CHPRC-03379
Draft A

Corrective Actions to Ensure Safe Storage of Waste in The Plutonium Uranium Extraction Plant Storage Tunnels 1 and 2

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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APPROVED
By Julia Raymer at 11:42 am, Aug 01, 2017

Release Approval Date

Executive Summary

On May 9, 2017, workers discovered a partial collapse of the timber roof structure in a portion of the Plutonium Uranium Extraction (PUREX) Plant Storage Tunnel 1 (hereinafter referred to as Tunnel 1). Actions were taken immediately to protect personnel in the area, monitor for potential releases, notify the regulatory agencies and public of the event, and implement response actions. Initial response actions included backfilling the collapsed zone with soil to provide radiation shielding, contamination control, protection from ambient conditions, and localized stabilization of the tunnel support structure. A temporary cover was placed over the tunnel to minimize water infiltration and provide a limited amount of dust/contamination control in the event of a future collapse. Additional surveillance activities of the tunnel were also implemented.

Because some of the waste is hazardous/dangerous waste, the PUREX tunnels are regulated under the *Resource Conservation and Recovery Act of 1976*[1] (RCRA) and the *Washington State Hazardous Waste Management Act of 1976*[2] and are included in the Hanford Facility RCRA Permit.[3] The PUREX tunnels are permitted as "miscellaneous units," subject to the requirements of WAC 173-303-680.[4] The partial collapse at Tunnel 1 prompted the Washington State Department of Ecology (Ecology) to issue Administrative Order (AO) Docket No.14156 to the U.S. Department of Energy (DOE) and CH2M HILL Plateau Remediation Company (CHPRC) directing three corrective actions.[5] This report provides the response to AO Corrective Action 2, which requires submittal of a draft report to Ecology by August 1, 2017 detailing corrective actions to

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[1] *Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq. Available at: https://elr.info/sites/default/files/docs/statutes/full/rcra.pdf.

[2] RCW 70.105, "Hazardous Waste Management," *Revised Code of Washington*, Olympia, Washington. Available at: http://apps.leg.wa.gov/RCW/default.aspx?cite=70.105.

[3] WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Revision 8c, as amended, Washington State Department of Ecology. Available at: http://www.ecy.wa.gov/programs/nwp/permitting/hdwp/rev/8c/index.html.

[4] WAC 173-303-680, "Dangerous Waste Regulations," "Miscellaneous Units," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-303-680.

[5] 17-NWP-053, 2017, "Administrative Order Docket #14156, United States Department of Energy - Hanford Site - PUREX Tunnel 1, WA7890008967," (letter to Doug. S. Shoop, U.S. Department of Energy, Richland Operations Office, and Ty Blackford, CH2M HILL Plateau Remediation Company, from Alexandra K. Smith), Washington State Department of Ecology, Richland, Washington, May 10. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0071344H.

ensure the safe storage of waste in Tunnel 1 and PUREX Storage Tunnel 2 (hereinafter referred to as Tunnel 2).

On May 31, 2017, DOE notified Ecology of its plan to address a significant threat of further failure of Tunnel 1 by void filling the tunnel with engineered concrete/grout (grout). This would be conducted as part of continuing response actions in accordance with Section J.4.5 of the Hanford Facility RCRA Permit PUREX Storage Tunnels contingency plan. Ecology responded to DOE on June 8, 2017, approving the plan to grout Tunnel 1 as a continuing response action and interim stabilization measure for the tunnel structure that would not preclude future closure or remedial decisions. The use of grout as void fill has been successful at the Hanford Site and throughout the DOE complex and can be effectively implemented at a reasonable cost.

During June 2017, structural integrity evaluations of Tunnels 1 and 2 were completed pursuant to AO Corrective Action 1. The Tunnel 1 structure was found to be overstressed and at risk of future collapse, confirming the need for near-term stabilization of the structure to ensure safe storage in Tunnel 1. The Tunnel 2 structure was also found to have overstressed design elements and is considered to have a potential risk for localized collapse. In response to this new information, additional surveillances were established for Tunnels 1 and 2.

In accordance with AO Corrective Action 2, a range of response actions were identified as potential options to ensure safe storage of waste in Tunnel 2. A phased approach of enhanced surveillance and monitoring will be conducted at Tunnel 2 until a response action is selected and implemented. A “Best and Brightest” panel will be convened to consider the tunnel design, operating history, and waste inventory to conduct an initial analysis of options and identify data needs. The output of the panel will feed a detailed alternative analysis for Tunnel 2. A response action for Tunnel 2 will be selected in consultation with the panel following the completion of the detailed alternative analysis.

The continuing response actions for Tunnel 1 will improve tunnel stability, provide additional radiological protection, and increase durability while not precluding future remedial actions or final closure decisions. Enhanced surveillance and monitoring of Tunnel 2 will ensure safe operations of the tunnel until a further response action is selected and implemented.

Contents

Figures

Tables

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Terms

AO	Administrative Order
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
Ecology	Washington State Department of Ecology
GPS	global positioning system
HDPE	high-density polyurethane
HDS	high-definition surveying
LiDAR	Light Detection and Ranging
PUREX	Plutonium Uranium Extraction (Plant)
RI/FS	remedial investigation/feasibility study
SPF	spray polyurethane foam
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*

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1 Introduction

The Plutonium Uranium Extraction (PUREX) Plant is located near the center of the Hanford Site (Figure 1) and is owned and operated by the U.S. Department of Energy (DOE). CH2M HILL Plateau Remediation Company (CHPRC), a prime contractor to DOE, is a co-operator of the plant. Part of the PUREX Plant consists of two tunnels constructed and used for storage of waste from plant operations and other Hanford Site sources. Discovery of a partial collapse at PUREX Storage Tunnel 1 by CHPRC workers on May 9, 2017 prompted the Washington State Department of Ecology (Ecology) to issue Administrative Order (AO) Docket No.14156 to DOE and CHPRC directing three corrective actions (17-NWP-053, 2017, "Administrative Order Docket #14156, United States Department of Energy - Hanford Site - PUREX Tunnel 1, WA7890008967"). This report satisfies Corrective Action 2 of the AO, which states the following:

> Starting immediately, develop corrective actions to ensure the safe storage of the waste in the PUREX Storage Tunnels 1 and 2 in light of the above described failure in PUREX Storage Tunnel 1, until a decision on permanent disposition of the PUREX Storage Tunnels 1 and 2 is determined as part of closure under the Dangerous Waste Regulations.
>
> By August 1, 2017, submit a draft report detailing the corrective actions to ensure the safe storage of the waste in the PUREX Storage Tunnels 1 and 2 to the Department of Ecology, Nuclear Waste Program for comment and approval.

To ensure continued safe storage of waste in PUREX Storage Tunnels 1 and 2 (hereinafter referred to as Tunnels 1 and 2), the DOE plan to void fill Tunnel 1 with engineered concrete/grout (hereinafter called grout) was approved by Ecology on June 8, 2017 (17-NWP-069, "Continued Response Actions to Partial Collapse of PUREX Tunnel 1"). A range of potential response actions were identified for Tunnel 2. A phased approach starting with enhanced surveillance and monitoring will be conducted at Tunnel 2 until a further response action is selected and implemented. A "Best and Brightest" panel will be convened to consider the tunnel design, operating history, and waste inventory to conduct an initial analysis of options and identify data needs. The output of the panel will feed a detailed alternative analysis for Tunnel 2. A response action for Tunnel 2 will be selected in consultation with the panel following the completion of the detailed alternative analysis. The stabilization response actions for Tunnel 1 will improve tunnel stability, provide additional radiological protection, and increase durability while not precluding future remedial action or final closure decisions. Enhanced surveillance and monitoring of Tunnel 2 will ensure continued safe storage until a further response action is selected.

2 Facility History/Background

The PUREX Plant processed spent nuclear fuel from reactors located on the Hanford Site from 1955 to 1989 to recover plutonium, uranium, and other radioactive isotopes. The PUREX storage tunnels are used for the storage of waste from the PUREX Plant and other onsite sources. Most of the waste stored in the tunnels consists of large failed equipment components. The tunnels were designed and constructed to provide a means of protecting workers from exposure to highly radioactive residues within the failed equipment. The relative size and location of the tunnels can be seen in Figure 2. Photographs of Tunnels 1 and 2 during construction are shown in Figure 3.

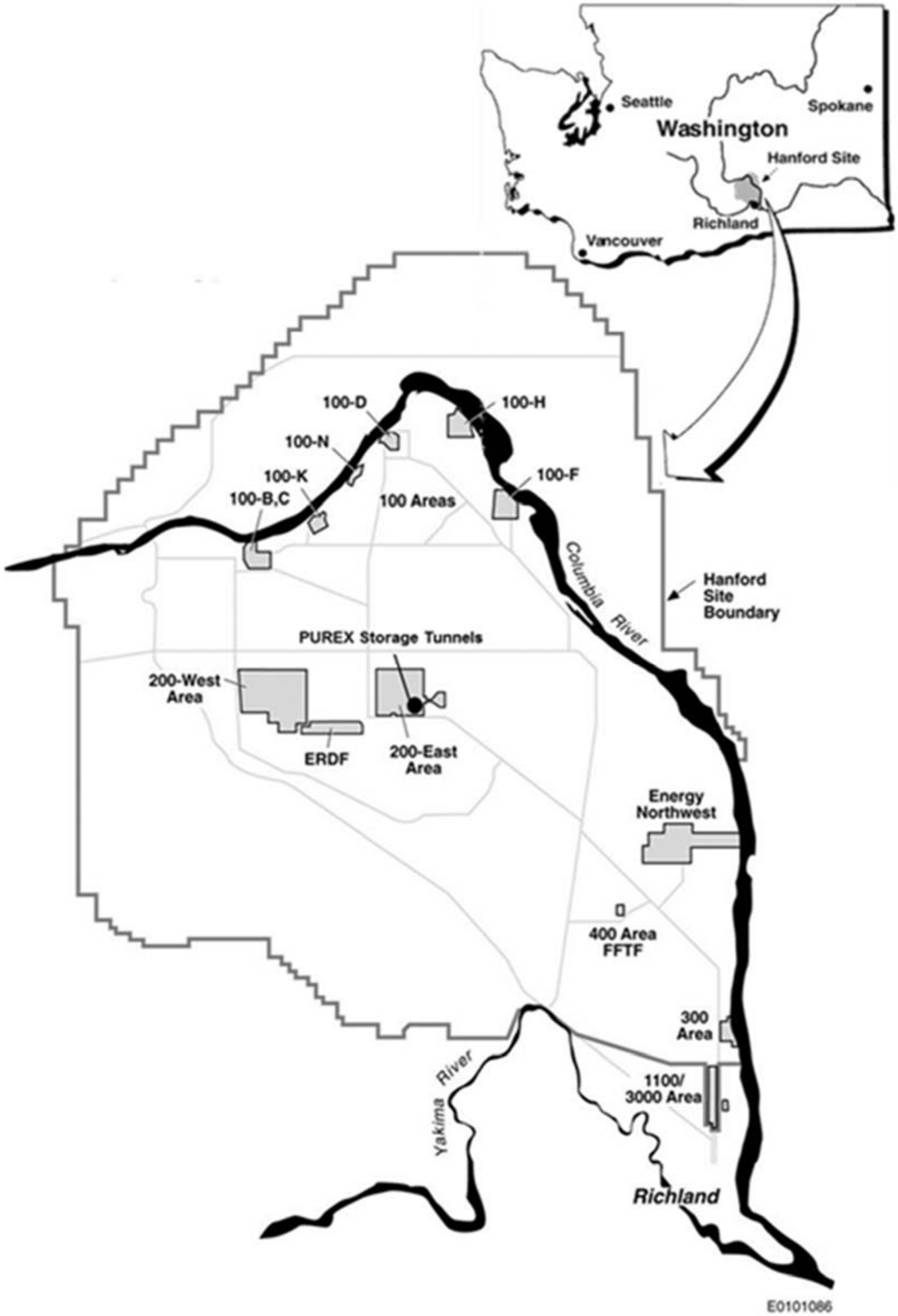

Figure 1. Location of PUREX Storage Tunnels

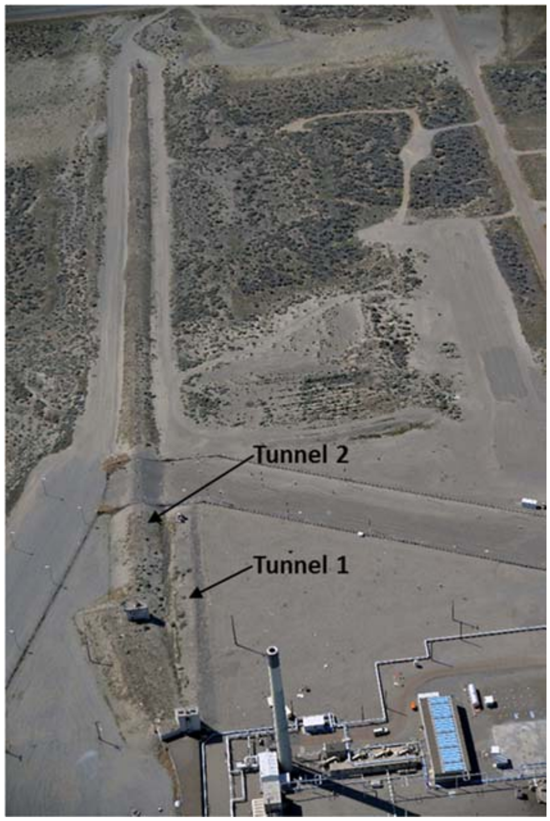

Figure 2. Relative Size and Location of Tunnels 1 and 2 (May 2014)

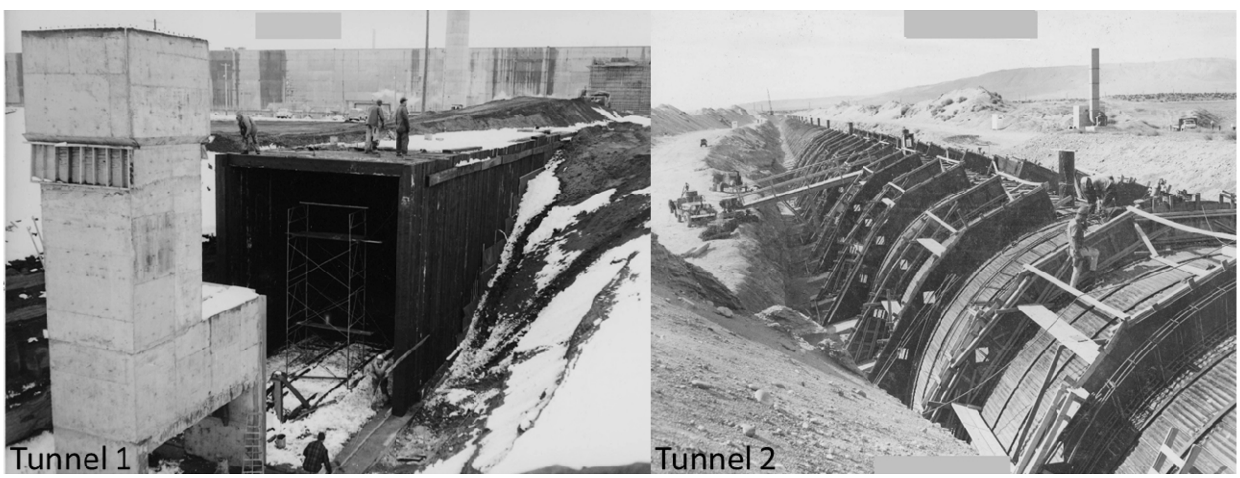

Figure 3. Tunnel 1 and Tunnel 2 during Construction

2.1 PUREX Storage Tunnel 1 Construction and Use

Construction of Tunnel 1 was completed in 1956. At approximately 5.8 m (19 ft) wide by 6.7 m (22 ft) high by 109 m (358 ft) long, Tunnel 1 provided storage space for up to eight railcars. The ceiling and walls were constructed of creosote pressure-treated Douglas fir timbers arranged side by side. The first 31.4 m (103 ft) of the east wall was constructed of reinforced concrete to allow for later construction of Tunnel 2 without disturbing Tunnel 1. A mineral-surface roofing material was used to cover the exterior

surface of the timbers before placement of approximately 2.4 m (8 ft) of soil overburden for protection of the structure and shielding for radioactivity from future waste inventory. Railroad tracks were laid on gravel bed at a 1% downward slope to allow railcars to roll to the end of the tunnel and remain in position. Between June 1960 and January 1965, all eight railcar positions were filled and the tunnel was subsequently sealed.

The combined volume of the equipment stored on the eight railcars presently in Tunnel 1 is approximately 596 m^3 (780 yd^3). The maximum process design capacity for storage in Tunnel 1 is approximately 4,129 m^3 (5,400 yd^3). An artist rendition of how the railcars and waste inventory might look in Tunnel 1 is depicted in Figure 4.

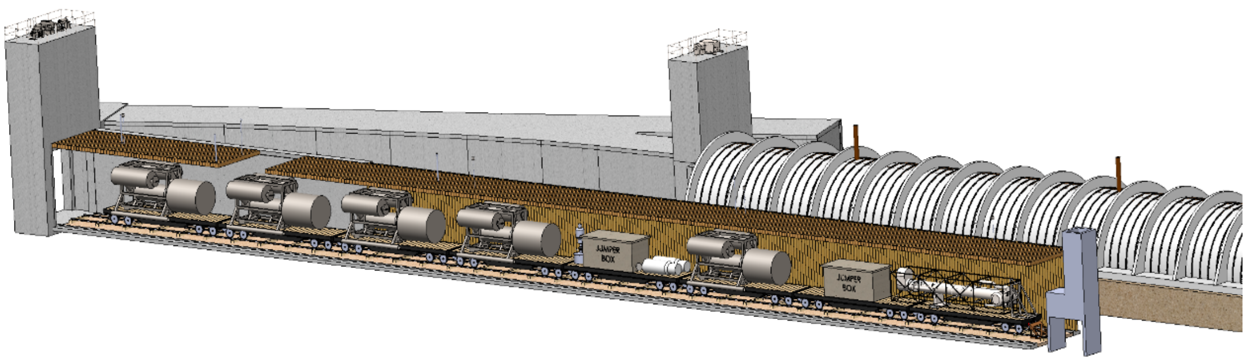

Figure 4. Artist Rendition of Waste Storage in Tunnel 1

2.2 PUREX Storage Tunnel 2 Construction and Use

Construction of Tunnel 2 was completed in 1964. At approximately 5.8 m (19 ft) wide by 6.7 m (22 ft) high by 514 m (1,686 ft) long, Tunnel 2 provided storage space for up to 40 railcars. Two structural failures during construction of Tunnel 2 prompted design modifications that were retrofitted to the structure resulting in its final configuration. The tunnel was constructed in the shape of a Quonset hut with a series of transverse steel rib beams supporting corrugated steel plate roof panels. Interior and exterior surfaces of the roof system were coated with a bituminous material. Steel ribs were supported by a continuous reinforced concrete wall foundation system. The steel roof structure was then further supported by a retrofit addition of a series of longitudinal steel wale beams supported by underhung anchor bolt connections embedded in reinforced arched concrete rib girders. Reinforced concrete thrust blocks placed over the top of existing wall footings were used to support the concrete rib girders. The constructed tunnel was covered with approximately 2.4 m (8 ft) of soil overburden for protection of the structure and shielding for radioactivity from future waste inventory. Railroad tracks were laid on the tunnel floor at a 0.1% downward slope to allow railcars to roll to the end of the tunnel and remain in position. The first railcar was placed in Tunnel 2 in December 1967 and the last in June 1996. A total of 28 railcars were placed in the tunnel.

The combined volume of equipment stored on the 28 railcars presently in Tunnel 2 is approximately 2,204 m^3 (2,883 yd^3). The maximum process design capacity for storage in Tunnel 2 is approximately 19,878 m^3 (26,000 yd^3). An artist rendition of how the railcars and waste inventory might look in Tunnel 2 is depicted in Figure 5.

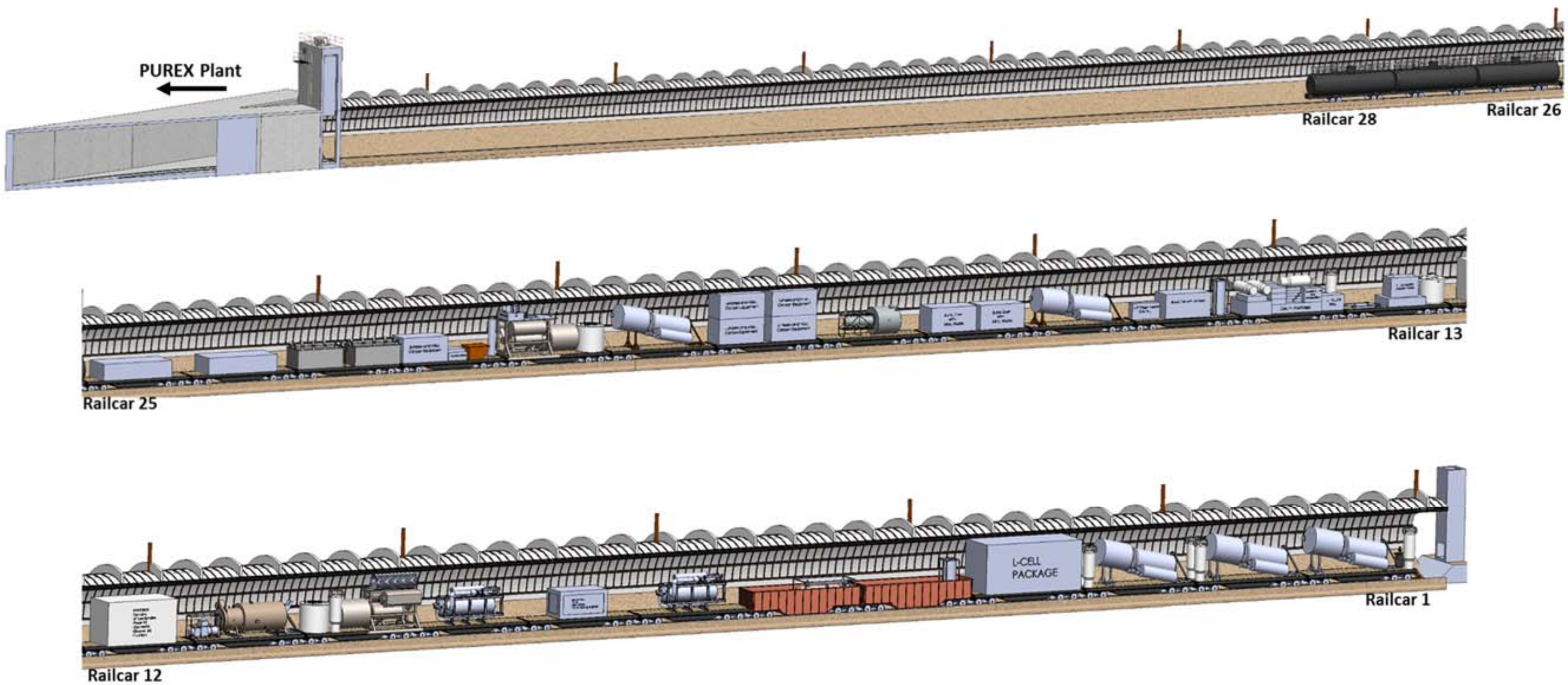

Figure 5. Artist Rendition of Waste Storage in Tunnel 2

2.3 Regulatory Framework

Some waste stored in the tunnels contains constituents regulated as hazardous/dangerous waste by the *Resource Conservation and Recovery Act of 1976* (RCRA) and the *Washington State Hazardous Waste Management Act of 1976* (RCW 70.105, "Hazardous Waste Management"). The hazardous/dangerous waste constituents include metals such as mercury, cadmium, silver, barium, and lead. Accordingly, Tunnels 1 and 2 are "miscellaneous units" under the Washington Dangerous Waste Regulations subject to the requirements of WAC 173-303-680, "Dangerous Waste Regulations," "Miscellaneous Units," and are included in WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, hereinafter referred to as the Hanford Facility RCRA Permit.

The PUREX Plant and tunnels are included within the 200-CP-1 Operable Unit and are subject to future remedial actions under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-085-80 (Ecology et al., 1989) requires submittal of a draft 200-CP-1 remedial investigation/feasibility study (RI/FS) work plan to Ecology by September 30, 2020. This action will initiate the process for development of cleanup decisions for Tunnels 1 and 2 and the associated stored waste. The CERCLA RI/FS process will be coordinated with the RCRA closure decision for the tunnels to prevent overlap and duplication of work.

2.4 Tunnel Inventory and Characterization

The tunnels contain a variety of equipment and other components used during operation of the PUREX Plant. This includes large vessels such as concentrators, dissolvers, heating and cooling coils, and ventilation system equipment, as well as steel or concrete boxes containing connectors known as jumpers and other miscellaneous failed equipment. These wastes were generally placed in the PUREX tunnels because they were highly radioactive and transport to the burial grounds for disposal was deemed to be too hazardous. Detailed descriptions of the failed equipment and components from the PUREX Plant through 1994 is contained WHC-IP-0977, *Estimation of PUREX Equipment and Materials that are Candidates for Removal and Waste Processing during PUREX Plant Closure*. In addition, there are three empty tank cars and two railcars containing wastes from the 324 and 325 Buildings in the 300 Area.

Initial characterization of tunnel inventory developed bounding inventory estimates of key radionuclides to support safety basis development and realistic estimates of hazardous constituents for permitting documentation. To make final cleanup decisions additional investigation and inventory development will be performed. Information that can be used for this purpose includes process flowsheets, drawings, historical records, and available sample data.

3 May 2017 Event Summary

On May 9, 2017, workers discovered a collapse in a portion of the Tunnel 1 wood timber roof structure resulting in a hole approximately 5.8 m (19 ft) wide by 5.2 m (17 ft) long. Immediate and follow-on actions included the following:

- The Emergency Operations Center was activated to manage the immediate response to the event, including response actions necessary to protect personnel (May 9).
- Informational notification was made to Ecology that the RCRA contingency plan was being implemented, although no evidence of release from the unit was found (May 9).

- Fifty-three truckloads of soil fill were placed through the roof opening at the collapsed area to provide contamination control, shielding, protection from ambient conditions, and stabilization of the tunnel support walls (May 10).
- A temporary protective cover was installed over the full length of Tunnel 1 (May 20).
- A 15-day report was prepared and submitted to Ecology in compliance with Permit Condition II.A.1 because the contingency plan was implemented (May 24).

In response to the event, Ecology issued the AO to DOE and CHPRC on May 10, 2017, directing three corrective actions (17-NWP-053). Corrective Action 1 required structural evaluations of Tunnels 1 and 2 and was completed on June 30, 2017. Corrective Action 2 is the subject of this report. Corrective Action 3 requires submission of draft RCRA permit modification and is due to Ecology by October 1, 2017.

On May 31, 2017, DOE notified Ecology of its plan to address the significant threat of further failure of Tunnel 1 by void filling the tunnel with grout (17-AMRP-0180, "Continued Response Actions to Partial Collapse of PUREX Tunnel 1"). This would be conducted as part of continuing response actions in accordance with Section J.4.5 of the Hanford Facility RCRA Permit PUREX Storage Tunnels contingency plan. Chapters 5 through 7 of this report reflect the options and considerations that led to the decision. Ecology responded to DOE on June 8, 2017, approving the plan to grout Tunnel 1 as an interim stabilization measure for the tunnel structure that will not preclude future closure or remedial decisions (17-NWP-069).

This report details the corrective actions necessary to ensure safe storage of the waste inventory in Tunnels 1 and 2, including the decision to void fill Tunnel 1. It has been prepared following a review of the conclusions of the structural evaluations prepared for AO Corrective Action 1 and consideration of current conditions, wastes stored in the tunnels, and potential options for near-term actions.

4 Structural Integrity Evaluation Summary

As required by AO Corrective Action 1, structural integrity evaluations were performed on both tunnels (17-AMRP-0201, "Administrative Order Number 14156 – Corrective Action 1 Submittal, Structural Integrity Evaluation for PUREX Storage Tunnels 1 and 2"). Available construction drawings and photographs were used as inputs for the evaluation. Limited site-specific geotechnical information was available for either the foundation soil or the cover soil for Tunnels 1 and 2. In addition, personnel access to the tunnel surface is restricted, and personnel entry into the tunnels to gather information was considered too hazardous based on uncertainties with the structural conditions and high levels of radioactivity. The structural evaluation methodology was based on the 2012 *International Building Code* (ICC 2012) standards and used load and resistance factor design techniques.

The structural evaluation reports concluded that Tunnels 1 and 2 do not meet current structural codes and standards as the following summarizes:

- CP-03364, *PUREX Tunnel 1 Engineering Evaluation*, indicates that the exact cause of the structural failure in Tunnel 1 cannot be determined, but likely factors are a combination of heavy rainfall and deterioration of the wood timbers over more than 60 years that the tunnel has been in service. In addition, the evaluation concluded that the vertical wall timbers within the tunnel are overstressed. Given the partial collapse on May 9 and the results from the structural evaluation, the potential for further collapse of Tunnel 1 exists.
- CP-03365, *PUREX Tunnel 2 Engineering Evaluation*, indicates that design loads on several structural support members exceed building code design capacities including the arched steel rib supports, wide

flange steel wale supports, and foundation soil-bearing pressures. Based on the evaluation results and considering that it has been in service for more than 50 years, the potential for localized collapse of Tunnel 2 exists, and structural stabilization is recommended as soon as possible.

The evaluations also cautioned that, although removal of soil overburden from the tunnel surface could result in reduced applied loads, the potential reduction in loads may not eliminate all overstressed conditions and could initiate a collapse caused by heavy equipment operations and/or from changes to the present load balance. Consequently, removal of soil overburden is not considered as an option (or as a component of an option) for ensuring continued safe storage of waste in Tunnels 1 and 2.

Chapter 5 identifies options for actions that could be taken to ensure continued safe storage of wastes.

5 Potential Options to Ensure Safe Storage

A team including environmental, structural, construction, and facility resources identified a range of options that could be implemented to ensure continued safe storage of the waste in Tunnels 1 and 2. Measures that involved additional structural engineering calculations, removal of soil overburden, or personnel entry for internal inspection of the tunnels were not carried forward as options based on the information presented in Chapter 4. Eleven options for continued safe storage of waste in the tunnels were developed as presented in Tables 1 through 11. A risk of tunnel failure exists, so timeliness is a key factor in evaluating the options.

Because the exact cause of the structural failure in Tunnel 1 cannot be determined and a significant threat of further failure of the tunnel remains, the plan to void fill Tunnel 1 has been approved as previously discussed (17-AMRP-0180 and 17-NWP-069). Although it is not being revisited in this report, the information presented in Chapters 5 and 6 reflect the development and analysis of options that led to the plan for Tunnel 1. All of the options are included in the context of this report for completeness.

A “Best and Brightest” panel will be convened utilizing senior personnel with science, engineering, tunneling, and construction experience to conduct an initial analysis of the options and identify data needs.

The actions planned to ensure continued safe storage of waste in Tunnels 1 and 2 are discussed in Chapter 6 of this report.

Table 1. No Further Action Baseline (Option 1)

Description	No further action will be taken on Tunnel 1 or Tunnel 2 to stabilize the tunnel structure or protect against potential future failure. The existing protective cover will remain on Tunnel 1 and be repaired as needed.
Advantages	• Does not preclude future remedial action or closure decisions
Disadvantages	• Does not prevent tunnel failure • Does not protect against added load from snowfall • Would not contain contamination spread in the event of a failure
Durability	• Does nothing to protect against further degradation of structural stability
Radiological Protection	• Provides no contamination control or shielding in the event of tunnel failure
Constructability	• No installation required
Comments	No additional risk reduction from present conditions (July 2017).

Table 2. High-Density Polyethylene Cover (Option 2)

Description	Placement of a heavy high-density polyethylene (HDPE) plastic cover over the structure. The use of an HDPE cover for protection from adverse ambient conditions is a widely used and versatile option. HDPE cover thickness can range from 40 to 120 mil. For this application, a cover would be custom fit in the field to the designed configuration.
Advantages	• Provides some contamination control in the event of a tunnel failure • Protects against water infiltration in soil overburden • Lightweight • Does not preclude future remedial action or closure decisions
Disadvantages	• Does not prevent tunnel failure • Does not protect against added load from snowfall • Stormwater can pool in areas • Would not be totally effective to contain contamination spread in event of tunnel failure • Surveillance of tunnel surface is more difficult due to obstructed visibility and limited access • Would require periodic replacement until final closure is implemented
Durability	• Limited lifespan due to weather exposure—wind can tear and sun can cause deterioration requiring maintenance repairs or replacement • Reliant upon Jersey barriers, ecology blocks, and tie downs to stay in place
Radiological Protection	• Limited contamination control under cover • Provides no shielding in the event of tunnel failure
Constructability	• Relatively easy and quick to install
Comments	Installed as a temporary protective measure on Tunnel 1 as part of initial response actions. Spray-on covers such as soil stabilization fixatives have advantages and disadvantages similar to those described and are not considered separately.
	

Table 3. Soft-Surface Tent Cover (Option 3)

Description	Construction of a tent over the entirety of the tunnel. The tent would be a custom design that would use materials that would prevent infiltration of rain and provide protection against wind. Although tents can be constructed from various materials (e.g., cotton, polyester, Protex®, Hydrotex®, polycotton, ripstop nylon), the design specification to meet the environmental and radiological requirements of this type of soft structure could require a long procurement timeframe.
Advantages	• Provides some contamination control in the event of tunnel failure • Protects against water infiltration in soil overburden • Provides limited protection against added load from snowfall • Does not preclude future remedial action or closure decisions
Disadvantages	• Does not prevent tunnel failure • Lead time to custom manufacture would be long • Construction activities could trigger tunnel failure • Could interfere with response actions in the event of a tunnel failure • Would likely become contaminated in a future event and controls would have to be established to control/allow personnel access • Surveillance of tunnel surface is more difficult due to obstructed visibility and limited access • Would require periodic replacement until final closure is implemented
Durability	• Limited lifespan due to weather exposure—wind can tear and sun can cause deterioration requiring maintenance repairs or replacement
Radiological Protection	• Limited contamination control within tent boundary • Provides no shielding in the event of tunnel failure
Constructability	• Relatively easy and quick to install
Comments	Interface of Tunnel 1 and Tunnel 2 would require special design and construction techniques.
	

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® Hydrotex is a registered trademark of Synthetex, LLC, Peachtree Corners, Georgia.

Table 4. Hard-Surface Tent Cover (Option 4)

Description	Construction of a hard surface tent. DOE has used hard structured tents in various locations throughout the DOE complex. These structures are typically constructed with an aluminum frame, a double-coated ultraviolet-resistant polyvinyl chloride roof cover, and options such as a rolling door or rigid wall. The hard surface tent provides better contamination control and more robust protection than a soft tent in the event of structural collapse of the tunnel.
Advantages	• More protection than HDPE cover or soft-sided tent • Provides some contamination control in the event of a tunnel failure • Protects against water infiltration in soil overburden • Protects against added load from snowfall • Does not preclude future remedial action or closure decisions
Disadvantages	• Does not prevent tunnel collapse • Construction activities could trigger tunnel failure • Surveillance of tunnel surface is more difficult due to obstructed visibility and limited access • Could interfere with response actions in the event of a tunnel failure • Would likely become contaminated in a future event and controls would have to be established to control/allow personnel access
Durability	• Relatively durable, but would require maintenance over time • Less susceptible to wind and weather than HDPE cover or soft-sided tent • If replacement of deteriorated cover is necessary, construction effort could be difficult
Radiological Protection	• Limited contamination control within tent boundary • Provides no shielding in the event of tunnel failure
Constructability	• Requires heavy equipment to construct • In relation to HDPE cover or soft-sided tent, construction requires more planning, longer schedule, and is more expensive
Comments	Interface of Tunnel 1 and Tunnel 2 would require special design and construction techniques.

Table 5. Pre-Engineered Building Construction (Option 5)

Description	Erection of a pre-engineered metal building over the length of the tunnel. Steel construction mounted on concrete foundation/footings would be the highest degree of protection and containment that could be constructed around the tunnel. The building could be designed with an active ventilation system to provide greater contamination control.
Advantages	• Most robust protection of options involving exterior covers • Provides more contamination control in the event of a tunnel failure in comparison with options involving exterior covers; active ventilation would further improve control • Protects against water infiltration in soil overburden • Protects against added load from snowfall • Does not preclude future remedial action or closure decisions
Disadvantages	• Does not prevent tunnel failure • Extended timeline to implement increases risk of tunnel failure prior to completion • Construction activities could trigger tunnel failure • Surveillance of tunnel surface is more difficult due to obstructed visibility and limited access • Could interfere with response actions in the event of a tunnel failure
Durability	• Most durable of options involving exterior covers • Periodic building maintenance required
Radiological Protection	• Provides contamination control within building • Provides limited shielding in the event of tunnel failure
Constructability	• Requires heavy equipment • In relation to other options involving exterior covers, construction requires the most planning, longest schedule, and is the most expensive; ventilation system would add more time and expense to design and construction
Comments	Interface of Tunnels 1 and 2 would require special design and construction techniques. May need to be sized to cover both tunnels to be effective.
	

Table 6. Injection of Poly Foam Void Fill (Option 6)

Description	Spray polyurethane foam (SPF) is a spray-applied plastic that can form a continuous insulation and air sealing barrier to fill voids within the tunnel. It is made by mixing and reacting unique liquid components at the job site to create foam. The liquids react very quickly when mixed, expanding on contact to create foam that insulates, seals gaps, and can form moisture and vapor barriers. SPF insulation is known to resist heat transfer extremely well, and it offers a highly effective solution in reducing unwanted air infiltration through cracks, seams, and joints thus providing control of contamination and preventing contamination spread in the event of a release. High-, medium-, and low-density SPF is available to be formulated for specific purposes.
Advantages	• Provides additional structural support to tunnel and prevents future tunnel failure • Provides ability to withstand added load from precipitation • Protects stored waste and acts as fixative for contamination • Does not preclude future remedial action or closure decisions
Disadvantages	• Injection operations could trigger tunnel failure • Extended timeline to implement increases risk of tunnel failure prior to completion • Chemical compatibility between foam materials and waste must be analyzed to prevent flammable and/or toxic off-gas generation • Generates heat during installation that may present a fire hazard and cured foam is combustible • May leave potential void spaces inside stored equipment that may be susceptible to future subsidence • Limits ability for in-situ characterization (e.g., use of robotic crawler-type characterization devices) of stored waste post-void fill • Complicates ability to segregate wastes requiring different disposition paths
Durability	• Variable based upon foam selected and interactions with tunnel and contents and expected design life • Ability to maintain integrity in high radiation fields is unknown
Radiological Protection	• Provides contamination control from stored waste • Provides limited shielding
Constructability	• Heat and off-gas generation and buoyancy of waste must be addressed in design and planning • Formulation of foam to meet design requirements may require additional tunnel penetrations to execute effective installation, increasing risk of tunnel damage/failure
Comments	SPF use for void fill applications at the Hanford Site has been rejected based on fire protection requirements.
	

Table 7. Controlled Collapse In Place (Option 7)

Description	Create a controlled collapse of the tunnel by using controlled implosions or by using heavy equipment to place strategic loads at specified points of the tunnel structure. The intent would be to use the existing overburden to fill the void spaces within the tunnel, and would likely require the placement of additional overburden to compensate for the decrease of the existing shielding that would occur. Controlled collapse can be achieved by several methods, but the most probable methods would be by controlled use of explosives, direct mechanical stress from heavy equipment, or the addition of overburden by equipment or a conveyor to cause planned structural failure.
Advantages	• Minimizes/removes future tunnel failure potential • Does not preclude future remedial action or closure decisions
Disadvantages	• Extended timeline to implement, increases risk of tunnel failure prior to completion • Difficult to control contamination migration and dose to workers during implementation • Could cause damage to stored equipment and boxes in the tunnel that could lead to contamination migration, dose to workers, and impacts to future remedial action or closure decisions • Limits ability for in situ characterization (e.g., use of robotic crawler-type characterization devices) of stored waste post-implementation • Complicates ability to segregate wastes requiring different disposition paths • May require additional soil overburden to achieve desired shielding as part of implementation
Durability	• High durability • May leave potential void spaces inside stored equipment and boxes that may be susceptible to future subsidence
Radiological Protection	• During implementation, potential for contamination spread and isolated areas of high dose rates, due to difficulty in controlling conditions • Soil provides some shielding post-implementation
Constructability	• Relatively easy to implement; however, the extent of the force required to cause the tunnel to collapse is unknown if the external force method is chosen • Limited availability of contractors qualified with explosives • Design and implementation would need to be done from the side to account for restricted access of personnel and equipment from tunnel surface
Comments	Controlled implosions have been used successfully for multiple projects on the Hanford Site, but inability to apply fixatives to exposed contamination prior to implosion presents a contamination control challenge.

Table 8. Sand or Clay Void Fill (Option 8)

Description	Injection of sand or clay (e.g., bentonite) into the tunnel to fill void spaces to provide both structural stability and minimize potential future subsidence of the overburden. Either sand or clay could be injected by creating sufficient penetrations to place or spray the sand or clay into the tunnel to fill voids. Sand could also be injected by mixing with water to create a slurry that would flow into voids. If properly distributed, the sand or clay would reduce dose rates from radiological sources and stabilize the structure of the tunnel. It could potentially be removed from the tunnel using a vacuum or slurry removal methods more readily than grout or foam.
Advantages	• Provides additional structural support to tunnel and prevents future tunnel failure • Provides ability to withstand added load from precipitation • Protects stored waste • May be removed if necessary to implement future remedial and closure actions • Does not preclude future remedial actions or closure decisions
Disadvantages	• Penetration or injection operations could trigger tunnel failure • Angle of repose presents a challenge to void fill operations. Could require numerous injection paths or large volumes of water to enable widespread void fill. If dry material is used air emissions could be an issue. If slurry method is used, water would remain free and potentially drive contamination into soil beneath the tunnel • Bentonite-type clays swell when in contact with water potentially creating future structural issues • May leave potential void spaces inside the tunnel, stored equipment, and boxes that may be susceptible to future subsidence • Limits ability for in situ characterization (e.g., use of robotic crawler-type characterization devices) of stored waste post-void fill • Complicates ability to segregate wastes requiring different disposition paths
Durability	• Does not require maintenance
Radiological Protection	• Provides contamination control from stored waste • Provides additional shielding
Constructability	• Relatively simple to execute • May require creating multiple penetrations through the tunnel walls and roof or slurry capabilities • Polymers could be introduced to the sand slurry to improve flowability • Air emissions and potential for flow into unintended systems or out of the tunnel structures must be addressed in design and planning
Comments	Option added as a result of input received in July 2017 public information workshop.

Table 9. Grout Void Fill (Option 9)

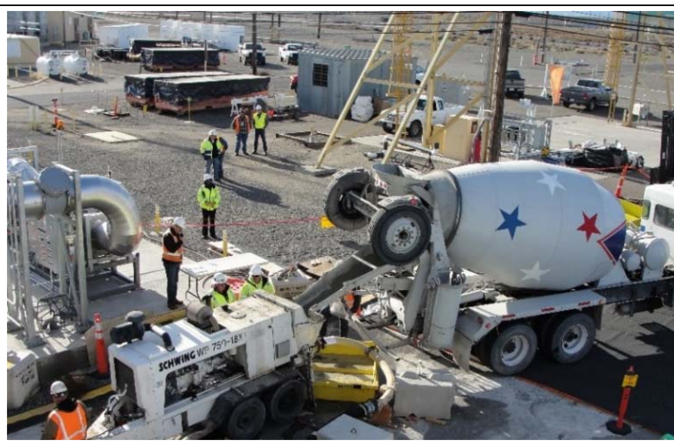
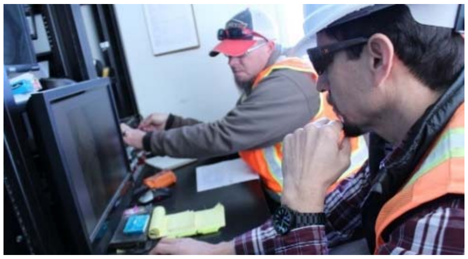
Description	Injection of grout into the tunnel to fill all void spaces to provide both structural stability and minimize potential future subsidence of the overburden. The grout mix can be tailored to specific compressive strength needs and desired flow characteristics to access small spaces. Grouting is routinely used across the Hanford Site and the nuclear industry to immobilize and stabilize contamination, reduce dose rates from radiological sources, and stabilize structures. Grouting material can be tailored to meet these objectives and ensure void spaces are corrected. Injection of grout would encapsulate the failed equipment/waste containers.
Advantages	• Provides additional structural support to tunnel and prevents future tunnel failure • Provides ability to withstand added load from precipitation • Protects stored waste and acts as fixative for contamination • Does not preclude future remedial actions or closure decisions
Disadvantages	• Injection operations could trigger tunnel failure • Limits ability for in situ characterization (e.g., use of robotic crawler-type characterization devices) of stored waste post-void fill • Complicates ability to segregate wastes requiring different disposition paths
Durability	• Does not require maintenance
Radiological Protection	• Provides contamination control from stored waste • Provides additional shielding • Offers protection from contamination on stored equipment during future remedial and closure actions
Constructability	• Relatively simple to execute • Some complexities if done during freezing weather • Batch plant may be considered based on volume of grout needed • Heat generation, buoyancy of waste, and potential for flow into unintended systems or out of the tunnel structures must be addressed in design and planning
Comments	The plan to grout Tunnel 1 to address the risk of further tunnel failure has been approved. Grout has been used successfully for multiple projects on the Hanford Site. Grout availability from suppliers may be limited during winter months.
	

Table 10. Stored Waste Retrieval (Option 10)

Description	Waste in the tunnel could be retrieved and processed for disposal or continued storage elsewhere. Retrieval could potentially be accomplished by reactivating the tunnel entry and crane facilities and removing the waste through the PUREX Plant. This would require extensive planning, engineering, and potentially replacement of existing equipment. Retrieval could also be accomplished by controlled demolition of the tunnel and removal of railcars and equipment using external equipment. Where a tunnel is filled with foam or grout as an interim measure, cutting technologies would have to be used to retrieve waste. Because of the variable nature of the waste packages in the tunnel as well as unknown dose and contamination levels, determination of conditions would be required prior to design and installation of equipment and facilities necessary to characterize, treat where necessary, size reduce, and repackage wastes. Alternately, a conservative approach could be employed where all activities would be conducted in a structure that provides containment and shielding for expected worst-case conditions. Based on current knowledge it is expected that some wastes could be disposed of in the Environmental Restoration Disposal Facility as low-level wastes and some could be dispositioned as contact-handled or remote-handled transuranic or transuranic mixed wastes for disposal in the Waste Isolation Pilot Plant. However, some of the waste may not have a clear disposition path and may have to be repackaged for continued storage onsite until a final disposition path is available.
Advantages	• Represents a final remedial action and closure pathway for the tunnel • Removes radiological source term and mixed waste • Cleanup decision process would also address remediation of remaining void space within the tunnel as well as potential soil contamination
Disadvantages	• Requires an extended and technically challenging effort for facility and equipment design, construction, and implementation • Involves lengthy period to complete regulatory decision documentation prior to implementation as a final action • Extended timeline to implement increases risk of collapse prior to completion • Risk of tunnel collapse during waste retrieval
Durability	• Provides a permanent solution to the tunnel
Radiological Protection	• Design and operation of facilities would require extensive dose and contamination control measures
Constructability	• Significant capital asset project
Comments	
	

Table 11. Surveillance and Monitoring Enhancements (Option 11)

Description	Enhanced surveillance and monitoring consists of a combination of increased active monitoring of the tunnel conditions and use of various tools to gather additional information to supplement the existing design/as-built knowledge base. Potential enhancements may include the following: • Visual surveillance of the tunnel surface and perimeter to identify changed conditions • Remote camera/video surveillance of the tunnel surface • Radiological surveys in vicinity of the tunnel to identify changes in background or contamination levels • Geophysical surveys to provide indication of depth of soil cover and rail car locations • Digital imaging (i.e., Light Detection and Ranging [LiDAR], global positioning system, high-definition surveying laser technologies) to detect changes in surface elevation over time • Robotic or other unmanned entry equipment to assess interior tunnel condition, location and condition of stored waste, and radiological conditions The potential methods and tools represent a mix of off-the-shelf items that could be immediately deployed and items that would require some modification for the specific tunnel conditions. Interior conditions may limit the value of information attainable by some tunnel entry tools.
Advantages	• Would detect visible changes with tunnel surface or changes in radiological conditions • May provide additional information on tunnel interior conditions, railcar positions, as-built construction, and radiological field/contamination levels to supplement existing knowledge base • Nonintrusive or remote information gathering methods minimize worker risk • Could be implemented along with any other options • Does not preclude future remedial actions or closure decisions
Disadvantages	• Does not prevent future tunnel failure • Does not protect against added load from precipitation • Operations could trigger future tunnel failure • Does not protect stored waste or provide any further tunnel stability
Durability	• Can be applied as long as necessary
Radiological Protection	• Offers no additional radiological protection in event of tunnel failure • Does not change existing radiological conditions
Constructability	• Activities and tools range from immediately available and deployable (e.g., walkdowns, exterior camera monitoring, exterior radiological surveys) to available and deployable with modifications based on the tunnel environment • Existing penetrations could be used for insertion of remote tunnel entry tools • Remote tunnel entry tools may require modification for radiological conditions and would likely be one-time use
Comments	Some surveillance and monitoring enhancements have already been implemented. A draft data quality objectives report was developed in 2017 and will be submitted to meet Tri-Party Agreement Milestone M-085-80A and reviewed by Ecology that identified approaches to evaluating the structural integrity of the tunnels that included remote sensing and imaging.
	

6 Approach to Ensure Safe Storage

Due to the risk of failure identified in the structural integrity evaluations (17-AMRP-0201), a plan has been approved to void fill Tunnel 1 with grout. The use of grout as void fill has been successful at the Hanford Site and throughout the DOE complex and can be effectively implemented at a reasonable cost. When implemented, the stabilization response action for Tunnel 1 will improve tunnel stability, provide additional radiological protection, and increase durability while not precluding future remedial actions or closure decisions.

Enhanced surveillance and monitoring activities have been implemented at both tunnels as an initial response to the event. The objective of the surveillance and monitoring activities is to provide timely identification of changes in the tunnel surfaces or in radiological conditions so prompt action can be taken to mitigate potential contamination events or collapse until the stabilization response actions are completed.

For Tunnel 2, a phased approach starting with enhanced surveillance and monitoring will be utilized. A “Best and Brightest” panel will be convened to consider the tunnel design, operating history, and waste inventory to conduct an initial analysis of options and identify data needs. The output of the panel will feed a detailed alternative analysis for Tunnel 2. A response action for Tunnel 2 will be selected in consultation with the panel following the completion of the detailed alternative analysis.

6.1 PUREX Storage Tunnel 1 Details and Corrective Actions

A significant threat of further failure at Tunnel 1 remains because the exact cause of the May 9, 2017 partial collapse cannot be determined. On May 31, 2017, DOE notified Ecology via letter (17-AMRP-0180) of its plan to address this threat by void filling Tunnel 1 with grout as part of continuing response actions consistent with Section J.4.5 of the Hanford Facility RCRA Permit PUREX Storage Tunnels contingency plan (WA7890008967). This continued response action will provide interim stabilization of Tunnel 1 and mitigate threats to human health and the environment. The use of grout as void fill has been successful at the Hanford Site and throughout the DOE complex and can be effectively implemented in a timely manner and at a reasonable cost, without precluding future remedial action or closure decisions. On June 8, 2017, Ecology agreed that this recovery action is the best option to protect human health and the environment, based on the remaining risk of additional failure for the rest of PUREX Storage Tunnel 1 (17-NWP-069).

The following information is provided for context of the considerations that led to the plan to void fill Tunnel 1 with grout.

- Protection (improving tunnel stability and protecting from exposure to radiological/chemical hazards in the event of a structural failure) – Void filling with grout will address tunnel stability and provide a high level of protection to the public, the workers, and the environment. It will prevent future catastrophic tunnel collapse by minimizing void space within the tunnels while enhancing the structural stability. The grout matrix also protects the stored waste, provides radiological protection by encapsulation and shielding of the source term, and mitigates the potential for release of the dangerous waste constituents from the tunnels.

- Retention (not precluding any future remedial action or closure decisions) – In general, future remedial action alternatives and closure options involve either in-place disposal or removal of the waste for disposal or storage elsewhere. Void filling with grout or similar material would likely be required if in-place disposal is selected as a remedial action or closure decision. If removal of the waste is selected, void filling with grout may facilitate retrieval of the waste packages contained in

the tunnels for processing by providing a stabilized and shielded waste form that can be safely size reduced and packaged for further characterization and disposition. Segregation of wastes requiring different disposition paths is more complicated after grout filling, but is still possible.

- Implementability (considering ease of construction/implementation or potential risks encountered during construction/implementation) – The planned approach is to access Tunnel 1 by reopening previous penetrations where possible, or by creating new penetrations where necessary. Grout fill will be injected into the tunnel in lifts to mitigate effects of heat generation during curing and resolve potential buoyancy issues associated with the waste packages by filling voids in the stored waste and anchoring waste in place. These types of actions are routinely performed by construction forces and should pose minimal construction risk. Grout has frequently been used at the Hanford Site as part of cleanup actions. Implementation at the U Plant Canyon, as part of the selected alternative for final remediation, has demonstrated the ability to inject grout in and around equipment, effectively filling void spaces and providing a durable and stable waste matrix. As part of the 105-KE fuel storage basin removal action, grout fill was successfully used to provide contamination control followed by removal and size reduction using standard demolition equipment to support disposal.

- Minimization (minimizing effort that would be required to maintain, repair, or replace the components of the completed response action until final closure/remediation is implemented) – Grout matrices are very durable. The stabilized tunnel will be nearly maintenance free compared to other options considered. The cured grout matrix will also provide a more stable surface for continued surveillance and monitoring until future remedial action and closure decisions are made and implemented.

- Timeliness (meeting the need for near-term implementation to minimize risk of collapse) – Injection of grout material into Tunnel 1 can be performed relatively quickly, in a matter of months. This minimizes the risk of further collapse of Tunnel 1.

- Cost (considering the relative cost of construction/implementation) – Grout is a readily available and low-cost material. Minimal infrastructure is required to initiate the void-filling process.

Planning is currently under way to implement this approved response action for Tunnel 1. In the interim, surveillance and monitoring enhancements that have been implemented at Tunnel 1 include the following:

- Daily Walkdowns – A walkdown of the areas around Tunnel 1 is performed to conduct visual observations and radiological surveys in the area and compare with previous observations and surveys. Walkdowns will be conducted daily (7 days per week including holidays) until the grouting operations at Tunnel 1 are completed.

- Video Observation – A video camera is mounted above Tunnel 1 to provide real-time observation of the tunnel surface. The live images are compared with static pictures taken immediately after the protective cover was placed to identify changes in the visible appearance of the tunnel surface. Comparison of the images will be conducted daily (7 days per week including holidays) until the grouting operations at Tunnel 1 are completed.

Following completion of grouting operations at Tunnel 1, the frequency and type of added surveillance and monitoring activities will be re-evaluated. Activities required by the Hanford Facility RCRA Permit (WA7890008967) will continue to be conducted as prescribed.

The corrective actions and relative timeline for Tunnel 1 activities are summarized by the following:

- Planning for interim stabilization (grouting) of Tunnel 1 was initiated in June 2017.
- Daily visual observations and radiological surveys of the exterior of Tunnel 1 were initiated in June 2017 and will continue until grouting is completed.
- A video camera used to observe the surface of Tunnel 1 was installed, and daily review of associated video footage was initiated in June 2017 and will continue until grouting is completed.
- Grouting operations are anticipated to be complete at Tunnel 1 by the end of calendar year 2017.

6.2 PUREX Storage Tunnel 2 Details and Corrective Actions

Because of similar concerns about the structural integrity and risk of failure, a phased approach starting with enhanced surveillance and monitoring will be utilized at Tunnel 2. A “Best and Brightest” panel will be convened to consider the tunnel design, operating history, and waste inventory to conduct an initial analysis of options and identify data needs. The output of the panel will feed a detailed alternative analysis for Tunnel 2. A response action for Tunnel 2 will be selected in consultation with the panel following the completion of the detailed alternative analysis.

Surveillance and monitoring enhancements that have been implemented at Tunnel 2 include the following:

- Daily Walkdowns – A walkdown of the areas around Tunnel 2 is performed to conduct visual observations and radiological surveys in the area and compare with previous observations and surveys. Walkdowns will be conducted daily (7 days per week including holidays) until the response actions at Tunnel 2 are completed.
- Video Observation – A video camera is mounted adjacent to Tunnel 2 to provide real-time observation of the tunnel surface. Comparison of the images will be conducted daily (7 days per week including holidays) until the response actions at Tunnel 2 are completed.

As part of the initial corrective action, future surveillance and monitoring enhancements for Tunnel 2 will involve deployment of more advanced remote imaging and sensing techniques at the tunnel to provide more active monitoring of tunnel conditions. Selection and installation of digital imaging systems such as Light Detection and Ranging (LiDAR), global positioning system (GPS), or high-definition surveying (HDS) laser technologies will provide highly accurate digital imaging that can detect minor changes in the tunnel surface over time. Other technologies, such as ground motion or sound detection, may also be implemented to identify changes in tunnel stability. Robotic or other unmanned equipment that can be deployed inside the tunnel to assess interior conditions will be investigated and deployed where feasible to provide useful information about tunnel conditions, location and condition of stored waste, and radiological conditions.

Following completion of response actions at Tunnel 2, the frequency and type of added surveillance and monitoring activities will be re-evaluated. Activities required by the Hanford Facility RCRA Permit (WA7890008967) will continue to be conducted as prescribed.

The corrective actions and phased sequence for Tunnel 2 activities progressively working from enhanced surveillance and monitoring towards further tunnel response action are summarized by the following:

- Daily visual observations and radiological surveys of the exterior of Tunnel 2 were initiated in June 2017 and will continue until response actions are completed.
- A video camera used to observe the Tunnel 2 surface was installed, and daily review of associated video footage was initiated in June 2017 and will continue until response actions are completed.
- An advanced monitoring system of the Tunnel 2 exterior will be selected and installed.
- A "Best and Brightest" panel will be convened to consider the tunnel design, operating history, and waste inventory to conduct an initial analysis of options and identify data needs.
- A detailed alternative analysis, using output from the panel, will be completed to select the Tunnel 2 response action.
- Additional data will be collected and evaluated (e.g., use of unmanned/robotic equipment to gather information on visual and radiological conditions from the Tunnel 2 interior) to confirm alternative selection and support design and implementation of the selected alternative.

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