be one of the lessons learned from Rocky Flats cleanup (GAO, 2006).

complexity of the remaining cleanup tasks provides an opportunity for S&T to have similar impacts.

1.2 S&T DEVELOPMENT IN THE CLEANUP PROGRAM

DOE-EM has sponsored S&T development since its creation to improve the efficacy, effectiveness, and safety of its cleanup efforts. Sponsored S&T development has included mission-directed basic scientific research, technology development and demonstration, and technology deployment into the cleanup program.

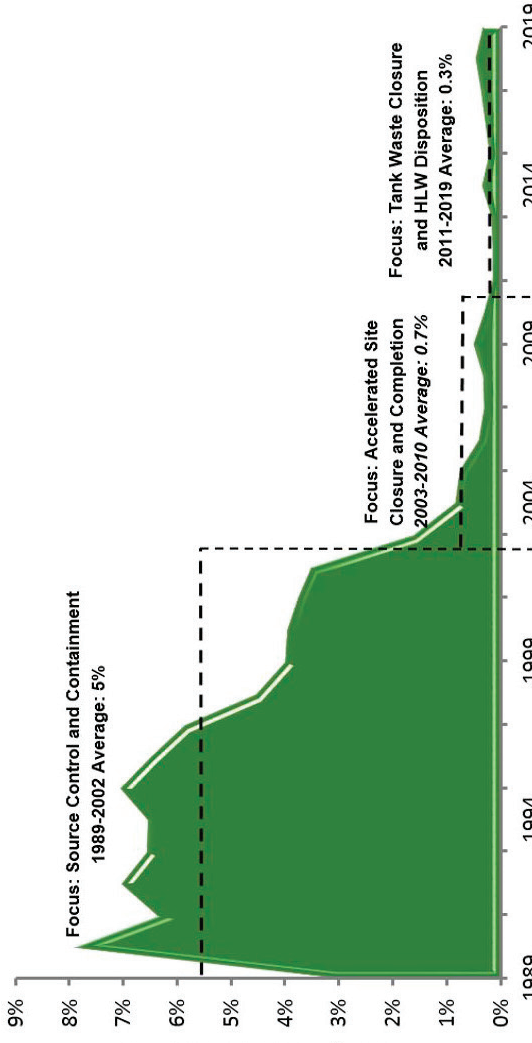
Funding for headquarters-managed S&T has varied substantially over time (see Figure 1.2). It peaked at around 5 percent (about $300 million) of the annual DOE-EM budget in the 1990s through early 2000s when the focus of the DOE-EM S&T program was on the characterization of affected soils and water and the implementation of actions to manage contamination. There were limited technologies available for cleanup of radioactive contamination at the time, so DOE-EM was driven to invest in technology development.

Funding for S&T declined steadily since then as DOE-EM's focus shifted to site closure and mission completion. Funding for headquarters-managed S&T development in FY2018 was about 0.5 percent ($35 million) of DOE-EM's annual budget. The projected funding for FY2019 is about 0.3 percent ($25 million) of DOE-EM's annual budget.

These funding variations reflect the perceived level of importance of S&T development relative to other budget priorities in the cleanup program by DOE-EM assistant secretaries. Congress also influences priorities for DOE-EM S&T and the overall viability of the S&T program through the annual appropriations process, including by increasing/decreasing funding dedicated to S&T and/or directing funding to particular organizations.

The perceived lack of importance of S&T development that started in the early 2000s is also reflected in the decline of collaborative work between DOE-EM and other DOE offices, notably DOE's Office of Science (SC). Starting in 1996, DOE-EM and DOE-SC designed and cooperatively managed the Environmental Management Science Program, a basic research program that focused exclusively on DOE-EM's difficult cleanup challenges. The program was discontinued after about 6 years. Today, DOE-SC sponsors environmental and energy research through its Office of Biological and Environmental Research and Office of Energy Research, but coordination with DOE-EM on cleanup mission–directed basic research is not obvious (see Chapter 2 for additional discussion).

The National Academies have published more than 100 advisory reports to the federal government on management and cleanup of the U.S. nuclear weapons complex. A recurring theme in many of these reports is



FY	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
EM ($B)	1.7	2.3	3.6	4.3	5.5	6.0	5.8	6.1	6.0	5.9	5.9	5.9	6.4	6.7	7.0	7.0	7.3	6.6	6.2	5.8	6.0	6.0	5.7	5.7	5.3	5.8	5.9	6.2	6.4	7.1	7.1
S&T ($M)	52	183	230	303	362	394	410	396	352	269	237	235	242	236	114	61	58	29	21	21	32	20	10	10	10	22	14	20	25	35	25
%	3.1	8.0	6.4	7.1	6.6	6.6	7.1	6.5	5.9	4.6	4.1	4.0	3.8	3.5	1.6	0.9	0.8	0.4	0.3	0.4	0.5	0.3	0.2	0.2	0.2	0.4	0.2	0.3	0.4	0.5	0.3

FIGURE 1.2 History of DOE-EM's annual budget for headquarters-managed S&T development. Funding peaked at around 5 percent (about $300 million) of the annual DOE-EM budget in the 1990s through early 2000s and has declined steadily since then. Funding for S&T development in fiscal year 2018 was about 0.5 percent (about $35 million) of DOE-EM's annual budget.
SOURCE: Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM.

the importance of S&T development for DOE-EM's cleanup mission.[7] Other advisory bodies, notably DOE's Secretary of Energy Advisory Board (SEAB), the Environmental Management Advisory Board (EMAB), and the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) omnibus committee agree (see Sidebar 1.1).

1.3 APPROACH FOR CARRYING OUT THIS STUDY

This study was carried out by the Committee on the Independent Assessment of Science and Technology for the Department of Energy's Defense Environmental Cleanup Program (referred to as the "committee" in this report), which was appointed by the president of the National Academy of Sciences. Brief biographies of the committee and staff members involved in this study are provided in Appendix C.

The committee comprises experts in disciplines relevant to the congressional request: chemistry and radiochemistry; geoscience; materials science; civil, nuclear, mechanical, and chemical engineering; and health physics. It also includes experts in disciplines relevant to technology development and evaluation, program management, and laws and regulations related to cleanup activities. This breadth of expertise allowed the committee to consider the many technical factors that affect a successful S&T development program and to provide actionable advice.

1.3.1 Committee Interpretation of Congressional Request

The committee viewed the congressional request (see Appendix A) as having both past-looking (study charge 1) and future-looking (study charge 2) elements.

Study charge 1 calls for a "review of DOE-EM's technology development efforts, including an assessment of the processes by which technologies are identified and selected for development." The committee addressed this charge by assessing the processes used by DOE-EM headquarters and sites for identifying, prioritizing, and funding S&T development to address their cleanup challenges. The committee paid particular attention to the processes used by DOE-EM for coordinating S&T development-related work within DOE headquarters, at DOE sites, and at national laboratories, as well as processes for integrating advice from these entities and others into S&T development prioritization and funding decisions. The committee's assessment related to study charge 1 is summarized in Chapter 2 of this report.

[7] Examples of National Academies reports on waste management and environmental cleanup of the U.S. nuclear weapons complex are given in Appendix B.

SIDEBAR 1.1
Excerpts from Past National Academies and Other Advisory Body Reports Illustrating the Importance of S&T for DOE-EM's Cleanup Mission

National Academies Reports

Science and technology play a key role in virtually all the activities of EM. They help to determine priorities for site cleanup by providing the basis for sound risk assessments, provide the tools for achieving remediation goals, and provide the scientific rationale that reassures stakeholders that the priorities and actions of the Department are in their best interests. (NRC, 1995, p. 150)

In some circumstances, technologies and processes for safe and efficient remediation or waste minimization do not exist. In other cases, the development of a new technology and processes might substantially reduce the costs of, or risks associated with, remediation and waste management. An effective technology development program focused on such opportunities is an essential element of an overall strategy for reducing the cost and speeding the pace of the Environmental Management Program. (NRC, 1995, pp. 6–7)

Many of EM's cleanup problems cannot be solved or even managed efficiently with current technologies, in part owing to their tremendous size and scope. … [A] basic research program focused on EM's most difficult clean-up problems may have a significant long-term impact on the clean-up mission. … Simply put, new technologies are required to deal with EM's most difficult problems, and new technologies demand new science. (NRC, 1996, pp. 1–2)

DOE's attempts to clean up contaminated groundwater and soil have been limited in part by technological difficulties. Because of such limitations, new technologies are needed to enable DOE to achieve remediation requirements for groundwater and soil at a reasonable cost. (NRC, 1999, p. 3)

[W]hile current D&D [deactivation and decommissioning] technologies probably can be made to work in the D&D of [DOE] facilities, there are opportunities to do the job more safely and effectively by developing and using new technologies. … There are strong safety and economic incentives for developing and using innovative D&D technologies that may be achieved through scientific research. The long time frame for completing D&D (50 years or more) allows for substantive research to be completed and applied. (NRC, 2001, pp. 2–3)

[C]losing the larger DOE sites will require decades. Problems that are not foreseen or appreciated today are likely to be encountered in buried waste retrievals. … Buried waste retrieval and monitoring of disposal facilities provide opportunities

continued

SIDEBAR 1.1 Continued

for the long-term, breakthrough research envisioned by Congress [when it created the Environmental Management Science Program], and these opportunities should not be overlooked in DOE's rush to meet short term needs. (NRC, 2002, p. 9)

Environmental Management Advisory Board Report

DOE should find a way to substantially increase project related R&D [research and development] funding to ensure that unanticipated technological issues can be expeditiously addressed. This will minimize project overruns and avoid external criticism associated with having a non-existent or limited R&D program which is too small for DOE-EM's large higher risk projects. (DOE-EMAB, 2014, p. 5)

Secretary of Energy Advisory Board Report

Finding ways to reduce the aggregate cost, to do the job more effectively and safely, and to speed up the work will clearly serve the American public. Technology offers that opportunity. Moreover, new technology is necessary because there are significant challenges associated with the cleanup work ahead. In fact, without the development of new technology, it is not clear that the cleanup can be completed satisfactorily or at any reasonable cost. (SEAB, 2014, p. 2)

CRESP Omnibus Risk Review Committee Report

Selection of the appropriate technologies and approaches to remediate sites is critical to achieving the CERCLA mandate to protect public health and the environment. Most contamination at sites in the DOE complex was produced over a period of decades. Thorough investigations and analyses must be conducted in order to determine the best technologies and approaches to address this contamination, based on land use assumptions, the baseline risk assessment, and other factors. (CRESP Omnibus Risk Review Committee, 2015, p. 67)

The congressional wording for study charge 2 called for a "comprehensive review and assessment of technologies or alternative approaches" applicable to DOE-EM cleanup activities. The committee interpreted the phrase "technologies and alternative approaches" to mean tools, processes, methods, and scientific knowledge that could be used by DOE-EM to clean up its contaminated sites. The committee considered technologies and approaches that are available to the cleanup program today as well as those that could potentially become available sometime in the future. The committee did not consider nontechnical alternative approaches, for example

regulatory reforms or stakeholder initiatives that could change the cleanup goals or standards.

The committee determined quickly in the review process that DOE-EM does not maintain an integrated list of past and present cleanup technologies and approaches that could be used to support the "comprehensive review and assessment" called for in study charge 2. Consequently, the committee was faced with the task of developing its own list of past and present cleanup approaches and technologies from more than 100 DOE sites—a time-consuming and expensive proposition. It was not clear to the committee whether the site-specific information needed to develop such a list is available in written form—or if available, whether the information would be released for use in this study. Cleanup work is being carried out by private companies under contract to the federal government; contractors take the lead in selecting which cleanup approaches and technologies to use. Sharing this information with the committee for use in a public report could put contractors at a competitive disadvantage.

The committee recommended to the National Academies that the wording of study charge 2 be revised to alleviate these practical concerns while still meeting the intent of the congressional study request. The revised Statement of Task (see Sidebar 1.2) was approved by the National Academies,

SIDEBAR 1.2
Statement of Task

The National Academies of Sciences, Engineering, and Medicine will conduct an independent assessment of technology development efforts within the Department of Energy's Office of Environmental Management (DOE-EM). This assessment will involve the following:

1. A review of DOE-EM's technology development efforts, including an assessment of the processes by which technologies are identified and selected for development.
2. A review and assessment of the types of technologies and/or alternative approaches for the DOE-EM cleanup program that could
   a. Reduce long-term costs,
   b. Accelerate schedules, and
   c. Mitigate uncertainties, vulnerabilities, or risks, or otherwise significantly improve the cleanup program.

The study will produce a consensus report that contains findings and recommendations. The report will not contain policy recommendations that involve nontechnical value judgments.

staff representing the congressional committee that requested the study, and DOE-EM. The revised study charge 2 focuses on "types of technologies and/or alternative approaches" that could reduce cost, time to completion, and risks associated with the cleanup and closure of the DOE-EM sites. The committee's assessment related to study charge 2 of the Statement of Task is provided in Chapter 3 of this report.

Many of the approaches and technologies that the committee is being called on to identify in study charge 2 do not exist today in readily deployable form. The committee recognized that breakthrough solutions and technologies were likely to become available to the cleanup program over its remaining 50-year-plus lifetime. The committee focused part of its efforts to address study charge 2 on assessing the underlying sources of such breakthrough solutions and technologies.

1.3.2 Committee Work Plan

The committee collected the information it needed to write its report from December 2017 to November 2018. During that period, the committee received briefings from national and international subject-matter experts and visited five major DOE-EM sites: Savannah River Site in January 2018; Hanford Site in April 2018; Idaho Site in May 2018; and Oak Ridge Reservation and the Portsmouth, Ohio, site in August 2018. Appendix D provides a list of presentations received during the committee's meetings and site visits. A brief description of the sites the committee visited, including their role during the Manhattan Project and the Cold War and current activities, can be found in Appendix E.

2

Review of DOE-EM Technology Development Efforts

This chapter addresses the first charge of the Statement of Task (see Sidebar 1.2 in Chapter 1), which calls for

> A review of DOE-EM's technology development efforts, including an assessment of the processes by which technologies are identified and selected for development.

Information to address this study charge was gathered from the following sources:

- Briefings from the Department of Energy's Office of Environmental Management (DOE-EM) headquarters staff on that office's technology development processes and programs.
- Briefings from DOE-EM site staff and cleanup contractors on technology development programs and processes at the Hanford (Washington), Idaho, Oak Ridge (Tennessee), Portsmouth (Ohio), and Savannah River (South Carolina) sites.
- Briefings from other national and international experts involved in cleanup activities and/or science and technology (S&T) development.
- Published documents that are cited in this chapter.

The chapter is organized as follows:

- Section 2.1 describes DOE-EM's S&T programs and processes for the period the committee conducted its review (December

2017–November 2018) and the committee's assessment of their effectiveness.
- Section 2.2 describes the initiatives that current DOE-EM leadership was exploring during the period of August 2018–October 2018 to improve the cleanup program.
- Section 2.3 provides the committee's findings and recommendations.

2.1 SCIENCE AND TECHNOLOGY IN DOE-EM

DOE-EM informed the committee that it spent approximately $120 million on S&T to support cleanup of the nuclear weapons complex in fiscal year (FY) 2018.[1] About $85 million of this funding was *site directed* and the remainder (~$35 million) was *headquarters managed*. Only about half of the headquarters-managed S&T (~$18.3 million) was subject to headquarters prioritization (*headquarters directed*); the remainder was allocated to support *congressionally directed* projects (~$15.4 million)[2] and a DOE mandate (~$1.3 million). See Figure 2.1 for the breakdown of DOE-EM S&T investments in FY2018.

The congressionally directed projects were the following:

- The Spent Nuclear Fuel Technologies Program at Idaho National Laboratory ($5 million). These funds were managed by DOE-EM's Office of Nuclear Materials and Idaho National Laboratory.
- The Nuclear Facilities Clean Air Technologies Program ($5 million). The funds were managed by DOE-EM's Technology Development Office, Mississippi State University's Institute for Clean Energy Technology, and DOE-EM's Office of River Protection.
- Independent review to support cost-effective, risk-informed cleanup decision making ($5 million). These funds were managed by DOE-EM's Office of Regulatory, Intergovernmental, and Stakeholder Engagement, the Consortium for Risk Evaluation with Stakeholder Participation, and Vanderbilt University.
- This National Academies study ($0.4 million). This study was requested by Congress but no funds were appropriated. Funds for this study are managed by DOE-EM's Office of Regulatory and Policy Affairs.

[1] Presentation by Rodrigo V. Rimando, Jr., Director, Technology Development Office, to the committee on October 19, 2018.

[2] Often referred to as "earmarks."

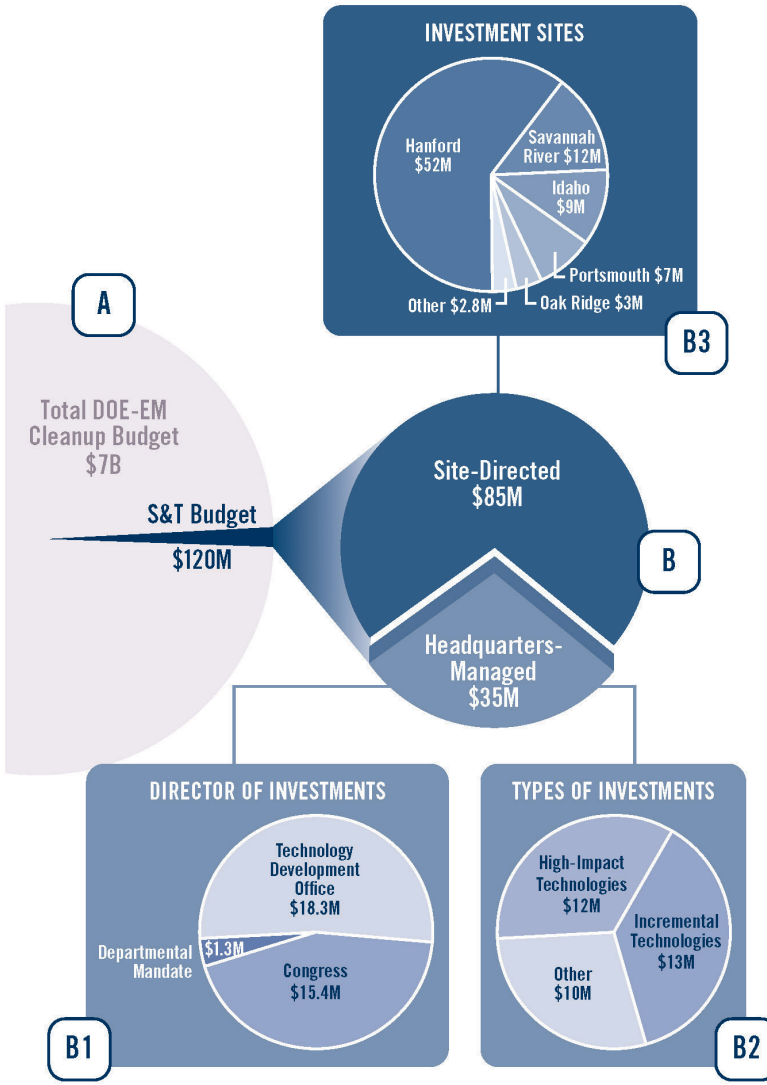


FIGURE 2.1 Breakdown of DOE-EM's S&T investments in 2018. (A) DOE-EM spent about $120 million on S&T to support cleanup of the nuclear weapons complex out of its $7 billion total cleanup budget. (B) About $85 million of this funding was *site directed* and the remainder (~$35 million) was *headquarters managed*. (B1) Of the $35 million of headquarters-managed S&T, only about half (~$18.3 million) was subject to headquarters prioritization (*headquarters directed*) and the remainder was allocated to support *congressionally directed* projects (~$15.4 million) and a departmental mandate (~$1.3 million). (B2) DOE-EM describes three types of headquarters-managed S&T (incremental technologies, high-impact technologies, and other investments) which are approximately equally funded. (B3) The majority of the site-directed S&T funds were allocated to Hanford, followed by Savannah River and Idaho.

The departmental mandate was the following:

- DOE's Small Business Innovation Research and Small Business Technology Transfer program ($1.3 million). These funds were managed by DOE's Office of Science.

DOE-EM received $25 million for headquarters-managed S&T (about 0.3 percent of DOE-EM's annual budget) in FY2019. Only $9 million of that amount is subject to DOE-EM headquarters prioritization.

2.1.1 Site-Directed S&T

Site-directed S&T focuses primarily on technology development and deployment to improve efficiencies and worker safety and achieve incremental improvements in current cleanup projects. Cleanup contractors take the lead for selecting this S&T and frequently involve national laboratories in its execution. DOE-EM provided to the committee a list of site-directed S&T activities and funding information for FY2018 (see Table 2.1). The committee observed that this S&T funding is not used exclusively for S&T development and deployment activities; some of it is also used for program or activity management or for purchasing equipment.[3]

The committee asked representatives of the DOE-EM sites that it visited to describe their processes for identifying and prioritizing cleanup challenges and funding S&T development. The site responses are summarized in Sections 2.1.1.1–2.1.1.5 below. DOE-EM does not provide detailed guidance or oversight of the decision-making processes that individual sites use to identify, select, or fund technology development.

2.1.1.1 Hanford

Technology needs for D&D activities carried out by the Richland Operations Office (RL) are identified in various regulatory documents such as the Remedial Design/Report Remedial Action Work Plan for the 300 Area (DOE-RL, 2014). Identified technology needs for RL's soil and groundwater program are intended to support the implementation of the remedies identified in the Record of Decision issued by the Tri-Party Agreement for cleanup of contaminated soil and groundwater along the Columbia River in the 100 Area of the Hanford Site (EPA, 1999). RL staff meet annually with

[3] For example, the Chief Technology Office program management of Hanford's Office of River Protection (ORP) consumed about 10 percent of ORP's S&T budget; the Portsmouth Gaseous Diffusion Plant spent nearly 90 percent of its S&T budget on purchasing equipment to improve worker safety during decontamination and demolition (D&D) and other activities.

TABLE 2.1 List of Site-Directed S&T Activities in Fiscal Year 2018

Project	Funding (million $)
Hanford, Office of River Protection	**42**
Chief Technology Office program management	4
Emergent technology • Hanford waste end effector (waste retrieval) • nonvisual tank inspection technology • online monitoring development	4
Low-activity waste pretreatment system/tank-side cesium removal support	5
Waste feed delivery qualification (low-activity waste) maturation/test platform	1.7
Immobilized low-activity waste glass testing for integrated disposal facility	7.9
Vapors management	6.2
Waste Treatment Plant glass for waste treatment	13.7
Hanford, Richland Office	9.6
Evaluate and develop alternative treatment strategies and methods for addressing deep vadose contamination, specifically focused on risk-driving contaminants Tc-99 and I-129	2.1
Define and characterize key processes and features that control contaminant migration and potential flux to groundwater in a complex subsurface deep vadose zone with comingled plumes (radionuclides, organics, metals)	2.4
Develop characterization and monitoring technologies for in situ characterization, measurement, and validation of deep vadose zone controlling processes (geochemical, microbiological, and hydrological properties) and apply them to monitor the impact of processes on contaminant movement (natural and simulated conditions); and provide the scientific and technical understanding for technology development and implementation of approaches to achieve risk-informed endpoints and meet cleanup and closure goals	5
Savannah River Site	11.9
Soil and Groundwater	
Humate injection technology to further address dilute portion of VOC plume in groundwater at A and M Areas	0.8
In situ chemical oxidation deployment to address high VOC concentrations in groundwater beyond the capture of the existing remediation systems at A and M Areas	1.2
Silver chloride injection to address I-129 contamination in groundwater at F Area	0.4

continued

TABLE 2.1 Continued

Project	Funding (million $)
Liquid Waste	
Vitrification—Alternative Reductant: Project replaces current formic acid flowsheet with glycolic acid flowsheet	4.3
Vitrification—Alternative Anti Foam Agent: Project explores alternative antifoam agents that do not decompose into flammable components	0.7
Vitrification—Frit Development: Project will develop a new frit composition to support processing of Salt Waste Processing Facility feeds	0.2
Vitrification—Implementation of Product Composition Control System Model: Project implements expanded glass composition (up to 6 percent TiO_2) models	0.05
Saltstone—Hydrogen Gas Release Potential Inadequacy in Safety Analysis: Project will establish flammability limits for organics in the saltstone disposal units	0.8
Saltstone—Thermal Properties: This project determines thermal properties of saltstone to support thermal modeling	1
Saltstone—Dynamic Leaching Method: Project is focusing on determining solubilities of Tc-99 and I-129 from the saltstone waste form	0.2
Tank Farm—Hydrogen Gas Release PISA: Project will establish flammability limits for organics in the tank farm	0.8
Tank Farm—Mercury: Project supports method development for mercury speciation and mercury analysis of tank farm samples to support long-term behavior of mercury in the Liquid Waste System	0.3
Closure—Waste Release: Project will determine solubility of radionuclides such as Pu, U, I, and Tc from waste residuals left in the waste tanks after waste removal activities are complete	0.6
Tank Farm—TCCR: Study establishes operating parameters and provides inputs to safety basis for the TCCR system	1.1
Tank Farm—SONAR: Study demonstrated the capability to determine volume of the residual waste in the waste tanks	0.4
Idaho National Laboratory[a]	**9.3**
Calcine Disposition Project: Retrieval technology	6.9
Sodium-Bearing Waste/Integrated Waste Treatment Unit • Fluidization engineering (design/testing) • Pilot plant operations • Engineering, chemistry, modeling, and optimization support for plant modifications	2.4

TABLE 2.1 Continued

Project	Funding (million $)
Portsmouth Gaseous Diffusion Plant	**6.7**
EOC Robot: Fluor-BWXT Portsmouth (FBP) purchased Quinetiq Talon Reconnaissance Robot	0.4
EarthCon Groundwater Plume Analytics and Modeling: PORTS utilized the services of EarthCon to conduct groundwater plume analytics, including a Ricker Method plume stability analysis on the five onsite trichloroethlylene groundwater plumes	0.1
Worker Safety for D&D: FBP purchased six Brokk multi-axis manipulator platforms	2.8
Worker Safety for D&D: FBP purchased two 9-wheel low-profile Omnicarts	3.1
Other Tools: GIS, modeling, waste tracking and manifesting	0.3
Oak Ridge Reservation	**2.7**
Mercury-related activities only • Simulated in-stream experiments using actual East Fork Poplar Creek water to determine the conditions that cause the methylation of mercury • Soil/sediment source zone stabilization and hydraulic isolation • Evaluation of water chemistry manipulation • Ecological manipulation and enhancement to decrease mercury bioaccumulation	

[a] Activities listed here were described by DOE-EM as "applied engineering activities" and not S&T activities.

NOTE: D&D = decontamination and demolition; EOC = Emergency Operations Center; FBP = Fluor-BWXT Portsmouth; GIS = geographic information system; I-129 = iodine-129; Pu = plutonium; Tc-99 = technetium-99; TCCR = Tank Closure Cesium Removal; U = uranium; VOC = volatile organic compound.

SOURCE: Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM, October 19, 2018.

staff from the Savannah River National Laboratory and Pacific Northwest National Laboratory to identify technical issues with the pump and treatment facilities and S&T to address those issues. The outcome of the meeting is an RL-generated statement of work for the national laboratories to carry out during the following year.

The contractor for the ORP has developed the River Protection Project Technology and Innovation Roadmap (Reid et al., 2017) to identify and prioritize immediate technology needs. Priority rankings are based on a priority letter developed with input from ORP assistant managers and technical leads. ORP also sponsors a grand challenge competition that focuses

on technology gaps requiring innovative solutions. These grand challenges are identified in a mission needs document that is also developed with input from ORP assistant managers and technical leads. The competition is open to federal employees, contractors, national laboratories, private companies, universities, and other stakeholders. Entries are judged by representatives from DOE, national laboratories, and federal contractors, and the top entries are considered for possible implementation by ORP.

2.1.1.2 Idaho

Research and development (R&D) at Idaho is managed by DOE's Office of Nuclear Energy, whereas DOE-EM is responsible for major waste retrieval and remediation activities at the site. The contractor for the Idaho Cleanup Project, which is responsible for designing and constructing the Integrated Waste Treatment Unit[4] (IWTU), has developed a "risk register" for the IWTU project. The risk register describes, among other information, the risks (technical, regulatory, financial, other) to the project, their likelihood of occurrence, and potential strategies to address them, some of which involve technology development. The contractor also established a technical review group to review technical approaches and results and provide recommendations. Members of the review group are from national laboratories, academia, and industry and have project-relevant experience.

2.1.1.3 Oak Ridge

The Oak Ridge Office of Environmental Management issued a 10-year program plan (biannual updated provided in DOE-OREM, 2017) that established cleanup and programmatic goals at the site until 2024. Cleanup of mercury contamination is the driver for all of the site's technology investments because of large historical losses of mercury to soils and surface waters at the Y-12 National Security Complex. S&T needs for mercury remediation are driven by recommendations in various strategic planning reports issued over the past few years (DOE-ORO, 2014; Pro2Serve, 2014; ORNL, 2015; DOE-EM, 2016b). The Water Resources Restoration Program, which is concerned with additional contaminants including tritium, strontium-90 (Sr-90), technetium-99 (Tc-99), uranium, and nitrates uses planning reports issued by the contractor (DOE-EM, 2013, 2017a) to identify S&T needs. Other S&T needs to reach final site closure have been identified but are not currently funded.

[4] The IWTU is used to treat and immobilize liquid sodium-bearing tank waste using steam reforming technology.

2.1.1.4 Portsmouth

There is no formal process for technology needs identification, selection, and development at Portsmouth. Instead, site personnel rely on frequent communications with other sites, including transfers of and visits by staff among sites; expertise at national laboratories and at DOE-EM headquarters; and federal and contractor staff attendance at the annual Waste Management Symposia to support technology identification and development. For example, a tetherless robot for remote measurement of uranium-235 residues in process piping (RadPiper; see Figure 3.4 in Chapter 3) emerged from meetings at a Waste Management symposium and built on existing relationships and agreements between DOE-EM and Carnegie Mellon University.

2.1.1.5 Savannah River

The soils and groundwater program at Savannah River uses the DOE-EM's 2007 Engineering and Technology Roadmap (DOE, 2007) as a starting point to identify technology needs. The liquid waste program (high-level radioactive waste disposition) uses the Liquid Waste Systems Plan (SRR, 2018), prepared by the site's liquid waste program contractor, to identify S&T needs. The Technology Optimization Blueprint (SRR, 2018) communicates potential S&T needs and maintains an Integrated Priority List. Prioritization criteria focus on reducing technical risks, costs, and schedules; improving safety; and meeting regulatory requirements. In 2018, the liquid waste program contractor initiated a call for projects to fill technical needs outlined in the Technology Optimization Blueprint (SRR, 2018).

2.1.2 Headquarters-Managed S&T

The Technology Development Office is the headquarters office responsible for S&T activities that span all stages of the technology lifecycle from basic research through technology deployment. The mission of that office (DOE-EM, 2016b) is as follows:

> The Technology Development Office provides leadership and develops mission strategies, policy, and guidance for technology development to support EM's mission. The office supports the use of state-of-the-art technology to reduce costs, accelerate schedules, and mitigate vulnerabilities; and has the overriding responsibility to support field offices by enabling the effective execution of the mission. In addition to integrating best practices across the DOE complex, the office manages EM's technology-based international, interagency, and academic interfaces to identify advancing technologies, solutions, materials and processes. The office fosters the

> transfer of commercially available technology and newly developed entrepreneurial technology to support cleanup.

As noted throughout this chapter, the office's activities address only portions of its mission as described in the statement above.

The Technology Development Office is currently (as of October 2018) staffed by four professionals and receives support from the Chief Engineer Office, which is also staffed by four professionals and provides technology assessments and advice to DOE-EM site offices. DOE-EM does not currently have a Chief Scientist to help ensure that research and scientific priorities line up with DOE-EM's mission.

The Technology Development Office does not use an independent technical advisory body to provide technical or programmatic reviews of the S&T program. DOE-EM has independent advisory bodies, most notably the Environmental Management Advisory Board and the Site-Specific Advisory Board (SSAB). However, these boards do not provide technical advice.

2.1.2.1 Types of Technologies Managed

A list of headquarters-directed S&T projects is presented in Table 2.2. These projects focused on domestic and a few international activities involving other government agencies, national laboratories, universities, and industry. A major theme of the headquarters-directed S&T is robotics and remote systems. A number of headquarters-directed S&T projects were not funded in FY2018 because of congressional direction of funding and budget appropriation delays.[5]

The DOE-EM report *Innovation and Technology: Charting the Path for Fiscal Years 2017–2021* (DOE-EM, 2016a) describes three types of headquarters-managed S&T. These are summarized in the following sections.

High-Impact Technologies

The Technology Development Office invested about $12 million in FY2018 on high-impact technologies to support S&T headquarters-directed and congressionally directed S&T. These investments aim to address knowledge and technology gaps that prevent DOE-EM from executing and completing its cleanup mission. High-impact technology development efforts are focused on the following five priorities:

[5] Presentation by Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM, to the committee on October 19, 2018.

TABLE 2.2 List of Headquarters-Directed S&T in Fiscal Year 2018

Recipient	Technical Scope	Period of Performance	Actual Funding in 2018 (million $)
Consortium for Risk Evaluation with Stakeholder Participation (CRESP)	To advance cost-effective, risk-informed cleanup and management of the nation's nuclear weapons production facility waste sites through improving the scientific and technical basis for environmental decisions made by DOE and by fostering public and public agency participation.	09/30/2006–02/28/2023	5
National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center, Houston, Texas	To collaborate on joint research, development, and deployment initiatives in robotics and related technology fields.	08/01/2016–08/01/2021	0.075
NuVision Engineering, Inc.	To support technology transfer and demonstration with a particular focus on mission mutual cooperation and collaboration with the United Kingdom to address the nuclear weapons development legacy.	04/01/2011–03/31/2019	None provided
Florida International University's (FIU's) Continued Research Support for the Department of Energy's Office of Environmental Management	To develop technical solutions for the environmental challenges faced across the DOE complex at sites such as Hanford, Oak Ridge, Savannah River, Idaho, and the Waste Isolation Pilot Plant. FIU executes research in environmental remediation; radioactive waste processing; facility deactivation and decommissioning (D&D); knowledge management and other information technology applications/tools for environmental management; and training and mentoring the next generation of scientists and engineers who will continue addressing DOE-EM environmental restoration technical challenges.	08/28/2015–08/29/2020	4

continued

TABLE 2.2 Continued

Recipient	Technical Scope	Period of Performance	Actual Funding in 2018 (million $)
Mississippi State University–Institute for Clean Energy Technology	Support for the safety and quality of permanent containment and confinement ventilation systems as well as modular worksite and breathing zone ventilation systems used to support nuclear, radiological, chemical, and other high-consequence facility and environmental operations.	01/20/2015–01/19/2020	5
Carnegie Mellon University	To provide specialized training for graduate students in robotics to support environmental remediation of nuclear sites.	06/01/2016–05/31/2021	None provided
Rutgers, The State University of New Jersey	To improve understanding of fundamental science governing the development and performance of nuclear waste glasses.	1/20/15–1/19/2020	0.3
Carnegie Mellon University	To develop, demonstrate and infuse a leap of sensing, robotics, spatial positioning, and visualization capability into underwater nuclear operations relevant to DOE-EM.	10/01/2016–09/30/2019	None provided
Washington State University Pullman, Washington, and Colorado School of Mines	To provide specialized training for graduate students in radiochemistry to support environmental remediation of nuclear sites.	10/01/2016–09/30/2021	None provided
The University of Texas at Austin	To develop mobile manipulation and survey system for H canyon and other applications across the DOE complex.	10/01/2016–09/30/2019	0.65
University of Massachusetts Lowell	To advance the field of humanoid robots applied to the DOE-EM mission of safe and environmental cleanup of nuclear facilities, while simultaneously making novel contributions to robotics and user-interface technologies.	09/28/2016–09/27/2019	0.5

Carnegie Mellon University (Pittsburg) in collaboration with Board of Regents, Nevada System of Higher Education, University of Nevada, Reno	To provide a methodology to explore and map radiation fields at nuclear sites by deploying an innovative and tightly integrated sensing, modeling, and planning on mobile platforms.	09/28/2016–09/27/2019	0.44
National Science Foundation	To collaborate on joint research, development, and deployment initiatives in both robotics and related technology fields.	05/24/2016–05/17/2022	0.075
Texas A&M University	To develop the technical basis for a marsupial configuration where an unmanned aerial vehicle can be deployed from a ground robotic vehicle.	09/22/2016–09/20/2019	0.15
Texas A&M–Galveston	To address two specific needs related to the accelerated decommissioning of the Fukushima Daiichi Nuclear Power Plant: (1) remove radioiodine from the Advanced Liquid Processing System (ALPS) wastewater, and (2) develop a stabilization technology for the secondary waste containing I-129 generated from the ALPS facility.	10/01/2016–09/30/2020	0.075
Massachusetts Institute of Technology	To provide an exoskeleton prototype for working in physically demanding crouching or kneeling positions.	09/22/2016–09/20/2019	0.15
Argonne National Laboratory Oak Ridge National Laboratory Korea Atomic Energy Research Institute	To develop systems enhancements to facilitate a new teleoperation concept of augmented teleautonomy for remote operation of tools for D&D tasks.	10/1/2016–9/30/2017	0.15
Savannah River National Laboratory Japan Ministry, Economy and Trade	To support information exchanges and facility visits for the U.S. National Laboratory Fukushima Support Network.	10/1/2016–9/30/2017	None provided

continued

TABLE 2.2 Continued

Recipient	Technical Scope	Period of Performance	Actual Funding in 2018 (million $)
Department of Homeland Security Domestic Nuclear Detection Office	To collaborate on joint research, development, and deployment initiatives in both robotics and related technology fields.	02/23/2017–01/31/2023	None provided
Department of Defense Naval Sea Systems Command	To collaborate on joint research, development, and deployment initiatives in both robotics and related technology fields.	01/30/2017–01/31/2023	0.075
Department of Defense U.S. Army Corps of Engineers	To collaborate on joint research, development, and deployment initiatives in sensor technologies and related technology fields.	10/01/2016–10/30/2022	0.025
Department of Defense, Army Research Laboratory	To collaborate on joint research, development, and deployment initiatives in both robotics and related technology fields.	9/1/2018–8/31/2020	0.025
National Renewable Energy Laboratory	To support department-wide energy I-Corps technology transfer program.	10/1/2016–9/30/2018	0.075

NOTE: This table does not include S&T activities performed by DOE's national laboratories, such as those related to the mercury and technetium-99 challenges, next-generation solvents, glass waste forms, and deep vadose work.
SOURCE: Rodrigo V. Rimando, Jr., Director, Technology Development Office, November 20, 2018.

1. *Technetium-99*: Tc-99 contamination has been identified as a problem at several sites, particularly Hanford, Savannah River, Portsmouth, and Paducah (Kentucky). S&T is focused on better characterizing Tc-99 in facilities, waste streams, and groundwater and soil; identifying treatment options for immobilization, including ion exchange or manipulation of oxidation states; and improving understanding of the mobility of technetium once it is treated or remediated (DOE-EM, 2018d).
2. *Mercury*: Mercury is a challenge for facility D&D and environmental remediation at Oak Ridge and Savannah River. S&T at Oak Ridge is focused on instrumentation for mercury detection in water, soil, sediment, and debris; mercury isotope analysis; remote sensing and quantification of mercury in infrastructure such as equipment and building walls and floors; and Y-12 remediation including in situ soil stabilization and grout formulation for macroencapsulation. S&T at Savannah River is focused on improving understanding of mercury chemistry and speciation in the liquid waste system; treatments that convert organomercury to inorganic mercury to reduce mercury leachability in saltstone, and inorganic mercury to elemental mercury to improve mercury removal in the 2H/3H evaporator (DOE-EM, 2016c).
3. *Cesium-137 and strontium-90*: Cesium-137 (Cs-137) and Sr-90 are present in tank waste and the environment at Hanford, Idaho, and Savannah River. S&T is focused on advancing the processing and handling of wastes containing these isotopes.
4. *Test beds*: Test beds are physical or virtual-reality platforms that can be used to demonstrate cleanup tools, processes, and approaches. Physical test beds allow S&T testing in nuclear and industrial facilities and in radioactive and chemically hazardous environments (DOE-EM, 2018b).
5. *Enhanced worker safety*: S&T is focused on technological advancements in robotics and remote systems to reduce worker injury rates and radiation exposures and to remove workers from hazardous areas.

The Technology Development Office director told the committee that these five priorities were selected by former DOE-EM Assistant Secretary Dr. Monica C. Regalbuto with input from DOE-EM site offices and contractors, coordinated with technical input from the national laboratories.[6] The committee was not provided with any convincing and/or documented

[6] Presentations from Rodrigo V. Rimando, Jr., Director, DOE-EM Technology Development Office, to the committee on December 5, 2017, and October 19, 2018.

evidence showing that these priorities are in fact the five highest technology development needs across the DOE-EM complex.

Incremental Technologies

The Technology Development Office invested about $13 million in FY2018 on incremental technologies to support headquarters-directed and congressionally directed S&T. These investments aim to improve existing cleanup capabilities and processes. Incremental technology development efforts are focused on the following three priorities:

1. *Enhancing waste processing and disposition*, for example, improving radionuclide separations processes, optimizing waste forms, and identifying waste-stream disposition pathways.
2. *Environmental operations* to improve the understanding of subsurface contaminant distributions and the physical, chemical, and biological processes that influence contaminant behavior; and to improve long-term monitoring of remediation systems.
3. *State-of-the-art tooling* to better characterize, stabilize, and remove contamination from high-hazard facilities.

It was not clear to the committee how these priorities were identified.

Basic Scientific Research

The Technology Development Office's investments in basic scientific research were not separately estimated because they are often included in high-impact and incremental technology investments. Investments in scientific research aim to provide knowledge and capabilities that bear on DOE-EM challenges. DOE-EM stated that this research is conducted in cooperation with DOE's Office of Science's Energy Frontier Research Centers, Office of Basic Energy Sciences. However, the committee received a briefing from the senior technical advisor for the Energy Frontier Research Centers and did not find sufficient evidence of any coordination between the two offices on DOE-EM mission-directed basic research.

Other Investments

The Technology Development Office also spent about $10 million in *program execution* to support S&T subject to headquarters prioritization and congressionally directed S&T. This category of investments includes national laboratory support and technical services as well as collaborations with other government agencies. The Technology Development

Office also funded S&T development to support specific cleanup projects at DOE-EM sites. For example, the office supported the development of the Tank Closure Cesium Removal (TCCR) system for removal of cesium from liquid waste at the Savannah River Site;[7] the RadPiper robotic system mentioned previously; and the Test Bed Initiative to provide a scale-up demonstration of options for retrieval and treatment of the low-activity portion of tank waste at the Hanford Site.

2.1.2.2 Processes for Selecting Headquarters-Directed S&T

As noted earlier, the Technology Development Office obtains input on S&T needs from DOE-EM sites and national laboratories, particularly the Savannah River National Laboratory, which is DOE-EM's lead national laboratory. DOE-EM also follows the process outlined in an internal Standing Operating Policies and Procedures document[8] for soliciting, evaluating, rating, and selecting projects related to international cooperation and collaboration. However, there is not a similar process or document for any other headquarters-directed S&T activities.

The committee found evidence that DOE-EM lacks integration mechanisms for its various S&T activities across the complex. For example, DOE-EM does not maintain inventories of

1. DOE complex-wide technical challenges and near-, mid-, and long-term S&T needs;
2. S&T available within and outside of DOE to address these challenges and needs; or
3. S&T developed and deployed across the complex to address these challenges and needs.

2.1.3 Coordination and Communication of S&T

The committee was informed about the existence of several formal channels between sites and headquarters that DOE-EM could use for communicating and coordinating S&T needs and for sharing of lessons learned. For example:

- There are liaisons between DOE-EM field offices for each site and DOE-EM headquarters; these liaisons can advocate for site technology challenges and needs.

[7] Operations for TCCR began in January 2019.

[8] Information provided by Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM on January 3, 2019.

- The Energy Facility Contractors Group (EFCOG) can facilitate the sharing of ideas and practices among site contractors and promote collaboration and exchange of lessons learned and best practices in cleanup activities including S&T. The group can also identify S&T needs across the complex and issue relevant reports (see, e.g., EFCOG, 2018).
- The Office of Environmental Management National Laboratory Network is tasked, among other things, with matching DOE-EM site needs with the best available and most relevant expertise in DOE's national laboratories and advising DOE-EM headquarters and the sites on new technologies. This network is led by the director of the Savannah River National Laboratory (DOE-EM's lead national laboratory).
- The Chief Engineer Office can provide technology assessments and advice to site offices.

The committee observed that these formal channels are not being used effectively to communicate and coordinate S&T needs across the complex or for sharing of lessons learned. For example, the committee was told that the National Laboratory Network primarily meets via phone conferences about once per month. In the committee's experience, this frequency and mode of communication is not sufficient for identifying and coordinating challenging technical tasks. The committee was also told that the Chief Engineer has developed a list of technologies utilized at DOE-EM cleanup sites; however, when the committee asked to see this list, it was informed that the list is not current and has not been updated for more than 1 year.

The committee was also told that, during the 30-year existence of DOE-EM's cleanup program, the cleanup workforce has developed additional ways to communicate and exchange information that are not formally documented. They were also informed that meetings such as the Waste Management Symposia, the RadWaste Summit, and other topical workshops allow for the cleanup workforce to interact and exchange information.

2.2 DOE-EM LEADERSHIP VIEWS ON S&T

In October 2018, the committee received a briefing from DOE-EM's *new* and then mostly acting[9] leadership on its views on the role of S&T

[9] At the time of the briefing (October 2018), two of the top three positions in DOE-EM's leadership were filled by temporary apppoinments. Assistant Secretary for DOE-EM Anne Marie White was sworn into office in March 2018; Mark A. Gilbertson was named Acting Principal Deputy Assistant Secretary in August 2018 and became Principal Deputy Assistant Secretary in December 2018; Kenneth G. Picha was named Acting Associate Principal Deputy Assistant Secretary for Field Operations in May 2018. He was replaced by Jeff C. Griffin in November 2018.

in the cleanup program. Mr. Mark A. Gilbertson and Mr. Kenneth G. Picha briefed the committee on behalf of Assistant Secretary Anne Marie White. They noted that the DOE-EM leadership has a mission-completion philosophy, which focuses on reducing DOE-EM's environmental liability. Mr. Gilbertson also noted that the cleanup industry is mature and has the tools that DOE-EM needs to complete its mission. Therefore, the current DOE-EM leadership is focused on S&T *deployment* instead of S&T *development*.

At the time of this writing, DOE-EM was developing an EM-wide strategic plan supported by a set of site-specific, 10-year alternative analyses focused on cleanup completion and site closure. DOE-EM was also exploring contracting and regulatory reform initiatives to improve the cleanup program (DOE-EM, 2018a). These initiatives include the following:

1. Revising the DOE-EM procurement model to provide incentives to contractors to reduce cleanup costs and timelines.
2. Reforming regulations related to
   - Interpretation of the definition of high-level radioactive waste[10] to provide additional disposal pathways for DOE-EM's tank wastes.
   - Nuclear safety management (10 CFR Part 830; DOE-EHSS, 2018) to improve operational efficiencies while maintaining robust safety performance by revising the process for facility hazard categorization and approval of safety documentation.

According to DOE-EM, the above-listed innovations could drive down cleanup timelines at some sites to 10 years. The committee was not tasked by Congress with assessing the effectiveness of these initiatives or the DOE-EM strategic plan and therefore has not evaluated this DOE-EM assertion.

The committee recognizes that there are nontechnical impediments that add to the high costs and long lifecycles of the cleanup program by preventing

1. A truly risk-informed approach to the cleanup program, for example, by revising definitions of waste to represent actual hazard, rather than defining it by origin, or by defining levels of risk below which human health risks are indistinguishable from background risks; and

[10] DOE-EM is requesting public comment (DOE-EM, 2018c) on its interpretation of the definition of the statutory term "high-level radioactive waste" as set forth in the Atomic Energy Act of 1954 and the Nuclear Waste Policy Act of 1982. DOE interprets the statutory term to allow some reprocessing wastes to be classified as non-high-level radioactive waste and disposed of in accordance with their radiological characteristics.

2. Identifying and developing alternative disposition pathways for high-level radioactive wastes.

The committee judges that the aggressive pursuit of S&T is essential for reducing cleanup lifecycle costs and timelines. There are technical challenges in the cleanup program that can be addressed only through technology innovation in a broad spectrum of scientific areas (see Chapter 3). The committee therefore judges that S&T must be an integral component of DOE-EM's strategic plan and its supporting initiatives.

2.3 FINDINGS AND RECOMMENDATIONS

Finding 1: DOE-EM projects that it will spend at least another 50 years and $377 billion to complete its cleanup of the nuclear weapons complex. These time and cost estimates are highly uncertain—and probably low—because of (1) substantial remaining uncertainties in the cleanup program's lifecycle costs, schedules, and risks; and (2) the possible future inclusion of additional DOE sites and facilities into the DOE-EM cleanup program.

Recommendation A: DOE-EM should obtain an independent assessment of the cleanup program's lifecycle costs and schedules from a government engineering organization—for example, the U.S. Army Corps of Engineers—that is specifically focused on identifying key remaining technical risks and uncertainties. DOE-EM should use this assessment to reevaluate the major cleanup challenges it faces, including the timeline and costs associated with addressing them with current S&T investments, and make any necessary adjustments to its S&T development program.

DOE-EM has successfully cleaned up 91 sites during its 30-year existence. However, much cleanup scope remains at the largest and most complex DOE sites that contain vast quantities of liquid and solid wastes stored in tanks or disposed underground, large volumes of contaminated soil and groundwater, and massive facilities to be decontaminated and demolished or stabilized.

During the course of this study, the committee received different estimates for DOE-EM's environmental liability ranging from as low as $232 billion (based on DOE-EM's IPABS estimate) to $377 billion (based on DOE's FY2018 financial statements) and at least an additional

50 years.[11] The committee asked DOE-EM for an explanation on the discrepancy between the different estimates. A DOE-EM staff member[12] noted that there are three categories of costs included in the environmental liability estimate prepared by DOE that are not included in the IPABS estimate. These are the following:

1. Not yet approved baseline change requests for cleanup activities,
2. Placeholder adjustments for activities that are deemed "more likely than not" to occur, and
3. Additional contingencies for funding assumptions.

In addition, DOE-EM's IPABS estimate is reported in escalated dollars[13] whereas the environmental liability based on DOE's financial statements is reported in constant (unescalated) dollars.[14] This makes the actual difference between the two estimates even larger and harder to compare.

Irrespective of the current liability estimate, the fact remains that because of significant technical challenges in the cleanup program, the total environmental liability has grown (GAO, 2017a) and will likely continue to grow in the future. A recent report by GAO identified this National Academies study as an opportunity for DOE-EM to better understand and manage its environmental liability (GAO, 2019).

DOE-EM's environmental liability estimates reflect current DOE cleanup baselines and do not account for additional cleanup scope likely to be assigned to DOE-EM in the future.[15] The current liability estimates are unreliable for additional reasons. For example, many cleanup projects remain in a planning stage, and DOE-EM does not yet have an understanding of their technical challenges. Furthermore, DOE-EM relies on a disposal path for high-level radioactive waste that does not currently exist.[16] There-

[11] As noted in Section 1.1 of Chapter 1, the recent update on Hanford's lifecycle cost and time estimates (DOE-RL, 2019) suggests that DOE's current $377 billion/50-year-plus estimate for complex-wide cleanup costs and timelines could be low by hundreds of billions of dollars and several decades.

[12] Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM.

[13] Estimates that use escalated dollars account for cost of money over time. Estimates that use unescalated (also referred to as current or constant dollars) allow comparability without the effect of future inflation.

[14] Written communication between Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM, and Ourania Kosti, the National Academies, on January 30, 2019.

[15] For example, DOE-EM's environmental liability could extend to 2095 at Idaho, 2137 at Hanford, and 2165 at Savannah River (Presentation by Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM, to the committee on December 5, 2017).

[16] Following the termination of the Yucca Mountain repository program, DOE proposed separate repositories for defense high-level and commercial waste. GAO reported that DOE's new approach excluded the costs and time frames for key activities. See GAO (2017b).

fore, the committee judges that DOE-EM underestimates the true lifecycle costs of the cleanup program, which are likely to continue to increase by billions of dollars in the future.

Although the committee appreciates the challenge of quantifying the lifecycle costs of the cleanup program because of the program's complexity, the first-of-a-kind projects involved, and untested technologies deployed, it strongly judges that a reliable, independent, and transparent assessment of the cleanup program's lifecycle costs and schedules is needed to inform Congress, stakeholders, and taxpayers and to identify the cleanup challenges that can be addressed with a robust S&T development program. The committee also judges that the U.S. Army Corps of Engineers (USACE) qualifies to perform this assessment (see Sidebar 2.1), which should include a technical risk and uncertainty analysis for DOE-EM's cleanup program. An assessment performed by USACE would reveal technology needs to address the identified risks and uncertainties. DOE-EM should use the findings of the independent assessment to set strategic priorities, refocus some of the program's S&T investments, and make any other necessary adjustments to its S&T development program. Best practices benchmarking for S&T development programs of similar complexity in international nuclear waste cleanup programs or other industries can help DOE-EM make decisions and set performance targets.

SIDEBAR 2.1
U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) is a federal agency under the Department of Defense and the largest facilities and infrastructure engineering organization in the federal government. Programs managed by USACE include civil works, military missions, environmental missions, emergency operations, and research and development. USACE has a significant engineering role in supporting federal agencies and a 30-year history of supporting the DOE-EM cleanup program.

When DOE-EM was created in 1989, USACE developed a lifecycle cost for the entire nuclear cleanup program. In 2007, USACE provided an assessment and recommendations to DOE-EM on how to improve its contract and project management capabilities, including cost estimation and schedule management. This assessment was part of DOE-EM's "Best-in-Class Initiative" and involved 16 DOE-EM sites (DOE, 2008). Inherent to cost estimation and schedule management was a review of the ongoing engineering and site remediation and construction work as well as the development of a risk register. As a result of this assessment, DOE-EM partnered with USACE to provide budget, construction management, engineering, and technical services to supplement DOE-EM personnel resources (DOE-EM, 2010).

Finding 2: Most DOE-EM-related S&T activities are site based, contractor driven and managed, and have a *short-term* focus on addressing technical challenges in existing cleanup projects. DOE-EM headquarters has a limited role in selecting, managing, and coordinating this site-based S&T to ensure that it meets the cleanup program's needs, particularly over the long term and across different sites.

Finding 3: DOE-EM's management of S&T is ad hoc and uncoordinated and thus less effective than it should be. DOE-EM lacks formal, documented processes for (1) managing the technology lifecycle—from basic research through technology deployment—and (2) sharing lessons learned, including failures, successes, and good practices, from its technology development and deployment efforts both within and outside of DOE-EM.

Recommendation B: DOE-EM should design and implement an *S&T management process* for identifying, prioritizing, selecting, developing, and deploying the new knowledge and technologies needed to address its cleanup challenges, including the technical risks and uncertainties identified from the assessment in Recommendation A. Independent peer review should be used to evaluate (1) the S&T management process before it is implemented, (2) S&T projects before they are funded, and (3) the overall effectiveness and impact of DOE-EM's S&T efforts.

DOE-EM relies on site contractors to identify S&T needs and make S&T investments focused on near-term cleanup needs, and it lacks the means to judge whether these site-directed investments are prioritized appropriately[17] and/or are a good return on dollars spent. This site-based approach, which gives site contractors (and the associated site offices) autonomy in selecting technologies to invest in and deploy, consistent with various compliance agreements (federal, state, or other), can work well for achieving short- and mid-term project-specific cleanup goals because site contractors are familiar with the cleanup project and are incentivized to

[17] For example, the committee is not aware of any S&T investments made by the Richland Operations Office or its contractor toward safer demolition of the Plutonium Finishing Plant despite the reported incidents of radioactive contamination of workers (see Sidebar 3.3 in Chapter 3 for more information) or toward stabilization of the PUREX tunnel that partially collapsed in May 2017.

optimize their fee-earning potential. However, this approach does not work well for tackling the longer-term, complex-wide cleanup challenges that DOE-EM faces (see Chapter 3). In addition, the committee saw evidence that if a site is on track to meet a remedial goal by using a baseline technology, it has little to no interest to explore alternative technologies that could drive down costs and completion schedules.[18]

It is the committee's expert opinion that integrated and headquarters-coordinated S&T management focused on identifying and reducing complex-wide liabilities is better suited to tackling DOE-EM's longer-term and complex-wide cleanup challenges and ensuring that S&T investments are sufficient and appropriate.

DOE-EM should develop and implement a formal S&T management process in place of its current piecemeal approach if it is to successfully complete its cleanup mission in a timely and cost-effective manner. The committee recommends that DOE-EM develop and implement an S&T management process having the following elements:

1. A priority-ranked inventory of cleanup challenges that can be addressed using existing and new S&T. The cleanup challenges considered should cover DOE-EM's current and future cleanup scope. The inventory can be rolled up from existing site inventories of cleanup challenges, supplemented by DOE-EM, the National Academies, GAO, and national laboratory reports on DOE-EM cleanup needs and challenges, as well as the results of the assessment from Recommendation A in this report.[19]
2. Strategies for *identifying* breakthrough S&T developed outside of the DOE-EM cleanup program. This will require DOE-EM to reach out more broadly to the domestic and international scientific and engineering communities and to encourage appropriate collaborations among DOE-Office of Science, university/college, industry, and national laboratory researchers. As noted later in this chapter, the committee recommends that the actual *development* of

[18] For example, the groundwater remediation goal at Test Area North at the Idaho Site is to meet drinking water standards by 2095. Site representatives informed the committee that the site is on track to meet the remedial goal by using in situ bioremediation at the source of the contaminated groundwater plume; pump and treat in the medial zone of the plume; and natural attenuation in the distal zone of the plume. Therefore, the site is not exploring any alternative technological approaches. Yet, the annual cost estimate for soil and groundwater remediation at the site was $45 million in FY2018 (DOE, 2017). Investments in new and/or alternative technologies today could save tens or even hundreds of millions of dollars over the lifecycle of this cleanup project.

[19] This priority-ranked inventory together with the recommended independent assessment of the environmental liability (Recommendation A in this report) will likely force DOE-EM to reevaluate the challenges it currently considers as its major challenges (see Section 2.1.2.1).

breakthrough S&T relevant to DOE-EM's mission be carried out outside of DOE-EM (see Recommendation C and supporting text).

3. Strategies for efficiently using national laboratory expertise, especially those laboratories that are colocated with large DOE-EM cleanup sites and have extensive technical knowledge about those sites.
4. Strategies for effectively engaging with DOE's Office of Science and with universities and colleges on S&T development.
5. Peer-review processes for evaluating the S&T management process, projects, and impacts. See additional discussion below.
6. Processes for documenting and sharing S&T outcomes and lessons learned, including problems, successes, and best practices from S&T development and deployment efforts, with DOE-EM and contractor staff at headquarters and sites, regulators, other interested stakeholders, DOE leadership, and Congress.
7. Strategies for encouraging S&T development by site contractors. This could be achieved for example by issuing performance-based cleanup contracts, which define contractor performance expectations in terms of milestones rather than technologies employed; incentivizing site contractors to deploy promising technologies, including the deployment of competing technologies to assess their relative effectiveness; and allowing cleanup contractors to spend a portion of their funding on S&T, similar to the DOE-National Nuclear Security Administration's Plant-Directed Research and Development and the Department of Defense's Independent R&D effort.
8. Strategies for using the S&T program to promote the development of future-generation technical workforces to serve the cleanup program.

As DOE-EM develops the S&T management process, it will also benefit from reviewing and adopting good practices from international cleanup programs. The committee saw evidence of an integrated management approach by the United Kingdom's Nuclear Decommissioning Authority (NDA). NDA has developed and implemented a defensible strategic approach to support, using science and technology, the challenges of its cleanup program. NDA performs an annual review[20] to determine whether its mission is supported by sufficient and appropriate S&T and makes appropriate adjustments.[21]

[20] This review is performed using Technical Baseline and Underpinning Research and Development documents.

[21] Although smaller in scale, the United Kingdom's Nuclear Decommissioning program total investments on S&T are around 3 percent annually across the whole program, with the NDA center investments (equivalent of DOE-EM headquarters) at about 0.3 percent. Briefing from Melanie Brownridge and James McKinney, Nuclear Decommissioning Authority, United Kingdom, October 15, 2018.

DOE-EM needs to develop a robust technical capability within headquarters before it implements the committee-recommended S&T management process so that it can become an effective and authoritative manager of its S&T program. Moreover, DOE-EM needs to effectively disseminate information about the S&T program and its contributions toward site cleanup and closure with federal and site staff, regulators, other stakeholders, and Congress. Effective communications can help raise the profile of the S&T program with stakeholders, DOE-EM's leadership, and Congress and help ensure sustainable funding and support.

Once the S&T management process is implemented, day-to-day activities could be carried out (under appropriate headquarters oversight) by a national laboratory or national laboratory consortium having the appropriate technical expertise. National laboratories would likely provide more programmatic continuity, flexibility, and technical expertise because there is generally less turnover at national laboratories, and laboratories can borrow and/or hire staff relatively quickly to obtain needed expertise and skillsets.

Peer review needs to be infused throughout the S&T management process, including

- A one-time, up-front review of the S&T management process so that it can be vetted and improved before it is implemented. The review group should have expertise in the development, implementation, and management of S&T programs.
- Reviews of individual S&T projects for scientific merit and relevance to DOE-EM's cleanup challenges, which can be used to prioritize and select projects for funding. The review group should have relevant technical expertise and knowledge of DOE's cleanup challenges and S&T needs.
- Periodic reviews of S&T outcomes and impacts, which can be used by DOE-EM management to improve the S&T effort. The review group should have expertise in S&T program management and scientific communication.

These reviews could be carried out by a standing committee of national and international subject-matter experts, specifically established by DOE-EM to provide advice to the S&T program, similar to DOE's Office of Science Biological and Environmental Research Advisory Committee and Basic Energy Sciences Advisory Committee. These aforementioned committees include representatives of universities, national laboratories, and industries with subject-matter expertise and operate in accordance to the Federal Advisory Committee Act (P.L. 92-463).

Finding 4: DOE-EM has substantially reduced investments in S&T development over the past 15 years and has focused instead on technology deployment in current cleanup projects. In particular, DOE-EM has demonstrated little to no interest in investing in S&T development that might lead to breakthrough solutions and technologies that can substantially reduce cleanup lifecycle costs, schedules, risks, and uncertainties.

Recommendation C: A portion of the technology development effort for the DOE-EM cleanup program should focus on breakthrough technologies and solutions that can substantially reduce cleanup lifecycle costs, schedules, risks, and uncertainties. Such a program would require substantial new funding *separate* from the DOE-EM budget and a different model for managing research and stimulating innovation. This technology development effort should be

- Managed by the Advanced Research Projects Agency–Energy (ARPA-E), a division within DOE with a record of investing in innovative solutions for complex technical challenges.
- Informed by the independent assessment of the cleanup program's key remaining risks and uncertainties called for in Recommendation A and the S&T management process for identifying, prioritizing, selecting, developing, and deploying the new knowledge and technologies called for in Recommendation B.
- Be independently peer reviewed to evaluate its impact on the cleanup program.

DOE-EM should work cooperatively with ARPA-E to identify and implement these breakthrough technologies and solutions into the cleanup program.

The DOE-EM cleanup program is benefiting today from S&T investments made in the past. For example, much of the work on glass formulations for long-term storage of high-level nuclear waste dates back to the 1980s (Lutze and Ewing, 1988). Similarly, DOE-EM needs to invest in S&T today to address future cleanup challenges. However, S&T has not been a high priority for DOE-EM since at least the early 2000s. Indeed, the headquarters-directed S&T budget has been a miniscule (0.3–0.5 percent)

portion of the annual DOE-EM budget for at least the past decade (see Figure 1.2 in Chapter 1). Even DOE-EM has recognized that "this level of funding for technology is not commensurate with the technical uncertainties and risks associated with the work EM has to accomplish in the next several decades" (DOE-EM, 2016a).

This committee was not tasked with recommending how much DOE-EM should spend on S&T each year and did not perform an industry-wide analysis to benchmark S&T investments. However, it agrees with the Secretary of Energy Advisory Board (SEAB, 2014) task force's assessment that "successful completion of the cleanup of the sites likely will require significant new technology" and that "advances in science and technology can provide the means for completing the EM mission more swiftly, more inexpensively, more safely, and more effectively" (SEAB, 2014, p. 3). The SEAB report recommended that DOE-EM increase headquarters-directed investments in S&T to about 3 percent of the annual DOE-EM budget.

The committee judges that an important spinoff benefit of S&T investments is rejuvenation of DOE-EM's S&T and associated workforce. The committee observed during its visits to DOE-EM sites that the S&T workforce is aging. It received the same message from DOE site personnel. DOE-EM will require at least two future generations of technical workers during the planned 50-year duration of its cleanup program. Continuous commitment to support S&T is one way to build this future workforce.

It was clear to the committee from the briefings it received that DOE-EM's leadership's priority is deployment of current technologies, not S&T development (see Section 2.2 in this chapter). Consequently, the committee determined that DOE-EM was not the appropriate organization to manage an S&T program focused on developing breakthrough S&T solutions to DOE-EM's most difficult cleanup challenges. The committee instead determined that ARPA-E is better qualified to manage such a program in coordination with DOE-EM. Such a program would require substantial new funding from Congress, *separate* from the DOE-EM budget.

ARPA-E is the DOE entity tasked with promoting and funding research and development of advanced energy technologies (see Sidebar 2.2). It was conceptualized following the National Academies report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (NAS et al., 2007). ARPA-E has a record of bringing together experts from different technical disciplines and professional communities to think about technical challenges in new and innovative ways. The committee judges that ARPA-E could do the same for the DOE-EM cleanup program.

A recent congressional bill (H.R.5906; ARPA-E Act of 2018) aimed to expand the goals of ARPA-E to include the development of non-energy research and to provide transformative solutions to improve the management,

SIDEBAR 2.2
Accelerating Innovation via the Advanced Research Projects Agency–Energy (ARPA-E)

In 2005, Congress asked the National Academies to "identify the most urgent challenges the U.S. faces in maintaining leadership in key areas of science and technology." The resulting National Academies report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (NAS et al., 2007), warned policy makers that U.S. advantages in science and technology—which made the country a world leader for decades—were eroding at a time when many other nations were gathering strength, and called for government intervention.

Congress passed the America COMPETES Act in 2007 to directly address one of the actions of the National Academies report, namely, to create a new research organization modeled after the Defense Advanced Research Projects Agency (DARPA). DARPA is credited with rapid development of innovations such as GPS, the stealth fighter, and computer networking. This new organization, the Advanced Research Projects Agency–Energy (ARPA-E), was created within the Department of Energy.

ARPA-E is intended to play a unique role in DOE's research and development enterprise by providing a link between fundamental, discovery-focused basic research and development and deployment of energy-related technologies. In this role, ARPA-E complements existing basic science and applied energy programs and strives to deliver transformative solutions to technical challenges to environmental, energy, and security issues. ARPA-E research is highly focused on specific challenges that, if solved, would provide dramatic benefits for the nation. ARPA-E research does not replace basic research, but rather builds from it, targeting specific technology barriers that can be meaningfully addressed with a defined investment over a finite period of time. In the context of DOE-EM's cleanup challenges, accelerating the process by which the fundamental knowledge generated by DOE's Office of Science and other basic research programs is transformed into innovative solutions that accelerate the cleanup of DOE's remaining waste legacy could bring significant benefits to the cleanup program and has the potential to increase worker safety, accelerate cleanup schedules and reduce cleanup costs, and reduce DOE-EM's environmental liability.

cleanup, and disposal of low- and high-level radioactive waste and spent nuclear fuel. The committee identified opportunities that could lead to breakthrough solutions and technologies that could be explored by the ARPA-E-managed breakthrough S&T development program. These opportunities are discussed in Chapter 3.

The committee recommends that DOE-EM should work cooperatively with ARPA-E to identify and implement these breakthrough technologies and solutions in the cleanup program. However, it is DOE-EM's responsibility to facilitate the transition of promising S&T results into applied

solutions. Therefore, a handoff mechanism from ARPA-E to DOE-EM needs to be developed so that promising breakthrough solutions get deployed in the cleanup program in an effective and timely manner. This cooperative effort can only be impactful if enthusiastically supported by DOE-EM's leadership.

Independent peer review should be used to evaluate the effectiveness of ARPA-E's technology development and DOE-EM's deployment efforts.

3

Review and Assessment of Technologies and Alternative Approaches

This chapter addresses the second charge of the Statement of Task for this study (see Sidebar 1.2 in Chapter 1), which calls for

> A review and assessment of the types of technologies and/or alternative approaches for the DOE-EM cleanup program that could
>
> a. Reduce long-term costs;
> b. Accelerate schedules; and
> c. Mitigate uncertainties, vulnerabilities, or risks, or otherwise significantly improve the cleanup program.

As noted in Chapter 1, this study charge calls for a *future-focused* review and assessment of technologies and alternative approaches that have the potential to *substantially* reduce cleanup program costs, schedules, and risks or uncertainties. Most of these technologies and alternative approaches are not available to be deployed in the Department of Energy's Office of Environmental Management (DOE-EM) cleanup program today. The Advanced Research Projects Agency–Energy (ARPA-E)-managed breakthrough science and technology (S&T) development program called for in Recommendation C in Chapter 2 of this report is intended to spur development and deployment of such technologies and alternative approaches into the cleanup program.

It is not possible to make detailed predictions about future advancements in S&T development that will lead to new cleanup capabilities over the 50-year-plus projected lifetime of DOE-EM's cleanup program.

Nevertheless, the committee judges that a focused and sustained S&T development effort could substantially improve DOE-EM's cleanup capabilities in the future—just as past investments in S&T development by DOE-EM and others have produced the cleanup technologies being used today. Cleanup of the nuclear weapons complex is not simply an engineering problem; as discussed in Chapter 2, it requires substantial new investments in S&T.

The committee used its collective judgment and experience to identify examples of the kinds of technologies and alternative approaches called for in study charge 2. These examples are presented in Section 3.1. They are intended to be broadly illustrative of the types of S&T development opportunities and are not intended to be definitive. Section 3.2 illustrates, again by example, how these technologies and alternative approaches could be applied to some key DOE-EM cleanup challenges to reduce long-term costs; accelerate schedules; mitigate uncertainties, vulnerabilities, or risks; or otherwise significantly improve the cleanup program.

Some of the examples presented in Section 3.1 might become the focus of the ARPA-E-managed breakthrough S&T development program called for in Recommendation C in Chapter 2. However, the core thrust(s) of the ARPA-E program will be informed by the cleanup risk and uncertainty analysis called for in Recommendation A in Chapter 2 as well as DOE-EM's S&T management process called for in Recommendation B in Chapter 2.

3.1 TECHNOLOGIES AND ALTERNATIVE APPROACHES

The technologies and alternative approaches in Finding 5 are posed as "change" or "action" statements. One can think of these statements as "knobs" that can be "turned" through a properly organized and focused S&T development and deployment effort to obtain the reductions in costs, schedules, and risks or uncertainties called for in study charge 2.

The examples of technologies and alternative approaches identified in Finding 5 are described briefly in the following subsections. The committee made no effort to assess the current status of these technologies and alternative approaches, judging that such an assessment was not needed to address study charge 2 and would add unnecessary length and detail to the chapter. These examples are intended to inform the design of the ARPA-E-managed breakthrough S&T development program identified in Recommendation C in Chapter 2, as noted previously in this chapter, and are not intended to constrain that design. The committee expects that DOE-EM and ARPA-E will undertake a detailed analysis of the usefulness, practicality, and current status of these technologies and alternative approaches as part of that design effort.

FINDING 5: The committee identified seven technologies and alternative approaches that could substantially reduce long-term cleanup costs; accelerate cleanup schedules; and mitigate uncertainties, vulnerabilities, or risks, or otherwise significantly improve the cleanup program. These involve changes to the following:

1. Waste chemistry at bulk and interfacial scales to facilitate treatment and disposal.
2. Nuclear properties of waste to facilitate treatment and disposal.
3. Human involvement in cleanup activities to increase cleanup efficiencies and reduce worker risks.
4. Interrogation approaches to characterize wastes and monitor cleanup remedies and environmental impacts.
5. Modeling and visualization approaches to manage large cleanup-related data sets and improve predictive capabilities.
6. Disposal pathways to increase waste disposition options.
7. Decision-making approaches to improve the quality and durability of cleanup decisions.

3.1.1 Change Chemistry at Bulk and Interfacial Scales

DOE-EM waste streams contain hazardous and/or radioactive elements in specific chemical forms, referred to as *chemical species*. The form of a species—for example, whether it is contained in a solid or aqueous phase—can greatly affect the ease with which that species can be removed from the waste stream for treatment and disposal. Systems for treating waste streams rely on chemical manipulations to isolate species of interest and facilitate their sequestration into waste forms suitable for storage or disposal. Chemical manipulations of waste in subsurface environments are also used to reduce the environmental mobility of contained species, essentially sequestering those species in place.

Many of the treatment systems used by DOE-EM today were designed more than a decade ago and employed the then-state of knowledge about chemical speciation. Scientific understanding of chemical speciation has advanced since then, particularly for complex chemical systems, but incorporation of that knowledge into new remediation approaches has lagged.

In addition, new foundational knowledge is needed for chemical speciation of contaminants in bulk solid phases; the interaction of these species at interfaces; and changes in speciation and interfacial interactions under

changing chemical conditions, including the effects of radiation damage and particle size diminution. Advancing the current understanding of chemical dynamics in bulk phases and at interfaces will likely enable the development of new remediation technologies, including advanced separations for treatment systems and in situ treatment approaches.

Some examples of potential future treatment technologies and approaches include

- Electrochemistry to modify chemical conditions, ranging from oxidation state changes of elements that are contaminants to in situ electrodeposition or vitrification;
- Interfacial control of reactivity leading to improved separations and/or sequestration;
- Understanding interfacial surface chemistries between suspended particulates to enable better rheology control in complex waste streams; and
- Use of biological processes to achieve oxidation state control of redox-sensitive contaminant species and to drive in situ sequestration.

3.1.2 Change Nuclear Properties

Much of the hazard associated with radioactive waste is derived from its elemental composition, isotopic composition, and molecular speciation. Some waste constituents are chemical hazards: for example, human exposure to uranium in drinking water can cause renal failure. Other waste constituents are radiation hazards: for example, external exposures to cesium-137 or internal exposures to plutonium-239 (e.g., through inhalation), depending on the amount, can cause acute health effects such as radiation sickness or long-term health effects such as cancer. Altering the number of protons and/or neutrons in the radioactive nuclei of waste constituents can reduce their chemical and radiation hazards. The alteration process is referred to as *transmutation*.

The feasibility of transmuting spent nuclear fuel and radioactive waste to reduce the need for long-term disposal has been examined by the National Academies (NRC, 1996) and other organizations.[1] Several barriers currently exist for applying these technologies to DOE-EM radioactive waste streams, including separation inefficiencies and high infrastructure and cost

[1] For example, DOE sponsored a program beginning in fiscal year 2000 to evaluate accelerator systems for transmuting long-lived nuclear waste stream constituents (Van Tuyle et al., 2002).

requirements. However, new tools are under development that have the potential to overcome some or all of these barriers.[2]

Some examples of potential treatment and technologies include

- High-efficiency and -specificity separations technologies to isolate radioactive constituents of interest from complex waste streams; and
- Low-cost, high-efficiency compact accelerators, plasma-based centrifuges, and/or lasers, for transmuting the separated radioactive constituents.

3.1.3 Change Human Involvement

Many DOE-EM cleanup activities are inherently dangerous. For example, retrieving and processing high-level radioactive waste from underground tanks and decontaminating and demolishing highly contaminated equipment and facilities require intensive manual labor and have the potential to expose workers and members of the public living near DOE-EM sites to industrial, chemical, and radiation hazards.

Minimizing the need for direct human involvement in hazardous cleanup activities can lead to reduced worker risks and improved cleanup efficiencies. Some examples of such technologies and alternative approaches include

- *Remote systems/robotics*, coupled with *artificial intelligence* (AI), to reduce the need to place humans in dangerous environments;
- Advanced person–machine interfaces that would allow workers to perform hazardous tasks remotely; and
- *Augmented reality/virtual reality* (AR/VR) to inform planning and to practice execution of particular cleanup actions. A building information model—a three-dimensional view of a structure or facility to show all systems as installed—is an example of a VR environment.

3.1.4 Change Interrogation Approaches

Interrogation approaches are means for remotely characterizing important properties of waste streams and/or contaminated facilities without

[2] For example, lasers are being investigated for use in making medical isotopes through transmutation reactions (see MIT Technology Review, 2011), and pulsed lasers are being investigated for transmuting nuclear waste (see Hirlimann, 2016). Most of this work is being carried out outside of the United States.

the need for physical sampling and analysis. An example of such an approach is microwave or electrical impedance tomography combined with advanced data manipulation and analysis to measure properties of subsurface environments.

Interrogation approaches have several potential applications in the DOE-EM cleanup program. For example, they could be used to image and understand the movement of contaminants in subsurface environments without drilling numerous groundwater monitoring wells. They could also be used to characterize the interiors of underground waste tanks and their contents without having to retrieve and analyze physical samples. Such approaches could transform the DOE-EM cleanup program through better-informed cleanup decisions, reduced worker risks, and reduced cleanup times and costs.

Some examples of interrogation approaches include

- Mobile, autonomous sensor systems deployed on drones that are capable of operating in extreme (i.e., high-radiation and aggressive chemical) environments;
- In-line sensor systems that enable on-the-fly monitoring of waste processing streams in extreme environments;
- Advanced data analysis systems that enable the fusion of disparate data sets;[3]
- Electrical resistivity of subsurface environments enabled by low-power wireless sensor networks;[4] and
- Stand-off spectroscopic analyses using vibrational technologies such as LIDAR and Raman techniques to provide chemical information in extreme environments.

3.1.5 Change Modeling and Visualization Approaches

Approaches for modeling and visualizing physical and chemical phenomena are being rapidly and dramatically transformed by increases in data availability and computational power, combined with advances in algorithms and new data visualization methods. Data-driven modeling approaches that merge multiple disparate data sets are increasingly being used to supplement process-based modeling approaches and uncover correlations and relationships among complex phenomena, for example, environmental

[3] Disparate data sets are made up of data that are unalike in character and therefore cannot be easily integrated. Subsurface groundwater monitoring data and climate monitoring data are examples of disparate data sets.

[4] For example, the E4D system created by the Pacific Northwest National Laboratory uses three-dimensional electrical resistivity and spectral induced polarization data for subsurface imaging and monitoring. See https://e4d.pnnl.gov/Pages/Home.aspx.

transport phenomena, that were previously hidden due to limited data availability. Advances in data visualization are also revealing correlations and trends that were hard to identify in the past. In general, so-called big data analytics are revolutionizing the way that industries, governments, and institutions are modeling problems and visualizing outcomes.

There is a continuum between modeling and visualization of small data sets using conventional statistical approaches and dealing with large and diverse data sets through rapidly evolving data science and artificial intelligence approaches. The latter approaches are expected to dominate in the near future and will bring new perspectives and efficiencies to decision making.

Advances in modeling and visualization have many potential applications in the DOE-EM cleanup program. Some examples for subsurface contaminant plume management include

- The merging of climate data and other remote-sensing data, monitoring well data and other subsurface sensing data, and visual inspections and observations to provide new or improved insights into complex flow and transport phenomena that affect contaminant plume behavior.
- The merging of subsurface observational and modeling data across all DOE-EM sites to reveal macrotrends, including the uncertainties associated with current modeling and predictive approaches.
- The merging of thermodynamic and dynamic (kinetic) approaches to understand and predict both equilibrium and nonequilibrium behaviors of contaminants.
- New four-dimensional (the three spatial dimensions plus the time dimension) visualization tools for subsurface groundwater contaminant plumes that include historical data as well as future projections. These could help all stakeholders visualize past and projected behaviors of plumes and reveal trends in cleanup progress under different remediation scenarios.
- Visualization of the structures of new materials that could be used for sequestering radioactive waste or for separating mixtures of radioactive materials.

Other examples relevant to decision making are provided in Section 3.1.7.

3.1.6 Change Disposal Pathways

DOE-EM's cleanup activities are generating thousands of radioactive and hazardous waste streams. DOE-EM must identify a *disposal pathway*—that is, processes to treat each waste stream to make it suitable for disposal and a facility to dispose of the treated waste—for each waste stream. The majority

of DOE-EM's current waste streams can be disposed of in near-surface engineered facilities, either at DOE sites or at commercial disposal facilities, with little or no treatment. However, near-surface disposal is not cost effective or environmentally protective for some waste streams, particularly those that contain radioactive constituents that are mobile in the environment.

There may be new disposal pathways for DOE-EM waste streams that are protective of human health and the environment but faster and less costly to achieve than current pathways. Some examples include

- Near-surface storage vaults to allow time for decay of waste streams containing short-lived radioactive constituents;
- Boreholes and deep-injection wells for disposal of short-lived, high-activity radioactive wastes;
- Pretreatment of waste streams to remove long-lived and/or environmentally mobile radioactive constituents that prevent disposal in near-surface engineered facilities;
- Low-temperature waste forms such as geopolymers, room-temperature ceramics, and composite cements to serve as durable alternatives to high-temperature waste forms such as glass and reduce volatilization of radioactive and hazardous constituents during processing; and
- New waste forms for stabilization of wastes that are mobile in the environment.

3.1.7 Change Decision-Making Approaches

Many of the challenges facing the DOE-EM cleanup program are sometimes referred to as "wicked problems." They are multivariate in nature, containing many independent variables (e.g., cost, risk, regulatory acceptance) that interact in complicated ways. Conventional top-down decision-making processes applied to wicked problems often have unintended consequences. These generally occur either because the decision maker is focused on only one part of the problem, or because the decision maker does not recognize the complex interdependencies among the various parts of the problem.

New and/or improved decision-making tools can lead to improvements in the quality of decisions made by the cleanup program. Decision quality depends both on the information needed to inform decision makers and on decision-making processes that uncover—and resolve—the complex interplay among the various aspects of the decision. Some examples include the following:

- Scenario development, modeling, simulation, and visualization tools to test and communicate the impacts of decision alternatives

(e.g., through simulation and scenario development) on cleanup cost, schedule, and risk reduction;
- Decision tools to enable risk-informed prioritization of cleanup activities at individual and multiple sites and prediction of impacts of such prioritization on cleanup costs and schedules;
- Modeling and visualization tools that elucidate the impacts of individual cleanup decisions on the remaining DOE-EM cleanup scope;
- Collaborative decision-making tools to more effectively involve key stakeholders (e.g., state, local, and tribal governments) in cleanup decision-making processes, which could help to improve the quality and durability of cleanup decisions and increase stakeholder trust in those decisions;
- Convergence science to develop new frameworks for more effectively communicating relevant information to the diverse groups of stakeholders involved in the cleanup program; and
- Visualization tools to present scientifically based analyses to regulators to support requests for regulatory changes.

3.2 APPLICATION OF TECHNOLOGIES AND ALTERNATIVE APPROACHES

The DOE-EM cleanup program has been under way for almost 30 years; consequently, the scope of the cleanup mission is well established and the technical challenges for completing it are generally recognized. Many of the key challenges for completing the cleanup mission have been identified in previous National Academies reports (see Appendix B). Those reports provide the basis for the committee's summary of nine key cleanup challenges, described below in no order of priority:

1. Characterize and retrieve heterogeneous radioactive and hazardous wastes[5] from large underground tanks without degrading tank integrity or the immediate surroundings.
2. Stabilize residual tank waste and underground tanks in place.
3. Improve the efficiency and effectiveness of in situ monitoring of physical and chemical conditions within and beneath underground tanks.
4. Develop real-time capabilities for in situ analysis and modification of waste streams and processing approaches to reduce the need for batching and batch storage.

[5] The term "hazardous waste" refers to solid and liquid wastes identified by the U.S. Environmental Protection Agency as having harmful effects on human health or the environment. A waste that contains both radioactive and hazardous components is referred to as a "mixed waste."

5. Separate long-lived and/or environmentally mobile radioactive constituents from waste streams.
6. Rapidly, remotely, and safely characterize and remove radioactive contamination from equipment and buildings.
7. Characterize and stabilize and/or retrieve contamination in the deep vadose zone.
8. Remotely monitor the physical and chemical environments in waste disposal cells and surface and near-surface barriers.
9. Monitor the locations and movements of subsurface contaminant plumes.

These cleanup challenges are briefly described in the following subsections. Table 3.1 shows by example how the technologies and alternative approaches described in Section 3.1 might be used to address these cleanup challenges.

The first five cleanup challenges focus on remediation of radioactive wastes stored in underground tanks at the Hanford and Savannah River Sites (see Figure 3.1 and Sidebar 3.1). Most of these wastes resulted from the chemical processing of irradiated uranium targets to produce plutonium for nuclear weapons. Smaller amounts of waste were also produced by other processes, for example, chemical processing of damaged research reactor fuel.

Cleanup of the waste tanks at Hanford and Savannah River is the largest cost driver at these sites: DOE-EM currently estimates that about $80 billion will be required to complete cleanup of the waste tanks over the next 30-plus years (see Figure 1.1). Moreover, retrieval and processing of tank waste have the potential to expose workers to both chemical and radioactive hazards and could pose public health risks today and in the future if not managed properly.

3.2.1 Characterize and Retrieve Heterogeneous, Highly Radioactive Wastes from Large Underground Tanks Without Degrading Tank Integrity or the Immediate Surroundings

Characterization of waste stored in underground tanks at Hanford and Savannah River is challenging because

1. It is voluminous (~90 million gallons [~340 million liters]) and stored in a large number (~220) of tanks.
2. It is heterogeneous, consisting of mixtures of liquids, crystallized salts, and solid sludge (see Figure 3.2).
3. It is radioactive and hazardous and poses health and safety risks to workers.

TABLE 3.1 Examples of Three Applicable Change Knobs for the DOE-EM Cleanup Challenges

Cleanup Challenge	Examples of Applicable Change Knobs
Characterize and retrieve tank waste	• Chemistry at bulk and interfacial scales • Human involvement • Interrogation approaches
Stabilize residual tank waste and tanks in place	• Chemistry at bulk and interfacial scales • Modeling and visualization approaches • Decision-making approaches
In situ tank monitoring	• Human involvement • Interrogation approaches • Modeling and visualization approaches
Analysis and modification of waste stream processing	• Chemistry at bulk and interfacial scales • Interrogation approaches • Modeling and visualization approaches
Separate radioactive constituents from waste streams	• Nuclear properties • Chemistry at bulk and interfacial scales • Disposal pathways
Characterize and remove radioactive contamination from equipment and buildings	• Human involvement • Interrogation approaches • Disposal pathways
Characterize, stabilize, and/or retrieve deep vadose zone contamination	• Chemistry at bulk and interfacial scales • Interrogation approaches • Modeling and visualization approaches
Monitor waste disposal cells and barriers	• Interrogation approaches • Modeling and visualization approaches • Decision-making approaches
Monitor locations and movements of subsurface plumes	• Human involvement • Interrogation approaches • Decision-making approaches

DOE has been able to characterize a subset of its tank wastes by direct sampling; however, in many cases this process does not provide sufficiently representative samples to make waste processing decisions. More detailed characterization estimates are made by retrieving waste from the tanks, transferring that waste to batch tanks and blending it, and then sampling the blended waste and conducting detailed chemical, radiological, and rheological analysis. This process is costly and time intensive.

Retrieval of the waste stored in underground tanks at Hanford and Savannah River is also challenging because

A

B

FIGURE 3.1 Single-shell tanks at various stages of construction at the Hanford Site. The tanks are constructed of a carbon steel shell (A) and encased in reinforced concrete and covered with soil (B). The group of tanks is referred to as a "tank farm."
SOURCE: Department of Energy.

SIDEBAR 3.1
Underground Storage Tanks at Hanford and Savannah River

About 90 million gallons (~340 million liters) of high-level radioactive wastes are being stored in more than 200 underground tanks at the Hanford and Savannah River Sites. Most of the tanks have capacities of 0.5–1.3 million gallons (1.9–4.9 million liters), are constructed of carbon steel surrounded by concrete shells, and are covered with 1–3 meters of soil. The interiors of the tanks are accessed through risers that run from the top of the tanks through the soil cover to the ground surface.

There are many variations in tank design at both sites. Some tanks have only a single carbon steel shell or containment. Other tanks have two containments with an annulus that can be monitored for leakage. In some tanks the outer containment only extends partway up the tank wall. Some tanks contain center pillars for structural support, and other tanks contain a jungle of cooling coils through which water is circulated to remove decay heat from the tank waste. The National Research Council (2006) provides additional information about the characteristics and operations of these tanks.

1. The waste contains large volumes of nonpumpable solids.
2. Access to tank interiors is limited by the small number and sizes of access ports, limiting both the size of equipment that can be introduced into the tanks and access to internal tank surfaces. Additionally, some tanks have internal structures such as pillars and cooling coils that further inhibit access and increase the difficulty of waste retrieval and tank cleaning.
3. Tanks with single containments, especially tanks that are known or suspected to have leaked, could leak (additional) waste into the subsurface during retrieval operations.

DOE-EM has developed or adapted a number of technologies to characterize and retrieve tank waste. However, characterization and retrieval processes continue to be costly, time intensive, and hazardous to workers.

The technologies and alternative approaches described in Section 3.1 can be applied to improve the characterization and retrieval of waste from tanks at Hanford and Savannah River. These include, for example (see Table 3.1),

- Approaches for modifying tank waste chemistry to improve the ease and efficiency of retrieval and also to reduce water use during retrieval operations;

FIGURE 3.2 Interior of a Hanford tank showing layers of saltcake and sludge. The tank wall is in the far background. The pumpable liquids have been removed from the tank.
SOURCE: Department of Energy.

- Robotics and human–machine interfaces to reduce the need for direct human involvement in waste retrieval operations; and
- Interrogation approaches for in situ characterization of the physical, chemical, and radiological properties of tank waste and for in situ characterization of tank interiors after retrieval operations are completed.

3.2.2 Stabilize Residual Tank Waste and Underground Tanks in Place

DOE-EM plans to close the underground waste tanks[6] at the Hanford and Savannah River Sites in place after waste retrieval operations are completed (see Sidebar 3.2). Eight of 51 tanks at the Savannah River Site have already been operationally closed as of late 2018 (DOE-EM, 2017b), and operations to close several more are under way. None of the 177

[6] A tank is "closed" by removing waste to the extent practical and then filling it with specially formulated grouts that provide structural support and inhibit the migration of residual waste into the environment. See SRR (2016).

SIDEBAR 3.2
Waste Tank Closure

Tank closure—which involves bulk retrieval of waste, cleaning to remove residual waste heels, and grouting to stabilize the tanks and any residual waste in place—is technically challenging, expensive, and time consuming because

- The waste is a heterogeneous mixture of liquid, solid, and sludge;
- At least 67 single-containment tanks at Hanford are known or suspected to have leaked waste into the subsurface (Gephart, 2003); and
- Tank access is limited by the number and sizes of rises and internal tank structures such as pillars and cooling coils.

DOE-EM plans to use grout to close all of its underground storage tanks at Hanford and Savannah River (see NRC, 2006, for details). The grouts to be used consist of various mixtures of Portland cement, fly ash, and slag. The Portland cement gives the grout structural strength, which helps prevent structural failure of the tank walls and roof from vertical and lateral soil loads. The high pH/low Eh of the fly ash and slag help reduce the solubility and mobility of any radionuclides and heavy metals in any residual tank wastes encapsulated in the grout.

The grouts used to close the tanks must perform their structural, chemical, and hydrological functions for thousands of years. This timescale is well outside any operating experience.

underground tanks at the Hanford Site have been closed as of late 2018. Once all of the tanks have been closed, the tank farms may be covered with engineered caps to reduce water ingress and inhibit physical access.

Technologies for stabilizing residual waste and tanks in place have, to date, been applied to tanks that lack complex internal structures. It is not clear how effective these technologies will be when applied to

- Leaking single-containment tanks,
- Double-containment tanks containing leaked waste between the inner and outer containments,
- Tanks with complex internal structures, and
- Tanks that contain relatively large amounts of unretrieved waste.

The technologies and alternative approaches described in Section 3.1 can be applied to improve the immobilization and/or encapsulation of residual waste in tanks after retrieval operations are completed. These include, for example (see Table 3.1),

- Approaches, including new processes and materials, for modifying the chemistry of residual tank waste to immobilize it in place;
- Models for estimating the long-term performance of tank closures at individual tank and tank-farm scales; and
- Tools for making risk-informed tank closure decisions to meet performance assessment goals.

These technologies and alternative approaches might allow DOE-EM to reduce the amount of waste that needs to be removed from damaged and/or hard-to-clean tanks while still meeting long-term safety and performance assessment goals.

3.2.3 Improve the Efficiency and Effectiveness of In Situ Monitoring of Physical and Chemical Conditions Within and Beneath Underground Tanks

DOE-EM monitors the conditions of its underground tanks through a number of means, including

- In situ measurements of tank waste temperatures,
- In situ measurements of tank liquid levels,
- In situ examinations of tank-wall and -floor conditions,
- Laboratory analyses of tank corrosion conditions using coupons of tank shell materials removed from the tanks at periodic intervals,
- Laboratory analyses of tank headspace gases to detect the products of chemical reactions in stored waste, and
- Laboratory analyses of soil samples collected from beneath tanks obtained by drilling (see Figure 3.3).[7]

The technologies and alternative approaches described in Section 3.1 can be used to improve capabilities to monitor the long-term effectiveness of tank closures. These include, for example (see Table 3.1),

- Instruments and sensors that can be installed in, around, and beneath operating tanks to provide continuous centralized monitoring of relevant conditions to reduce costs, time, and the need for direct worker involvement.
- Instruments and sensors that can be installed in tank closures—that is, within closed tanks and in overlying caps—to monitor physical and chemical conditions and to assess the effectiveness of closure

[7] Limited to a small number of single-shell tanks at Hanford.

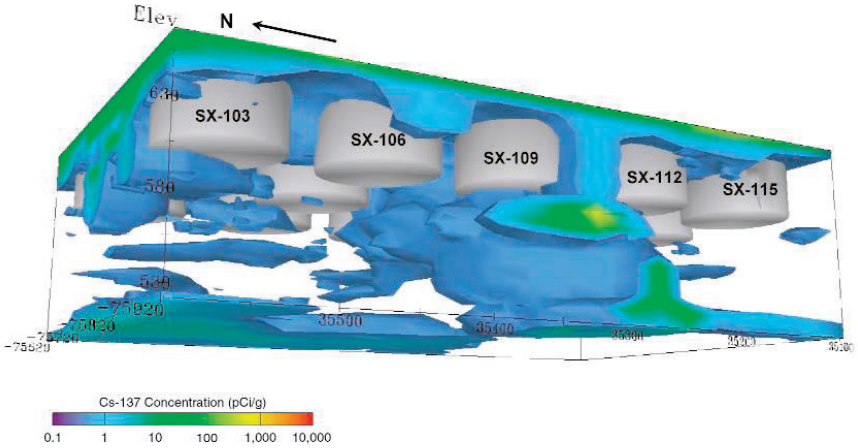


FIGURE 3.3 Cesium-137 contamination beneath the SX tank farm at Hanford in picocuries per gram (pCi/G) of soil. The view is from below the tanks looking toward the surface. The tanks are labeled with numbers prefixed by "SX." This figure illustrates enhanced visualization of subsurface contaminant distributions at the time soil samples were collected in the 1990s; current contaminant levels are lower due to radioactive decay.
SOURCES: Taken from Figure 2.4 in NRC (2000). Graphic from the Department of Energy Richland Operations Office.

remedies. These instruments and sensors need to be capable of self-calibration and long-term operation and/or easy replacement.

- Models that integrate the data collected from the instruments and sensors above to analyze the performance of operating tanks and tank closures with little or no operator intervention.

3.2.4 Develop Real-Time Capabilities for In Situ Analysis and Modification of Waste Streams During Processing to Reduce the Need for Batching and Batch Storage

The current flowsheets for processing tank wastes at the Hanford and Savannah River Sites are based on batch processing principles. Waste is retrieved from one or more waste tanks and then moved to a "batch tank" for blending and physical, chemical, and radiological characterization. Such characterization usually involves the physical collection of one or more samples of waste for laboratory analysis. The waste remains in the batch tank until these analyses are completed, which presently can take days to weeks.

Once these analyses are completed, the waste in the batch tank is compositionally modified as needed to meet processing flowsheet specifications. Adjustments are made by blending the waste in the batch tank with waste

from other tanks or by introducing additives to adjust the physical, chemical, and radiological properties of the waste batch. Then additional waste samples may need to be drawn from the batch for laboratory analysis. The waste in the batch tank is moved to the next stage of the processing flowsheet only after it meets flowsheet processing specifications.

The technologies and alternative approaches described in Section 3.1 can be applied to reduce the time and cost of processing tank wastes by introducing real-time capabilities for in situ analysis and modification of waste streams during processing. These include, for example (see Table 3.1),

- Approaches for rapid modification of waste stream chemistry to meet processing specifications;
- Sensors for rapid in situ measurement of process-critical physical, chemical, and radiological properties of the waste; and
- Modeling and visualization tools for making real-time waste-form performance predictions for given waste stream compositions.

3.2.5 Separate Long-Lived and Environmentally Mobile Radioactive Constituents from Waste Streams

Some DOE-EM waste streams contain long-lived and/or environmentally mobile radioactive constituents that are difficult to remove by current waste processing approaches and may preclude their disposal in near-surface engineered facilities. Three such constituents are tritium (hydrogen-3), technetium-99 (Tc-99), and iodine-129 (I-129), which have half-lives of about 12.3 years, 211,000 years, and 15.7 million years, respectively. All three isotopes were produced in DOE's plutonium production reactors at Hanford and Savannah River, and tritium occurs as a groundwater contaminant at both sites. DOE-EM identifies Tc-99 and I-129 to be risk drivers in DOE's performance assessment for near-surface disposal of low-activity waste at Hanford and Savannah River.[8]

Tritium is difficult to remove from groundwater because it exhibits chemical behaviors similar to that of naturally occurring hydrogen isotopes (protium [hydrogen-1] and deuterium). Tritium removal technologies such as distillation and electrolysis are unsuitable for treating large volumes of contaminated groundwater because of the required time and energy inputs.[9] Consequently, DOE-EM's strategy for remediating tritium contamination

[8] Rodrigo V. Rimando, Jr., Director, Technology Development Office, DOE-EM, October 19, 2018, briefing to the committee.

[9] The Fukushima Daiichi nuclear accident has spurred the development of more efficient technologies for removing tritium from contaminated groundwater. To the committee's knowledge, none of these technologies have progressed to commercial availability.

in groundwater is to delay (where feasible) its discharge into surface waters to provide time for radioactive decay.

Tc-99 and I-129, along with other fission products and transuranic isotopes, are present in tank wastes at Hanford and Savannah River. These wastes are being processed to produce two waste streams, a *high-level radioactive waste stream* and a *low-activity radioactive waste stream*. The flowsheet used to produce these two waste streams preferentially partitions the cationic fission products (e.g., cesium, strontium) into the high-level radioactive waste stream, which will be disposed of in a yet-to-be-sited-and-constructed federal repository. Fission products that exist as anionic species, including Tc-99 (TcO_4^-) and I-129 (IO_3^-), remain in the low-activity waste stream destined for onsite disposal. These species are more mobile in the environment than cationic fission products because soils generally have low anion-exchange capacities.

The technologies and alternative approaches described in Section 3.1 can be applied to separate and disposition environmentally mobile radioactive constituents from waste streams. These include, for example (see Table 3.1),

- Technologies for transmuting radionuclides to reduce their environmental hazards;
- Approaches for rapid and real-time characterization of waste streams to identify and separate environmentally mobile constituents;
- Processes and materials for separating or sequestering mobile radionuclides;
- Materials for immobilizing environmentally mobile radionuclides in existing or new waste forms; and
- Approaches for treating large volumes of groundwater to remove tritium.

Technologies for separating and transmuting radionuclides have potentially wide application to many DOE waste streams, particularly waste streams that contain radioactive constituents that cannot be disposed of in near-surface engineered facilities because of their hazard. These technologies are not yet ready for deployment in the DOE-EM cleanup program because of technical barriers and high implementation costs. However, it is not inconceivable that such technologies could become available over the expected multidecade life of the cleanup mission.

3.2.6 Rapidly, Remotely, and Safely Characterize and Remove Radioactive Contamination from Equipment and Buildings

There are hundreds of chemically and radioactively contaminated facilities across the DOE complex. These facilities include analytical laboratories, plutonium production reactors, and materials production facilities; the latter include massive "canyons" at the Hanford, Idaho, and Savannah River Sites that were used to reprocess uranium targets to recover plutonium (see Sidebar 3.3). The contamination includes both chemicals (e.g., solvents

SIDEBAR 3.3
Plutonium Finishing Plant

The Plutonium Finishing Plant is an industrial site located in the 200 West Area on the Central Plateau at the Hanford Site that originally contained more than 60 buildings. The plant was used to convert plutonium nitrate—the product of chemical processing of irradiated uranium targets in Hanford's production reactors—to metallic plutonium for use in nuclear weapons. The plant operated from 1949 to 1989 and produced most of the plutonium in the U.S. stockpile.

DOE-EM began work to decontaminate and demolish plant facilities in the early 2000s. Those activities included

- Stabilizing and shipping residual plutonium to Savannah River;
- Removing contaminated equipment, including process tanks, glove boxes, and various machinery, from the buildings; and
- Demolishing facilities to slab-on-grade.

Decontamination and demolition (D&D) activities were carried out by workers dressed in protective gear with respirators. Most of the facility demolitions were done in the open-air by spraying fixative to minimize dust.

DOE-EM began the final phase of demolition on the Main Processing Facility in 2016. Demolition was halted in late 2017 after contamination was discovered outside of posted radiological boundaries. More than 30 vehicles were contaminated and several workers received radiation doses (all but one below a 50-year committed dose of 10 mrem). Although contamination levels were generally low, the fact that contamination occurred in the face of numerous protective and monitoring measures came as an unwelcome surprise, and it also illustrates the hazard potential for D&D activities.

An investigation was carried out by DOE-EM and the contractor to determine why the contamination occurred, and numerous measures were put into place to prevent a recurrence. DOE-EM authorized the contractor to resume lower-risk demolition activities at the plant in September 2018.

The Richland Operations Office provides updates on D&D of the Plutonium Finishing Plant at https://www.hanford.gov/page.cfm/Updates_on_Plutonium_Finishing_Plant.

and metals) and radioactive materials (a wide range of isotopes and material forms) and occurs as

- Residual waste in process lines, tanks, filters, and drains;
- Contamination on equipment and facility surfaces; and
- Contamination and residual waste within and under building foundations.

Deactivation and demolition (D&D) (or disposition[10]) of these contaminated facilities are major cost and schedule drivers in the cleanup program: DOE estimates that it will cost about $74 billion and take about 50 years to complete facility D&D (see Figure 1.1). These estimates do not include the surplus and obsolete facilities that DOE-EM may receive in the future from DOE's National Nuclear Security Administration, Office of Nuclear Energy, and Office of Science.

Current approaches for facility D&D are labor intensive, time consuming, and produce large volumes of contaminated waste that must be dispositioned in near-surface engineered facilities. DOE-EM is applying robotics and remote systems in some facility cleanups (see Figure 3.4), but workers still perform most of the characterization and decontamination work manually. This work is physically difficult, particularly when performed in protective gear, and can be dangerous.

The technologies and alternative approaches described in Section 3.1 can be applied to improve the efficiency, effectiveness, and safety of D&D activities across the DOE complex. These include, for example (see Table 3.1),

- Smart autonomous robots to reduce and/or eliminate the need for manual labor in facility D&D;
- Technologies for rapid in situ characterization of radioactive and chemical hazards in equipment and facilities; and
- Technologies for removing contamination from equipment and facilities to minimize radioactive and hazardous waste volumes and allow recycling or productive reuse of building equipment and materials.

3.2.7 Characterize and Stabilize and/or Retrieve Contamination in the Vadose Zone

The vadose zone comprises the unsaturated portion of the soil column between the ground surface and groundwater table. This zone ranges in

[10] For example, DOE-EM may cover its large canyons with caps rather than demolishing them.

FIGURE 3.4 Photo of the RadPiper tetherless, battery-powered robotic system designed to crawl through piping at DOE uranium enrichment plants and make autonomous measurements of uranium-235 deposits using a gamma-ray detector system. The robot was developed by Carnegie Mellon University with support for DOE-EM.
SOURCE: https://www.radpiperrobot.com.

maximum thickness from about 90 meters at the Hanford Site to about 240 meters at the Idaho Site (NRC, 2000, Table 2.2). The vadose zones at these sites contain radioactive and chemical contaminants that were intentionally discharged and/or accidently leaked into the ground (see Figure 3.5). Characterizing and retrieving or stabilizing this waste in situ is technically challenging, particularly when it is located below practical excavation depths (typically 10–20 meters).

Contaminant transport in the vadose zone is controlled by fine-scale heterogeneities in hydrological and geochemical properties, including porosity, permeability, pH, and redox potential. Characterizing and modeling this heterogeneity to predict contaminant distributions has met with limited success. Moreover, even when contaminant distributions in the vadose zone are known, recovering contaminants, or stabilizing them in situ by modifying subsurface hydrological or geochemical properties, is challenging, particularly for metals and radioisotopes that are distributed in large subsurface volumes.

The technologies and alternative approaches described in Section 3.1 can be applied to better characterize, stabilize, and/or retrieve contamination in the vadose zone. These include, for example (see Table 3.1),

- Approaches for manipulating in situ subsurface properties, especially geochemical and hydrological properties, to stabilize vadose zone contamination in place;

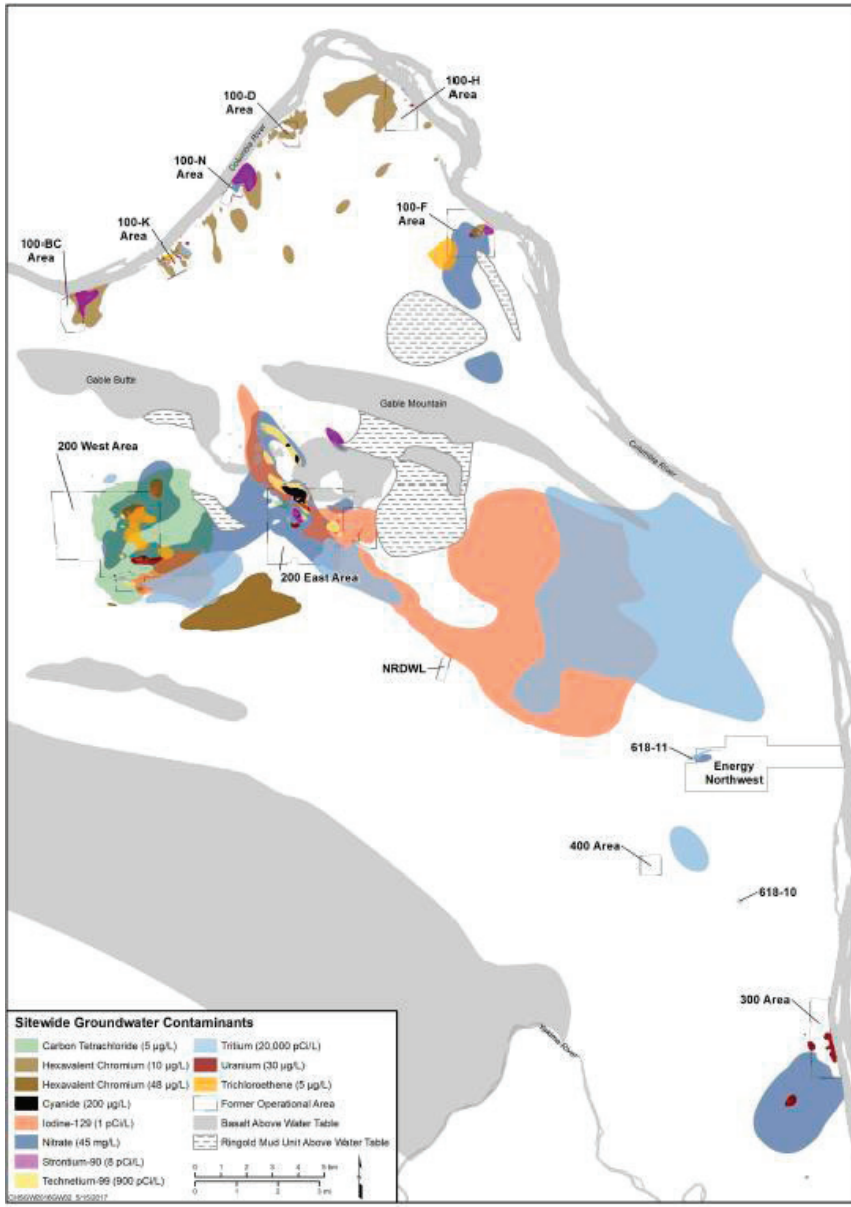


FIGURE 3.5 Groundwater plumes at the Hanford Site. Plumes originating in the Central Plateau (200 Area) of the site contain carbon tetrachloride, chromium, iodine, nitrate, technetium, tritium, and uranium. Plumes originating along the Columbia River corridor contain chromium, strontium, and uranium. The river is located about 15 miles from the Central Plateau. SOURCE: U.S. Department of Energy's Office of River Protection.

- Interrogation technologies to characterize hydrological and geochemical properties of the vadose zone; and
- Improved modeling and visualization of contaminant fate and transport in the vadose zone.

3.2.8 Remotely Monitor the Physical and Chemical Environments in Waste Disposal Cells and Surface and Near-Surface Barriers

Large quantities of chemical and radioactive wastes will remain at DOE sites after the cleanup mission is completed. DOE is building near-surface waste cells at all of its large sites (and at many smaller sites) to dispose of cleanup-related materials—including, for example, contaminated soil, contaminated equipment, facility demolition debris, and waste streams that have been treated for near-surface onsite disposal. Moreover, DOE may construct engineered caps (see Sidebar 3.4) over portions of its sites that will not be completely cleaned up—including, for example, tank farms, contaminated facilities that are not cost effective to demolish (e.g., canyons), and other contaminated areas that cannot be practically or cost-effectively remediated.

Engineered cells are designed to maintain the waste in a structurally stable configuration to prevent its out-migration, whereas engineered caps are designed to prevent water intrusion and inhibit intrusion by plants and animals. These engineered structures must function as long as the waste remains hazardous, that is, over many hundreds to some thousands of years. Regular surveillance and maintenance of these structures will be required to ensure that they continue to function as designed.

Surface monitoring of these structures will likely be effective for identifying gross maintenance needs but probably not effective for detecting small internal structural changes that could signal incipient losses of function. In situ monitoring of geophysical, geochemical, and/or hydrological conditions within the structures might be necessary to detect these small internal changes. For example, small changes in tilt within the structure might indicate the initiation of differential settling, or small changes in electrical resistivity might indicate the initiation of water intrusion. Such changes could occur well before visual or gross structural failure of the engineered structure.

The technologies and alternative approaches described in Section 3.1 can be applied to better monitor the physical and chemical environments in waste disposal cells and surface and near-surface barriers. These include, for example (see Table 3.1),

- Smart sensors for autonomous, continuous, and centralized in situ monitoring of engineered structures to detect incipient losses of function.

SIDEBAR 3.4
Prototype Hanford Barrier

The Pacific Northwest National Laboratory and three contractor companies directed a research and development program to evaluate the effectiveness of various barrier designs for containing subsurface radioactive contamination at the Hanford Site. This program started in 1983, operated for about 15 years, and utilized two facilities:

- A Field Lysimeter Test Facility containing 18 lysimeters was used to simulate multilayer surface barriers and generate data that could be used to test models for predicting long-term barrier performance (Gee et al., 1989).
- A Prototype Hanford Barrier was constructed over a crib (i.e., an underground structure that was used to dispose of liquids to the subsurface from a nearby tank farm) as part of a CERCLA treatability test of barrier performance.

The prototype barrier (see Figure S3.4) has an area of 2.5 hectares (6.2 acres) and contains several structural elements (DOE-RL, 2016):

- At the top is a silt loam evapotranspiration barrier which is intended to store precipitation for later release by evapotranspiration.
- In the middle is a gravel capillary barrier containing graded gravels which is intended to enhance storage capacity, inhibit downward water flow, and inhibit plant and animal intrusion.
- At the bottom is an asphalt-concrete barrier underlain by a layer of compacted soil. The barrier functions as a backup water and intrusion barrier to the barriers above it.
- A gentle (10:1) gravel slope on the west side and a steep (2:1) basalt riprap slope on the east side of the barrier are intended to stabilize barrier layers above.

The barrier functioned well during the almost 10-year period of monitoring following its construction. The barrier was structurally stable and through-drainage was well below the <0.5 millimeter/year barrier design goal.

This R&D program serves as an excellent example of how S&T can be deployed in the DOE-EM cleanup program to address longer-term and complex-wide technology needs.

continued

SIDEBAR 3.4 Continued

FIGURE S3.4 Oblique view of the prototype Hanford Barrier. The silt-loam evapotranspiration barrier is the light-colored rectangle near the center-top of the photo. The gravel slope surrounds the barrier. Construction equipment is shown for scale.
SOURCE: DOE-RL, 2016, Figure 2.3.

- Models that link functional changes in engineered structures to their geophysical, geochemical, and/or hydrological properties.

Decision tools to monitor sensor outputs and provide predictions of functional losses. These sensors must be cost effective, self-calibrating, and have long operational lives or be easily replaceable.

3.2.9 Monitor the Locations and Movements of Subsurface Contaminant Plumes

Groundwater contamination is a pervasive problem across the DOE complex. Groundwater contaminants include solvents, metals, and radionuclides that were intentionally discharged or accidentally leaked into the ground during site operations. Records of discharges and leaks are generally poor to nonexistent.

These contaminants have in some cases migrated through the unsaturated zone to mix with moving groundwater to form contaminated water volumes, or *plumes*, having dimensions ranging from less than a square kilometer to more than 100 square kilometers (see Figure 3.5). The plumes migrate with the groundwater and can travel offsite or discharge into surface waters. The plume may continue to be fed by contaminant source areas, the locations of which may be poorly known.

Monitoring the locations and movements of contaminant plumes usually currently requires the installation of boreholes into and through the contaminated groundwater volume. The boreholes are sampled periodically to assess changes in contaminant concentrations. Sampling is carried out by personnel in the field and is labor intensive. Dozens of boreholes may be required to monitor a single plume.

The technologies and alternative approaches described in Section 3.1 can be applied to better monitor locations and movements of subsurface contaminant plumes. These include, for example (see Table 3.1),

- Smart sensors for autonomous, continuous, and centralized in situ monitoring of locations and movements of contaminant plumes—and that reduce the need for direct human involvement in monitoring processes.
- Decision tools to monitor sensor outputs and provide predictions of plume locations and movements. These sensors must be cost effective, self-calibrating, and have long operational lives or be easily replaceable.

References

CRESP (Consortium for Risk Evaluation with Stakeholder Participation) Omnibus Risk Review Committee. 2015. A Review of the Use of Risk-Informed Management in the Cleanup Program for Former Defense Nuclear Sites. https://www.tri-cityherald.com/news/local/hanford/article33023001.ece/BINARY/Omnibus%20Risk%20Review%20Report_FINAL.

DOE (Department of Energy). 2007. Engineering and Technology Roadmap: Reducing the Uncertainty in the EM Program. Washington, DC.

DOE. 2008. Root Cause Analyses: Contract and Project Management. Corrective Action Plan. https://science.energy.gov/~/media/opa/pdf/processes-and-procedures/doe/Final_CAP_Report_Website.pdf.

DOE. 2017. Department of Energy FY 2018 Congressional Budget Request, DOE/CF 0132, Vol. 5. https://www.energy.gov/sites/prod/files/2017/06/f34/FY2018BudgetVolume5.pdf.

DOE. 2018. Department of Energy FY 2019 Congressional Budget Request; Budget in Brief. DOE/CF-0144. https://www.energy.gov/sites/prod/files/2018/03/f49/DOE-FY2019-Budget-in-Brief_0.pdf.

DOE-EHSS (Department of Energy's Office of Environment, Health, Safety and Security). 2018. Proposed rules: 10 CFR Part 830, RIN 1992–AA57, nuclear safety management. *Federal Register* 83(153):38982. https://www.gpo.gov/fdsys/pkg/FR-2018-08-08/pdf/2018-16863.pdf.

DOE-EM (Department of Energy's Office of Environmental Management). 2010. Report on Acquisition and Project Management Continuous Improvement. https://www.energy.gov/sites/prod/files/em/FINALREPORTonAcquisitionandProjectManagementContinuousImprovement-2Nov10.pdf.

DOE-EM. 2013. Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee. DOE/OR/01-2628/V2&D1. https://www.nrc.gov/docs/ML1806/ML18064A894.pdf.

DOE-EM. 2016a. Innovation and Technology: Charting the Path for Fiscal Years 2017-2021.

DOE-EM. 2016b. Mission and Functions. August 30. https://www.energy.gov/sites/prod/files/2016/08/f33/OFFICIALMISSIONFUNCTION_FINAL_UpdatesAugust2016.pdf.

DOE-EM. 2016c. Technology Plan to Address the EM Mercury Challenge. https://www.energy.gov/sites/prod/files/2016/05/f32/2016%2C%20EM%20Technology%20Plan%20to%20Address%20Mercury.pdf.

DOE-EM. 2017a. Offsite Groundwater Assessment, Remedial Site Evaluation, Oak Ridge, Tennessee. DOE/OR/01-2715&D2_R. https://doeic.science.energy.gov/uploads/A.0100.037.2570.pdf.

DOE-EM. 2017b. SRS Celebrates 20 Years Since First Tank Closure. https://www.energy.gov/em/articles/srs-celebrates-20-years-first-tank-closure.

DOE-EM. 2018a. Assistant Secretary White Lays Out Plans for Contracting, Regulatory Reform at Radwaste. https://www.energy.gov/em/articles/assistant-secretary-white-lays-out-plans-contracting-regulatory-reform-radwaste.

DOE-EM. 2018b. Hanford Test Bed Program Initiative. https://www.energy.gov/sites/prod/files/2018/07/f53/Hanford%20Test%20Bed%20Initiative%20Fact%20Sheet%207-12-18.pdf.

DOE-EM. 2018c. Request for public comment on the U.S. Department of Energy interpretation of high-level radioactive waste. *Federal Register* 83(196):50909-50911.

DOE-EM. 2018d. Technetium Management Technology Roadmap.

DOE-EMAB (Department of Energy's Environmental Management Advisory Board, Science & Technology Subcommittee). 2014. Report to the Environmental Management Advisory Board: DOE-EM Technology Development and Deployment Program. https://www.energy.gov/sites/prod/files/2014/07/f17/S%20%20T%20Report%20and%20Recommendations%20052214.pdf.

DOE-OREM (Department of Energy's Oak Ridge Office of Environmental Management). 2017. Program Plan FY 2014 to 2024: Continuing Progress. Restoring the Environment. Enabling Missions. Oak Ridge, Tennessee. https://www.energy.gov/sites/prod/files/2017/11/f46/OREM%2010-Year%20Plan.pdf.

DOE-ORO (Department of Energy's Oak Ridge Operations Office). 2014. Mercury Technology Development Plan for Remediation of the Y-12 Plant and East Fork Poplar Creek. DOE/ORO-2489.

DOE-RL (Department of Energy's Richland Operations Office). 2014. Remedial Design Report/Remedial Action Work Plan for 300-FF-2 Soils. https://pdw.hanford.gov/arpir/pdf.cfm?accession=0081152H.

DOE-RL. 2016. Prototype Hanford Barrier: 1994 to 2015. DOE/RL-2016-37, Revision 0. Richland, WA: Richland Operations Office. https://www.hanford.gov/c.cfm/sgrp/DOE-RL-2016-37/DOE-RL-2016-37_R0.pdf.

DOE-RL. 2019. 2019 Hanford Lifecycle Scope, Schedule and Cost Report. DOE/RL-2018-45, Revision 0. Richland, WA: Richland Operations Office. https://www.hanford.gov/files.cfm/2019_Hanford_Lifecycle_Report_w-Transmittal_Letter.pdf.

EFCOG (Energy Facility Contractors Organization). 2018. Low-Level Waste/Mixed Low-Level Waste Initiative, EFCOG Waste Management Working Group. https://static1.squarespace.com/static/55c4c892e4b0d1ec35bc5efb/t/5b97bfb26d2a73cf213aca4a/1536671671422/September+2018+Bulletin+2018.pdf.

EPA (U.S. Environmental Protection Agency). 1999. EPA Superfund Record of Decision Hanford 200-Area (USDOE) and Hanford 100-Area (USDOE). EPA/ROD/R10-99/039. https://www.emcbc.doe.gov/SEB/CPCC/Documents/library/Regulatory/EPA%20Superfund%20-%20Interim%20Action%20ROD,%20U.S.%20DOE%20Hanford%20100%20Area%20and%20200%20Area%20100-BC-1,%20100-BC-2,%20100-DR-1,%20100-DR-2,%20100-FR-1,%20100-FR-2,%20100-HR-1,%20100-HR-2,%20100-KR-1....%20-%20(EPA-ROD-R10-99-039).pdf.

GAO (U.S. Government Accountability Office). 2006. Nuclear Cleanup of Rocky Flats. DOE Can Use Lessons Learned to Improve Oversight of Other Sites' Cleanup Activities. GAO-06-352. https://www.gao.gov/new.items/d06352.pdf.

GAO. 2017a. High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others. GAO-17-375. Testimony Before the Committee on Oversight and Government Reform, House of Representatives. https://www.gao.gov/products/GAO-17-375t.

GAO. 2017b. Nuclear Waste: Benefits and Costs Should Be Better Understood Before DOE Commits to a Separate Repository for Defense Waste. Report to Congressional Addressees. GAO-17-174. https://www.gao.gov/assets/690/684918.pdf.

GAO. 2019. Department of Energy: Program-Wide Strategy and Better Reporting Needed to Address Growing Environmental Cleanup Liability. GAO-19-28. Report to the Chairman of the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate https://www.gao.gov/assets/700/696632.pdf.

Gee, G. W., R. R. Kirkham, J. L. Downs, and M. D. Campbell. 1989. The Field Lysimeter Test Facility (FLTF) at the Hanford Site: Installation and Initial Tests. PNL-6810. Richland, WA: Pacific Northwest Laboratory. https://www.osti.gov/biblio/6518216.

Gephart, R. E. 2003. Hanford: A Conversation About Nuclear Waste and Cleanup. Columbus, OH: Battelle Press.

Hirlimann, C. 2016. Laser Induced Nuclear Waste Transmutation. https://www.researchgate.net/profile/Charles_Hirlimann/publication/301837643_Laser_induced_nuclear_waste_transmutation/links/5820a50a08aeccc08af65744/Laser-induced-nuclear-waste-transmutation.pdf.

Lutze, W., and R. C. Ewing, eds. 1988. Radioactive Waste Forms for the Future. Amsterdam: North-Holland. http://inis.iaea.org/search/search.aspx?orig_q=RN:20061516.

MIT (Massachusetts Institute of Technology) Technology Review. 2011. How to transmute elements with laser light. Physics arXiv Blog. https://www.technologyreview.com/s/423107/how-to-transmute-elements-with-laser-light.

NAS, NAE, and IOM (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine). 2007. Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Washington, DC: The National Academies Press. https://doi.org/10.17226/11463.

NRC (National Research Council). 1995. Improving the Environment: An Evaluation of DOE's Environmental Management Program. Washington, DC: National Academy Press. https://doi.org/10.17226/5173.

NRC. 1996. Building an Effective Environmental Management Science Program: Initial Assessment. Washington, DC: National Academy Press. https://doi.org/10.17226/9219.

NRC. 1999. Ground Water & Soil Cleanup: Improving Management of Persistent Contaminants. Washington, DC: National Academy Press. https://doi.org/10.17226/9615.

NRC. 2000. Research Needs in Subsurface Science. Washington, DC: The National Academies Press. https://doi.org/10.17226/9793.

NRC. 2001. Research Opportunities for Deactivating and Decommissioning Department of Energy Facilities. Washington, DC: National Academy Press. https://doi.org/10.17226/10184.

NRC. 2002. Research Opportunities for Managing the Department of Energy's Transuranic and Mixed Waste. Washington, DC: The National Academies Press. https://doi.org/10.17226/10513.

NRC. 2006. Primarily Tank Waste Retrieval, Processing, and On-site Disposal at Three Department of Energy Sites: Final Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/11618.

NRC. 2010. Science and Technology for DOE Site Cleanup: Workshop Summary. Washington, DC: The National Academies Press. https://doi.org/10.17226/11932.

ORNL (Oak Ridge National Laboratory). 2015. Mercury Remediation Technology Development for Lower East Fork Poplar Creek. ORNL/SPR-2014/645. https://info.ornl.gov/sites/publications/Files/Pub53267.pdf.

Pro2Serve (Professional Project Services, Inc.). 2014. Strategic Plan for Mercury Remediation at the Y-12 National Security Complex, Oak Ridge, Tennessee. DOE/OR/01-2605&D2. Department of Energy's Office of Environmental Management. https://doeic.science.energy.gov/uploads/F.0608.006.0972.pdf.

Reid, D. S., T. A. Wooley, and S. E. Kelly. 2017. River Protection Project Technology and Innovation Roadmap. Department of Energy's Office of Environmental Management. https://www.osti.gov/servlets/purl/1420311.

SEAB (Secretary of Energy Advisory Board). 2014. Report of the Task Force on Technology Development for Environmental Management. Washington, DC: Department of Energy. https://www.energy.gov/sites/prod/files/2015/01/f19/Report%20of%20the%20SEAB%20Task%20Force%20on%20Tech%20Dev%20for%20EM_FINAL.pdf.

SRR (Savannah River Remediation, LLC). 2016. Radioactive Liquid Waste: Operational Closure of Tanks. Fact Sheet. https://www.srs.gov/general/news/factsheets/srr_tank_closure.pdf.

SRR. 2018. Liquid Waste Project Technology Development & Support Optimization Blueprint Fiscal Year 2018. SRR-CWDA-2017-00066. Washington, DC: Department of Energy.

Van Tuyle, G. J., D. R. Bennett, J. W. Herczeg, E. D. Arthur, D. J. Hill, and P. J. Finck. 2002. U.S. accelerator-driven transmutation of waste (ATW) program objectives, and technology development efforts. *Progress in Nuclear Energy* 40(3-4):357-364.

A

Congressional Request for the National Academies' Study

National Defense Authorization Act for Fiscal Year 2017 (P.L. 114-328)

SEC. 3131. INDEPENDENT ASSESSMENT OF TECHNOLOGY DEVELOPMENT UNDER DEFENSE ENVIRONMENTAL CLEANUP PROGRAM.

(a) ASSESSMENT.—Not later than 60 days after the date of the enactment of this Act, the Secretary of Energy shall seek to enter into an agreement with the National Academy of Sciences to conduct an independent assessment of the technology development efforts of the defense environmental cleanup program of the Department of Energy.
(b) ELEMENTS.—The assessment under subsection (a) shall include the following:
    (1) A review of the technology development efforts of the defense environmental cleanup program of the Department of Energy, including an assessment of the process by which the Secretary identifies and chooses technologies to pursue under the program.
    (2) A comprehensive review and assessment of technologies or alternative approaches to defense environmental cleanup efforts that could—
        (A) reduce the long-term costs of such efforts;
        (B) accelerate schedules for carrying out such efforts;
        (C) mitigate uncertainties, vulnerabilities, or risks relating to such efforts; or

(D) otherwise significantly improve the defense environmental cleanup program.

(c) SUBMISSION.—Not later than the date that is 18 months after the date of the enactment of this Act, the National Academy of Sciences shall submit to the congressional defense committees and the Secretary a report on the assessment under subsection (a).

B

Major National Academies Reports on Waste Management and Environmental Cleanup of Nuclear Weapons Complex

NASEM (National Academies of Sciences, Engineering, and Medicine). 2017. Low-Level Radioactive Waste Management and Disposition: Proceedings of a Workshop. https://doi.org/10.17226/24715.

NRC (National Research Council). 2014. Best Practices for Risk-Informed Decision Making Regarding Contaminated Sites: Summary of a Workshop Series. https://doi.org/10.17226/18747.

NRC. 2011. Waste Forms Technology and Performance: Final Report. https://doi.org/10.17226/13100.

NRC. 2010. Science and Technology for DOE Site Cleanup: Workshop Summary. https://doi.org/10.17226/11932.

NRC. 2009. Advice on the Department of Energy's Cleanup Technology Roadmap. https://doi.org/10.17226/12603.

NRC. 2006a. Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory: Interim Status Report. https://doi.org/10.17226/11781.

NRC. 2006b. Tank Waste Retrieval, Processing, and On-Site Disposal at Three Department of Energy Sites: Final Report. https://doi.org/10.17226/11618.

NRC. 2005a. Improving the Characterization and Treatment of Radioactive Wastes for the Department of Energy's Accelerated Site Cleanup Program. https://doi.org/10.17226/11200.

NRC. 2005b. Improving the Regulation and Management of Low-Activity Radioactive Wastes. https://doi.org/10.17226/11595.

NRC. 2005c. Risk and Decisions About Disposition of Transuranic and High-Level Radioactive Waste. https://doi.org/10.17226/11223.

NRC. 2005d. Tank Wastes Planned for On-Site Disposal at Three Department of Energy Sites. https://doi.org/10.17226/11415.
NRC. 2004. Improving the Characterization Program for Contact-Handled Transuranic Waste Bound for the Waste Isolation Pilot Plant. https://doi.org/10.17226/10900.
NRC. 2003a. End Points for Spent Nuclear Fuel and High-Level Radioactive Waste in Russia and the United States. https://doi.org/10.17226/10667.
NRC. 2003b. Improving the Regulation and Management of Low Activity Radioactive Wastes: Current Regulations, Inventories, and Practices: Interim Report. https://doi.org/10.17226/10835.
NRC. 2003c. Improving the Scientific Basis for Managing DOE's Excess Nuclear Materials and Spent Nuclear Fuel. https://doi.org/10.17226/10684.
NRC. 2003d. Long-Term Stewardship of DOE Legacy Waste Sites: A Status Report. https://doi.org/10.17226/10703.
NRC. 2002a. Characteristics of Remote-Handled Transuranic Waste at the Waste Isolation Pilot Plant. https://doi.org/10.17226/10492.
NRC. 2002b. Remedial Action at the Moab Site—Now and for the Long Term: Letter Report. https://doi.org/10.17226/10402.
NRC. 2002c. Research Opportunities for Managing the Department of Energy's Transuranic and Mixed Waste. https://doi.org/10.17226/10513.
NRC. 2001a. Characterization of Remote-Handled Transuranic Waste for the Waste Isolation Pilot Plant. https://doi.org/10.17226/10244.
NRC. 2001b. Evaluation of Criteria for Selecting a Salt Processing Alternative for High-Level Waste at the Savannah River Site: Interim Report. https://doi.org/10.17226/10088.
NRC. 2001c. Improving Operations and Long-Term Safety of the Waste Isolation Pilot Plant: Final Report. https://doi.org/10.17226/10143.
NRC. 2001d. Research and Development on a Salt Processing Alternative for High-Level Waste at the Savannah River Site. https://doi.org/10.17226/10170.
NRC. 2001e. Research Needs for High-Level Waste Stored in Tanks and Bins at U.S. Department of Energy Sites: Environmental Management Science Program. https://doi.org/10.17226/10191.
NRC. 2001f. Research Opportunities for Deactivating and Decommissioning Department of Energy Facilities. https://doi.org/10.17226/10184.
NRC. 2001g. Science and Technology for Environmental Cleanup at Hanford. https://doi.org/10.17226/10220.
NRC. 2001h. A Strategic Vision for Department of Energy Environmental Quality Research and Development. https://doi.org/10.17226/10207.

NRC. 2000a. Alternatives for High-Level Waste Salt-Processing at the Savannah River Site. https://doi.org/10.17226/9959.
NRC. 2000b. Improving Operations and Long-Term Safety of the Waste Isolation Pilot Plant: Interim Report. https://doi.org/10.17226/9842.
NRC. 2000c. Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites. https://doi.org/10.17226/9949.
NRC. 2000d. Long-Term Research Needs for Deactivation and Decommissioning at Department of Energy Sites: Interim Report. https://doi.org/10.17226/10004.
NRC. 2000e. Long-Term Research Needs for High-Level Waste at Department of Energy Sites: Interim Report. https://doi.org/10.17226/9992.
NRC. 2000f. Natural Attenuation for Groundwater Remediation. https://doi.org/10.17226/9792.
NRC. 2000g. Research Needs in Subsurface Science. https://doi.org/10.17226/9793.
NRC. 1999a. Alternative High-Level Waste Treatments at the Idaho National Engineering and Environmental Laboratory. https://doi.org/10.17226/9743.
NRC. 1999b. Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology. https://doi.org/10.17226/9448.
NRC. 1999c. An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks. https://doi.org/10.17226/6366.
NRC. 1999d. Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants. https://doi.org/10.17226/9615.
NRC. 1999e. Interim Report of the Committee on Cesium Processing Alternatives for High-Level Waste at the Savannah River Site. https://doi.org/10.17226/9703.
NRC. 1999f. Peer Review in Environmental Technology Development Programs: The Department of Energy's Office of Science and Technology. https://doi.org/10.17226/6408.
NRC. 1999g. The State of Development of Waste Forms for Mixed Wastes: U.S. Department of Energy's Office of Environmental Management. https://doi.org/10.17226/9459.
NRC. 1999h. Technologies for Environmental Management: The Department of Energy's Office of Science and Technology. https://doi.org/10.17226/9656.
NRC. 1998a. Interim Report of the Committee on Subsurface Contaminants at DOE Complex Sites: Research Needs and Opportunities. https://doi.org/10.17226/9497.

NRC. 1998b. Research Reactor Aluminum Spent Fuel: Treatment Options for Disposal. https://doi.org/10.17226/6099.
NRC. 1998c. A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy. https://doi.org/10.17226/6290.
NRC. 1998d. Study of the Decision Process Related to Long-Term Disposition of U.S. Department of Energy Waste Sites and Facilities: Interim Report.
NRC. 1998e. Systems Analysis and Systems Engineering in Environmental Remediation Programs at the Department of Energy Hanford Site. https://doi.org/10.17226/6224.
NRC. 1997a. Barrier Technologies for Environmental Management. https://doi.org/10.17226/5539.
NRC. 1997b. Building an Effective Environmental Management Science Program: Final Assessment. https://doi.org/10.17226/5557.
NRC. 1997c. Evaluation of the U.S. Department of Energy's Alternatives for the Removal and Disposition of Molten Salt Reactor Experiment Fluoride Salts. https://doi.org/10.17226/5538.
NRC. 1997d. Innovations in Ground Water and Soil Cleanup. https://doi.org/10.17226/5781.
NRC. 1997e. Peer Review in the Department of Energy-Office of Science and Technology: Interim Report. https://doi.org/10.17226/5939.
NRC. 1996a. Affordable Cleanup? Opportunities for Cost Reduction in the Decontamination and Decommissioning of the Nation's Uranium Enrichment Facilities. https://doi.org/10.17226/5114.
NRC. 1996b. Barriers to Science: Technical Management of the Department of Energy Environmental Remediation Program. https://doi.org/10.17226/10229.
NRC. 1996c. Building an Effective Environmental Management Science Program: Initial Assessment. https://doi.org/10.17226/9219.
NRC. 1996d. Environmental Management Technology-Development Program at the Department of Energy: 1995 Review. https://doi.org/10.17226/5172.
NRC. 1996e. Glass as a Waste Form and Vitrification Technology: Summary of an International Workshop. https://doi.org/10.17226/5488.
NRC. 1996f. The Hanford Tanks: Environmental Impacts and Policy Choices. https://doi.org/10.17226/5403.
NRC. 1996g. Letter Report on the Fiscal Year 1997 Program Announcement for the Department of Energy's Environmental Management Science Program.

NRC. 1996h. The Potential Role of Containment-in-Place in an Integrated Approach to the Hanford Reservation Site Environmental Remediation. https://doi.org/10.17226/9533.
NRC. 1996i. The Waste Isolation Pilot Plant: A Potential Solution for the Disposal of Transuranic Waste. https://doi.org/10.17226/5269.
NRC. 1996j. Nuclear Wastes Technologies for Separations and Transmutation. https://doi.org/10.17226/4912.
NRC. 1995a. Committee on Environmental Management Technologies Report for the Period Ending December 31, 1994.
NRC. 1995b. Improving the Environment: An Evaluation of DOE's Environmental Management Program. https://doi.org/10.17226/5173.
NRC. 1995c. Safety of the High-Level Uranium Ore Residues at the Niagara Falls Storage Site, Lewiston, New York. https://doi.org/10.17226/9161.
NRC. 1994a. Alternatives for Ground Water Cleanup. https://doi.org/10.17226/2311.
NRC. 1994b. Building Consensus Through Risk Assessment and Management of the Department of Energy's Environmental Remediation Program. https://doi.org/10.17226/9480.
NRC. 1994c. Letter Report of the Committee on Buried and Tank Wastes to John E. Baublitz, Acting Deputy Assistant Secretary Environmental Restoration, U.S. Department of Energy, Concerning the Integrated Large-Scale Aquifer Pumping and Infiltration Test at INEL.
NRC. 1994d. Letter Report of the Committee on Buried and Tank Wastes to Thomas P. Grumbly, Assistant Secretary for Environmental Restoration and Waste Management, U.S. Department of Energy, Concerning Systems Analysis at Hanford.
NRC. 1993. Comments and Recommendations Based on the Report The Shallow Land Burial of Low-Level Radioactively Contaminated Solid Waste.
NRC. 1992a. HSST Panel Comments on Draft Systems Engineering Study for Closure of Hanford Single-Shell Tanks.
NRC. 1992b. Review of Analyses by the U.S. Department of Energy of Selected Technical Issues in the Environmental Protection Agency Standards for High-Level and Transuranic Radioactive Wastes (40 CFR 191).
NRC. 1992c. WIPP Committee Letter Report on Bintests at the WIPP Site.
NRC. 1991a. HSST/BTRU-INEL Panel's Letter Report of Review Comments on the Department of Energy's Intent to Prepare a Programmatic Environmental Impact Statement on the Department's Proposed Integrated Environmental Restoration and Waste Management Program.

NRC. 1991b. WIPP Panel Letter Report Summarizing Views on the Status of DOE's Scientific and Technical Program to Assess the WIPP's Ability to Isolate Transuranic (TRU) Waste and to Demonstrate Compliance with the Relevant Regulations.
NRC. 1989a. BRWM Letter Report of Review Comments on DOE's Applied Research, Development, Demonstration, Testing, and Evaluation Plan.
NRC. 1989b. BRWM Letter Report on the U.S. Department of Energy Predecisional Draft II of the Environmental Restoration and Waste Management Five-Year Plan.
NRC. 1989c. WIPP Panel Letter Report of Review Comments on DOE Document DOE/WIPP 89-011: Draft Plan for the Waste Isolation Pilot Plant Test Phase: Performances Assessment and Operations Demonstration.
NRC. 1988a. WIPP Panel Letter Report on Brine Accumulation in the WIPP Facility.
NRC. 1988b. WIPP Panel Letter Report on Intermediate-Scale Experiments of Room Closure Rates.
NRC. 1987a. BRWM Letter Report on the Defense Waste Management Plan for Buried Transuranic Waste, Transuranic Contaminated Soil, and Difficult-to-Certify Transuranic Waste.
NRC. 1987b. Scientific Basis for Risk Assessment and Management of Uranium Mill Tailings.
NRC. 1987c. WIPP Panel Letter Report on the Planned Sorbing Tracer Tests at the Waste Isolation Pilot Plant.
NRC. 1985a. BRWM Letter Report Transmitting Recommendations on the Management of Defense Wastes at Hanford to the U.S. Department of Energy.
NRC. 1985b. The Management of Radioactive Waste at the Oak Ridge National Laboratory: A Technical Review.
NRC. 1984a. Review of the Scientific and Technical Criteria for the Waste Isolation Pilot Plant.
NRC. 1984b. Social and Economic Aspects of Radioactive Waste Disposal.
NRC. 1983. Review of the Criteria for the Site Suitability, Design, Construction, and Operation of the Proposed Waste Isolation Pilot Plant (WIPP): Interim Report.
NRC. 1981. Radioactive Waste Management at the Savannah River Plant: A Technical Review.
NRC. 1980. Continuing Evaluation of the Carlsbad Site: Report to the U.S. Department of Energy.
NRC. 1979a. Implementation of Long-Term Environmental Radiation Standards: The Issue of Verification.

NRC. 1979b. Solidification of High-Level Radioactive Wastes.
NRC. 1979c. WIPP Panel Letter Report on the U.S. Department of Energy's Draft Site Characterization Report, SAND-78-1956.
NRC. 1979d. WIPP Panel Letter Report Regarding the Desirability of Sinking an Exploratory Shaft at the WIPP Site.
NRC. 1978a. Geological Criteria for Repositories for High-Level Radioactive Waste.
NRC. 1978b. Radioactive Wastes at the Hanford Reservation: A Technical Review.
NRC. 1976. Shallow Land Burial of Low-Level Radioactively Contaminated Solid Waste.
NRC. 1975. Interim Storage of Solidified High-Level Wastes.
NRC. 1974. Transportation of High-Level Nuclear Wastes: Letter Report of the Panel on Transportation of Radioactive Wastes.
NRC. 1972. An Evaluation of the Concept of Storing Radioactive Waste in Bedrock Below the Savannah River Plant Site.
NRC. 1970a. Disposal of Solid Radioactive Waste in Bedded Salt Deposits.
NRC. 1970b. Radioactive Waste Management: An Interim Report of the Committee on Radioactive Waste Management.
NRC. 1966. Review of Radioactive Waste Disposal Technology—Report to the Division of Reactor Development and Technology, U.S. Atomic Energy Commission.
NRC. 1958. Thermal Considerations in Deep Disposal of Radioactive Waste.
NRC. 1957. The Disposal of Radioactive Waste on Land. https://doi.org/10.17226/10294.
NRC. 1956. Summary report of the Committee on Disposal and Dispersal of Radioactive Wastes. In The Biological Effects of Atomic Radiation: Summary Reports from a Study by the National Academy of Sciences.

C

Committee and Staff Biographies

COMMITTEE

Patricia J. Culligan, Ph.D., is the Robert A. W. and Christine S. Carlton Professor of Civil Engineering at Columbia University and a faculty member of the Earth Institute. From July 2012 until July 2017, she served as the founding associate director of Columbia's Data Science Institute. Dr. Culligan's expertise lies in the field of geoenvironmental engineering, with an emphasis on water resource management in both urban and rural settings. She has conducted research aimed at understanding and controlling the migration of contaminants from waste disposal sites. She has also studied the behavior of miscible contaminants, non-aqueous-phase liquids and colloids in soil and fractured rock, and the effectiveness of in situ remediation strategies for the cleanup of waste sites. In addition, she has interest and experience in the design of land-based disposal sites for waste materials. Dr. Culligan has served on the National Academies of Sciences, Engineering, and Medicine's Nuclear and Radiation Studies Board and on several National Academies studies, including *Development and Implementation of a Cleanup Technology Roadmap*. She earned a B.Sc. in civil engineering from the University of Leeds and an M.Phil. and a Ph.D. in civil engineering from Cambridge University, England.

M. John Plodinec, Ph.D., has more than 40 years of experience in waste characterization and immobilization. During his involvement with the Department of Energy's Defense Waste Processing Facility (DWPF), he was responsible for programs ranging from waste characterization to waste

form development. He was the primary technical lead for the DWPF product qualification program tasked with achieving the concurrence of the regulatory community. He also coordinated waste immobilization programs across the DOE complex, and internationally, for DOE's Office of Environmental Management (EM). He represented EM in development of the Waste Acceptance Product Specifications, which govern all of the high-level waste (HLW) glass products produced in the United States. He was made a fellow of the American Ceramic Society in recognition of his work on HLW immobilization. He received his B.A. in chemistry from Franklin and Marshall College and his Ph.D. in physical chemistry from the University of Florida.

Sue B. Clark, Ph.D., is a Regents Distinguished Professor of Chemistry with tenure at Washington State University in Pullman and holds the position of Battelle Fellow and Chief Scientist and Technology Officer in the Energy and Environment Directorate with Pacific Northwest National Laboratory. In this joint appointment, she leads research efforts focused on the chemistry and chemical engineering of processing nuclear materials. Her current research areas include chemistry of radioactive waste systems, environmental chemistry, actinide separations, and radioanalytical chemistry. Her research support has included grants and contracts from the U.S. Department of Defense, the U.S. Department of Homeland Security, the U.S. Nuclear Regulatory Commission, and the U.S. Department of Energy's Office of Science and National Nuclear Security Administration. Dr. Clark served as a board member on the U.S. Nuclear and Radiation Studies Board from 2011 to 2014, and served on the National Academies' Nuclear and Radiation Studies Board from 2004 to 2009; she was also a member of many of the study committees established by the board. Dr. Clark currently serves as a consultant to the Helmholtz Association in Germany, and previously to the Nuclear Energy Agency of France, the Korean Atomic Energy Research Institute, and the Battelle Memorial Institute. She received a B.S. in chemistry from Lander College, an M.S. in inorganic chemistry from Florida State University, and a Ph.D. in inorganic and radiochemistry from Florida State University.

Paul T. Dickman, M.S., is a senior policy fellow with Argonne National Laboratory focusing on international nuclear energy, nonproliferation, and national security policy. For more than 30 years, Mr. Dickman has been in the forefront of nuclear energy and national security programs in the United States and internationally. He has held senior leadership positions at the U.S. Nuclear Regulatory Commission, where he served as chief of staff to Chairman Dale E. Klein, and at the Department of Energy's (DOE's) National Nuclear Security Administration, where he served as deputy director for

the Office of Policy. During his career, he has held several managerial and senior staff positions within DOE and the national laboratory system. He also serves as an adviser to the Japanese government on the decommissioning of the Fukushima accident site. Mr. Dickman received a B.A. in history of science from the University of Denver and an M.S. in natural sciences in nuclear chemistry and physics from the University of Wyoming.

Barbara L. Hamrick, J.D., serves as the radiation safety officer and chief health physicist at University of California, Irvine (UCI) Health. Prior to joining the UCI Health team, Ms. Hamrick spent nearly 20 years as a health physicist in regulatory programs at the federal, state, and local levels. While with the California Department of Public Health, Ms. Hamrick worked closely with other regulatory partners across multiple jurisdictions coordinating decommissioning efforts at several sites in California. She currently serves on the U.S. Environmental Protection Agency's Radiation Advisory Committee. Ms. Hamrick's professional interests lie in the acute and long-term health effects of radiation exposure, risk communication, and the intersection of science and administrative law. Ms. Hamrick received a J.D. in law from Loyola Law School in Los Angeles, and an M.S. and a B.S. in physics from UCI. She is a diplomate of the American Board of Health Physics and a fellow of the Health Physics Society.

Robert T. Jubin, Ph.D., is project manager for the Department of Energy's Nuclear Technology Research and Development—Material Recovery and Waste Form Development Programs at Oak Ridge National Laboratory. He has more than 40 years of experience with nuclear fuel reprocessing, including solvent extraction and development of advanced centrifugal contactors; management of volatile radionuclides; and management of gaseous radioactive wastes. His solvent extraction experience includes an extended assignment with the Commissariat à l'Énergie Atomique et aux Énergies alternatives at Fontenay-aux-Roses, near Paris, France, where he helped to develop the DIAMEX process for separation of actinides and lanthanides from high-level liquid wastes. Dr. Jubin is a fellow of the American Institute of Chemical Engineers and received its 2013 Robert E. Wilson Award for outstanding chemical engineering contributions and achievements in the nuclear industry. He received the 2016 American Nuclear Society Fuel Cycle & Waste Management Division Significant Contributions Award for his work in the area of nuclear fuel reprocessing and radioactive waste treatment technologies. He also chairs the American Society of Mechanical Engineers' Gas Processing Subcommittee. He retired from the U.S. Air Force Reserve in 2007 at the rank of colonel. He received a B.S. in chemical engineering from the University of Akron and an M.S. in engineering management and a Ph.D. in chemical engineering, both from the University of Tennessee.

William Lee, Ph.D., is co-director of the Institute of Security Science and Technology at Imperial College London and Ser Cymru Professor in Materials for Extreme Environments, Nuclear Futures Institute, Bangor University, United Kingdom. His research focuses on the relation between processing, properties, and microstructures in a broad range of ceramics. He is the immediate past president of the American Ceramic Society, a member of the Leverhulme Trust Panel of Advisors, the Royal Academy of Engineering International Activities Committee, and the Scientific and Environmental Advisory Board, Tokamak Energy Ltd. He is also an International Atomic Energy Agency technical expert. Dr. Lee was deputy chair of the UK government Advisory Committee on Radioactive Waste Management from 2007 to 2013, a member of the UK government's Nuclear Innovation and Research Advisory Board from 2014 to 2017, and has acted as special advisor nuclear to the House of Lords Science and Technology Committee (2013). He received a B.Sc. in physical metallurgy from Aston University and a D.Phil. in radiation damage in sapphire from Oxford University.

Alexandra Navrotsky, Ph.D., is the Distinguished Interdisciplinary Professor of Ceramic, Earth and Environmental Materials Chemistry and the Edward Roessler Chair in Mathematical and Physical Sciences at the University of California, Davis (UC Davis). Her research interests have centered on relating microscopic features of structure and bonding to macroscopic thermodynamic behavior in minerals, ceramics, and other complex materials. She has made contributions to mineral thermodynamics, mantle mineralogy, and high-pressure phase transitions; silicate melt and glass thermodynamics; order-disorder in spinels, framework silicates, and other oxides; ceramic processing; oxide superconductors; nanophase oxides, zeolites, nitrides, and perovskites; and the general problem of structure-energy-property systematics. The main technical area of her laboratory is high-temperature reaction calorimetry. She is director of the UC Davis Organized Research Unit on Nanomaterials in the Environment, Agriculture and Technology. She received a B.S., an M.S., and a Ph.D. from the University of Chicago. She was elected to the National Academy of Sciences in 1993.

James A. Rispoli, M.Sc., M.A., is a former assistant secretary of energy for environmental management who served for 3.5 years during the administration of President George W. Bush. As assistant secretary of energy, Mr. Rispoli led the nation's cleanup of waste and environmental contamination from nuclear-related research and production activities. He managed the largest capital construction portfolio in the Department of Energy (DOE), with the biggest project valued at more than $12 billion and the smallest in excess of $400 million. His previous position was as director of the DOE's Office of Engineering and Construction Management. He

is currently senior executive advisor at Project Time and Cost, LLC, an Atlanta-based engineering company of which he was previously president and CEO for 3 years. Additionally, he is a professor of practice at North Carolina State University, where he teaches at the graduate level. Prior to joining DOE, Mr. Rispoli was vice president and managing principal of Dames & Moore's Pacific-Ocean area operations, and president of M&E Pacific, responsible for Metcalf and Eddy's Hawaii offices. In both firms, he led major engineering, environmental, and construction projects for private clients and state and federal governmental agencies. He served in the U.S. Navy, retiring at the rank of captain, Civil Engineer Corps, where he held executive-level environmental, construction, and facilities management positions. He serves on the National Academies' Board on Infrastructure and the Constructed Environment and is chair of the NAS's Federal Facilities Council. Mr. Rispoli also serves on DOE's Environmental Management Advisory Board. Mr. Rispoli received a B.Eng. in civil engineering from Manhattan College, an M.Sc. in civil engineering from the University of New Hampshire, and an M.A. in business management from Central Michigan University. A licensed engineer in five states, he is a board-certified environmental engineer (radiation protection), a distinguished member of the American Society of Civil Engineers, and a member of the National Academy of Construction.

Rebecca A. Robbins, Ph.D., is currently the predisposal unit head within the Division of Nuclear Fuel Cycle and Waste Technology at the International Atomic Energy Agency (IAEA). In this role she is responsible for working with IAEA member states to develop and disseminate IAEA guidance in all aspects of the characterization, processing, packaging, and storage of radioactive waste. She has more than 20 years of experience in the nuclear industry, working originally for BNFL in the United Kingdom and then its associated companies in the United States, including EnergySolutions. She began her career working in research and development into innovative waste management technologies at BNFL's corporate laboratory before moving into the field of low-level waste (LLW) disposal. She supported the post-closure safety case for the UK LLW disposal site at Drigg and the development and deployment of technologies for processing of radioactive waste for storage and disposal. She has devised and implemented process flowsheets for both solid and liquid waste processing plants, including the Advanced Mixed Waste Treatment Plant for the processing of 65,000 m^3 of transuranic waste at the Idaho National Laboratory site for BNFL Inc. Her expertise in radioactive waste management has been applied to the development of strategies to manage legacy waste cleanup challenges worldwide for both governmental and commercial entities. She served on the National Academies' Planning Committee on Low-Level Radioactive

Waste Management and Disposition: A Workshop. She earned a Ph.D. in chemistry from the University of Leeds, United Kingdom.

Robin D. Rogers, Ph.D., is a research professor at the University of Alabama and president, owner, and founder of 525 Solutions, Inc., in Tuscaloosa, Alabama. He has previously served at Northern Illinois University as presidential research professor; the University of Alabama as Robert Ramsay Chair of Chemistry, distinguished research professor, and director of the Center for Green Manufacturing; Queen's University of Belfast in Northern Ireland as chair of Green Chemistry and co-director of QUILL; the Chinese Academy of Sciences Institute for Process Engineering as honorary professor; and McGill University as Canada Excellence Research Chair in Green Chemistry and Green Chemicals. His research interests cover the use of ionic liquids and green chemistry for sustainable technology through innovation and include materials (advanced polymeric and composite materials from biorenewables), separations (novel strategies for separation and purification of value-added products from biomass), energy (new lubricant technologies and selective separations), and medicine (elimination of waste while delivering improved pharmaceutical performance). He has served on several National Academies studies on radioactive waste management and cleanup. Dr. Rogers obtained a B.S. and a Ph.D. in chemistry from the University of Alabama.

Pol D. Spanos, Ph.D., is Lewis B. Ryon Professor of Mechanical Engineering and of Civil Engineering at Rice University. Professor Spanos's research efforts focus on the dynamics and vibrations of structural and mechanical systems under a variety of loads. Systems exhibiting nonlinear behavior and/or exposed to hazard- or risk-inducing conditions receive particular attention. His group is also interested in fatigue and fracture issues of modern composite materials and in signal-processing algorithms for dynamic effects in biomedical applications. Solution techniques developed by Professor Spanos are applied to diverse areas such as vehicle and robot dynamics; estimation of seismic spectra; flow-induced vibrations of offshore rigs, marine risers, and pipelines; dynamic analysis and certification of payloads in aerospace missions; directional oil well drilling; vibration and aseismic protection of structures and equipment; wind loads simulation; and signal processing for electrocardiograms, electroencephalograms, and bone mechanics. He is a member of the academies of several foreign countries, the U.S. National Academy of Engineering, and the American Academy of Arts & Sciences. He received a 5-year diploma in engineering sciences and mechanical engineering from the National Technical University of Athens and an M.S. in civil engineering and a Ph.D. in applied mechanics from the California Institute of Technology.

STAFF

Ourania (Rania) Kosti, Ph.D., is a senior program officer at the National Academies of Sciences, Engineering, and Medicine's Nuclear and Radiation Studies Board (NRSB). Dr. Kosti's interests within the NRSB focus on radiation health effects, and she is the principal investigator for the National Academies' Radiation Effects Research Foundation Program that supports studies of the atomic bombing survivors in Japan. Prior to her current appointment, she was a postdoctoral fellow at the Lombardi Comprehensive Cancer Center at Georgetown University Hospital in Washington, DC, where she conducted research on biomarker development for early cancer detection using case-control epidemiological study designs. She focused primarily on prostate, breast, and liver cancers and trying to identify those individuals who are at high risk of developing malignancies. Dr. Kosti also trained at the National Cancer Institute (2005–2007). She received a B.Sc. in biochemistry from the University of Surrey, United Kingdom, an M.Sc. in molecular medicine from University College London, and a Ph.D. in molecular endocrinology from St. Bartholomew's Hospital in London, United Kingdom.

Kevin D. Crowley, Ph.D., has been an advisor to the NRSB since entering phased retirement in August 2017. His professional interests focus on the application of science and technology to improve societal well-being, advance public policy making, and enhance international cooperation, particularly with respect to the safety, security, and efficacy of nuclear and radiation-based technologies and applications. He previously held several positions at the National Academies, including senior board director of the NRSB (2005–2017), director of the Board on Radioactive Waste Management (1996–2005), and principal investigator for a long-standing cooperative agreement between the National Academy of Sciences and the Department of Energy to provide scientific support to the Radiation Effects Research Foundation in Hiroshima, Japan (2010–2017). Before joining the National Academies staff in 1993, Dr. Crowley held teaching and research positions at Miami University of Ohio, the University of Oklahoma, and the U.S. Geological Survey. He holds an M.A. and a Ph.D., both in geology, from Princeton University.

D

Presentations and Site Visits

December 5, 2017, Washington, DC, Presentations

- Overview of Environmental Management Science and Technology Program. Rodrigo V. Rimando, Jr., Department of Energy–Office of Environmental Management.
- Report of the Secretary of Energy Advisory Board's Task Force on Technology Development for Environmental Management. Richard A. Meserve, Covington & Burling LLP.
- Comments from Congress on the Study Request. Drew Walter and Leonor Tomero, House Armed Services Committee.
- Perspectives from the Government Accountability Office. David Trimble and Timothy Persons, Government Accountability Office.
- Perspectives from the Nuclear Regulatory Commission on Science and Technology for the Department of Energy's Defense Environmental Cleanup Program. Christine Ridge, U.S. Nuclear Regulatory Commission.

January 29–31, 2018, Savannah River, South Carolina, Presentations and Site Visit

- Savannah River Remediation Technology Deployment Initiatives and Needs. Kent Fortenberry, Vijay Jain, and David Dooley, Savannah River National Laboratory.

- Incorporating Innovation into Soil and Groundwater Cleanup at the Savannah River Site. Brian Looney, Savannah River National Laboratory.
- Innovative Technologies and Approaches for Excess Assets Nuclear Facility Deactivation and Decommissioning Operations. Mike Serrato, Savannah River National Laboratory.
- Technology Impacts of NM Processing and Disposition. Bill Bates and Jimmy Winkler, Savannah River National Laboratory.
- Specific Technology and Deployment Initiatives and Needs in SRS Nuclear Materials. Bill Bates and Jimmy Winkler, Savannah River National Laboratory.
- SRNL's Role in EM Mission Success. Jeff Griffin, Savannah River National Laboratory.
- Technology Impacts to Liquid Waste Mission. David Dooley, Savannah River National Laboratory, and Kent Fortenberry, Savannah River Remediation.
- Soil, Groundwater, and D&D Technology Implementation and Needs. Chris Bergen, Savannah River Nuclear Solutions.
- Comments from the Environmental Protection Agency. Jon Richards, Environmental Protection Agency.
- Perspectives from the Savannah River Site Citizens Advisory Board. Gil Allensworth, Savannah River Site Citizens Advisory Board.
- Perspectives from the Citizens for Nuclear Technology Awareness. James Marra, Executive Director, Citizens for Nuclear Technology Awareness.
- Perspectives from the Community Reuse Organization. Rick McLeod, Community Reuse Organization.
- Perspectives from the SRS Heritage Foundation. Joseph Ortaldo and Walt Joseph, SRS Heritage Foundation.

April 23–25, 2018, Hanford, Washington, Presentations and Site Visit

- Hanford Overview. Brian Vance and Jon Peschong, Office of River Protection.
- Overview of Office of River Protection Mission Challenges, Opportunities, Highlights, and Recommendations. Elaine Diaz, Office of River Protection.
- Office of River Protection Key Technology Development Priorities for FY18. Naomi Jaschke, Office of River Protection.
- WRPS Technology Development Process and Initiatives. Jason Vitali, Washington River Protection Solutions.
- Perspectives from Hanford Communities. Pam Larsen, Hanford Communities.

- Perspectives from the Hanford Advisory Board. Susan Leckband, Hanford Advisory Board.
- Perspectives from the Tri-Cities Development Economic Council. David Reeploeg, Tri-Cities Development Economic Council.
- Perspectives from the Washington State Department of Ecology. Alex Smith, Washington State Department of Ecology.
- Nez Perce Tribe's Involvement with Cleanup at the Hanford Site. Jack Bell, Nez Perce Tribe Environmental Restoration and Waste Management Program.
- Perspectives from Confederated Tribes of the Umatilla Indian Reservation. Matt Johnson, Confederated Tribes of the Umatilla Indian Reservation.
- Perspectives from Yakama Nation Fisheries. Dave Rowland, Yakama Nation Fisheries.

May 16–17, 2018, Idaho Falls, Idaho, Presentations and Site Visit

- Idaho Department of Environmental Quality Communications Related to CERCLA Projects at the Idaho National Laboratory. Mark Clough, Idaho National Laboratory.
- Integrated Waste Treatment Unit Approach to Resolve Issues and Prepare for Operations. Joe Giebel and Leo Thompson, Fluor Idaho.
- Idaho Spent Fuel Overview. Ken Brewer, Fluor Idaho.
- Calcine Retrieval Project Update. Howard Forsythe, Fluor Idaho.
- Dry Storage of Aluminum-Clad Spent Nuclear Fuel. Michael Connolly, Idaho National Laboratory.
- Behavior/Chemistry of Oxyhydroxide Layers During ASNF Dry Storage. Tedd Lister, Idaho National Laboratory.
- Radiation Chemistry Inside Aluminum-Clad Spent Nuclear Fuel Dry Storage Canisters. Gregory Horne, Elizabeth Parker-Quaiffe, and Peter Zalupski, Idaho National Laboratory; and Chris Vest and Charles Crawford, Savannah River National Laboratory.
- Multiphysics Modeling of Coupled Thermal Convective Transport of Radiolysis Generated Species Inside Sealed and Unsealed Canisters. Hai Huang and Alex Abbound, Idaho National Laboratory; Kellie Metzger and Tracy Rudisill, Savannah River National Laboratory.
- Perspectives from the Idaho Department of Environmental Quality. Mark Clough, Idaho Department of Environmental Quality.
- Chairs Round Robin EM SSAB Chairs Meeting. Keith Branter, Idaho Cleanup Project Citizens Advisory Board.
- Perspectives from the Regional Economic Development Eastern Idaho. Dana Kirkham, Regional Economic Development Eastern Idaho.

- Perspectives from Fort Hall Business Council, Shoshone-Bannock Tribes. Talia Martin, Fort Hall Business Council, Shoshone-Bannock Tribes.

August 8–9, 2018, Portsmouth, Ohio, Presentations and Site Visit

- Technology Impacts. Marty Reibold, Fluor.
- Future Needs and Potential Technologies. Marty Reibold and J. D. Chiou, Fluor.
- Programmatic Path Forward. Marty Reibold and J. D. Chiou, Fluor.
- Perspectives from Ohio EPA. Jim Sferra.
- Perspectives from PORTS Environmental Management Site Specific Advisory Board. Julie Galloway, Portsmouth Site Advisory Board.
- Perspectives from Southern Ohio Diversification Initiative. Kevin Shoemaker, Southern Ohio Diversification Initiative.

August 9–10, 2018, Oak Ridge, Tennessee, Presentations and Site Visit

- Technology Development and Challenges at Oak Ridge. Kent Fortenberry, UCOR.
- Deactivation and Demolition (D&D) Processes and Future D&D Challenges Where Technologies Are Needed. John Wrapp, Oak Ridge Reservation.
- ORR Waste Stream Challenges: Where Technologies Are Needed. John Wrapp, UCOR.
- Overview of Mercury Contamination at the Oak Ridge Y-12 Site: History, Hydrogeochemical Setting, and Challenges. Scott Brooks, Oak Ridge National Laboratory.
- The Use of Science and Technology to Address Mercury at Y-12. Janice Hensley, UCOR.
- ORR Environmental Remediation Issues That Could Benefit from Technology Development. R. H. Ketelle, Environmental Management Operations, UCOR.
- Integration of Science and EM. Eric Pierce, Oak Ridge National Laboratory.
- Perspectives from the Tennessee Department of Environmental Conservation. Mike Higgins, Tennessee Department of Environmental Conservation.
- Perspectives from the Oak Ridge Site Specific Advisory Board. Dennis Wilson, Oak Ridge Site Specific Advisory Board.
- Perspectives from the Energy Technology and Environmental Business Association. Tim Griffin, Energy Technology and Environmental Business Association.

- Perspectives from the Oak Ridge City Council. Ellen Smith, Oak Ridge City Council.

PRESENTATIONS VIA REMOTE CONFERENCING

March 14, 2018

- Pathways from Scientific Advances to Technology Development Relevant to DOE-EM's Cleanup Mission: Energy Frontier Research Centers. Andy Schwartz, Energy Frontier Research Centers, Office of Basic Energy Sciences, Department of Energy.
- Biological and Environmental Research. Sharlene Weatherwax, Biological and Environmental Research, Office of Basic Energy Sciences, Department of Energy.

May 3, 2018

- A Robotics Perspective. Philip Heermann, Sandia National Laboratories.
- UK Nuclear Robotics in Twelve Minutes. Robert Buckingham, UKAEA.
- Unmanned Aerial Systems for Primary Containment Vessel Exploration. Monica Garcia, Southwest Research Institute.
- NASA and DOE-EM Robotics. Robert Ambrose, NASA JSC Engineering.
- Applied Research in Robotics and Remote Systems for Nuclear Environments. Bill Hamel, University of Tennessee, Knoxville.

May 31, 2018

- Convergent Research to Address Societal Needs. Joseph DeSimone, University of North Carolina.
- Growing Convergence Research at NSF. Dragana Brzakovic, National Science Foundation.
- Collaboration Models for High Impact Research and Development in DOE-EERE. Michael Berube, Vehicle Technologies Office, Department of Energy.
- Traveling Wave Reactor: Lessons Learned. John Gilleland, TerraPower.

June 4, 2018

- Waste Management Working Group Presentation for the National Academies for the National Academies Assessment of Science and Technology for DOE-EM Environmental Cleanup Program. Sonny Goldston, EFCOG Waste Management Working Group.

August 21, 2018

- Briefing from John Marra, Chief Engineer, DOE-EM.

September 7, 2018

- Advanced Waste Glass Program. John Vienna, Pacific Northwest National Laboratory.
- Office of River Protection Glass Science Program. Albert A. Kruger, Office of River Protection.

October 5, 2018

- Briefing from Mark Gilbertson and Kenneth G. Picha, DOE-EM.

October 15, 2018

- Nuclear Decommissioning Authority R&D: Delivering Progress in Nuclear Decommissioning. Melanie Brownridge and James McKinney, Nuclear Decommissioning Authority, UK.

October 19, 2018

- Briefing from Rodrigo V. Rimando, Jr., Technology Development Office, DOE-EM.

E

DOE Sites Visited by the Committee

The committee visited five Department of Energy (DOE) sites during the study. This appendix provides a brief description of these sites, including their roles during the Manhattan Project and Cold War and major cleanup activities since 1989, when DOE's Office of Environmental Management (EM) was established. Information in this appendix was obtained primarily from the following two sources: NRC (2010) and the DOE fiscal year (FY) 2019 congressional budget request (DOE, 2018).

HANFORD SITE

The Hanford Site consists of 1,500 square kilometers in southeastern Washington adjacent to the Columbia River. It was established in 1943 to produce plutonium and perform research on plutonium production. Its mission ended in 1987. Most of the activities at the site occurred in three distinct industrial zones, referred to as "areas": fuel fabrication took place in the 300 Area; fuel irradiation in the 100 Area; and chemical processing of the irradiated fuel in the 200 Area (also referred to as the "Central Plateau"). The 1989 Hanford Federal Facility Agreement and Consent Order, or Tri-Party Agreement, among DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology provides the regulatory framework for cleanup activities at Hanford.

Two offices manage the cleanup activities at Hanford: The Office of River Protection (ORP) manages the treatment of radioactive liquid waste in underground storage tanks. ORP also manages the Waste Treatment and Immobilization Plant project that aims to immobilize Hanford's tank

wastes for both onsite and offsite disposal. The Richland Operations Office (RL) manages all remaining cleanup activities at Hanford, including soil and groundwater remediation, facility decontamination and demolition, stabilization and disposition of nuclear materials and spent nuclear fuel, and disposition of wastes other than the tank wastes.

IDAHO SITE

The Idaho Site consists of 2,300 square kilometers in the desert of eastern Idaho, along the western edge of the upper Snake River Plain. It was established in 1949. Its mission was to design and test nuclear reactors and reprocess spent nuclear fuel, primarily from research, test, and naval reactors, to recover fissile materials. Its current mission is to conduct research and testing of new nuclear reactor concepts under DOE's Office of Nuclear Energy. The site has distinct geographic areas: the Idaho Nuclear Technology and Engineering Center (INTEC), the Materials and Fuels Complex, the Central Facilities Area, the Advanced Reactor Technology Complex (RTC), the Radioactive Waste Management Complex (RWMC), and Test Area North (TAN). The 1995 Settlement Agreement among the State of Idaho, DOE, and the U.S. Navy provides the regulatory framework for cleanup activities at Idaho.

The site's cleanup mission is carried out under the Idaho Cleanup Project (ICP). ICP has several objectives, including the treatment of sodium-bearing waste currently stored in underground tanks at INTEC, removing targeted waste from subsurface disposal in the RWMC, transferring transuranic waste out of Idaho, removing DOE's inventory of spent nuclear fuel and calcine waste from Idaho, and demolishing inactive facilities.

OAK RIDGE RESERVATION

The Oak Ridge Reservation consists of 225 square kilometers west of Knoxville, Tennessee. The reservation was established in the early 1940s and has three industrial areas: Oak Ridge National Laboratory (ORNL) is an active federal research facility that was originally constructed as a research and development facility to support plutonium production technology. The Y-12 National Nuclear Security Site (Y-12) is an active federal manufacturing and storage facility that was built to produce highly enriched uranium by electromagnetic separation and is now used to store the nation's supply of enriched uranium and manufacture parts for nuclear weapons. The site now referred to as the East Tennessee Technology Park (ETTP) hosted five plants for enriching uranium using the gaseous diffusion process. All of those plants have been demolished and the site is now a private industrial park. The 1992 Federal Facility Agreement for the Oak Ridge Reservation among

DOE, EPA, and the Tennessee Department of Environment and Conservation provides the regulatory framework for cleanup activities at Oak Ridge.

The site's cleanup mission includes operation of the onsite disposal facility and other waste management facilities, processing of legacy transuranic waste debris at the Transuranic Waste Processing Center, as well as demolition of remaining DOE-EM facilities at East Tennessee Technology Park, Oak Ridge National Laboratory, and the Y-12 National Security Complex. The mission may be expanded in the future to include excess facilities identified by ORNL and Y-12. The site awarded a contract and is at early stages of constructing the Outfall 200 Mercury Treatment Facility for mercury remediation at Y-12.

PORTSMOUTH

The Portsmouth Site consists of 15 square kilometers at Piketon, Ohio. It was established in 1956 with the mission to produce enriched uranium to support the nation's nuclear weapons program and the U.S. Navy, and later (in the 1960s) to enrich uranium for use by commercial nuclear reactors. Uranium enrichment operations ceased in 2001. A 1989 U.S. District Court Consent Decree establishes the Ohio EPA as the oversight body for the site's cleanup.

Cleanup activities at Portsmouth primarily involve D&D of inactive facilities.

SAVANNAH RIVER

The Savannah River Site (SRS) consists of 800 square kilometers near Aiken, South Carolina. The site was established in 1950 to produce special radioactive isotopes for use in the production of nuclear weapons, primarily plutonium and tritium. The site contains five production reactors (none are active today; two are used for storing nuclear materials), two chemical separation plants (one, the H Canyon, is still active), and fuel fabrication facilities. Additionally, a heavy-water extraction plant was built to supply heavy water for SRS reactor operations. SRS remains an active DOE research site with research and development activities conducted at the Savannah River National Laboratory (SRNL) and other laboratories onsite. SRNL was recognized as DOE-EM's corporate laboratory in 2006. The 1993 Federal Facility Agreement among DOE, EPA, and the South Carolina Department of Health and Environmental Control provides the regulatory framework for cleanup activities at Savannah River.

Cleanup activities at SRS are carried out under the Liquid Waste Program. This program manages the tank farms, operates the Defense Waste Processing Facility (DWPF) for vitrification of high-level waste stored in

underground tanks at the site, and operates the Saltstone Production and Disposal Facility for the disposal of low-activity radioactive waste. The program will also be responsible for managing the Salt Waste Processing Facility which is currently under development. This facility is designed to separate cesium, strontium, and actinides from liquid tank wastes for immobilization in the DWPF and reduce the activity of waste destined for disposal in the saltstone facility.

Robert Berry, Chair
Portsmouth EM Site Specific Advisory Board

Under Item VI. DECISION MAKING, Section C. *Requirements for Recommendations to EM*, Subsection 1 of the Portsmouth EM Site Specific Advisory Board Operating Procedures as revised on October 7, 2011, it states: "If consensus or a 2/3 majority cannot be reached, a majority and a minority report(s) may be written. These reports may be submitted to EM, but must be clearly marked as representing two (or more) points of view."

Further, Subsection 4 states: "...all recommendations will be signed by the Chair and Vice Chair and conveyed to EM in writing within fifteen (15) calendar days."

In addition, Subsection 5 states: "The Board requests that EM provide timely response to the Board recommendations and explain the basis for EM's decision and how it will implement any recommendations that are accepted."

All without consideration as to whether the recommendation was achieved by consensus, by 2/3 majority or by simple majority/minority of members of the Board present.

Therefore, please find attached the Board majority report on Recommendation 18-02, which requires signatures of Chair and Vice Chairs and conveyance to EM within fifteen (15) calendar days of today's date of June 6, 2019.

Respectfully,

Dennis J. Foreman
On Behalf of the Board majority

ATTM.

Cc: Greg Simonton, DOE Federal Coordinator
Eric Roberts, EHI Consultants

PORTS SSAB

Portsmouth EM Site Specific Advisory Board

Chair
Robert Berry

Vice Chair
Lisa Bennett
Carlton Cave

Board Members
Dr. Todd A. Burkitt
Bradley Burns
Maddeline C. Caudill
Al Don Cisco
Jody B. Crabtree
Dennis J. Foreman
Wade R. Fraley
Brandon Greene
Carl R. Hartley
Turman L. Helton
Ronda J. Kinnamon
Irma C. Payne
Cynthia Quillen
Jimmy E. Smalley
Beckie J. Thomas-Kent
Judy R. Vollrath

Deputy Designated Federal Official
Joel Bradburne

DOE Federal Coordinator
Greg Simonton

SUPPORT SERVICES
EHI CONSULTANTS
PHONE: 740-289-5249
FAX: 740-289-1578
EMAIL: JULIE@PORTS-SSAB.ORG

Recommendation 18-02
May 10, 2018

RECOMMENDATION 18-02: Portsmouth (PORTS) Environmental Management (EM) Site Specific Advisory Board (SSAB) Recommends DOE Open Waste Disposition Record of Decision and Offer Second Public Comment Period

BACKGROUND: From the beginning of the Portsmouth Decontamination and Decommissioning Project, the issue of waste disposition has been at the center of public dialogue. Many community groups, including this board, have provided input, all with the common goals of providing future economic opportunities and environmental protections for the region.

Despite this agreement, how the D&D waste is to be disposed has been a divisive and damaging topic for our communities. It is the position of the Portsmouth SSAB that the waste disposition issue is unresolved and the longer this divide exists, the deeper the wounds will become among concerned parties. The waste disposition issue needs a conclusion that is satisfactory to the public and there are such varying views on the topic that it is unclear which path forward is appropriate.

Therefore, the Portsmouth SSAB offers the following recommendation to finally bring this issue to an end so we can all move forward toward our collective, and broader, objectives.

RECOMMENDATION: The Portsmouth SSAB recommends the U.S. Department of Energy open the Waste Disposition Record of Decision and provide a second Public Comment Period that could lead to modifications to the existing Record of Decision. This recommendation does not call for any specific modifications with the understanding the board would provide input at the time of the second Public Comment Period. Rather, the board's position is that a second Public Comment Period is necessary based on the level of unrest and uncertainty that exists on the issue of waste disposition within multiple segments of our community.

This is not a criticism of DOE's previous process, but rather a recognition that many citizens believe additional information has come to light that the public should have had access to before the initial Public Comment Period (e.g., TSCA requirements, geological conditions, etc.). Regardless of the merit of those arguments, there is no debate that a community consensus on this issue does not exist and that a second, and final, Public Comment Period will give the community an opportunity to demonstrate community preference to DOE for how the D&D waste is to be disposed.

It should be noted that the Portsmouth SSAB has consistently taken a position that on-site disposal is acceptable under certain conditions. DOE has yet to formalize the commitments requested by the board in Recommendation 13-02, although the recent

efforts by DOE to more firmly commit DOE to the consolidation of landfills and plumes within Perimeter Road is appreciated. However, as illustrated in Portsmouth SSAB Recommendation 15-05, the board does not accept on-site disposal unless all conditions outlined in 15-05 are formally committed to in regulatory agreements.

The Portsmouth SSAB would like to thank DOE for its interaction with the board. The DOE has consistently offered detailed information to the board on a range of complex topics. The board believes this type of interaction with the community is imperative and that there is value in understanding community concerns. For those same reasons, the board believes this recommendation offers a viable path forward to a conclusion of this controversy, a conclusion that is necessary for our community and for project continuity.

Thank you.

Department of Energy
Washington, DC 20585

October 4, 2019

Robert Berry, Chair
Portsmouth Site Specific Advisory Board
1862 Shyville Road, Suite 115
Piketon, Ohio 45661

Dear Mr. Berry:

Thank you for your August 26 letter, providing the Environmental Management Site-Specific Advisory Board (EM SSAB) recommendations concerning improving the Office of Environmental Management's (EM) Science and Technology (S&T) Program. It is my understanding that the EM SSAB Chairs wish to respond to the National Academies of Sciences' (NAS) report, "Independent Assessment of Science and Technology for the Department of Energy's (DOE) Defense Environmental Cleanup Program" (2019), which assesses the success of the EM S&T program, a program that defines needs for near-term and out-year cleanup of radioactive material.

We appreciate the Chairs' engagement to ensure successful EM cleanup efforts. EM Headquarters has previously met with NAS representatives concerning this report. We were pleased to see that NAS, EM SSAB, and EM share a common interest with regard to the EM S&T program direction.

As we move forward with our EM Technology Development program, we plan to take the NAS and EM SSAB findings and recommendations into consideration. The first step taken to address the NAS and EM SSAB recommendations is understanding the current capital technology investment in the field. At this time, EM's Technology Development office at DOE-Headquarters is teaming with DOE-EM field offices to conduct an assessment of all technology development activities currently being sponsored, to determine if the projects are focused on addressing high-priority, near-term site needs. At the conclusion of each site review, recommendations will be made to the site office. In addition, we plan to host a meeting with the Advanced Research Projects Agency-Energy (ARPA-E) to discuss their involvement and make a determination on a path forward.

We are also requesting the Environmental Management Advisory Board to review the NAS Report and provide their recommendations on how to best utilize our limited resources to realign the S&T Program.

Please note that DOE continues to conduct internal analyses and evaluations of breakthrough solutions with technical merit to reduce risk, schedule, and cost that address implementation of those recommendations posed by the EM SSAB on the NAS report.

Thank you for your continued support of EM's environmental cleanup mission. If you have any questions, please contact Mr. David Borak, EM SSAB Designated Federal Officer, at (202) 586-9928, or Mr. Kurt Gerdes, Director for Technology Development, at (301) 903-7289.

Sincerely,

William I. White
Senior Advisor for Environmental Management
to the Under Secretary for Science

cc: Jeff Griffin, EM-3
Kurt Gerdes, EM-3.2
Elizabeth Connell, EM-4
Linda Suttora EM-4.3 (Acting)
David Borak, EM-4.32