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Federally Funded Research and Development Center (FFRDC) Team Draft Report Overview

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2021 NDAA-3125 Meeting #3

April 26-28, 2022

SRNL-STI-2022-00199

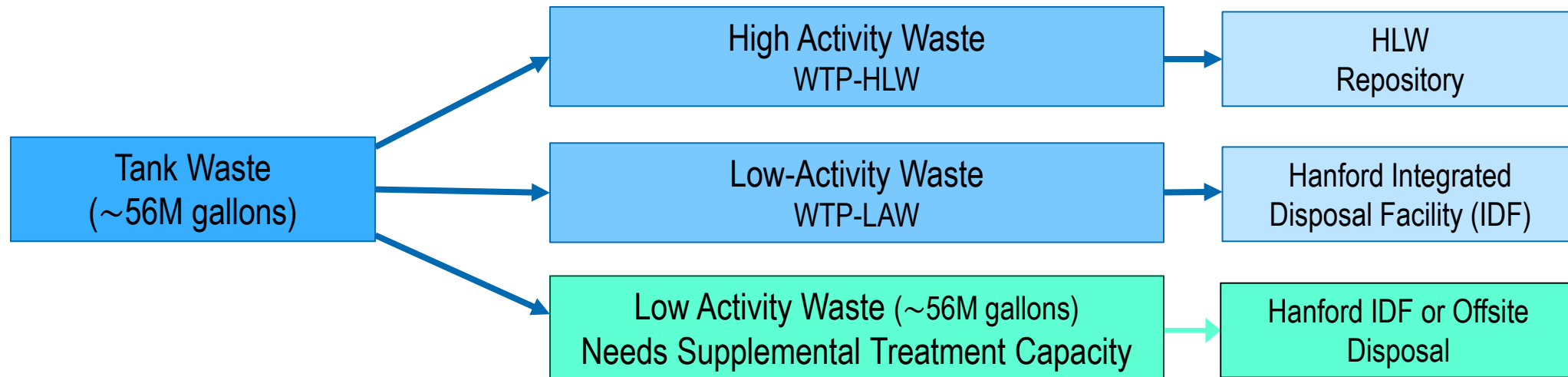
The information in this briefing represents the draft professional opinions
of the FFRDC team, provided for review by the National Academies



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FFRDC Team Scope

- **2021 NDAA Section 3125**
 - Continued Analysis of Approaches for Supplemental Treatment of Low-Activity (LAW) Waste at Hanford Nuclear Reservation
- **Supplemental LAW Treatment Capacity Needed to Meet Mission Schedule Objectives**



- **WTP LAW Facility Does Not Have Capacity to Treat all LAW**

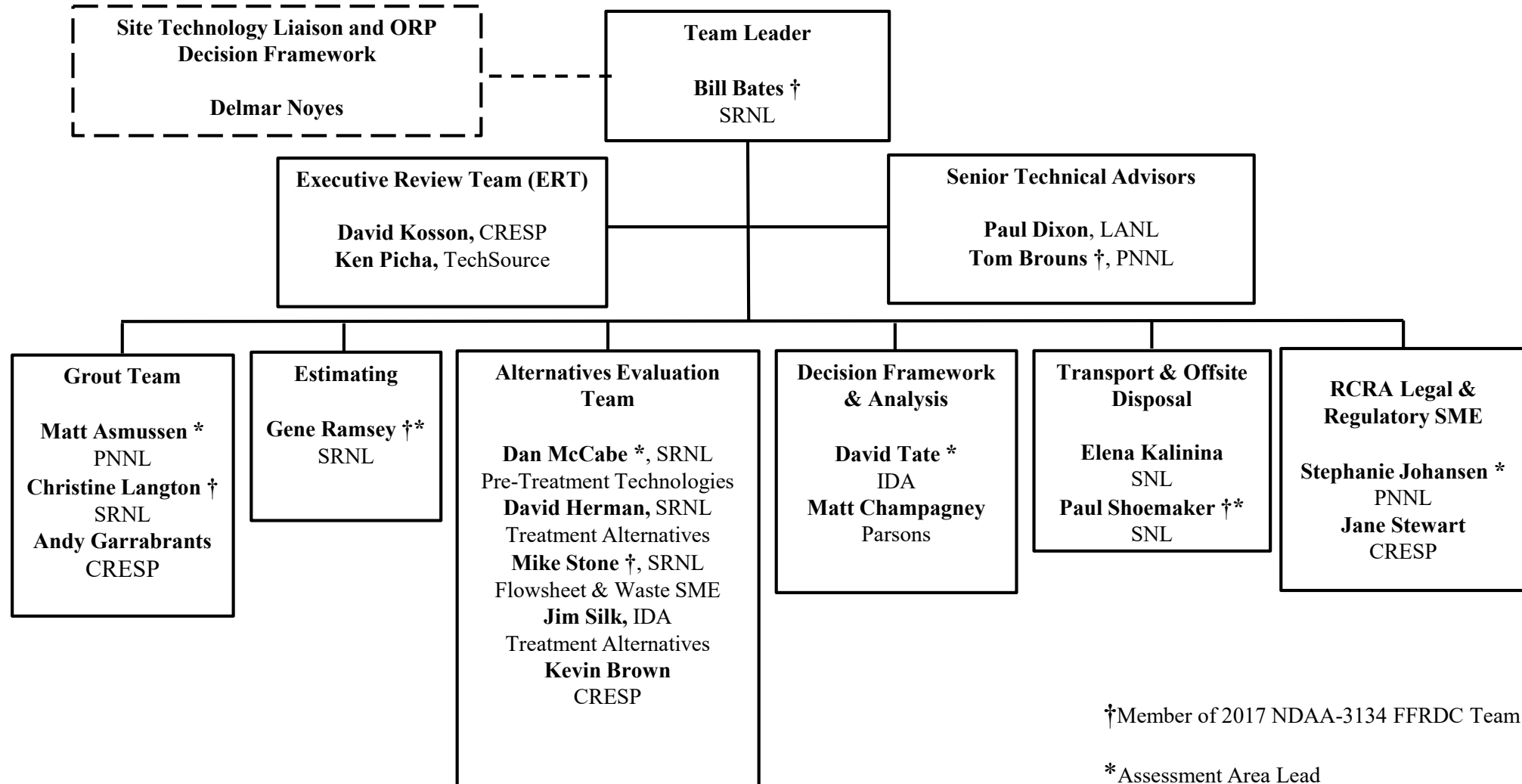
Terminology

- **Terminology is Important**

- Tank waste is determined by DOE **to be** or **not to be** high level waste (HLW) only at the conclusion of treatment, prior to disposal
- Tank waste may be managed conservatively to DOE requirements for HLW until disposed
- In many instances, the tank waste program uses the terminology of HLW to refer to the tank waste even though the waste has not been determined to be HLW

- **Use of HLW terminology in the FFRDC presentations does not imply a determination of waste classification**

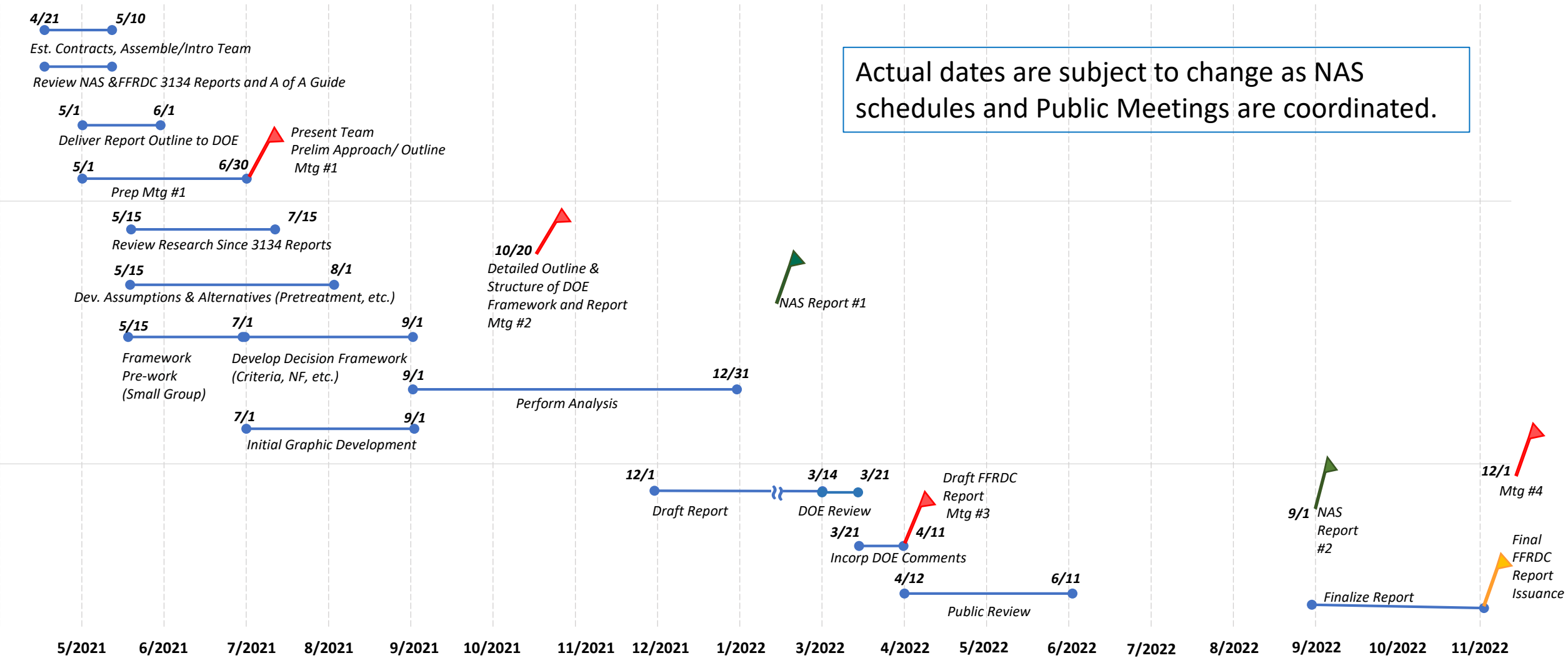
FFRDC Team Structure



†Member of 2017 NDAA-3134 FFRDC Team

*Assessment Area Lead

FFRDC Team Schedule



Order of Presentations

- **Bill Bates (SRNL)** — FFRDC Team Draft Report Overview
- **Michael Stone (SRNL)** — Process and Feed Vector Overview
- **David Tate (IDA)** — Decision Framework Overview
- **Stephanie Johansen (PNNL)** — On-Site Disposal Description
- **Elena Kalinina (SNL)** — Off-Site Disposal and Transportation Description
- **Dan McCabe (SRNL)** — Alternative Descriptions
- **Matt Asmussen (PNNL)** — Uncertainty Drivers in the Alternatives and Updated Information Since 2017-NDAA-3134
- **Dan McCabe (SRNL)** — Alternative Analyses
- **William Ramsey (SRNL)** — Cost and Schedule Methodology & Estimates
- **Matt Champagney (Parsons)** — Assessment Summary and Results
- **Bill Bates (SRNL)** — Wrap Up — Summary and Conclusions

FFRDC Analysis per NDAA Section 3125

- “... shall be designed, to the greatest extent possible, to *provide decisionmakers with the ability to make a direct comparison between approaches for the supplemental treatment of low-activity waste at the Hanford Nuclear Reservation based on criteria that are relevant to decision making and most clearly differentiate between approaches.*”
- **Technologies**
 - Vitrification — Glass Waste Form
 - Fluidized Bed Steam Reforming (FBSR) — Granular Waste Form
 - Grout — Cementitious Waste Form
- **Timing**
 - Intent to Finish LAW Treatment Concurrent with WTP-HLW Vitrification Facility Mission

FFRDC Analysis “Criteria” from the NDAA

- **Effective Treatment Technology & Waste Form**
- **Differences Among Treatment Approaches**
- **Compliance with Technical Standards**
- **Differences Among Disposal Sites**
- **Potential Modifications to Facility Designs**
- **Pretreatment of Long-Lived Radionuclides to Reduce Disposal Cost**
- **Whether to Remove Radionuclides & Impact on Secondary Waste**
- **Other Relevant Factors:**
 - Cost & Risk of Delays Impacting Tank Performance
 - Prior Experience
 - Outcomes of Test-Bed Initiative (TBI)

FFRDC Analysis Approach

- **Review 2017 NDAA Section 3134 Final NAS Review Report (#4)**
- **Review Progress on Technologies since 2019**
- **Develop Alternatives (23)**
 - Storage
 - *Existing DSTs or New Facilities*
 - Pretreatment
 - *Cs, Sr, Tc, I, Land Disposal Restriction Organics, etc.*
 - Primary Treatment
 - *Vitrification, FBSR, Grout*
 - Primary Disposal
 - *Onsite (IDF), Off-Site (TX or UT)*
 - Secondary Waste Treatment & Disposal
- **Screened Alternatives**
- **Remaining 15 Alternatives for Analysis**

FFRDC Analysis Approach (cont.)

- **Developed Detailed Analysis Criteria – These are the 4 “Top Tier”**
 - **Long Term Effectiveness**
 - *Environmental and Safety Risk After Disposal*
 - **Implementation Schedule and Risk**
 - *Environmental and Safety Risks Prior to Mission Completion Including Risks Driven by Waste Tank Storage Duration*
 - **Likelihood of Successful Mission Completion**
 - *Affordability and Robustness to Technical Risks*
 - **Lifecycle Costs**
- **Two Other Criteria Identified but Excluded from Direct Comparison of Alternatives**
 - **Securing and Maintaining Necessary Permits/Authorities (Regulatory Approval)**
 - **Community/Public Acceptance**
- **Assessed 15 Alternatives Against all Criteria**
- **Selected Four (4) Alternatives for Comparative Analysis**
 - **Vitrification, FBSR, and two Grout Alternatives**
- **Developed Recommendation and Supporting Conclusions**

NAS Committee Review #1 Report

- **Recommendations Were Very Helpful In Completion of the Analysis**
 - A. Address Risks Related to Failure of Tanks
 - B. Identify and “Narrow” Factors to Salient Decision Relevant Differences Among Alternatives
 - C. Identify and Analyze Major Uncertainties
 - D. Distinguish Differences Based on Above
- **Also Reviewed Appendix C and other Suggested Improvements**

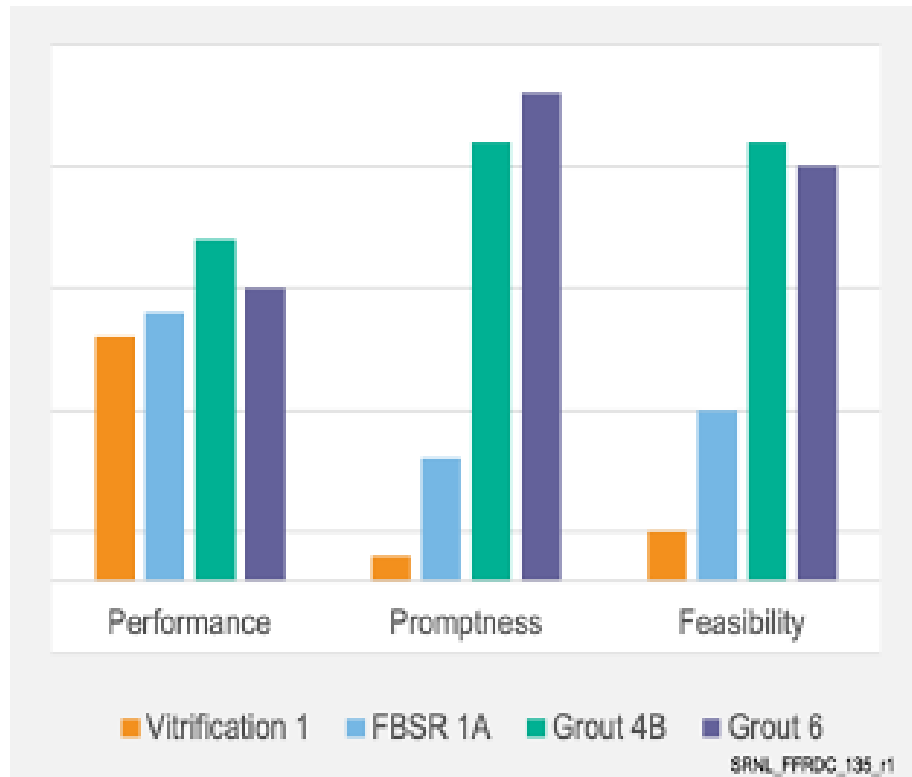
Comparative Analysis

Table 5-1. High-Level Comparison of the Four Consolidated Alternatives for Supplemental Treatment of Low-Activity Waste

Alternative			
Vitrification 1: Disposal onsite at Hanford	FBSR 1A: Solid monolith product disposal onsite at Hanford	Grout 4B: Off-site grouting/disposal	Grout 6: Phased Approach Off-site grouting/disposal, then on-site grouting/disposal
Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)			
Highly effective for primary waste; moderately effective for secondary waste. Medium confidence in the assessment.	Effective. Medium confidence in the assessment, due to technology immaturity.	Highly effective. High confidence in the assessment.	Highly effective. Good to high confidence in the assessment.
Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)			
High risk due to significant cost-based startup delays and operations limits. Moderate technical implementation risk. Construction finishes 2049, mission does not complete without significant additional annual budget.	High risk due to construction time required and technical execution risk. Construction finishes 2039; mission completes 2070.	Low risk due to immediate start, minimal construction, low-temperature process, likely capacity, and modest transportation and operations costs. Limited facilities (e.g., evaporator and load-out station) needed; mission completes 2065.	Very low risk due to immediate start, flexible timing of conversion to on-site low-temperature process, and inexpensive operations. Grout plant construction finishes 2039; mission completes 2065.
Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)			
Very low probability of successful completion due to affordability.	Low probability of successful completion, due to technical risk.	Very high likelihood of successful completion.	High likelihood of successful completion.
Criterion 4: Lifecycle cost (discounted lifecycle costs)			
\$7.6B construction; \$5.1B operations (unaffordable, \$1.36B shortfall)	\$3.4B construction; \$2.2B operations	\$0.4B construction; \$3.4B operations	\$1.4B construction; \$2.7B operations

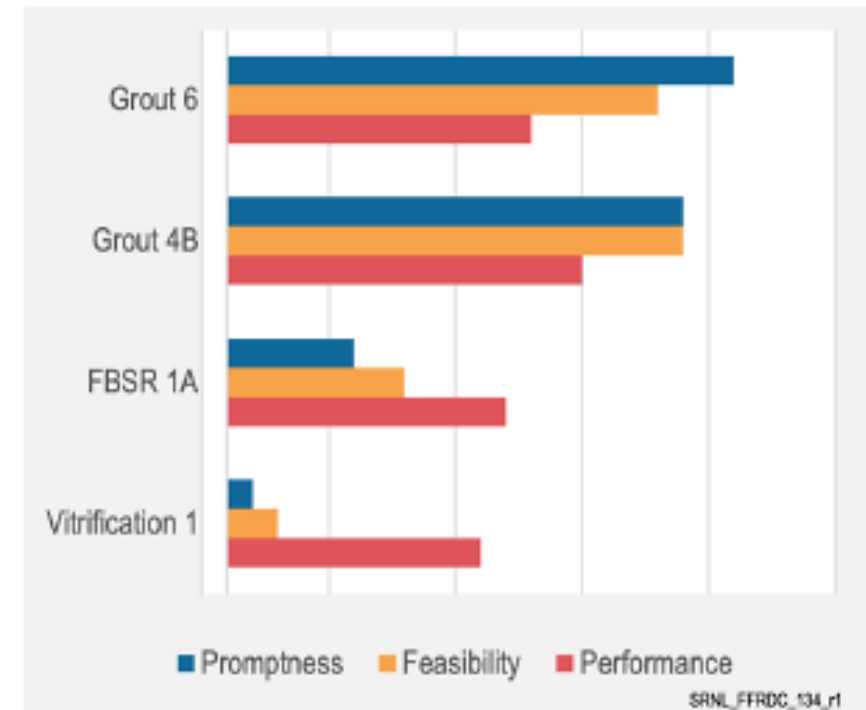
FBSR = fluidized bed steam reforming.

Comparison by Criteria



Performance = Criterion 1, Promptness = Criterion 2, and Feasibility = Criterion 3.

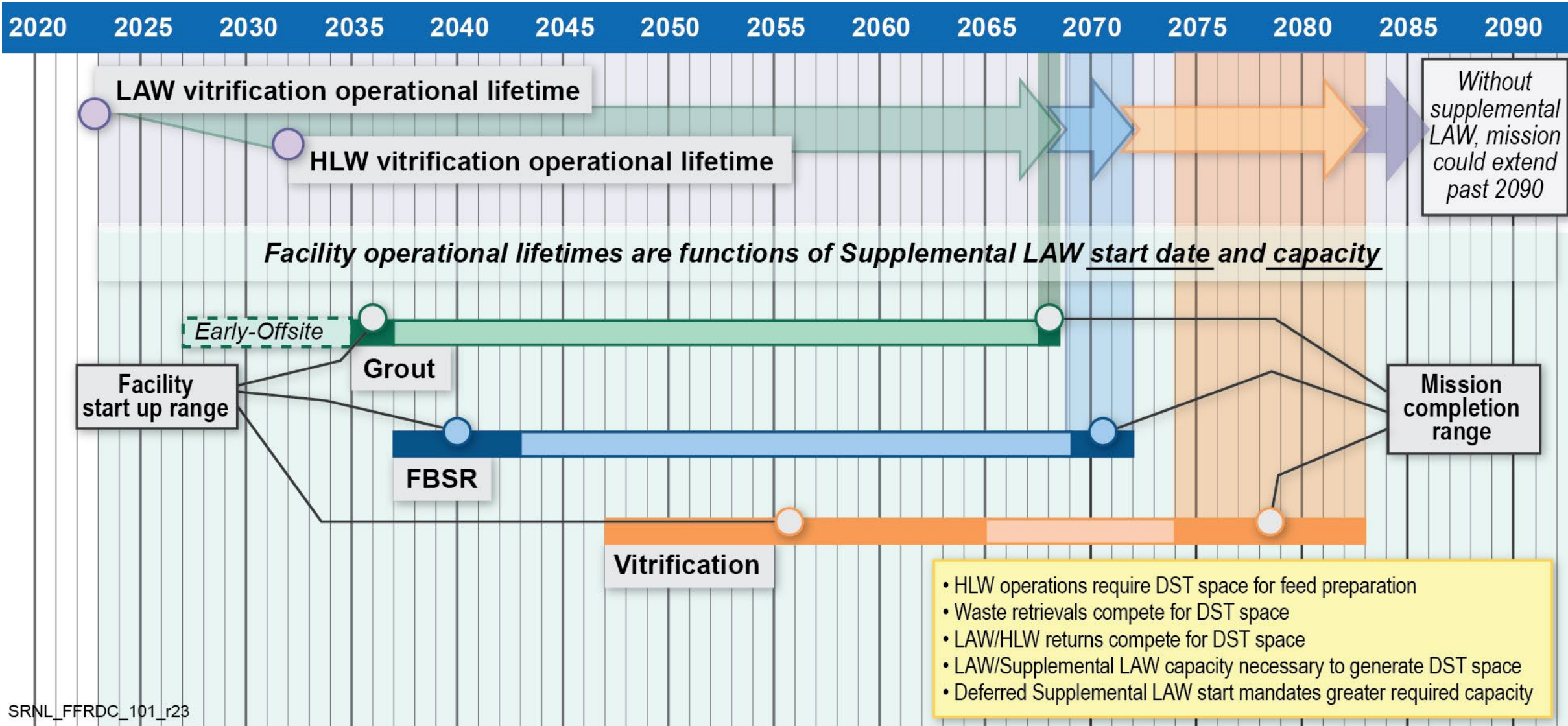
Figure 4-3. Comparison by Criterion



Performance = Criterion 1, Promptness = Criterion 2, and Feasibility = Criterion 3.

Figure 4-2. Qualitative Alternatives Comparison of Four Representative Alternatives

Schedule Durations



For reference, WMEIS projected 2018 thru 2093 if no LAW Supplemental Treatment (EIS Alternative 2B)

LAW Supplemental Alternatives: Total Discounted Cost and OPEX Cost

	Hot Operations	LAW Supplemental Operations Complete	Total Cost (M) Discounted (3% basis)	Total OPEX Cost (M) Discounted (3% basis)
Vitrification 1	2050	2075	\$12,700	\$5,090
FBSR 1A	2040	2070	\$5,530	\$2,150
FBSR 1B	2040	2070	\$6,280	\$2,910
Grout 1A	2036	2068	\$2,730	\$1,620
Grout 1B	2036	2068	\$3,410	\$2,310
Grout 1C	2036	2068	\$3,120	\$1,920
Grout 2A	2036	2068	\$3,400	\$1,850
Grout 2B	2036	2068	\$4,320	\$2,770
Grout 2C	2036	2068	\$3,850	\$2,210
Grout 4A	2027	2065	\$3,340	\$2,930
Grout 4B	2027	2065	\$3,850	\$3,440
Grout 5A	2036	2068	\$3,350	\$1,610
Grout 6	2027	2065	\$4,130	\$2,730

Recommendation

- ***DOE should expeditiously secure and implement multiple pathways for off-site grout solidification/immobilization and disposal of LAW in parallel with the DFLAW vitrification process.***
 - **Rapid Risk Reduction** – DST Space, Accelerate Waste Retrievals, Waste Stabilized
 - **Environmental Protection** – Reduce Onsite Disposal Inventory, Offsite Disposal with No Credible Pathway to Potable Water
 - **Flexibility** – Can Route LAW Selectively
 - **Time to Enable Transition(s)** – If On-Site Treatment and/or Disposal are Pursued, Benefit from Operating Experience
 - **Reduction or Elimination of Need for Future Capabilities**
 - **Minimized Financial Demands** – Closest to Current Funding Levels
 - **Most Likely to be Successfully Implemented**



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Process and Feed Vector Overview



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Flowsheet Overview: Significant Changes from 2017 Evaluation

- **Process based on System Plan 9 (assumes vitrification)**
 - Previous study used System Plan 8
- **AP tank farm tank used to stage and deliver LAW to the WTP LAW and LAW Supplemental Treatment**
- **Total Operating Efficiency (TOE)**
 - System Plan 8 assumed 70%
 - Some recent studies (e.g., SP9, Scenario 1B) of the WTP flowsheet have assumed 50% or 40%
 - *Based on TOE of comparable facilities*
 - Defense Waste Processing Facility, West Valley Demonstration Project, others
 - *Increases number of melters needed for LAW supplemental treatment*
 - Four assumed in System Plan 8
 - **Seven melters required at 40%**
- **ETF**
 - Capacity of LERF-ETF exceeded by effluents from LAW supplemental treatment in SP9
 - **New LERF-ETF required**
 - Existing LERF-ETF assumed adequate in previous study
- **I-129 in Glass**
 - Increased uncertainty of iodine capture of in glass
 - *Estimates of glass capture range from <20% to 96%*
 - *Single pass capture is expected to be low*
 - *The high uncertainty results from differences in the assumed I-129 capture in the primary offgas system*
 - Condensate from the primary offgas system is evaporated and recycled to the melter feed
 - The caustic scrubber in secondary offgas treatment system is expected to capture most of the iodine not captured in glass
 - *Some I-129 capture could occur in other unit operations*
 - *Uncertainty in iodine capture in secondary offgas system also has high uncertainty*
 - *The baseline assumes the material is transferred directly to LERF/ETF for treatment*
 - ETF can treat the I-129, but inventory limits for I-129 could be exceeded in ETF
 - I-129 assumed to be sent to IDF in grouted solids from the ETF
 - Potential mitigation measures to address
 - *Recycle the caustic scrubber effluents to the LAW feed with the primary offgas condensate*
 - Operation of WTP-LAW will reduce the uncertainty if a vitrification process is used for supplemental treatment of LAW

What is LAW Supplemental Treatment?

- **Treatment Facility for Pretreated Supernate from Hanford Tank Waste**
 - Treats LAW when feed rate exceeds the capacity of the WTP-LAW facility
 - *Prevents slowing down HLW treatment due to lack of capacity for LAW treatment*
 - Complete treatment facility (no returns to any upstream facility)
 - *Includes any additional pretreatment that may be needed for LAW supplemental treatment process*
 - LDR Organics
 - Tc-99
 - I-129
 - *Includes processing liquid secondary waste to allow recycle and/or treatment at the Hanford Liquid Effluent Retention Facility / Effluent Treatment Facility (LERF-ETF)*
- **Purely a Conceptual System at the Moment**
 - Many aspects are still TBD
 - *Immobilized waste form*
 - *Capacity*
 - *Location*

WTP-LAW: Two LAW melters

Design Capacity: 15 MT (glass)/day each

Footprint – 330 ft x 240 ft x 90 ft

Concrete – 28,500 cubic yards

Structural Steel – 6,200 tons

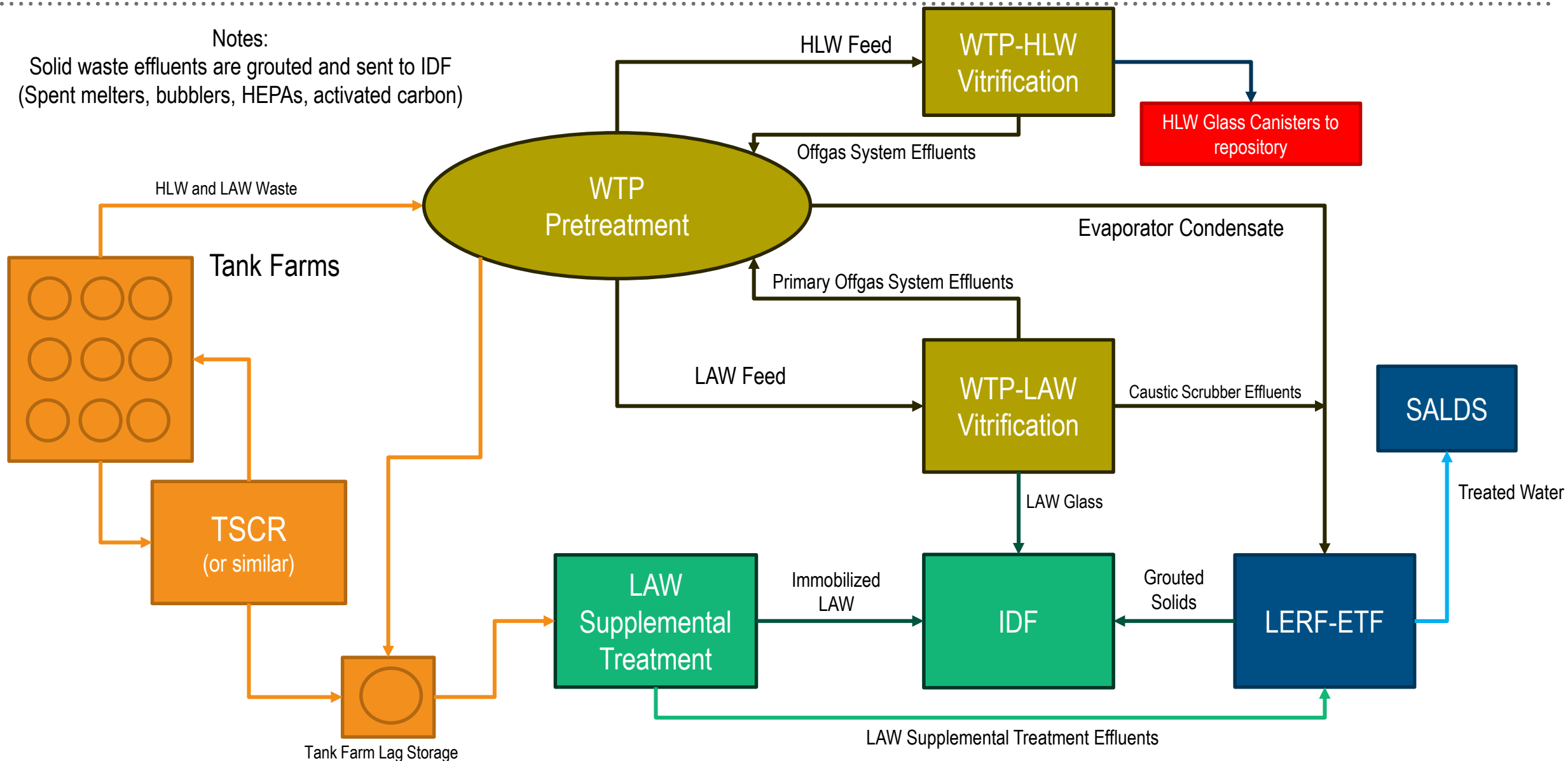
Craft hours to build: 2,337,000



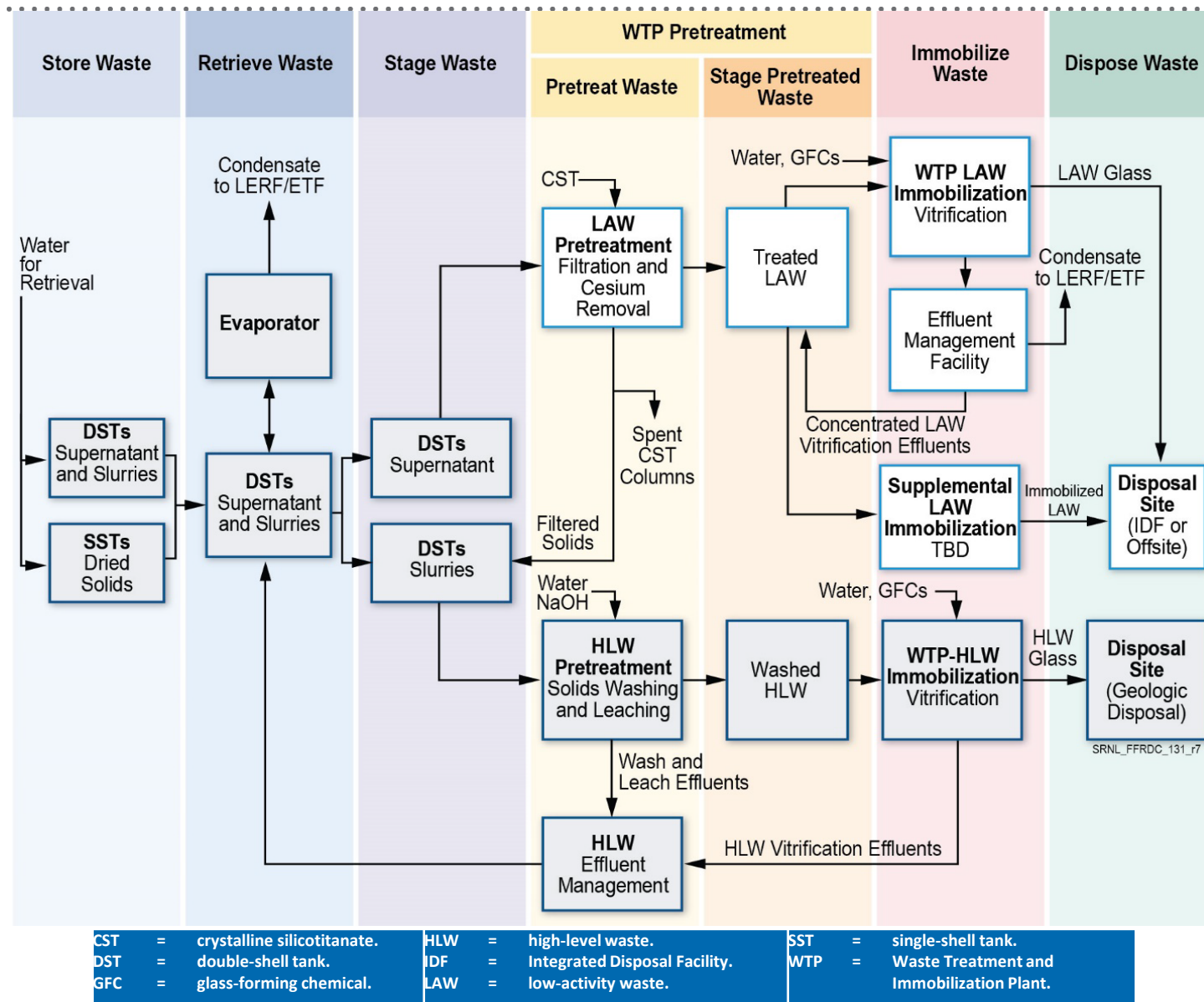
Overall Treatment Flowsheet: SP9-1B

Notes:

Solid waste effluents are grouted and sent to IDF
(Spent melters, bubblers, HEPAs, activated carbon)

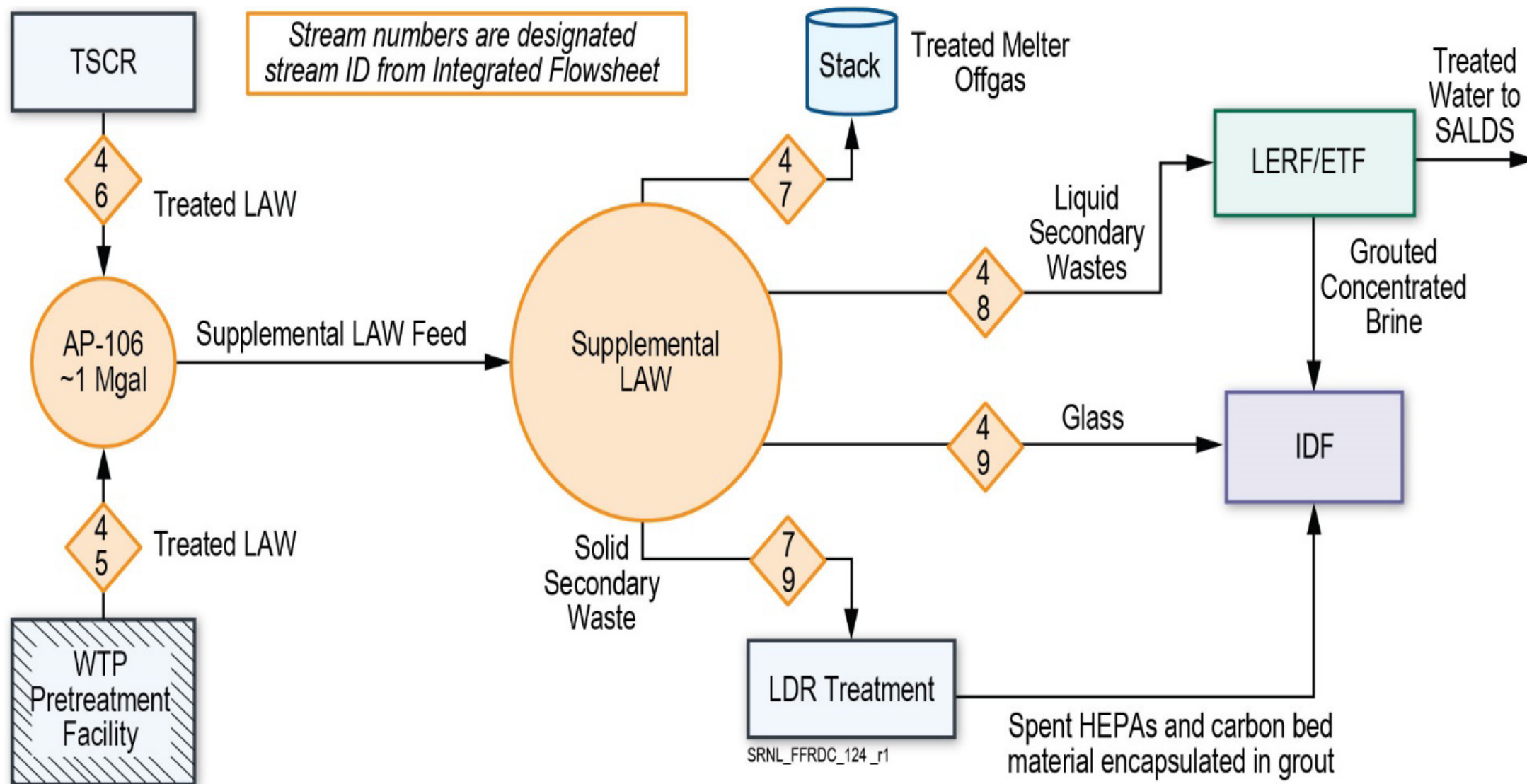


Overall Tank Waste Mission Simplified Flow Diagram

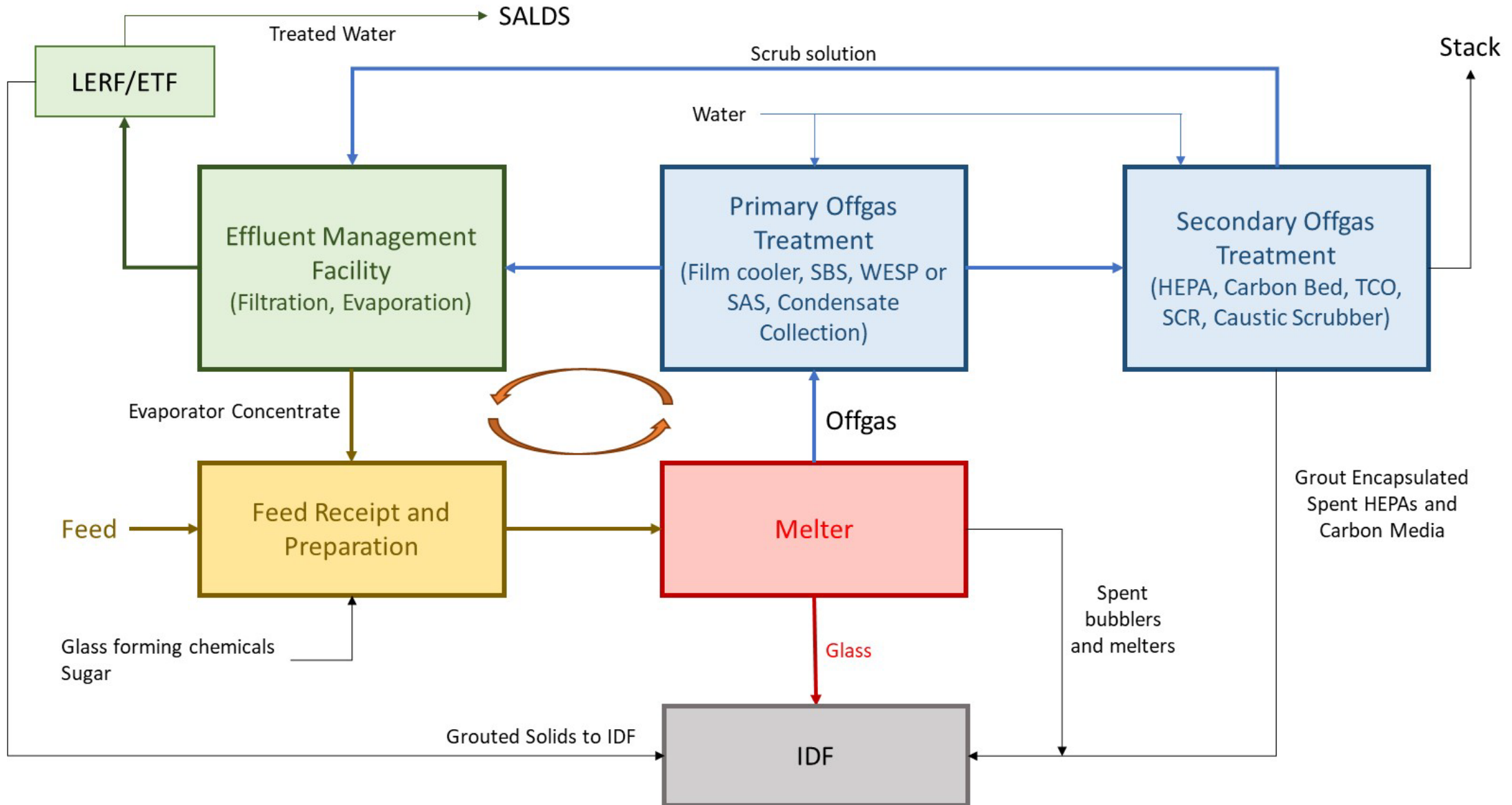


- Waste in SSTs consists of solids with free liquids removed to extent possible
- Water or supernatant is added to sluice waste from SSTs into a DST
 - Available DST space needed for retrievals impacted by rate of LAW treatment
- Waste staged for treatment in DSTs
- Waste is typically pretreated prior to immobilization
 - Solids are typically washed to remove anions and leached to remove Al
 - Supernatant are filtered to remove solids and cesium is removed via ion exchange processes
- DFLAW uses a DST to stage the pretreated LAW waste
- Immobilization of wastes via vitrification or other process
 - Secondary wastes can be generated and require additional treatment
- Disposal at IDF or offsite disposal site completes treatment

LAW Supplemental Treatment Feeds and Effluents: SP9-1B



Vitrification Flow Diagram



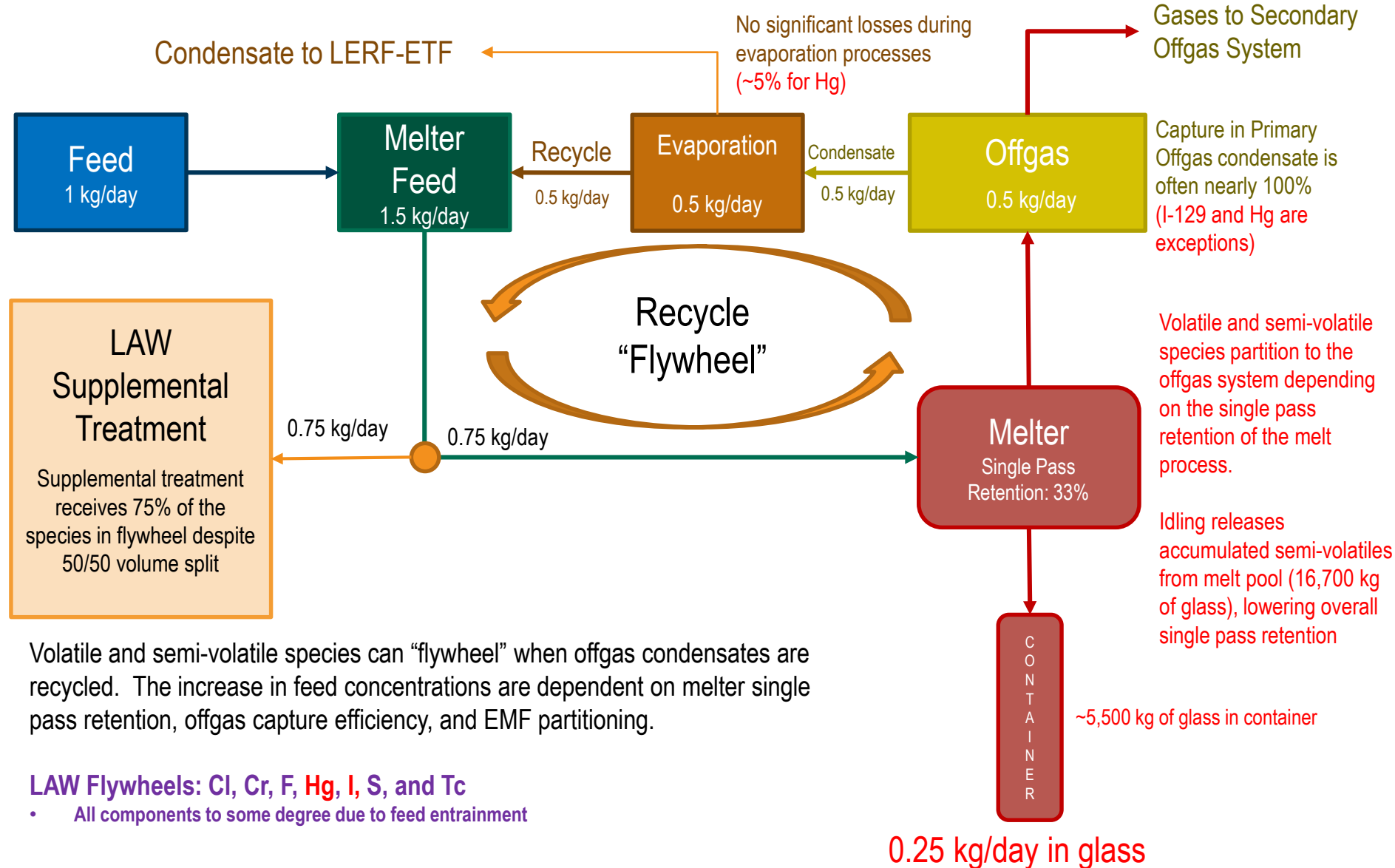
Semi-volatile Recycle “Flywheel” in Combined WTP-LAW Operations

Graphic illustrates the path through the process for 1 kg of a semi-volatile component, such as Tc, in the feed.

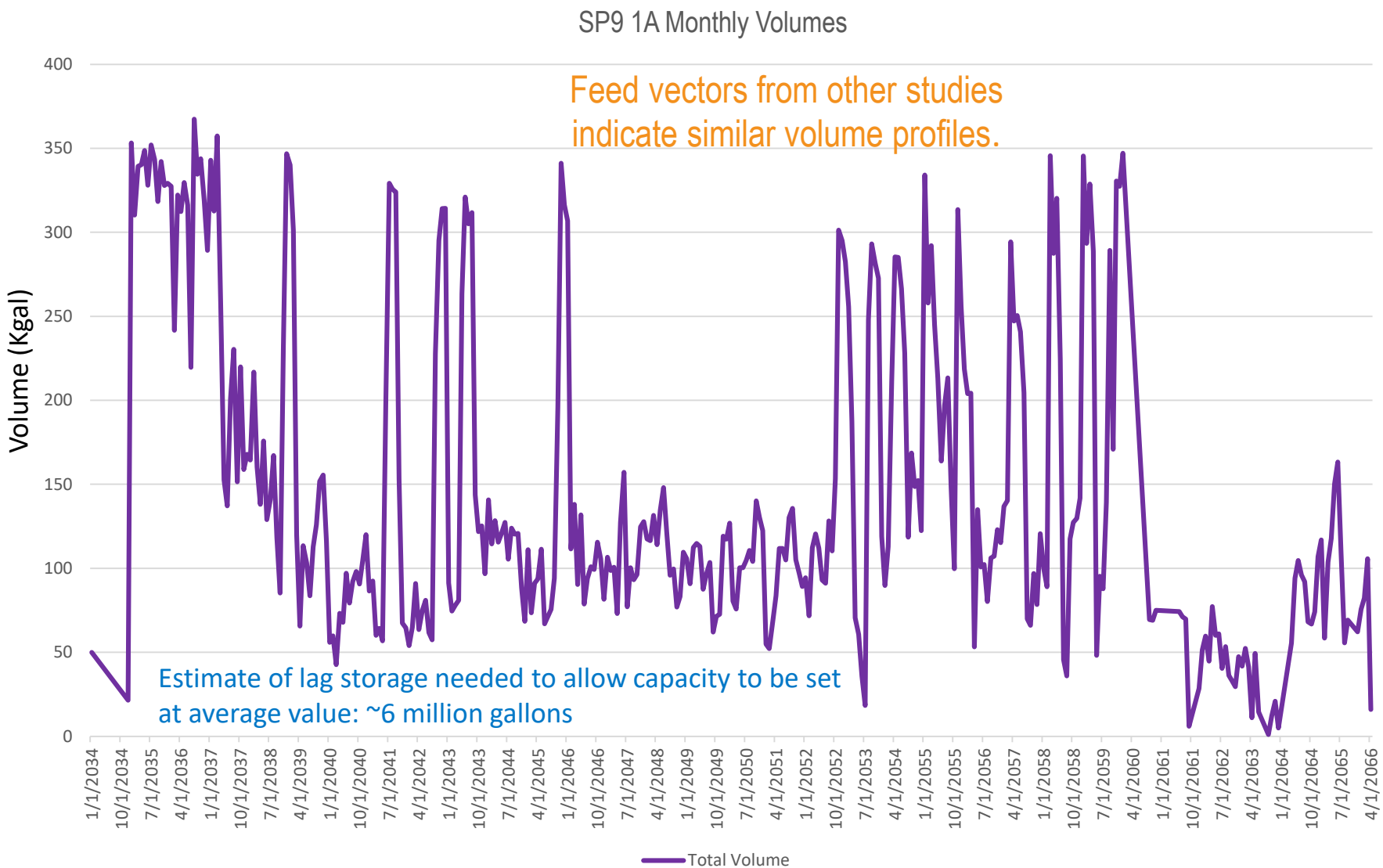
WTP-LAW flywheel is intentional to force Tc-99 into glass.

Despite assuming an even split between LAWST and WTP-LAW, 75% of Tc-99 is immobilized in LAWST.

Recycle handling during a DFLAW flowsheet could eliminate the link between WTP-LAW and LAW-ST, reducing the amounts of semi-volatiles sent to LAW-ST from the SP9-1B values.



LAW Supplemental Treatment Capacity Required by Month: Grout



Overall waste volume determines needed capacity for grout facility

System Plan 8

Max: 370,000 gal/month
Ave: 160,000 gal/month
Min: 7,200 gal/month
Total: 54,000,000 gallons
Turndown: 50:1

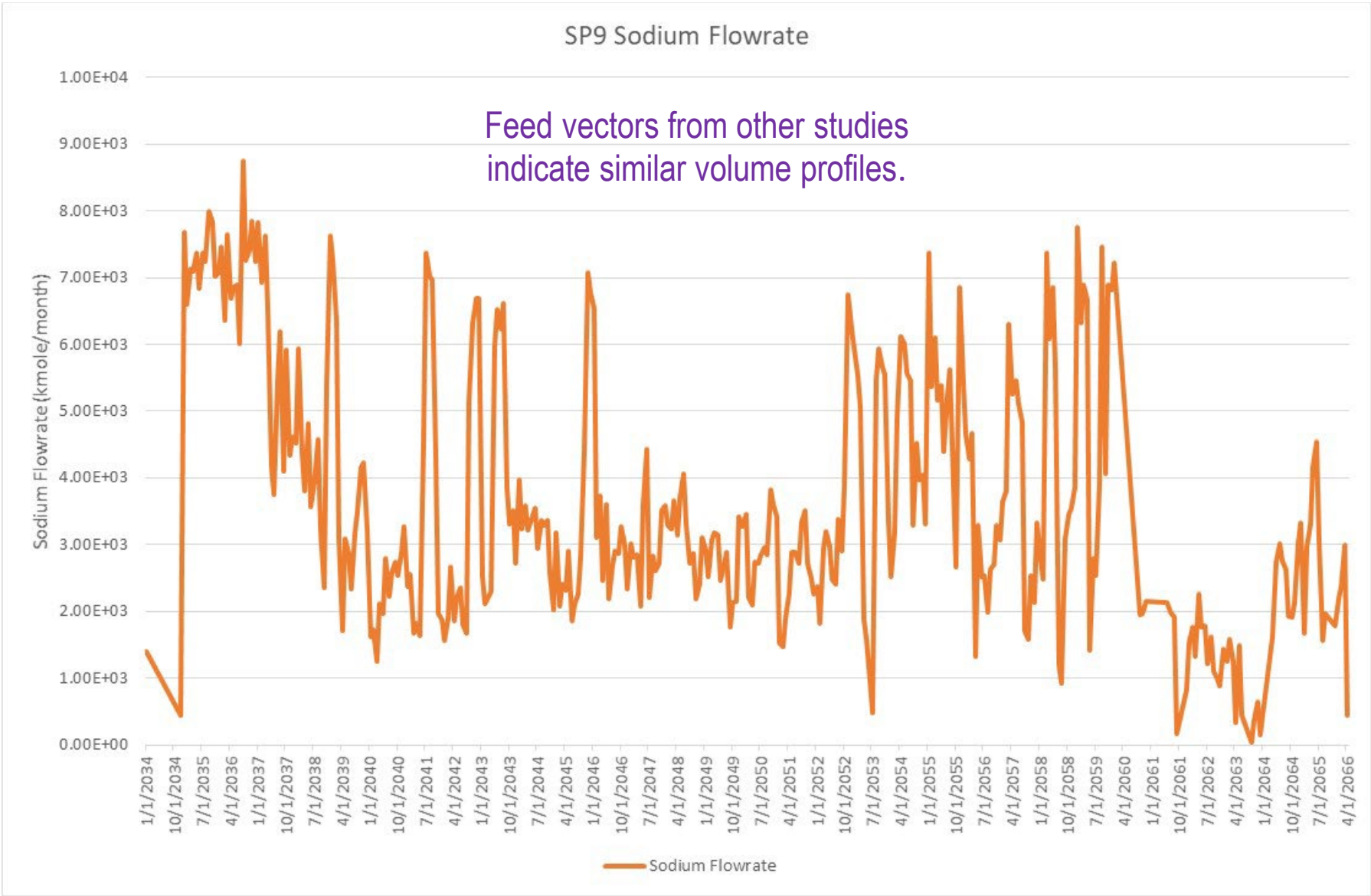
System Plan 9 1A

Max: 367,000 gal/month
Ave: 145,000 gal/month
Min: 1,100 gal/month
Total: 52,000,000 gallons
Turndown: 300:1

System Plan 9 1B

Max: 264,000 gal/month
Ave: 114,000 gal/month
Min: 700 gal/month
Total: 57,000,000 gallons
Turndown: 370:1

LAW Supplemental Treatment Capacity Required by Month: Thermal Treatment



- Waste sodium determines needed capacity for vitrification process
- One melter can treat 40 to 80 MT of sodium/month depending on waste loading and operating efficiency

System Plan 8

Max: 296 MT/month
Ave: 138 MT/month
Min: 8 MT/month
Total: 47,000 MT

System Plan 9 1A

Max: 271 MT/month
Ave: 113 MT/month
Min: 1 MT/month
Total: 40,000 MT

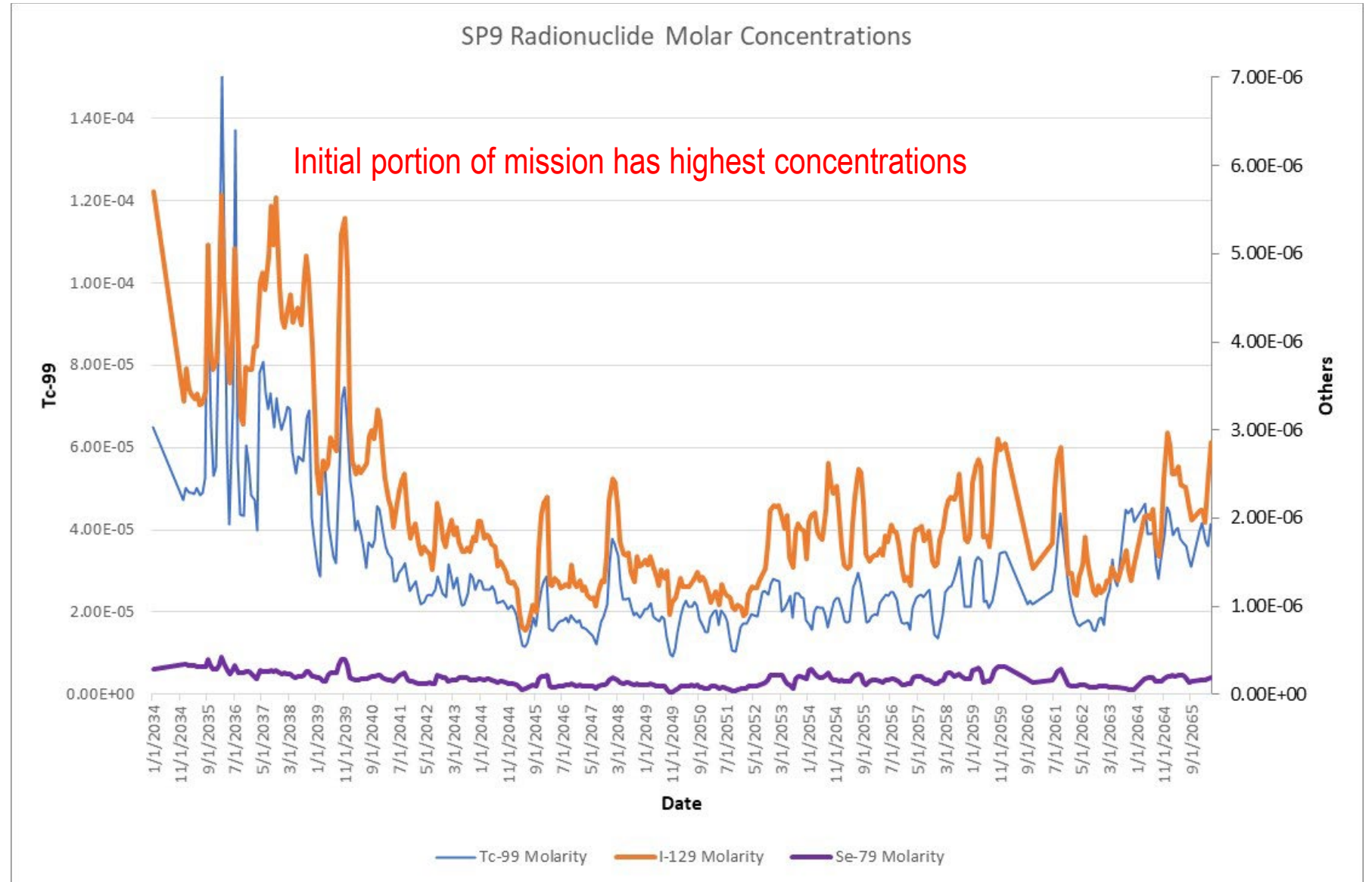
System Plan 9 1B

Max: 195 MT/month
Ave: 87 MT/month
Min: 1 MT/month
Total: 43,000 MT

Radionuclides of Concern in LAW Supplemental Treatment

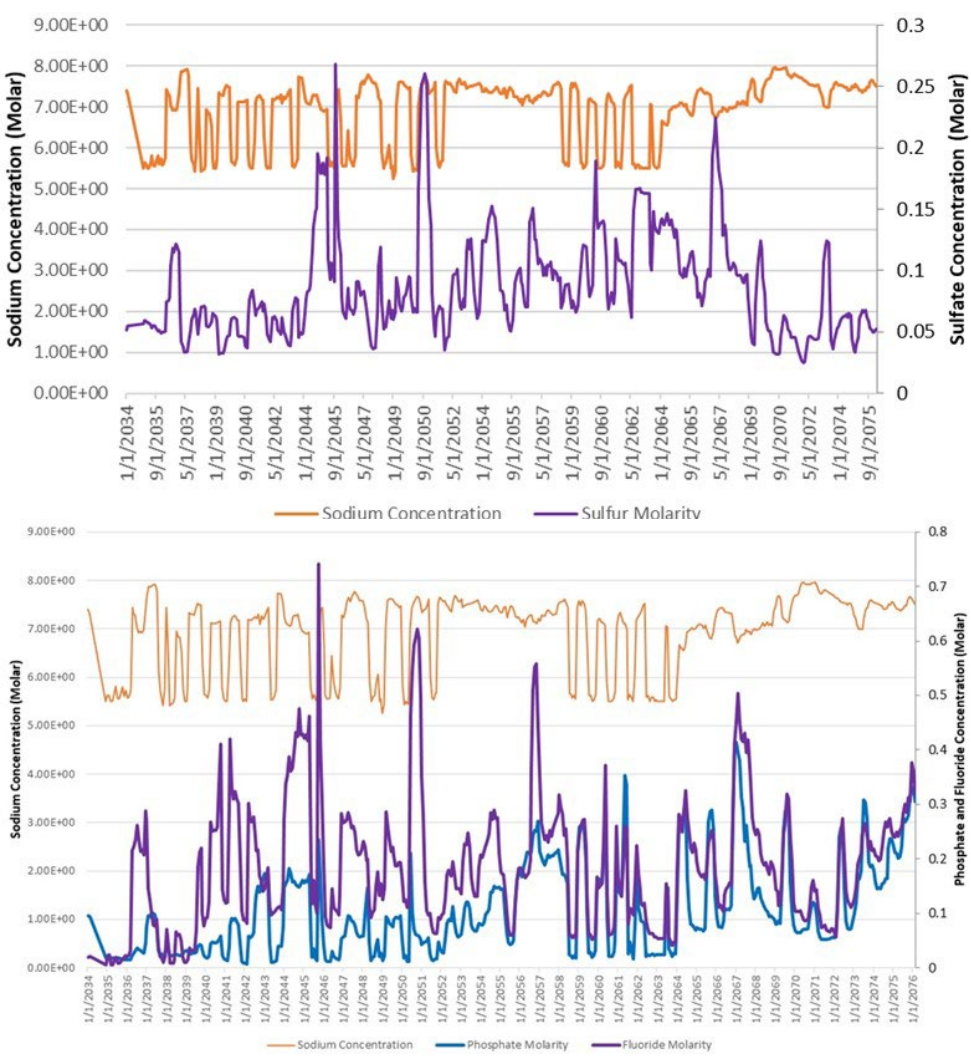
- The IDF Performance Assessment identified Tc-99 and I-129 as the constituents that were most likely to challenge groundwater protection performance standards
- Se-79 also included on chart based on comments received on 2017 evaluation

Feed vectors from other studies indicate similar profiles.



LAW Supplemental Treatment Feed: Chemical Composition

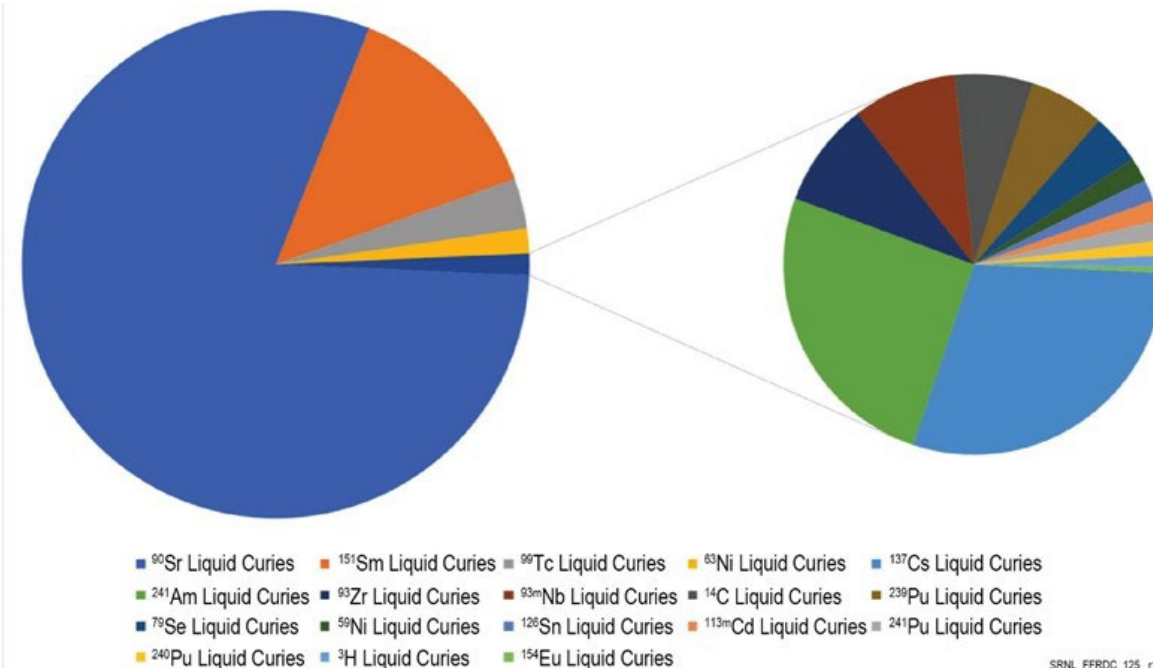
Analyte	Average	Maximum	Minimum	Units
Sodium	159	183	121	g/L
Nitrate	106	195	29.5	g/L
Free Hydroxide	48.8	87.9	7.59	g/L
Nitrite	28.4	64.0	6.27	g/L
Carbonate	17.3	45.24	3.21	g/L
Aluminum	11.1	25.9	1.26	g/L
TOC	5.29	78.5	0.49	g/L
Fluorine	3.56	14.09	0.10	g/L
Phosphate	3.28	12.82	0.24	g/L
Oxalate	3.12	13.77	0.34	g/L
Sulfur	2.78	8.60	0.81	g/L
Chlorine	1.66	4.24	0.46	g/L
Potassium	1.23	6.53	0.17	g/L
Silicon	0.66	3.66	0.05	g/L
TOC = total organic carbon.				



Sodium, sulfate, phosphate, and fluorine

LAW Supplemental Treatment Feed: Radionuclide Composition per SP9-1B (assumes no Sr removal)

Radionuclide	Total Amount in Feed (Ci)	Radionuclide	Total Amount in Feed (Ci)
⁹⁰ Sr	301,560 (3,016)	²³⁸ U	5.29
¹⁵¹ Sm	50,913	²⁴² Cm	4.59
⁹⁹ Tc	12,000	²³⁷ Np	4.36
⁶³ Ni	5,930	²⁴⁴ Cm	3.31
¹³⁷ Cs	1,533	⁶⁰ Co	2.17
²⁴¹ Am	1,322	¹⁵² Eu	2.10
⁹³ Zr	463.8	¹⁵⁵ Eu	1.98
^{93m} Nb	458.6	²⁴³ Am	0.633
¹⁴ C	346.3	²³¹ Pa	0.482
²³⁹ Pu	330.2	²²⁷ Ac	0.322
⁷⁹ Se	222.5	¹²⁵ Sb	0.243
⁵⁹ Ni	106.7	²⁴³ Cm	0.243
¹²⁶ Sn	95.1	²³⁵ U	0.220
^{113m} Cd	89.3	²³⁶ U	0.135
²⁴¹ Pu	88.1	²³² U	0.128
²⁴⁰ Pu	67.8	²²⁸ Ra	0.047
³ H	48.1	²³² Th	0.039
¹⁵⁴ Eu	26.1	²⁴² Pu	0.031
²³³ U	15.0	²²⁹ Th	0.027
¹²⁹ I	12.2	²²⁶ Ra	0.0015
²³⁸ Pu	11.7	¹³⁴ Cs	0.0000016
²³⁴ U	5.35	¹⁰⁶ Ru	0.000000006



Radionuclides in Feed Vector Greater than 0.01% of Total Activity

LAW Supplemental Treatment Feed Curies

⁹⁰Sr represents 80%
⁹⁰Sr plus ¹⁵¹Sm represent 94%
⁹⁰Sr, ¹⁵¹Sm, ⁹⁹Tc, ⁶³Ni, ¹³⁷Cs represent 99%

Direct feed options for LAW assumed to utilize CST for Cs removal which will also capture most of the Sr-90 (>99%)
 99% Sr-90 removal by CST assumed for this study.

Additional Notes

- **Feed vector from SP9-1B used to generate data shown in previous slides**
 - This feed only applies to a single plant in East Area
- **Modular alternatives required evaluation with additional data**
 - Data pulled from the Best Basis Inventory
 - Evaluated on a per tank and per tank farm basis
 - **Data examples included in report appendices**
 - Modular approaches would result in less incidental blending
- **Offsite Grout 4B evaluated with a separate model run by WRPS**
 - Waste retrievals accelerated as needed to ensure full utilization of DST space
 - HLW processing adjusted based on availability of DST space for HLW pretreatment effluents (assumes a DFHLW flowsheet)
- **WRPS's TOPSim Model does not perform a Sum of Fractions analysis for final waste form**
 - Generation of waste above the limit is considered a modeling anomaly that would be corrected prior to processing

- *Waste Form Performance Constituent Concentrations*
- *Grout Driver Constituent Concentrations*
- *Waste Phase Volume*
- *Volume Increase to DST System*
- *Waste Form Performance/Grout Driver Constituent Inventories by Waste Phase*
- *RCRA Metal Constituent by Waste Phase*
- *Tank Waste Sampling History*
- *Sum of Fractions Plot*
- *Non-Wastewater/Wastewater Exceedance*

Impact of Waste Tank Leaks

- **Assessment of risks of future tank leaks, etc., not in scope of this evaluation**
 - Expertise of team not suited to assess tank leak risks
- **One of the criterion evaluated for each alternative was the potential for mission acceleration**
 - Acceleration of the tank waste treatment mission allows acceleration of bulk waste removal from tanks
- **Programmatic impact of new tank leak varies depending in the severity of the leak and the tank impacted**
 - A leak from an SST has less programmatic impact than a leak in a DST
 - A leak from a DST can have a significant programmatic impact
 - *Impact is greater if the DST has a designated use (e.g., AP-106 is designated as the staging tank for pre-treated LAW during DFLAW)*
 - *Acceleration of tank waste treatment mission creates tank space to reduce the programmatic impact of a DST leak*

The Hanford site has extensive programs in place to ensure tank integrity, monitor the condition of the waste tanks, and to detect and monitor any leaks.



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Decision Framework Overview

Dr. David Tate

Senior Defense Analyst, IDA

Systems and Defense Analyses

Decision Framework & Analysis Team Lead

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Decision Framework

- **Overall Goal:** “...to provide decisionmakers with the ability to make a direct comparison between approaches for the supplemental treatment of Low-Activity Waste [...] based on criteria that are relevant to decision-making and most clearly differentiate between approaches.” (FY21 NDAA, Section 3125 (B))
- **Analytical Approach: Hierarchical Decomposition and Recomposition**
 - Identify technically feasible alternatives
 - Choose top-tier decision-informing criteria to be directly compared
 - Analyze hierarchy of underlying factors affecting these criteria
 - Establish measures of effectiveness (MOE) for fundamental factors
 - Evaluate each fundamental factor according to its MOE for each alternative
 - Roll up lower-tier evaluations to higher-tier assessments
 - Show explicit criterion tradeoffs among alternatives



Hierarchical Taxonomy of Decision-Informing Criteria

- **Intended to Capture All Factors of Potential Relevance to Decision Makers in a Way that Makes the High-Level Tradeoffs Between Alternatives as Clear as Possible**
- **Incorporates All Statutory Factors from Section 3134 (2017) and Section 3125 (2021)**
 - Some explicitly, some implicitly – crosswalk provided in Appendix I.E
- **Includes Both Assessment of Designed Performance and Assessment of Shortfall Risks**
- **Top-Tier Criteria are Patterned After NEPA / RCRA / CERCLA / AEA (DOE 435.1) Decision Factors**
 - Familiar to decision makers
 - Already similar to NDAA-specified list of factors to consider
 - Explicitly cited as information of interest in FY2017 Section 3134 language
- **Shows Key Tradeoffs (e.g., Performance vs. Feasibility) at the Top Tier**
- **Supports Analysis of Alternatives (AofA) Approach to Informing Decision-Makers**
 - Consistent with GAO and DOE guidance for Analysis of Alternatives
 - Establishes an objective and consistent assessment framework prior to examination of individual alternatives

Tier 1 and 2 Taxonomy of Criteria to Be Assessed for Each Alternative

1. Long-Term Effectiveness

(environmental and safety risk after disposal)

1. Residual threat to health and environment upon successful completion
2. Long-term risks upon successful completion

Note: Only alternatives assessed as likely to comply with anticipated regulations and applicable standards for mobility and toxicity of wastes at project completion were evaluated in the Report. Alternatives unlikely to comply were screened out.

2. Implementation Schedule and Risk

(environmental and safety risks prior to completion, including risks driven by waste tank storage duration)

1. Specific risks or benefits related to ongoing tank degradation
2. Risks to humans (other than tank degradation)
3. Risks to the environment (other than tank degradation)
4. Duration

3. Likelihood of Successful Mission Completion

(including affordability and robustness to technical risks)

1. Likelihood and consequences of failing to complete due to technical problems
2. Likelihood and consequences of failing to complete due to resource constraints
3. Likelihood and consequences of failing to complete due to unavailability of key services and materials

Tiers 1 and 2 Taxonomy of Criteria (continued)

4. Lifecycle Costs

(discounted lifecycle costs)

1. Capital project costs (Design, construction, cold commissioning)
2. Operations costs (onsite and offsite)
3. Shutdown and decommissioning costs

5. Securing and Maintaining Necessary Permits/Authorities

(regulatory approval)

6. Community / Public acceptance

1. State, Local, and Tribal government acceptance (non-regulatory)
2. Community and public acceptance

With respect to Criteria 5 and 6, the FFRDC team concluded that stakeholders should have the benefit of this and other analyses prior to formulating input as part of the decision-making process. Likewise, securing regulatory approval is part of the negotiation process between government agencies, and it would be inappropriate for the FFRDC team to assign likelihoods to specific outcomes.

Criterion 1: Long-Term Effectiveness

1.1 Residual threat to health and environment upon successful completion

1.1.1 Residual toxicity of wastes

1.1.2 Mobility of primary and secondary wastes to a groundwater source (given intended disposal site(s))

1.1.3 Total volume of primary and secondary waste forms

1.2 Long-term risks upon successful completion

1.2.1 Confidence in estimated residual toxicity

1.2.2 Confidence in immobilization with regard to groundwater

1.2.3 Confidence in total volume of primary and secondary waste forms produced

Criterion 2: Implementation Schedule and Risk

2.1 Specific risks or benefits related to ongoing tank degradation

2.2 Risks to humans (other than tank degradation)

2.2.1 Effort required to ensure worker safety

2.2.2 Transportation risks

2.3 Risks to the environment (other than tank degradation)

2.3.1. Wastewater discharges (intentional)

2.3.2. Atmospheric discharges

2.3.3. Transfer/process tank (onsite) spills

2.3.4. Offsite transportation spills

2.3.5. Secondary waste streams generated

2.3.6. Greenhouse gas emission

2.4 Duration

2.4.1. Duration to hot startup

2.4.2. Duration to full capacity

2.4.3 Duration of operations

2.4.4 Risk of additional mission delay (technical / engineering or budgetary)

Criterion 3: Likelihood of Successful Mission Completion

3.1 Likelihood / consequences of failing to complete for technical reasons

- 3.1.1 Technical / engineering risks that could stop the project before completion
- 3.1.2 Robustness to known technical risks
- 3.1.3 Adaptability to the full range of tank waste compositions
- 3.1.4 Potential to incorporate future technology advances

3.2 Likelihood / consequences of failing to complete due to resource constraints

- 3.2.1 Average annual spending vs. \$450M / year budget
- 3.2.2 Projected peak spending vs. \$450M / year budget
- 3.2.3 Schedule flexibility – ability to stop and start operations if needed
- 3.2.4 Expected work accomplished / remaining at most likely failure point
- 3.2.5 Worst case work remaining at failure

3.1 Likelihood / consequences of failing to complete due to unavailability of key services or materials

Criterion 4: Lifecycle Cost (discounted present value)

4.1 Capital project costs (design + construction + cold commissioning)

4.2 Operations costs

4.3 Shutdown and decommissioning costs

For Criterion 4 assessment, anticipated costs for each alternative were categorized, escalated by category, constrained to the inflated \$450M / year budget (with carryover) for construction, deflated to constant FY2023 dollars, then discounted at 3% annually to get the present value of future costs.

Examples of the Full Hierarchy for Specific Bottom-Tier Criteria

1. Long-term effectiveness

1.1 Residual threat to health and environment upon successful completion

1.1.2 Mobility of primary and secondary wastes to potable water, given disposal site

1.1.2.4 RCRA metals

1.1.2.4.1 Mercury

2. Implementation schedule and risk

2.4 Duration

2.4.4 Risk of additional mission delay

2.4.4.2 Delay due to annual operating costs exceeding available funds

3. Likelihood of successful mission completion

3.1 Likelihood and consequences of failing to complete for technical/engineering reasons

3.1.1 Technology and engineering risks that could stop the project before completion

3.1.1.5 Technology maturity (including Test Bed Initiative)

Recap: Top-Tier Criteria

- 1. Long-Term Effectiveness**

(environmental and safety risk after disposal)

- 2. Implementation Schedule and Risk**

(environmental and safety risks prior to completion, including risks driven by waste tank storage duration)

- 3. Likelihood of Successful Mission Completion**

(including affordability and robustness to technical risks)

- 4. Discounted Lifecycle Costs**

(present value)

- 5. Securing and Maintaining Necessary Permits/Authorities**

(regulatory approval)

- 6. Community / Public acceptance**



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On-Site Disposal Description

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2021 NDAA-3125 Meeting #3

April 26-28, 2022

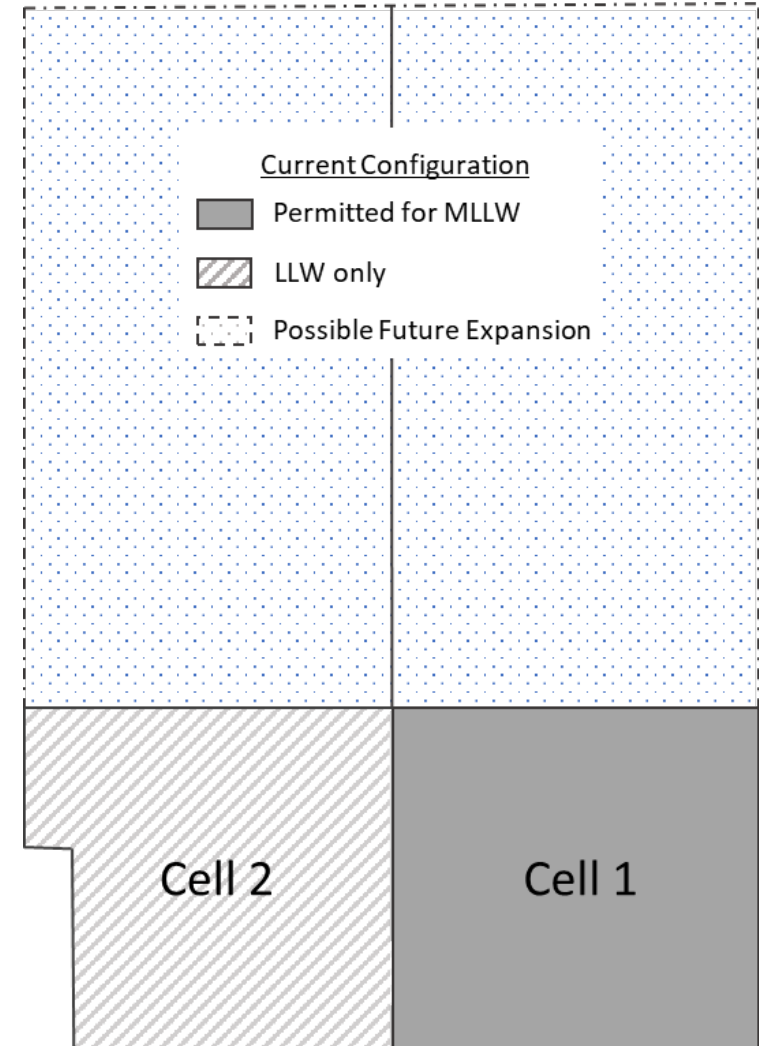
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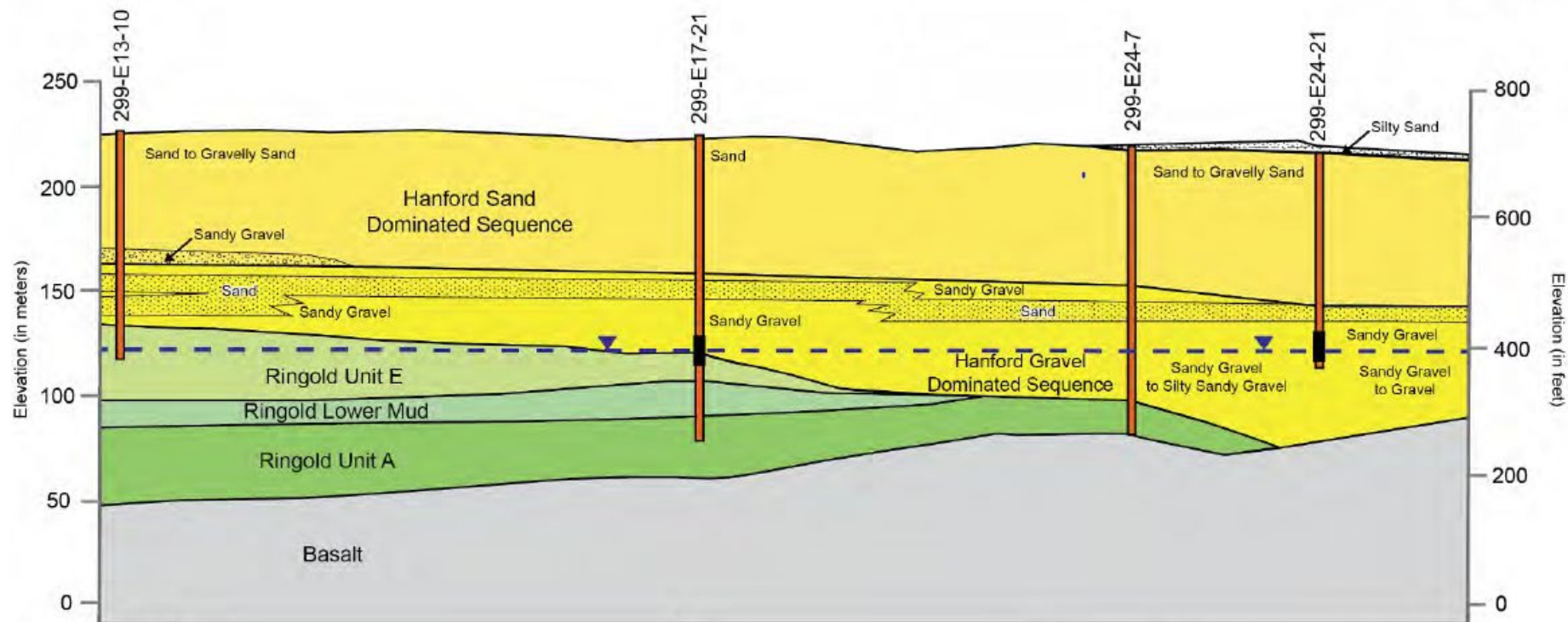
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IDF Description

- Constructed in 2006 in the 200 East Area of the Hanford Site, IDF is approximately 300 to 330 ft above the water table.
- Comprised of two expandable disposal cells.
- The disposal cells include a modified RCRA Subtitle C Barrier, a system to collect leachate, and leak detection capabilities.
- Dangerous waste operations have not started. Start of dangerous waste operations is planned to support WTP.



IDF Southwest-to-Northeast Cross Section



- The soils in the project area are sandy with high rates of infiltration.
- The recharge of water into the ground at the IDF site is expected to be small. This condition results primarily from the low levels of annual precipitation that occur in the region of the IDF.
- Although the groundwater beneath IDF is currently contaminated due to other past-practices on the Hanford Site, the groundwater could be potable.

Key Regulatory Requirements

Disposal must comply with DOE O 435.1 and associated manual DOE M 435.1-1.

- ***Performance Assessment for the Integrated Disposal Facility, Hanford Site, Washington (RPP-RPT-59958)***

- Most recent performance assessment. Publicly released in 2019. Analyzes long-term impact of near-surface disposal through modeling.

- **Waste Incidental to Reprocessing (WIR)**

- Demonstrates that vitrified waste from WTP is not high-level waste and may be managed as low-level waste (LLW).
- WIR Evaluation requires removal of key radionuclides, meets the performance objectives specific to the disposal location (described in the performance assessment) and waste will not exceed Class C LLW concentration limits.
- A final WIR Evaluation has not yet been published.

- **Waste Acceptance Criteria**

- Defines acceptance criteria for LLW and MLLW and the requirements for complying with the RCRA Permit.
- Addresses specific radionuclide disposal limits, waste form restrictions, and descriptions of acceptable waste packages.
- Includes the waste designation and management requirements of WAC 173-303-140, “Dangerous Waste Regulations,” “Land Disposal Restrictions,” requirements.

Current RCRA Permit and Waste Acceptance Criteria

- **IDF is permitted under Revision 8c of the Hanford Facility RCRA Permit.**
- **The IDF permit authorizes disposal in only one cell (Cell 1), limited to:**
 - Immobilized LAW from WTP
 - Immobilized LAW from the demonstration bulk vitrification system
- **Waste Acceptance Criteria for the IDF (IDF-0002) includes the following requirements:**
 - Wastes must be compliant with RCRA Land Disposal Restrictions (LDR) (40 CFR 268, “Land Disposal Restrictions”)
 - Transuranic wastes are prohibited
 - Free liquids must be <1% by weight volume
 - Comply with the maximum void space requirements for containers (i.e., must be >90% full)

- **Creation and maintenance of a modeling Risk Budget tool**
 - The Risk Budget Tool was developed and provided to Ecology in January 2020.
 - The Risk Budget Tool involves modeling future impacts of the planned IDF waste forms to the vadose zone and groundwater.
 - Results will be compared to performance standards such as drinking water standards.
 - If modeling indicates results within 75% of a performance standard, the permit requires DOE and Ecology to discuss mitigation measures or modified waste acceptance criteria.
- **Permit conditions require new glass formulations to be evaluated in the performance assessment.**
- **The IDF RCRA permit requires dangerous waste constituents to be analyzed for long-term performance. DOE included the dangerous waste constituents in the IDF radiological performance assessment.**

Permit Modification Request

- **The IDF RCRA permit was originally issued over 15 years ago and required submittal of permit modifications prior to initiating facility operations. DOE also identified process improvements needed to support operations.**
- **A major permit modification request was submitted to Ecology in December 2019 and is under review with Ecology. Upon approval, the permit would:**
 - Allow disposal of mixed waste in Cell 2
 - Allow for disposal of grouted secondary waste from WTP vitrification activities
 - Remove the option for acceptance of demonstration bulk vitrification system immobilized LAW
 - Add a waste storage pad
 - Add a waste treatment pad

IDF Capacity and Estimated Waste Volumes

IDF Maximum Disposal Capacities

Disposal Configuration	Maximum Disposal Capacity (m ³)
Currently permitted	82,000
Proposed disposal	505,000
Potential expanded capacity*	2,260,000

* Construction activities would require a permit modification request

Estimated Disposal Volumes to the Integrated Disposal Facility

	Vitrification	Grout	FBSR
WTP vitrification volume to IDF (m ³)	105,000	105,000	105,000
Waste from alternative to IDF (m ³)	83,000	380,000	255,000
Total	188,000	485,000	360,000

FBSR = fluidized bed steam reforming.
IDF = Integrated Disposal Facility.

WTP = Waste Treatment and Immobilization Plant.



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Off-Site Disposal and Transportation Description

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Transport & Offsite Disposal Lead

2021 NDAA-3125 Meeting #3

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SRNL-STI-2022-00199



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Topics

- **Waste Acceptance Criteria**
- **Waste Class Determination**
- **Class A, B, C and Greater Than Class C Volumes in Different Alternatives**
- **Regulatory Aspects of Transport**
- **Transportation packagers and annual shipping volumes**
- **Transportation routes**
- **Off-Site Transportation and Disposal Costs**
- **EnergySolutions Waste Disposal Facility in Clive, Utah**
- **Waste Control Specialists (WCS) Waste Disposal Facility near Andrews, Texas**
- **Summary**

Waste Acceptance Criteria (WAC) for Disposal

Radiological Criteria for Long-Lived Nuclides - same for Clive and WCS

Radionuclide	Class A Limit		Class B Limit		Class C Limit	
C-14	0.8	Ci/m ³	¹	Ci/m ³	8	Ci/m ³
C-14 in Activated Metals	8	Ci/m ³	¹	Ci/m ³	80	Ci/m ³
Ni-59 in Activated Metals	22	Ci/m ³	¹	Ci/m ³	220	Ci/m ³
Nb-94 in Activated Metals	0.02	Ci/m ³	¹	Ci/m ³	0.2	Ci/m ³
Tc-99	0.3	Ci/m ³	¹	Ci/m ³	3	Ci/m ³
I-129	0.008	Ci/m ³	¹	Ci/m ³	0.08	Ci/m ³
Alpha-emitting transuranic radionuclides with half-lives greater than five (5) years	10	nCi/g	¹	nCi/g	100	nCi/g
Pu-241	350	nCi/g	¹	nCi/g	3,500	nCi/g
Cm-242	2,000	nCi/g	¹	nCi/g	20,000	nCi/g
Ra-226 ²	10	nCi/g	¹	nCi/g	100	nCi/g

WAC are the criteria the waste must meet to be accepted for disposal

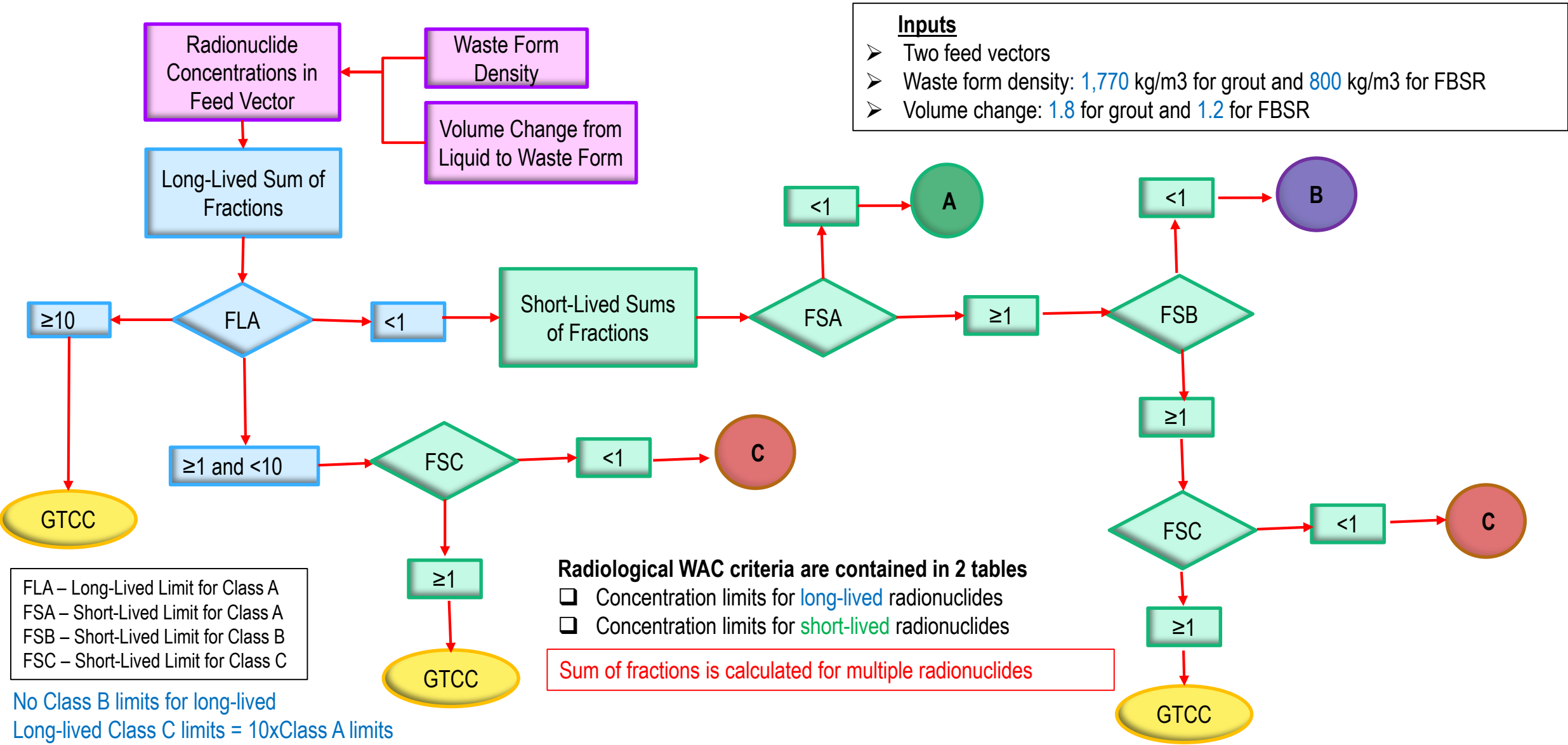
- WAC based on many factors (Criteria to protect intruder, NRC's Branch Technical Position on Concentration Averaging, operational considerations, license requirements, criteria to ensure characteristics of actual wastes are consistent parameters used to model long-term site-specific performance)

Radiological Criteria for Short-Lived Nuclides – same for Clive and WCS

Radionuclide	Class A Limit		Class B Limit		Class C Limit	
Total radionuclides with half-lives less than five (5) years	700	Ci/m ³	³	Ci/m ³	³	Ci/m ³
H-3	40	Ci/m ³	³	Ci/m ³	³	Ci/m ³
Co-60	700	Ci/m ³	³	Ci/m ³	³	Ci/m ³
Ni-63	3.5	Ci/m ³	70	Ci/m ³	700	Ci/m ³
Ni-63 in Activated Metals	35	Ci/m ³	700	Ci/m ³	7,000	Ci/m ³
Sr-90	0.04	Ci/m ³	150	Ci/m ³	7,000	Ci/m ³
Cs-137	1	Ci/m ³	44	Ci/m ³	4,600	Ci/m ³

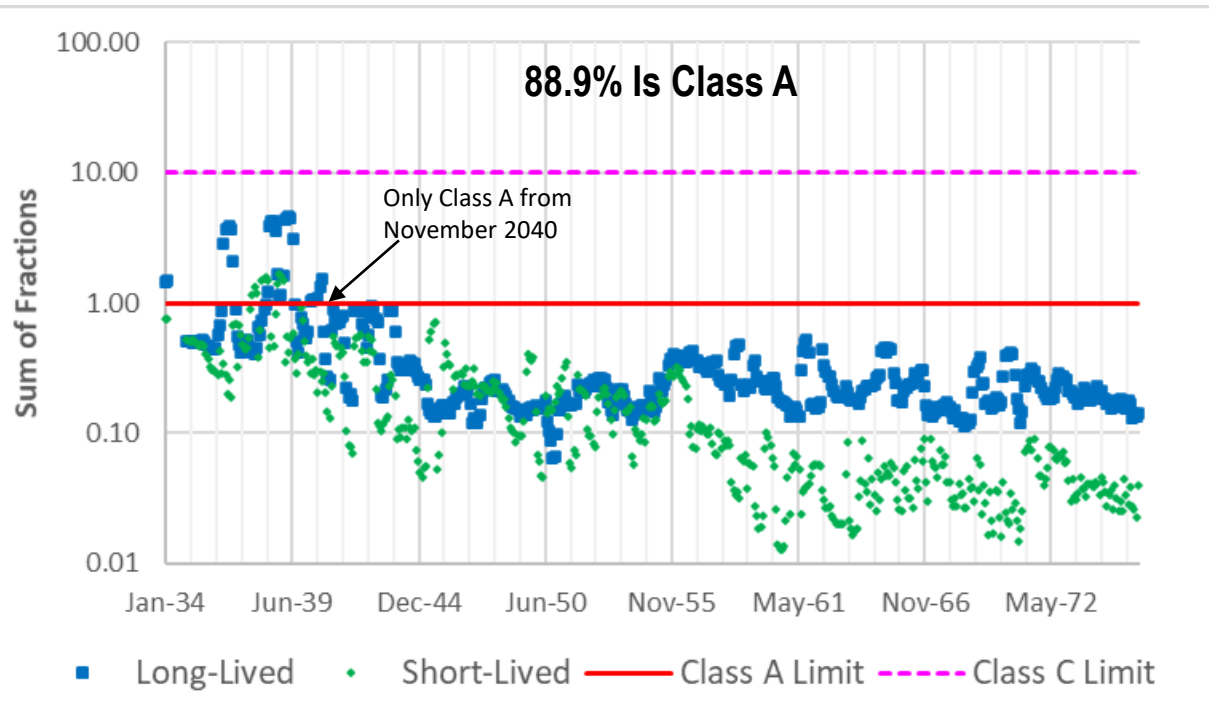
- Each limit is the full limit
- If multiple nuclides, then **sum of fractions** must be used

How the Waste Class Determination Was Done



Sum of Fractions for Grout and FBSR Alternatives

Sum of Fractions for Grout 1B Alternative

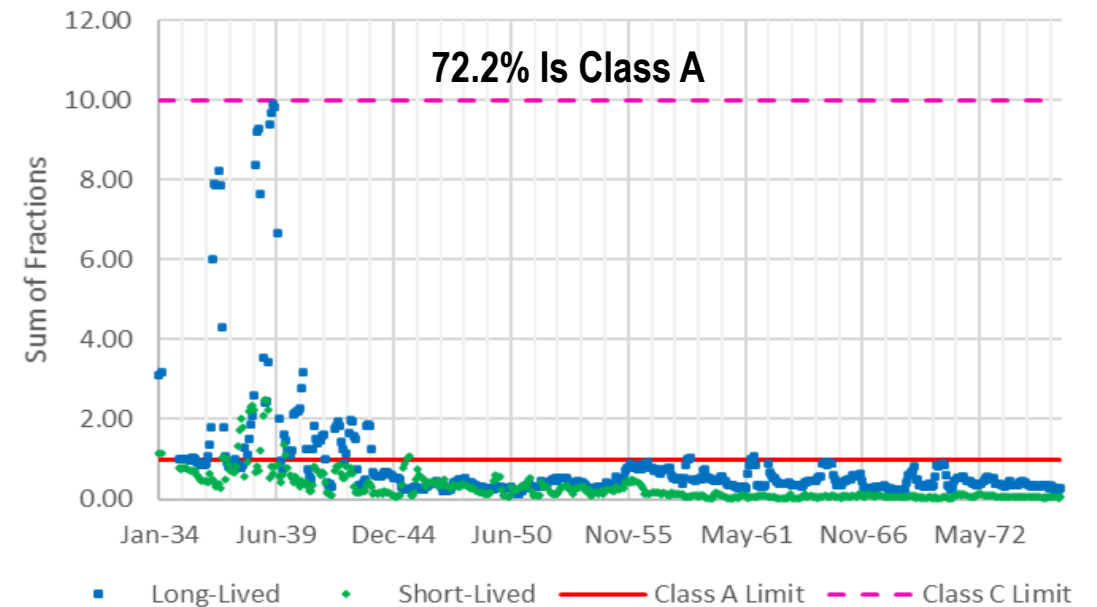


- Before November 2040, some grout is Class B and C
- Starting from November 2040, all grout is Class A

Removing 30% of long-lived alpha-emitting transuranic radionuclides would result in 90.1% of Class A

- The feed vector in Grout Alternative 1B is the same as in FBSR Alternative.
- There is more Class B and C in FBSR Alternative because of smaller volume increase and lower FBSR density.

Sum of Fractions for FBSR Alternative



- It is assumed that 30% of long-lived alpha-emitting transuranic radionuclides is removed by treatment.

Class A Volumes in Different Alternatives and Available Off-Site Disposal Volumes

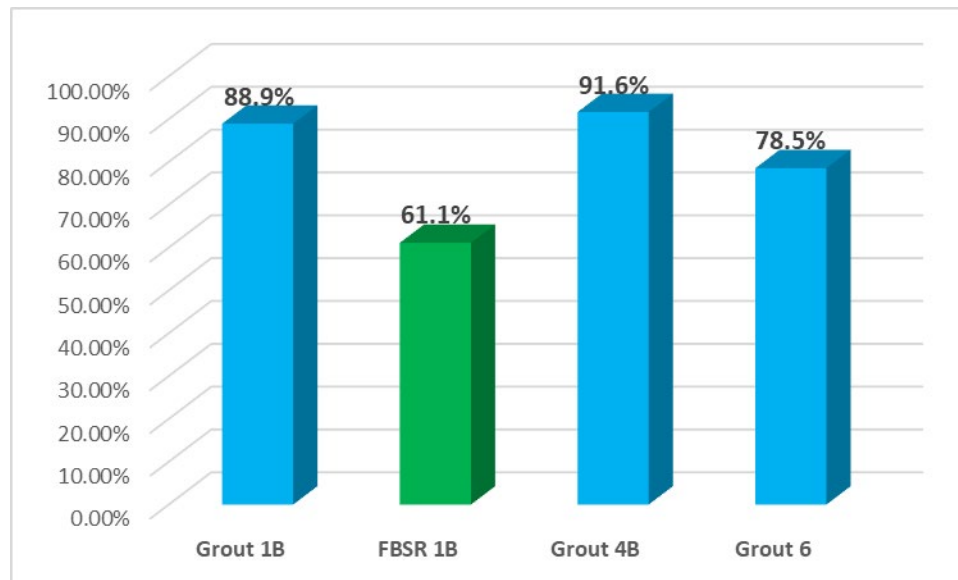
- Radiological **W**aste **A**cceptance **C**riteria (**WAC**) are identical at WCS and Clive – waste classified as Class A at Clive would be classified as Class A at WCS.
- Waste classified as Class A can be accepted for the off-site disposal at Clive and WCS.

With 99% Sr-90 and 99% Cs-137 removed:

- 83% to 89% of waste in grout alternatives is Class A waste
- 72% of waste in FBSR alternatives is Class A waste



Percent of Total Waste Volume that Is Class A



The available disposal volumes at Clive and WCS are **sufficient** for disposal of Class A waste generated in grout and FBSR alternatives.



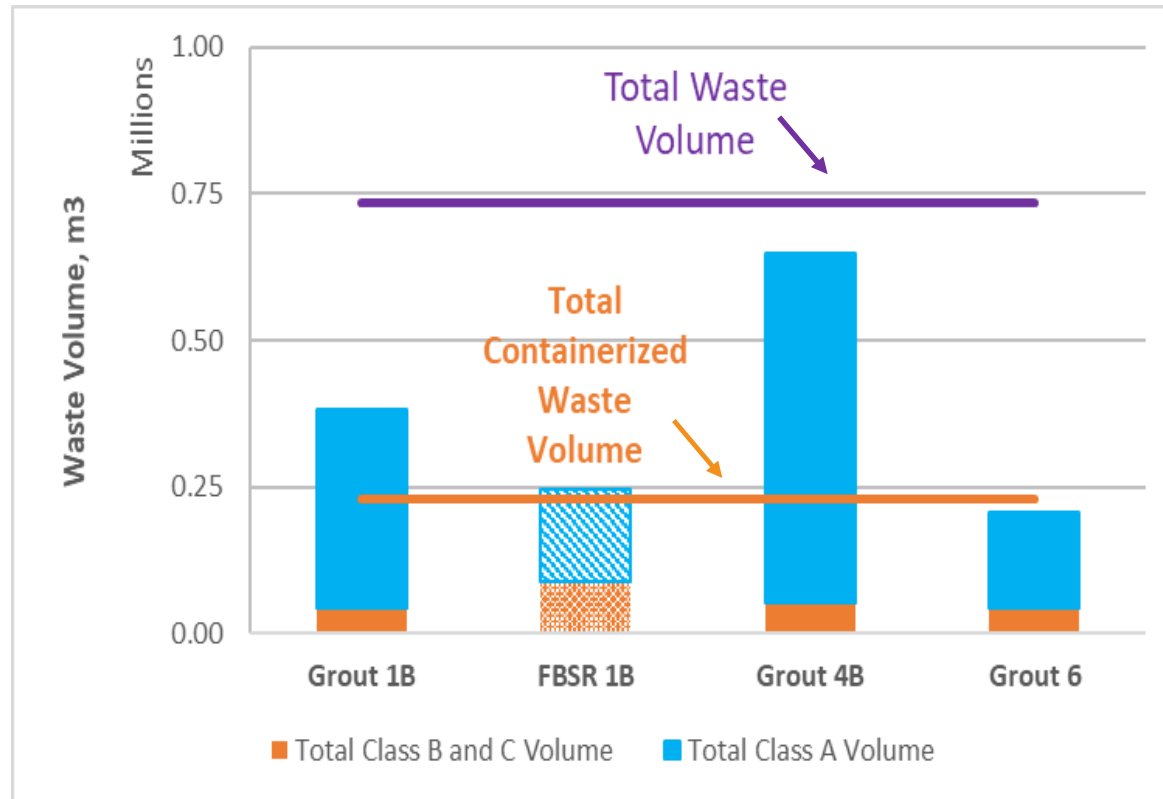
Total Class A Volumes Compared to Disposal Volumes at Clive and WCS



Class B, Class C, and Greater than Class C Waste

- Waste classified as Class B or C can be accepted for the off-site disposal only at WCS.
- WCS specifies total disposal volume (A, B, and C waste) and total containerized disposal volume (B and C waste).

Total Volumes of Class A and Classes B and C Waste Compared to Total and Containerized Disposal Volumes at WCS



Off-site Transportation – Regulatory

- **Class A, B, and C waste forms can be transported off-site.**
- **Regulatory Aspects of Transport**
 - Radioactive materials are transported routinely and safely every day
 - For example - DOE/EM completed ~ 5,500 shipments of radioactive materials in FY 2016 with no reportable accidents (Office of Packaging and Transportation Annual Report FY2016)
 - 49 CFR 171-173 regulates: Highway routing, Placarding, Occupational exposure and working conditions
 - 10 CFR 71 governs “Packaging and Transportation of Radioactive Material”
 - *Ensures safe transport under normal conditions of transport and hypothetical accident conditions*
 - *Uses a graded approach for shipping containers, for normal form materials*
 - **Low Specific Activity (LSA) materials are exempt**
 - Type A container – if specific activity > LSA limit & radiological content < A2 limit
 - Type B cask – if specific activity > LSA limit & radiological content > A2 limit
 - Type A container ~ inexpensive, Type B cask is ~ expensive

A2 limit for each nuclide is defined in Appendix A to 10 CFR 71
A2 is maximum number of curies of a nuclide allowed in Type A container

Do Liquids, Grout, and FBSR Meet the **Low Specific Activity (LSA)** Limits?

The **Low Specific Activity (LSA)** is least hazardous category of materials with specific activity (**SA**) that satisfies the limits and descriptions set forth in **10 CFR 71.4**.

LSA materials may be shipped in **Industrial Packages (IPs)** that are exempt from **NRC** certification.

LSA-II material: Average solid **SA** < $10^{-4} A_2/\text{g}$ for solids
Average liquid **SA** < $10^{-5} A_2/\text{g}$ for liquids

Average **SA** [Ci/g] = Total Concentration [Ci/m³]/Density[g/m³]

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

where f(i) is the fraction of activity for radionuclide I in the mixture, and A₂(i) is the appropriate A₂ value for radionuclide I.



LSA-II Limit

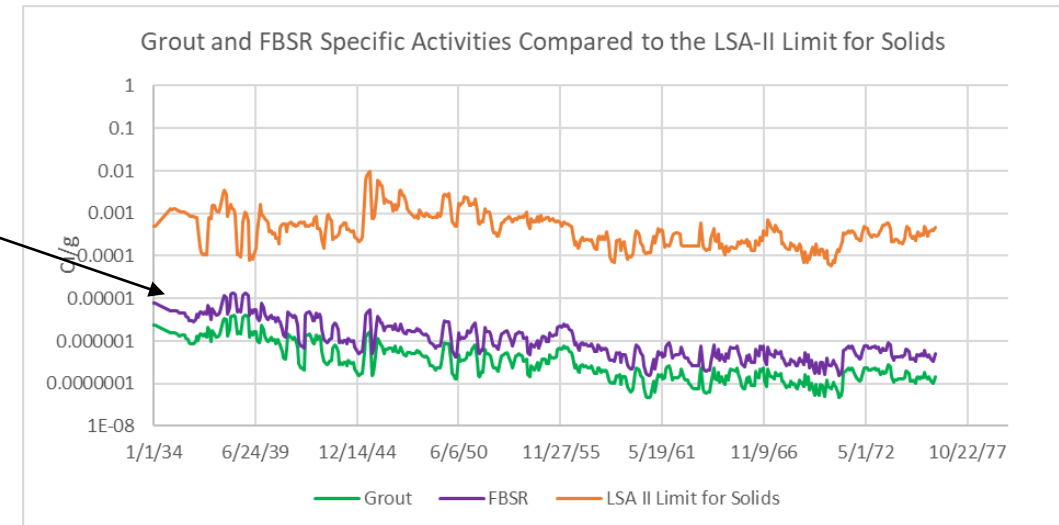
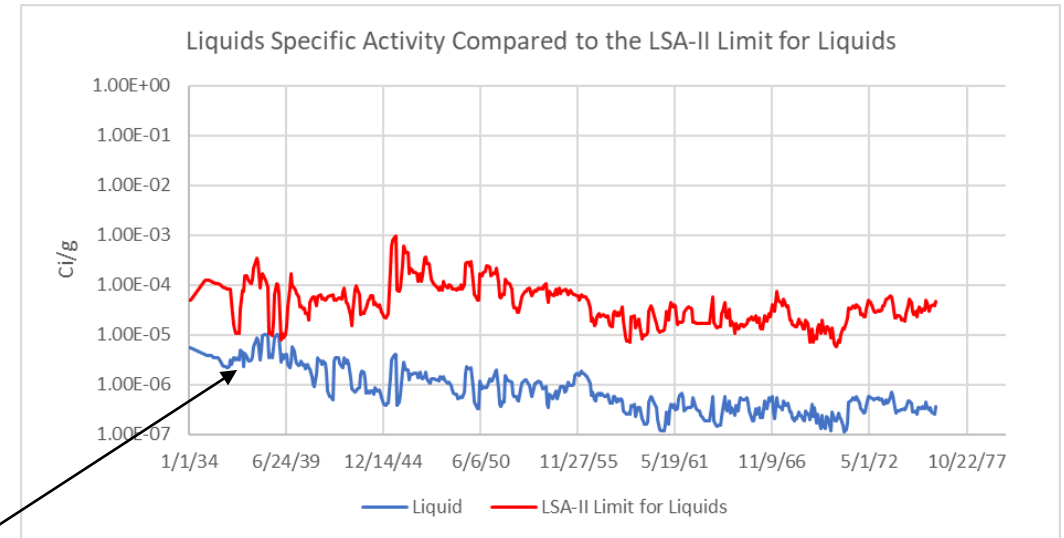
LSA-II (liquids) > SA(liquids)

LSA-II (solids) > SA(solids)

Can be transported in IPs

Simple package design - Low cost

Specific Activity Examples for Feed Vector SP9 1B



How the Transport Will Look Like?

- Grout and FBSR can be transported in soft-sided bags on gondola railcar.
- Liquids can be transported in **5,000 gal** tankers
- Both, Clive and WCS can treat liquids and generate grout.
- The liquids can be also treated at PermaFix.

Tankers and Trains per year Assuming 30 Tankers per Train

Feed Vector	Total Months	Annual Volume Kgal	Tankers per Year	Trains per Year
SP9 1B	496	1,360	272	10
Early Start	424	2,702	541	19
Early Start,2040	142	2,587	518	18

Tankers with Radioactive Liquid Arriving at Clive



Unit trains transport more than 90 rail cars of one type of freight in one car type for one destination

Gondolas and Trains per year Assuming 30 Gondolas per Train

Alternative	Total Months	Annual Volume m ³	Gondolas per Year	Trains per Year
Grout 1B	461	8863	176	6
FBSR 1B	350	5349	49	2
Grout 4B	386	18534	368	13
Grout 6	111	17708	352	12

6 bags of grout or 13 bags of FBSR per gondola

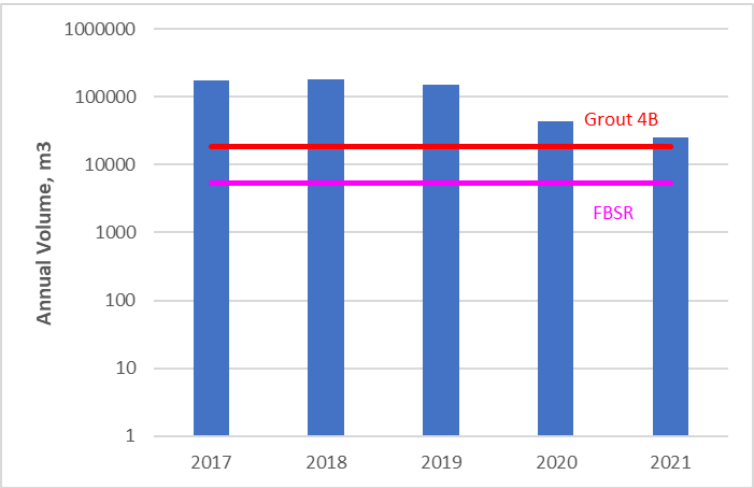


Transportation Routes to Clive and WCS

Route Characteristics

Route Parameter	Route to WCS (Texas)	Route to Clive (Utah)
Total population, persons	1,779,152	341,089
Total distance, mi	2,502.99	1,213.49
Number of states crossed	10	5
Total rural distance, mi	2,064.12	1,119.75
Total suburban distance, mi	400.95	87.84
Total urban distance, mi	37.92	5.9

Clive Annual Volumes and WIPP Average Annual Volume Compared to Grout and FBSR Average Annual Volumes

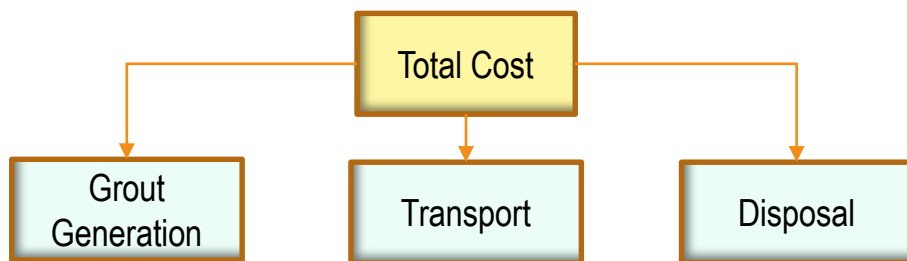


Potential Transportation Routes



- Rail carriers determine routes through the use of the [Rail Corridor Risk Management System \(RCRMS\)](#), which analyzes routes based on various risk factors. Of the options identified, the **lowest-risk routes** are chosen.

Off-Site Transportation and Disposal Costs



Assumptions

- Class A goes to Clive and to WCS, different split fractions assumed.
- Classes B and C go to WCS

Rail Transport Costs

- \$14,000 per loaded gondola to WCS
- \$7,000 per empty gondola to Clive
- \$5,000 per empty gondola (WCS and Clive)

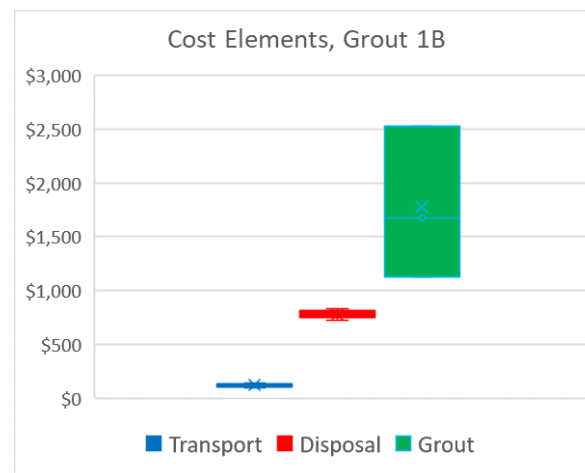
Grout Generation Costs

- \$20 per gal (industry min)
- \$30 per gal (average)
- \$45 per gal (industry maximum)

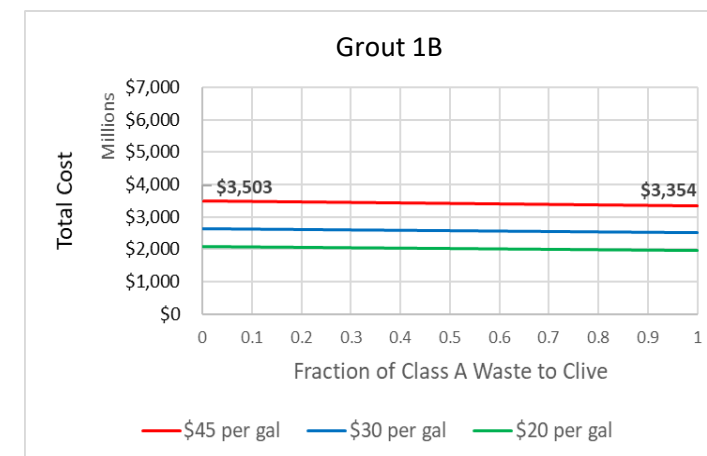
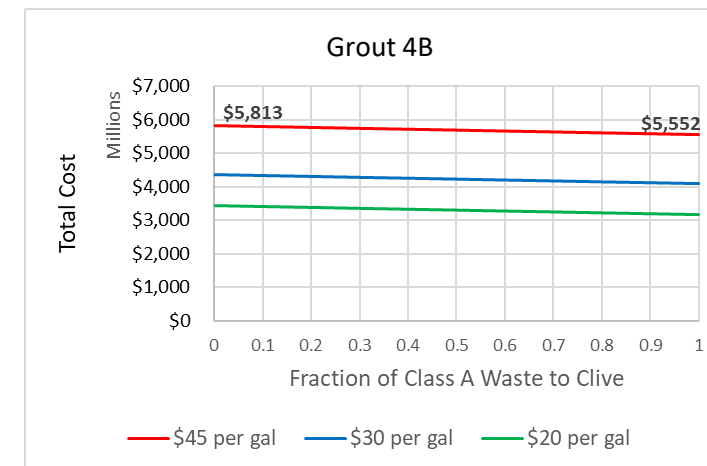
Disposal Costs

- \$1,160.14 per m3 Class A at Clive
- \$1,460 per m3 Class A at WCS
- \$7,830 per m3 Class B and C at WCS

The total cost is dominated by the grout generation. As a result, the total cost in “All Class A to WCS” is only 5- 7% higher than “All Class A to Clive”



Total Cost as a Function of Fraction of Class A to Clive

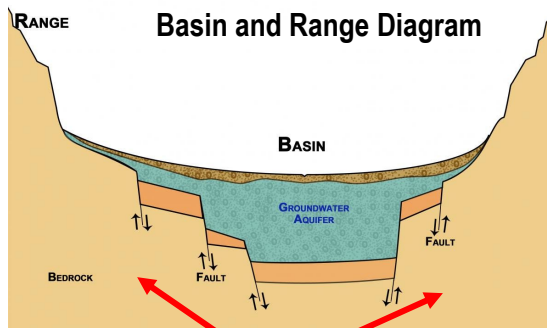


EnergySolutions Waste Disposal Facility in Clive, Utah

- DOE investigated 29 sites candidates for the uranium tailings disposal.
- After 8 years of characterization and evaluation, DOE selected the Clive site located in Utah's West Desert.
- The main reasons were:
 - Remote location
 - Low precipitation – 8.53 in/yr..
 - Groundwater is not potable and not suitable for irrigation and livestock
 - Low-permeability clay soils

EnergySolutions began the commercial waste disposal activities at the facility in 1988.

- The state of Utah is authorized by the NRC as an Agreement State and has regulatory authority over the Clive facility.
- In 2015, the state created the Division of Waste Management and Radiation Control (DWMRC) that has regulatory oversight over the Clive facility



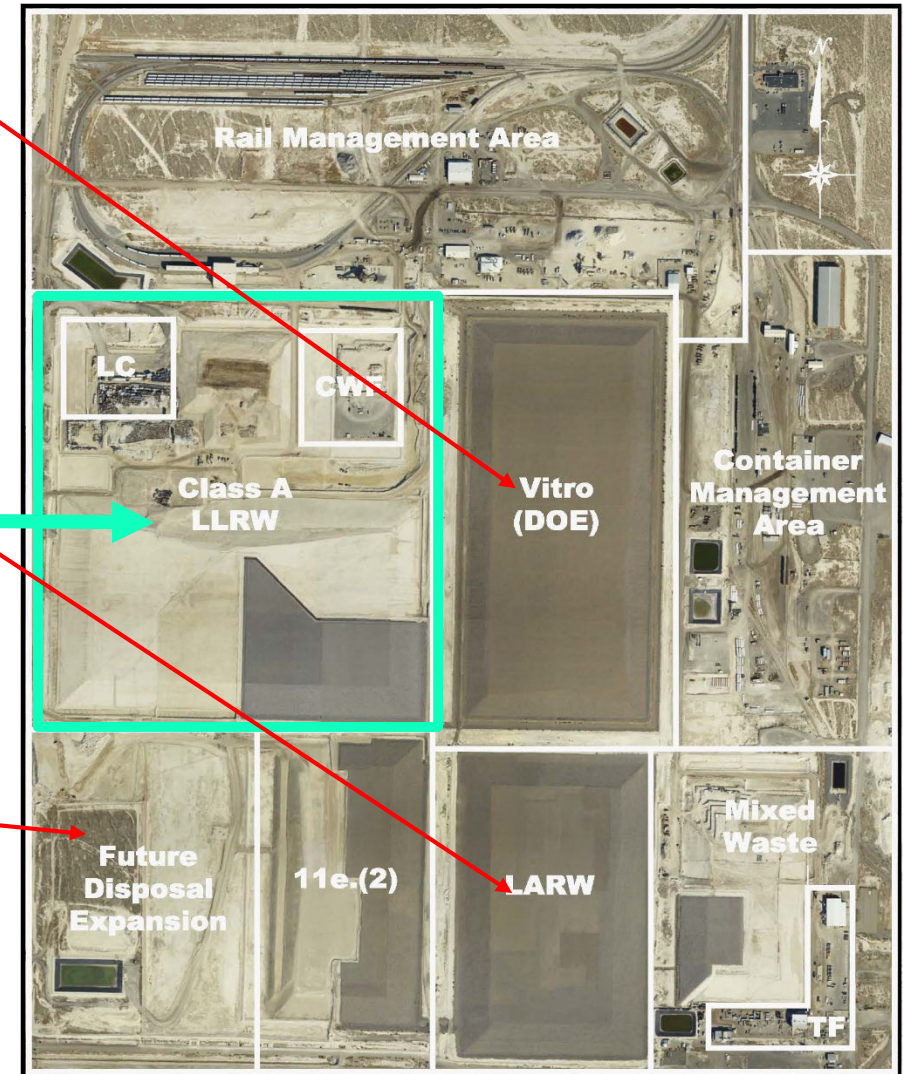
There is no groundwater flow through the ranges



Clive Disposal Embankments (Cells)

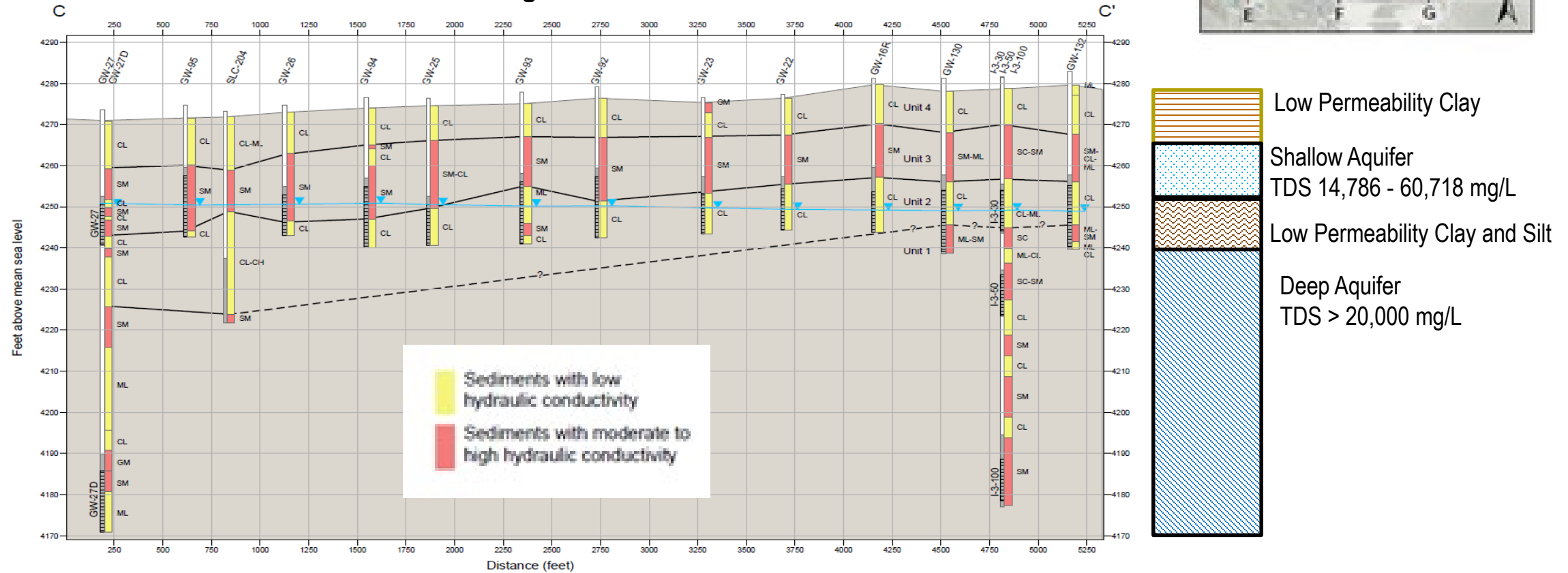
Clive Facility Layout

- The Vitro tailings were relocated to Clive in 1984 – 1988. This area is owned and monitored by the DOE.
- LARW embankment was closed in 2005
- At present, waste is placed in disposal cells:
 - Class A West (CAW)
 - Mixed waste
 - 11e.(2)
- The most recent amendment (2012) was to combine 2 embankments into the Class A West (CAW) embankment.
CAW is where the **LAW from Hanford** would be placed.
- The future disposal expansion will house the depleted uranium (DU) if the DU disposal license is granted.
- Clive received waste from EPA, DOE, DoD, utilities, and other commercial entities.



Hydrogeologic Cross-Section through the Clive Site

- Groundwater beneath the facility is classified as a **Class IV saline groundwater** (TDS > 10,000 mg/L)
- Naturally occurring concentrations of arsenic, selenium, thallium, radium, and uranium exceed EPA and Utah drinking water standards

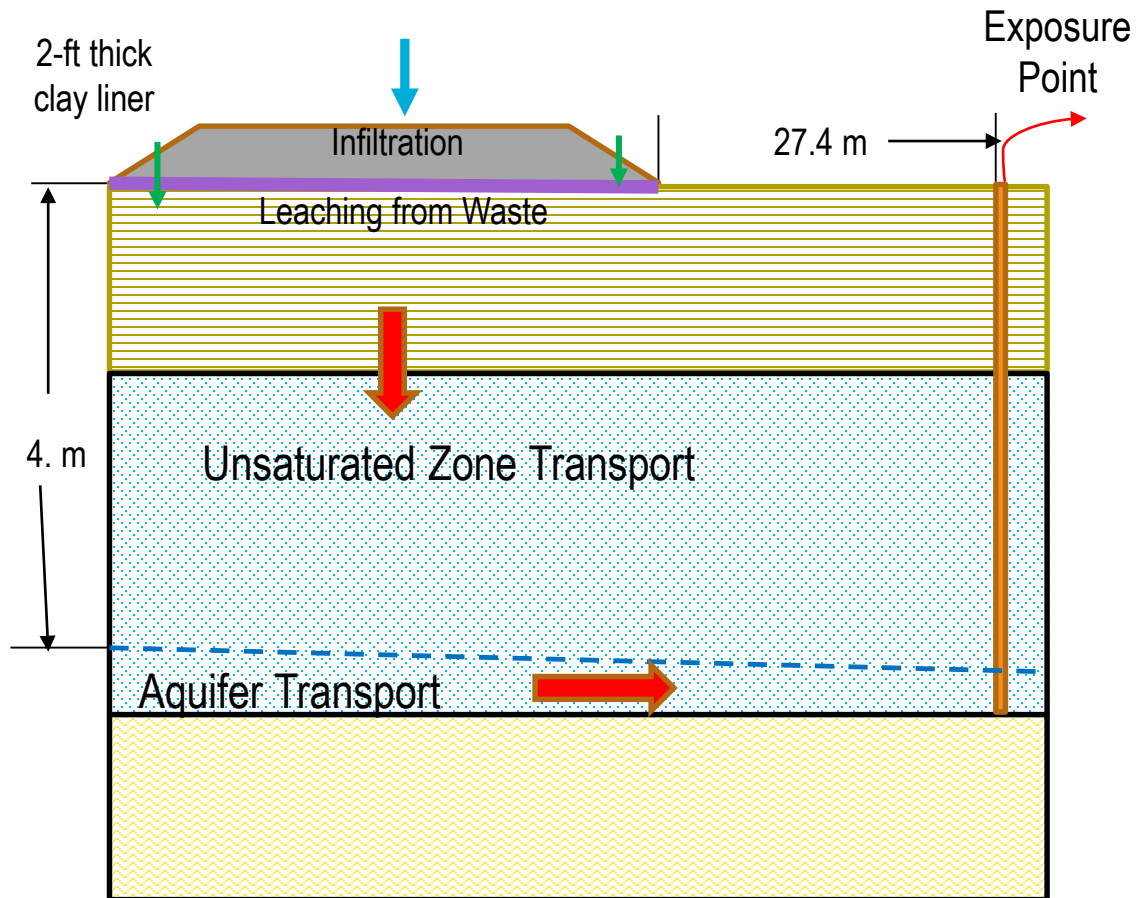


2021 Hydrogeologic Report, renewal of the EnergySolutions Ground Water Quality Discharge Permit, No. UGW450005.

Disposal Performance Assessment

- **10 CFR 61.41, Protection of the General Population from Releases of Radioactivity**
 - Concentrations of radioactive material released to the general environment in groundwater, surface water, air, soil, plants, or animals must not result in an annual dose exceeding **25 mrem** to the whole body, **75 mrem** to the thyroid, and **25 mrem** to any other organ of any member of the public.
 - *None of the exposure pathways at the site are viable because human activity at Clive has historically been very limited due to the lack of potable and irrigation water. However, the groundwater pathway was analyzed in great detail.*
- **10 CFR 61.42, Protection of Individuals from Inadvertent Intrusion**
 - Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after institutional controls are removed. The standard used by NRC and others for LLW has been **500 mrem** annual dose.
 - *Utah regulations require special provisions to protect inadvertent intruders from disposed LLRW only for Class C LLRW.*
- **Radiation hazards associated with Class A waste are such that: should intrusion into disposed waste occur following the 100-year institutional control period, doses were projected to be within acceptable limits**
- **In addition, the intruder protection is warranted by the facility remoteness from population centers, lack of resources at the site, and the embankment cover system.**

Groundwater Protection Levels (GWPL)



- Clay cover degrades immediately, and the infiltration water moves through the cover instantaneously
- Kd values (partition between sorbed and dissolved): site-specific Kd or the lowest measured soil Kd values from literature

- Groundwater protection levels (**GWPL**) must be met per Ground Water Quality Discharge Permit (GWQD).
- The radionuclide concentration limits must not be exceeded for at least 500 years following closure of the facility.

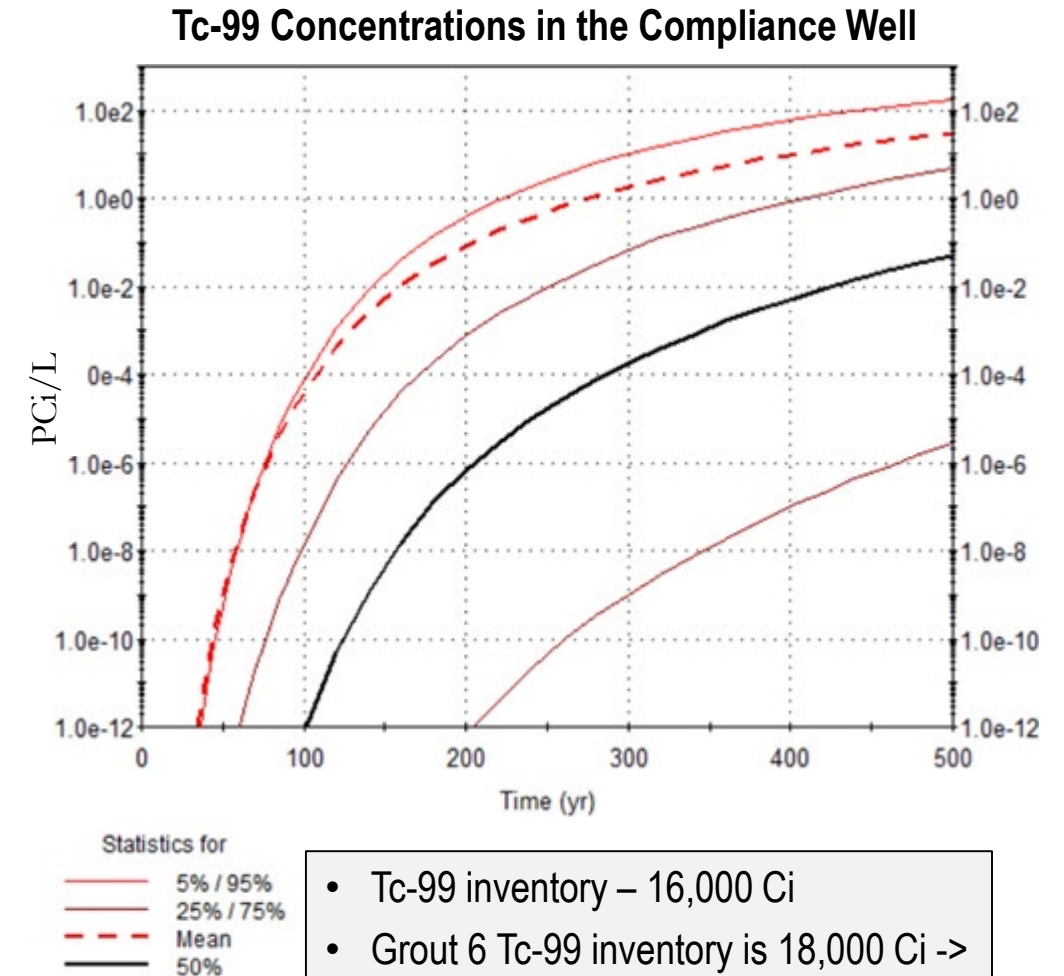


*The groundwater pathway was analyzed to provide evidence that concentrations in the compliance monitoring well are below the **GWPLs***

- Groundwater model evaluated **260** radionuclides and **13** metals. **92** radionuclides and **7** surrogates were explicitly modeled
- **Results**
 - None of the **99** radionuclides exceeded the **GWPLs** at the water table within 500 years
 - **16** radionuclides exceeded the GWPLs at the water table at some time after 500 years and their transport in the shallow aquifer was modeled.
 - All radionuclides modeled would remain below the **GWPLs** at a compliance well.
 - None of the metals would arrive or exceed **GWPLs** at the water within 200 years compliance period established for heavy metals

Depleted Uranium Performance Assessment

- **A separate probabilistic PA analysis was performed for the proposed disposal of the depleted uranium (DU) in a designated DU disposal cell**
 - The PA considers both the groundwater pathway and the air pathway.
 - The compliance period is 10,000 years
- **Intruder Scenario**
 - Intruders: ranch hands, hunters, and off-highway vehicle riders
- **Members of the Public Scenario**
 - Knolls Recreation Area, 8 mi to the west used by off-highway vehicle riders
- **Additional simulations was done for 2.1 Myr.**
- **Long-term, or “deep time” scenarios**
 - Possibility of future deep lakes in the Bonneville Basin
 - As each lake returns, estimates are made of the radionuclide concentrations in the lake and in the sediments surrounding and subsuming the site.
- **Results**
 - None of the 95th percentile dose estimates for these receptors exceeds 1 mrem/year, and all of the peak mean dose estimates are at or below 0.1 mrem/year.
 - Receptor doses are dominated by radon inhalation for the air pathway and groundwater concentrations of 99-Tc for the groundwater pathway.



Waste Control Specialists (WCS)

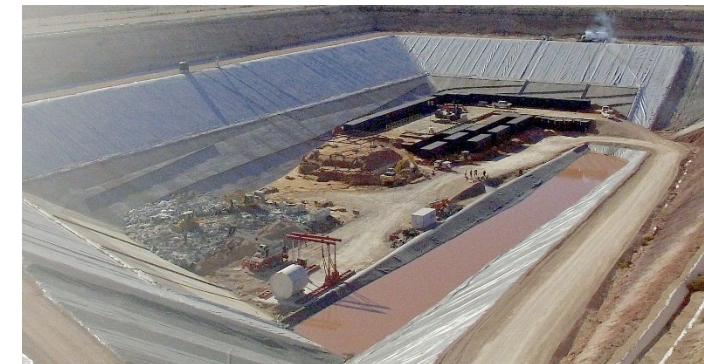
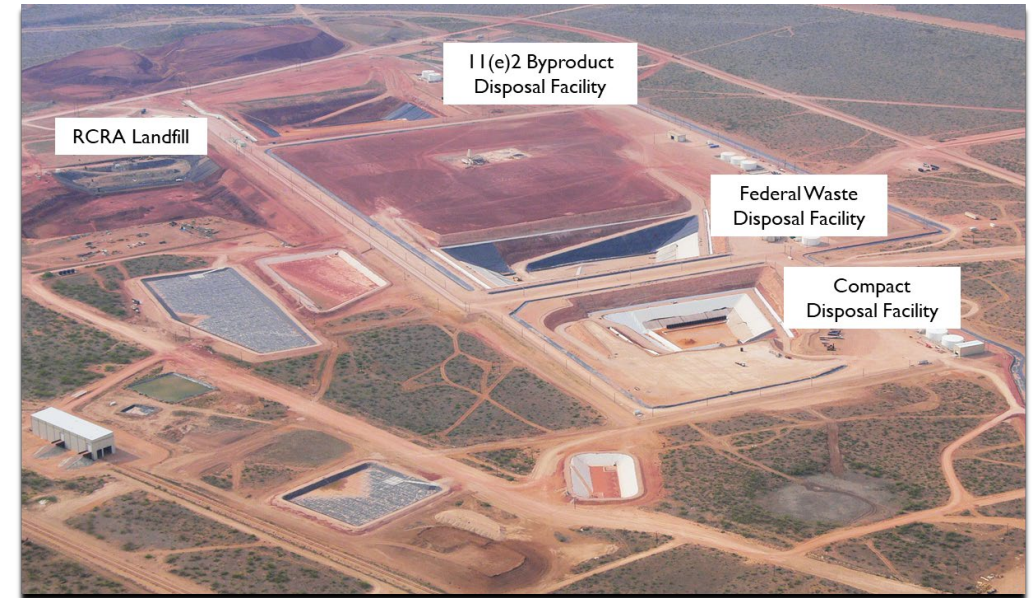
- Commercial facility operated by Waste Control Specialists LLC
- Located in west Texas (near Andrews)
- Sparsely-populated area
- Semi-arid climate: rainfall 16 in./yr., evaporation 60 in./yr..
- Underlain by 600-foot-thick low permeability red-bed clays
- No potable groundwater beneath the site
- Licensed by Texas, an NRC “Agreement State”
- Licensing process took 5 years (August 2004 - September 2009)
- Licensed for Class A, B & C LLW and Class A, B & C MLLW
- Received first Federal LLW shipment in 2012

Federal Waste Disposal Facility (FWD)

- Limits: **737,000 m³** and **5,600,000 curies** total
- DOE signed Agreement to take ownership of the FWD after closure

If all Class A, B, and C is disposed at FWD, the total activity will range from **480,000** to **1,390,000 Ci** (**9%** to **25%** of the limit) depending on alternative.

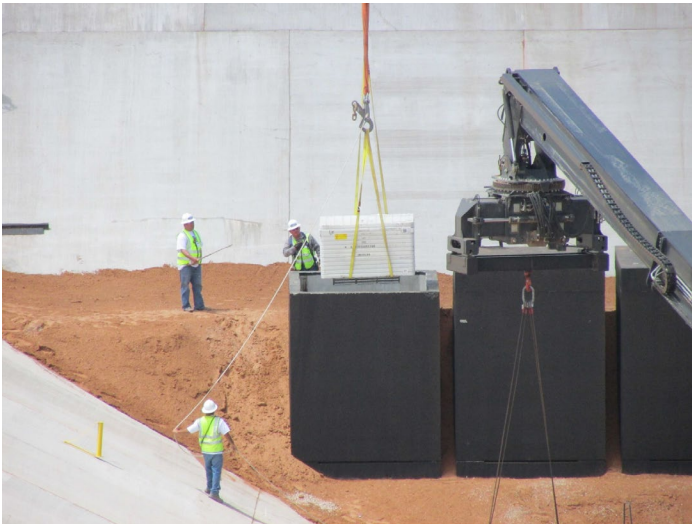
WCS Site Layout



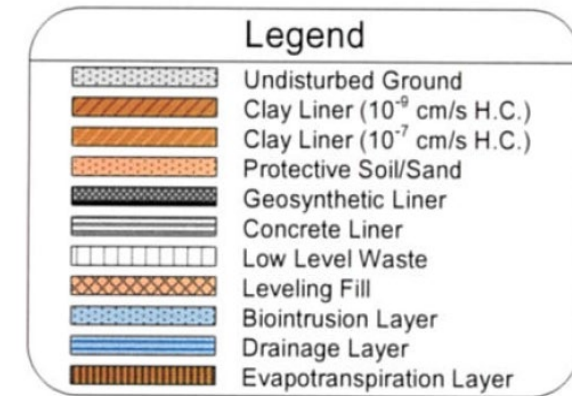
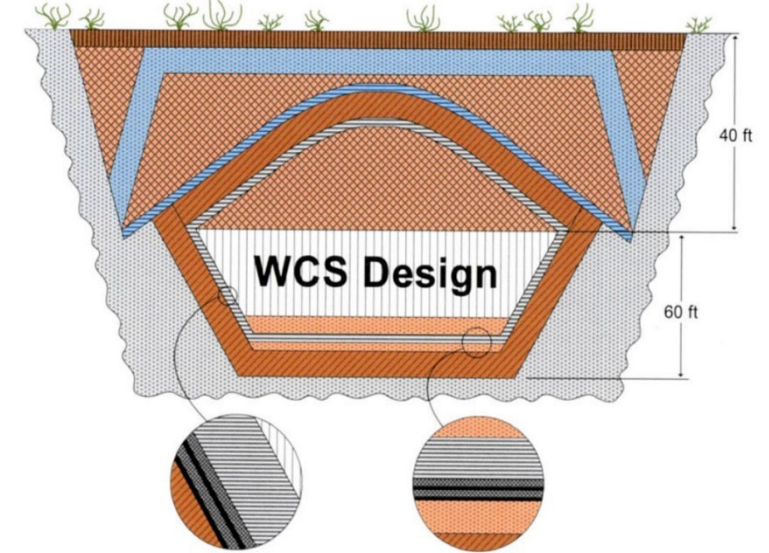
Design of Federal Waste Disposal Facility

- Wastes are emplaced **25 to 45 ft** (~8 to 14 m) below the land surface
- **Natural barrier:**
 - **600 ft** thick low permeability red clay with hydraulic conductivity $\sim 1 \times 10^{-9}$ cm/s (for comparison, concrete is 1×10^{-10} cm/s)
- **Engineered barriers:**
 - 7-ft (2-m) thick, multi-layer liner (11.8 in. (0.3 m) reinforced concrete + RCRA compliant geosynthetic layer)
 - Class B and C-wastes disposed in modular concrete containers (MCCs)

Rectangular MCC



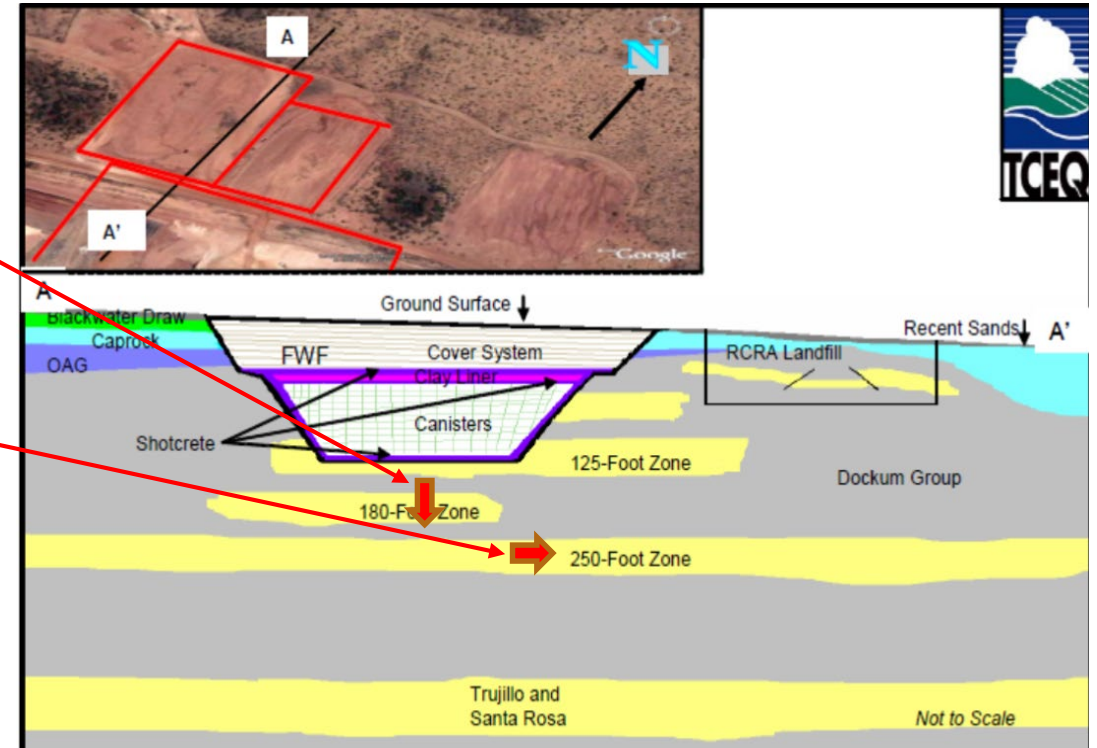
The MCCs are 6-in. (150 mm) thick, steel-reinforced concrete containers.



Groundwater Pathway

- In the updated 2011 PA the groundwater pathway dose was determined to be zero.
- **Downward flow in the unsaturated red clay:**
 - Current climate conditions: 0 to 0.02 mm/yr.
 - Future-climate conditions: 0.01 to 0.3 mm/yr.
- **225-foot zone**
 - First from the surface
 - laterally continuous saturated zone
 - Low permeability sandstone and siltstone
 - Yield insufficient to support a household or for livestock in a year
 - TDS from 3,800 to 4,700 mg/L, not potable water
- **Performance Assessment (PA) Assumptions**
 - Groundwater is withdrawn from a well at the edge of the disposal facility
 - Water is used for drinking and livestock watering
 - The water is assumed to be potable
 - The total withdrawal includes the 225-ft zone yield and the additional water needed to support a household from an uncontaminated external source

Conceptual Cross Section of the WCS FWF



Source: TCEQ 2008, Figure EA-4

225-foot zone is called 250-foot zone in the source figure and 225-foot zone elsewhere

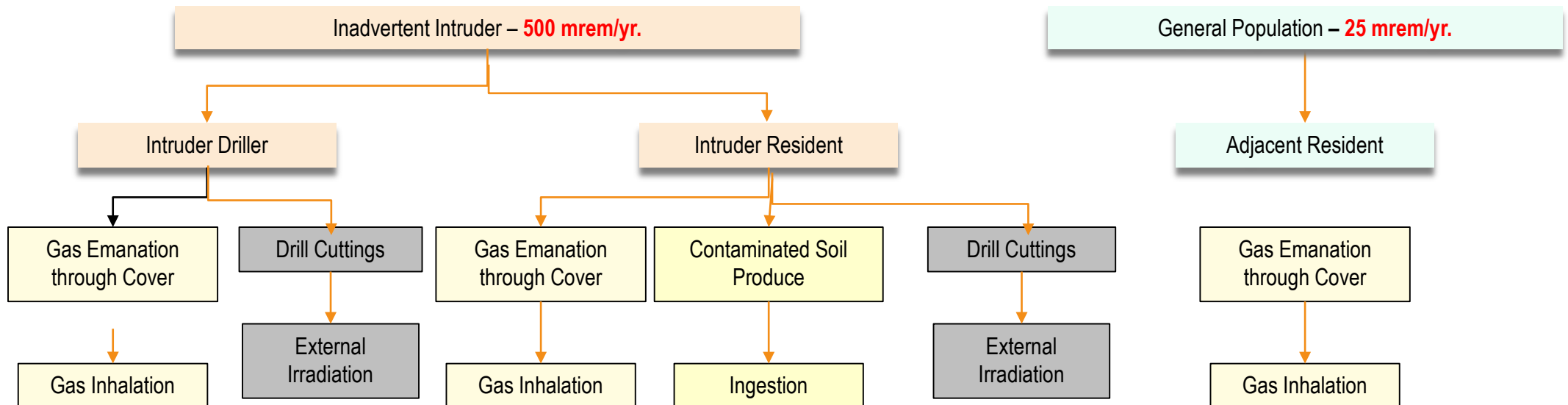
Key Exposure Pathway and Timing of Peak Doses

- Per 30 Texas Administrative Code §336.709 (1) “A minimum period of 1,000 years after closure or the period where peak dose occurs, whichever is longer, is required as the period of analysis”.
 - Peak dose of 0.009 millirem per year at 564,000 years is driven by Ra-226

Timing of Peak Doses

Decay Classification	Transport Classification	Radionuclide Example	Time of Peak Dose with No Waste Intrusion (years post-IC)	Time of Peak Dose with Waste Intrusion (years post-IC)
Short-lived	Low mobility	⁹⁰ Sr, ¹³⁷ Cs	N/A	0
Short-lived	High mobility	³ H	0-100	0-100
Long-lived	Low mobility	⁷⁹ Se	1,000,000+	10,000-100,000
Long-lived*	High mobility	¹²⁹ I, ¹⁴ C	10,000-100,000	1,000-10,000
Long-lived	High mobility	⁹⁹ Tc	100,000-1,000,000	100,000-1,000,000
In-growth	High mobility	²²² Rn	1,000,000+	1,000,000+

Key Exposure pathway



Summary

- 83% to 89% of waste in grout and 72% of waste in FBSR alternatives is Class A.
- All Class A waste (grout or FBSR) can be disposed off at Clive or WCS based on the available disposal volumes for bulk waste.
- 11% to 17% of waste in grout and 27% of waste in FBSR alternatives is Class B and Class C.
- All class B and C waste (grout or FBSR) can be disposed off at WCS based on the available containerized disposal volume.

This will leave sufficient volume for all Class A waste.

- Grout, FBSR, and liquid waste forms meet the LSA-II requirements and can be transported in IPs, such as soft-sided bag for grout/FBSR and 5,000 gal tankers for liquid.
- Assuming 30 gondolas or tankers per train, 10-19 trains per year would be required for liquids and 2-13 trains per year would be required for grout/FBSR.
- The total cost is dominated by the grout generation. As a result, the total cost in “All Class A to WCS” is only 5-7% higher than “All Class A to Clive” scenarios. Besides costs, the considerations can be given to the transport distances and population along the routes.
- Both, Clive and WCS are located in sparsely populated areas with no surface water. The climate at both sites is arid/semi-arid with low precipitation and low infiltration. Both, Clive and WCS **do not have potable water**.
- The natural and engineered barriers at both sites provide adequate protection for members of public and inadvertent intruders.
- The latest license amendments are recent and are based on sound scientific and engineering analyses. The amendment review and approval by the state authorities included public hearings and comments.



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Alternative Descriptions

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2021 NDAA-3125 Meeting #3

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SRNL-STI-2022-00199



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Development and Evaluation of Alternatives for Supplemental Treatment of Low Activity Waste (LAW)

- **Identified 23 alternatives for consideration – reduced to 15 for full evaluation**
 - Extended/expanded on alternatives in NDAA17 report
 - More grout alternatives considered than others – same technology but deployed multiple ways
 - *Low cost of grout enables flexibility*
 - *Multiple grout configurations have been used throughout the complex*
 - *Offsite grout production and disposal options*
 - *Vit for onsite disposal is pseudo baseline – considering offsite disposal is unnecessary*
 - *Vit and FBSR require extensive infrastructure – limiting feasibility of modular approaches*
 - *Recognition of ⁹⁰Sr removal by CST enabled considering disposal as Class A at EnergySolutions - Clive facility*
 - *NDAA 3125 (c)(1)(F) specifically asked for additional study into topical areas for grout option in the NDAA17 report*
 - *NDAA 3125 (c)(5) specifically asked for modification to facility designs to enhance performance (e.g. grout monoliths in vaults)*
 - *NDAA 3125 (c)(8)(C) directed consideration of outcome of Test Bed Initiative (Phase 1)*
 - Drafted flowsheet diagrams and descriptions contain sufficient detail to allow evaluation
 - *Obtained input from Subject Matter Experts, as needed*
- **Utilized an Analysis of Alternatives method for full evaluation**
- **Identified 4 Key Alternatives for comparison here**

Key Parameters and Assumptions

- **Defining Parameters**

- Hanford System Plan 9, Scenario 1B used to define feed to Supplemental treatment of LAW
 - *No assumed immobilization baseline*
- Cost not used to screen out alternatives
- Offsite disposal sites considered in this study do not have a pathway to potable water
- Information from Performance Assessments use DOE O 435.1 guidance

- **Key General Assumptions**

- WTP LAW melters operate for entire mission at full capacity
- High Level Waste (HLW) processing begins in 2033
 - *Supplemental LAW must be available within 6 months of HLW start*
- Maximum capacity must treat 360,000 gallons/month; Total volume is 57 Mgal at ~7 M [Na⁺]
- Alternatives include an evaporator to reach optimum Na⁺ concentration
- Enabling assumptions:
 - *Waste Acceptance Criteria (WAC)-compliant grout or Fluidized Bed Steam Reformer (FBSR) waste form can be disposed offsite*
 - *Grout or FBSR waste form can be disposed in IDF once compliance with the PA is demonstrated*
- IDF water infiltration rates are the same as 2017 IDF PA

Key Assumptions

- **Vitrification**

- 40-50% Total Operating Efficiency (TOE: percentage of time facility is operating – opposite of downtime)
 - *Consistent with System Plan 9, Scenario 1B assumptions for WTP HLW and LAW vitrification*

- **Fluidized Bed Steam Reforming (FBSR)**

- 50% TOE (same as vitrification)

- **Grout**

- If LDR organics require treatment; evaporation and/or treatment will resolve or waste is vitrified
- Getters for ¹²⁹I are included for grout formulations for onsite IDF disposal, if needed
- ¹²⁹I and ⁹⁹Tc removal is not required (but is evaluated in Grout 1C and 2C)
- Grout plant is sized based on days-only operation (TOE < 50%)

- **Funding**

- Projected expenditures compared to nominal budget, but not screened out if exceeded
- Cost escalations are 4% on capital, 2.4% on operating, and 3% discount rate per OMB

Detail and additional assumptions contained in Volume 2, Appendix C of report

Current Alternatives

Alternative Designation	Alternative Title	Brief Description	Primary Waste Disposal	Full Evaluation?
No action	No Action	Operate WTP LAW melters only (no additional facility)	Onsite	No
Vitrification 1	Single Vitrification Plant	Construct additional melter facility	Onsite	Yes
Vitrification 2	Increased LAW Vitrification Rate	Operate WTP LAW melters only, but take steps to increase vitrification rate	Onsite	No
Vitrification 3	Near-Tank Vitrification	Construct modular vitrification facilities/ melters near waste tanks	Onsite	No
FBSR 1A	Fluidized Bed Steam Reforming – On-site Disposal	Construct FBSR facility; dispose monolith waste form onsite	Onsite	Yes
FBSR 1B	Fluidized Bed Steam Reforming – Off-site Disposal	Construct FBSR facility; dispose granular waste form offsite	Offsite	Yes
FBSR 2A	Modular Fluidized Bed Steam Reforming – On-site Disposal	Construct FBSR facilities; dispose monolith waste form onsite	Onsite	No
FBSR 2B	Modular Fluidized Bed Steam Reforming – Off-site Disposal	Construct FBSR facilities; dispose granular waste form offsite	Offsite	No

Key Alternatives

Current Alternatives continued

Alternative Designation	Alternative Title	Brief Description	Primary Waste Disposal	Full Evaluation?
Grout 1A	Single Grout plant – On-site Disposal	Construct single grout plant in 200 West Area; dispose containerized grout in IDF	Onsite	Yes
Grout 1B	Single Grout plant – Off-site Disposal	Construct single grout plant in 200 West Area; dispose containerized grout offsite	Offsite	Yes
Grout 2A	Separate Grout Plants for 200 East and West Areas – On-site Disposal	Construct grout plants in 200 East and West Areas; dispose containerized grout in IDF	Onsite	Yes
Grout 2B	Separate Grout Plants for 200 East and West Areas – On-site Disposal	Construct grout plants in 200 East and West Areas; dispose containerized grout offsite	Offsite	Yes
Grout 3A	Individual Grout Plants for Each Tank Farm or Tank Farm Group – On-site Disposal	Construct multiple modular grout plants in 200 East and West Areas; dispose containerized grout in IDF	Onsite	No
Grout 3B	Individual Grout Plants for Each Tank Farm or Tank Farm Group – Off-site Disposal	Construct multiple modular grout plants in 200 East and West Areas; dispose containerized grout offsite	Offsite	No
Grout 4A	Off-site Vendor for Grouting – On-site Disposal	Ship liquid to off-site vendor for grouting; dispose containerized grout in IDF	Onsite	Yes
Grout 4B	Off-site Vendor for Grouting – Off-site Disposal	Ship liquid to off-site vendor for grouting; dispose containerized grout offsite	Offsite	Yes

Current Alternatives continued

Alternative Designation	Alternative Title	Brief Description	Primary Waste Disposal	Full Evaluation?
Grout 5A	Single Grout Plant – On-site Monolith in Vault Disposal	Construct single grout plant in 200 West Area; dispose a monolith of grout in vaults	Onsite	Yes
Grout 5B	Single Grout Plant – On-site Containers in Vault Disposal	Construct single grout plant in 200 West Area; dispose containerized grout in vaults	Onsite	Yes
Grout 1C	Single Grout Plant with Technetium/ Iodine Removal and On-site Disposal	Remove ⁹⁹ Tc and ¹²⁹ I, followed by Grout 1A	Onsite	Yes
Grout 2C	Separate Grout Plants for 200 East and West Areas with Technetium/ Iodine Removal with On-site Disposal	Remove ⁹⁹ Tc and ¹²⁹ I, followed by Grout 2A	Onsite	Yes
Grout 1D	Single Grout Plant with Technetium/ Iodine Sample-and-Send with Off-site/On-site Disposal	Analyze LAW; grout all; select on-site or off-site disposal of container based on ⁹⁹ Tc and ¹²⁹ I content	Onsite /Offsite	Yes
Grout 2D	Grout 2A + Sample Technetium/ Iodine/Send Offsite/Onsite	Analyze LAW; grout all in modular plant; select on-site or off-site disposal of container based on ⁹⁹ Tc and ¹²⁹ I content	Onsite /Offsite	No
Grout 6	Phased Off-site and On-site Grouting in Containers	Phased approach of off-site vendor grouting and off-site disposal, followed by on-site grouting and on-site disposal	Onsite /Offsite	Yes
⁹⁹ Tc = technetium-99. ¹²⁹ I = iodine-129. FBSR = fluidized bed steam reforming.		IDF = Integrated Disposal Facility. LAW = low-activity waste. WTP = Waste Treatment and Immobilization Plant.		

“Building Blocks” of Alternatives

- **Storage** of pretreated waste either
 - in existing Double Shell Tanks (DSTs) or
 - process feed tanks

- **Pretreatment as needed** consisting of one or more of:
 - ^{137}Cs removal (preceded by filtration)
 - ^{99}Tc removal
 - ^{129}I removal
 - Evaporation/Land Disposal Restricted (LDR) organic chemicals destruction or removal

- **Primary treatment and immobilization**
 - On-site vitrification
 - On-site FBSR
 - On-site grouting
 - Off-site grouting

- **Primary disposal**
 - On-site at Integrated Disposal Facility (IDF)
 - On-site in new disposal Grout Disposal Unit (GDU) vault
 - Off-site in state or NRC-licensed MLLW facility
 - (e.g., EnergySolutions [Clive, Utah] and/or
 - Waste Control Specialists [Andrews, Texas])

- **Secondary waste treatment and disposal.**
 - On-site IDF
 - Off-site (only for off-site grout production)



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Uncertainty Drivers in the Alternatives and Updated Information Since 2017-NDAA-3134

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2021 NDAA-3125 Meeting #3

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Uncertainty/Confidence in the Alternatives Analysis

- **In the assessment of the various alternatives (Volume II: Appendix D), the final rankings contained a summary of uncertainty/confidence and technical risks around the assessments of the four main criteria:**
 - Long-term effectiveness (environmental and safety risk after disposal) (Criterion 1),
 - Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by waste tank storage duration) (Criterion 2),
 - Likelihood of successful mission completion (including affordability and robustness to technical risks) (Criterion 3), and
 - Lifecycle costs (discounted) (Criterion 4).
- **There could be low uncertainty (high certainty) associated with an assessment that was favorable or unfavorable, or vice-versa. For example:**
 - A rating of “Effective with medium confidence in the assessment” is one where there is moderate uncertainty (qualitative or quantitative) in the items that led to the ranking, however the assessment could change as the uncertainty is resolved.
 - A rating of “Low probability of success with high confidence in the assessment” is one where there is high confidence that even with a breakthrough the alternative will still have low probability of success.
- **The sources of uncertainty/risk in each criteria vary between the alternatives.**

Overall Uncertainty/Confidence in the Alternatives Analysis

- **Low uncertainty/risk or high confidence –**
 - Sufficient supporting data/experience exists for **all** sub-criteria.
 - The overall assessments made **are unlikely to change** with future developments/changes.
 - High confidence could be assigned to the descriptions provided of each criteria.
- **Moderate uncertainty/risk or medium confidence –**
 - High confidence could be assigned to the descriptions provided of **most** criteria and **discrete uncertainties** were identified.
 - Sufficient supporting data/experience exists for **most** sub-criteria.
 - Gaining further knowledge/development **could have an impact** on the overall assessments made.
 - Technical challenges identified are **considered feasible to overcome** with future development.
- **High uncertainty/risk or low confidence–**
 - Low confidence could be assigned to the descriptions provided of **most** criteria, and **several broad uncertainties** were identified.
 - **Minimal supporting** data/experience exists for select sub-criteria that are considered crucial for success of the alternative.
 - Gaining further knowledge/ development **could have an impact** on the overall assessments made.
 - Technical challenges identified are considered **unlikely to overcome** without significant breakthroughs.
- **The next slides will cover the drivers of these uncertainty assignments.**

Uncertainty/Confidence in Long Term Effectiveness (Criterion 1)

- **Alternatives that utilized an off-site disposal pathway had high confidence in the assessment of long-term effectiveness**
 - Alternatives: Grout 4B, Grout 6*
 - No major drivers of uncertainty
 - Due to the absence of a pathway to potable water and likelihood to meet waste acceptance criteria.
- **Alternatives that considered disposal on-site at the Hanford Integrated Disposal Facility (IDF) all had moderate confidence in the assessments made.**
 - Alternatives: Vitrification 1, FBSR 1A, Grout 6*
 - Various drivers of uncertainty
 - The long-time frames under evaluation induce temporal uncertainty with shallow disposal at a facility with a pathway to potable water.



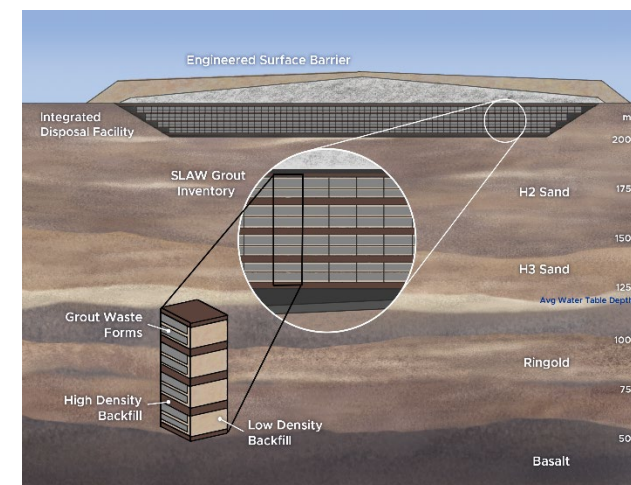
Clive, UT Federal Disposal Facility



Hanford Integrated Disposal Facility

Uncertainty/Confidence in Long Term Effectiveness cont. – On-site Disposal (Criterion 1)

- **Mobility of iodine, technetium, and nitrate to potable water and associated confidence in immobilization**
 - All “on-site disposal” alternatives: Vitrification 1, FBSR 1A, Grout 6*
 - *Uncertainties associated with main contaminants’ performance in grout waste forms covered in first public meeting and in Section E.3 of draft report.*
 - *Uncertainties associated with performance of vitrified waste forms relate to long-term projections of waste form performance, on-going updates to representation in PA modeling and behavior of secondary waste forms.*
 - *Uncertainties associated with FBSR waste forms performance arise from the smaller dataset available on these waste forms.*
 - Source term for contaminants released from waste forms in the IDF dependent on partitioning between waste streams, concentration in waste form, water infiltration rate, transport pathways and local chemistry within facility. All processes that carry uncertainty.
 - Using a risk-budget approach source term contributions from each theoretical waste form combination can be above or below the drinking water standards.
 - For GDU alternatives, the performance of a large disposal unit in performance assessment has not been updated since 1995 performance assessment.
 - This uncertainty is not a driver with off-site disposal where there is no pathway to potable water.



Cross-section of IDF

Matlack et al. 2021 VSL-21R4970-1

Uncertainty/Confidence in Long Term Effectiveness, cont. (Criterion 1)

- Effectiveness of treatment for LDR organics

- Alternatives: All grout alternatives
 - Several recent analyses have provided groundwork for confirming the presence/absence of LDR organics in the Hanford wastes through historical analyses, recent tank samplings, and degradation calculations.
 - Some organics suspected to be present in the Hanford tanks may have degraded (chemical or radiolytic) while in storage in the tanks. Updated sampling of the tank wastes can address the uncertainty with starting inventory
 - Evaporation has been evaluated to remove LDR organics, and further work is ongoing to confirm the efficacy of the evaporation approach to key organics suspected to be present in Hanford wastes.

- Secondary waste inventory, volume and disposal location of secondary waste

- Alternatives: Vitrification 1, FBSR 1A
 - Uncertainty arises from partitioning of various key contaminants between secondary waste streams
 - Leads to uncertainty in waste form inventory and resulting release source terms in Performance Assessment (PA) modeling
 - Example: iodine partitioning and decontamination factors in WTP (VSL-21R4970-1)

LDR Organics Estimated in Exceedance of Waste Standards in Tank Waste based on Vapor Data

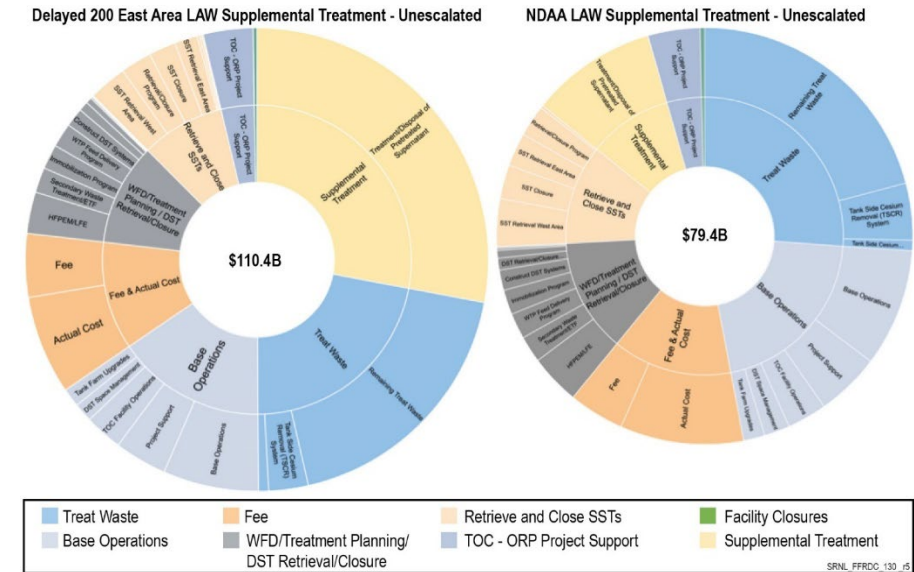
(Table 4 From 3134 study, List being updated in ongoing work outside FFRDC effort)

Compound	Compound
Pyridine	2-nitropropane
Methanol	Phenol
Acetic acid ethyl ester	1,2-benzenedicarboxylic acid
Propanenitrile	1-phenylethanone
Acetonitrile	2-methylphenol
2-methyl-1-propanol	1,2-benzenedicarboxylic acid diethyl ester
Dichloromethane	N-nitrosomorpholine
4-methyl-2-pentanone	2-propanone
9H-fluorene	N-methyl-N-nitrosomethanamine
2-propenol	2-butanone
N-nitroso-n-propyl-1-propanamine	1-butanol

Implementation Schedule and Risk (Criterion 2)

• Vitrification 1 – High Risk

- Delays due to annual operating costs exceeding budget (see Ramsey presentation)
- Radiation Exposure
 - *Buildup of radionuclides (Tc-99, Cs-137, I-129, others) in the recycle flywheel between the melter, off-gas, and evaporator systems increases the exposure risk*
 - *Regular change out of consumables (e.g. bubblers, melters, high efficiency particulate air (HEPA) filters)*
- Chemical Exposure
 - *Toxic and radioactive off-gas required to be handled*
 - *High number of workers required*
 - *Use of hazardous chemical in secondary waste handling (e.g., NaOH, anhydrous NH₄)*
- Intentional wastewater discharges
 - *Resulting discharges to the State Approved Land Disposal Site (SALDS)*
 - *~2-3 gallons/gallon of low-activity waste*
- Secondary waste streams generated
 - *Require additional handling and produces the risks above*



Implementation Schedule and Risk (Criterion 2)

- **FBSR 1A – High Risk**

- Delays due to technical issues

- *Technology has not been demonstrated at scale with similar waste to produce the mineralized waste form in an integrated system.*
 - *Feed system and off-gas system are complex*
 - *Delays due to technical uncertainties contribute to increased cost risk and therefore potential for lengthening mission duration.)*

- Delays due to annual operating costs exceeding budget (see Ramsey presentation)

- Radiation Exposure

- *Risk of radioactive dust generation*
 - *Regular exposure from hands-on maintenance*

- Chemical Exposure

- *Toxic and radioactive off-gas before destruction in thermal oxidation*
 - *High number of workers required*
 - *Cryogenic hazards*

- Particulate Exposure

- *High volume of fine powder (clay) and other granular solids (coal, GAC, alumina) with various transport mechanisms has potential risk of worker exposure to particulates.*
 - *Product is granular with potential dust from PGF.*



Example FBSR Granular Product (PNNL-20704)

Implementation Schedule and Risk (Criterion 2)

- **Grout 4B (low risk) and Grout 6 (very low risk)**

- Increased transportation requirements
 - *No transports of raw materials onto site (4B);*
 - *Many rad liquid transports of decontaminated LAW to offsite (previous Kalinina presentation);*
 - *Rad liquid on-site transport of evaporator condensate to ETF (assumed to be by truck);*
 - *Many offsite transports of solid radioactive materials (grouted waste) from vendor to offsite.*
- Low operation risk due to expansive relevant experience in solidifying salt wastes resulting from reprocessing
 - *Extensive discussion in Volume II: Appendix L*
 - *Savannah River Site – 17 Mgal of low-level salt waste, comparable composition to blended Hanford LAW (next slide), grouted on-site*
 - *West Valley Demonstration Project – 800,000 gallons of supernate and sludge wash liquid + 800,000 gallons of sodium bearing waste-water grouted and shipped for off-site disposal*
 - *SPRU – 10,000 gallons of PUREX and REDOX waste grouted and disposed off-site*
 - *Los Alamos – Liquid wastes from plutonium activities at TA-55*
 - *Test Bed Initiative (TBI) – Phase 1 at Hanford with 3 gallons of Hanford waste grouted and disposed off-site.*
 - *Other uses of grouting for waste immobilization.*



Arial View of Saltstone Disposal Units

Implementation Schedule and Risk (Criterion 2)

Table A-1. Comparison of Maximum Concentrations in the Projected Feed Compositions, Tested with Cast Stone, in Saltstone Salt Batches, and in Saltstone Waste Acceptance Criteria

Waste Constituent	Maximum Value (mol/L)				
	Supplemental LAW	DFLAW	Tested	Saltstone Salt Batches	Saltstone Waste Acceptance Criteria
Sodium	7.69	6.13	7.80	7.51	-
Hydroxide	-	2.00	2.43	2.75	11.47
Nitrate	3.05	2.76	3.90	2.82	8.27
Nitrite	1.19	0.99	1.51	0.98	5.63
Phosphate	0.03	0.04	0.08	0.01	0.37
Aluminum	0.98	0.16	0.87	0.39	5.23
Carbonate	0.62	-	0.74	0.32	2.42
Chromium	0.07	0.01	0.08	0.00	0.03
Sulfate	0.18	0.08	0.23	0.13	0.72
Fluoride	0.13	0.09	0.09	-	0.26
Chloride	0.10	0.19	0.14	-	0.27
Potassium	0.15	0.26	0.22	-	0.94
DFLAW = direct-feed low-activity waste.			LAW = low-activity waste.		

Likelihood of Successful Mission Completion (Criterion 3)

- **All alternatives had high confidence in the assessments made regarding likelihood of project completion.**
 - Vitrification 1: Extremely Low Probability
 - FBSR 1A: Extremely Low Probability
 - Grout 4B: Very High Probability
 - Grout 6: High Probability

Costs (Criterion 4)

- **The facility cost estimates are Class 5 with a nominal range of -10 / +100% based on guidance from Program and Project Management for the Acquisition of Capital Assets - DOE Order 413.3B.**
 - See G. Ramsey presentation for details.

Technical Updates Since 2017-NDAA-3134

- **2017-NDAA-3134 Ask:**

- “Testing over a comprehensive range in LAW chemistry consistent with ranges anticipated in the feed vector. Westsik et al. (2013a) [PNNL-22747] did include a high sulfate LAW composition (which captures most of the feed vector range), but variations in other constituents should also be considered as should appropriate waste loadings.”

- **Update:**

- The comparison of the composition of the supplemental LAW projected feed against LAW grout testing to date (previous slide) strongly suggests that a single grout formulation could be used to immobilize a variable waste feed.
- In cases where the baseline formulation does not give desirable properties, there is experience in identifying successful substitute formulations to achieve the required performance.
- High confidence exists in the ability to adapt to waste composition.

Comparison of Maximum Concentrations in
Projected SLAW Feed Vector and
Concentrations Tested to Date

Waste Constituent	Max Value (mol/L)	
	SLAW	Tested
Sodium	7.69	7.80
Hydroxide	-	2.43
Nitrate	3.05	3.90
Nitrite	1.19	1.51
Phosphate	0.03	0.08
Aluminum	0.98	0.87
Carbonate	0.62	0.74
Chromium	0.07	0.08
Sulfate	0.18	0.23
Fluoride	0.13	0.09
Chloride	0.10	0.14
Potassium	0.15	0.22

Technical Updates Since 2017-NDAA-3134

- **2017-NDAA-3134 Ask:**

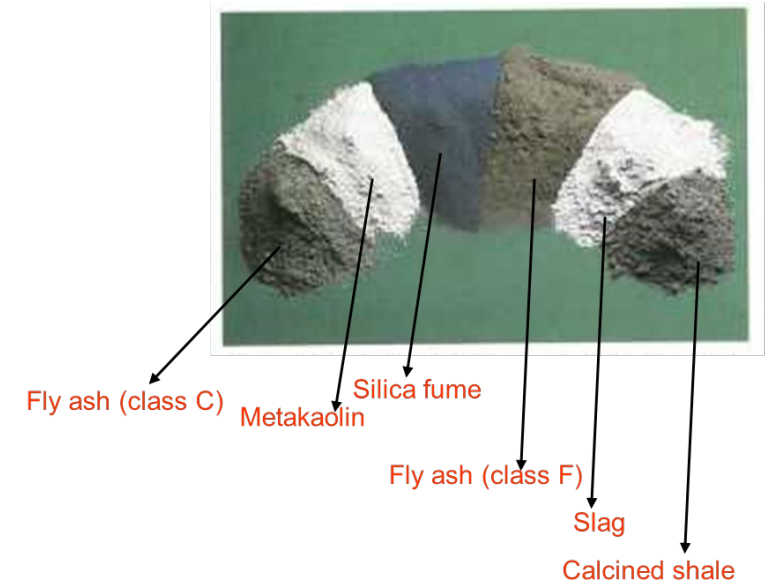
- Testing of dry mix constituents in a manner to elucidate causes in observed differences in effective diffusion coefficients. This is particularly true for technetium, which showed a 100x variation in the screening tests. Understanding the cause of this variability would allow optimization of mix designs for maximum retention.”

- **AND**

- “Testing of a range of alternative substitutes for mix design components with uncertain future availability (should be performed).”

- **Update:**

- An analysis of available data did not identify definitive cause and effect relationships between dry-mix constituents and resultant contaminant effective diffusivities.
- Recent work has been ongoing for LAW and other liquid wastes that has provided insight into alternative formulations and amendments/additives for enhanced retention of specific contaminants of concern.
- There is high confidence that an effective and durable grout waste form can be designed for Hanford LAW.



Example Grout Dry Reagents

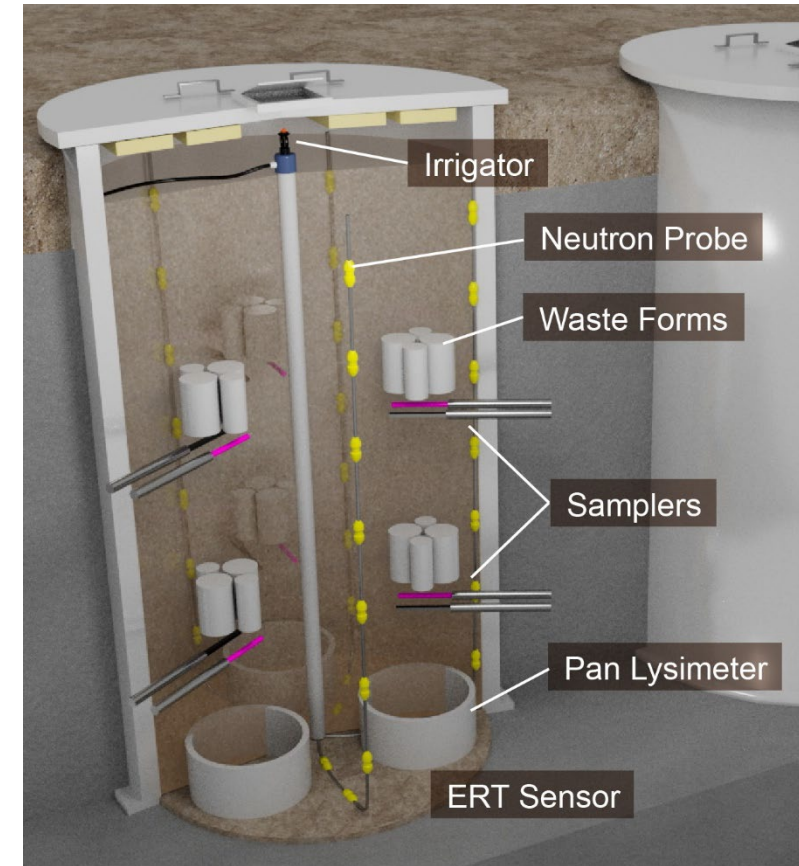
Technical Updates Since 2017-NDAA-3134

- **2017-NDAA-3134 Ask:**

- “Testing to assess rates of oxygen ingress into Cast Stone monoliths and its impact on technetium release rates.”

- **Update:**

- In summary, the changing redox state within a grouted waste form for secondary waste was considered in sensitivity cases in the IDF PA and as a dynamic process in the SRS Saltstone PA.
- Other modeling efforts to represent oxygen ingress (or other key processes including carbonation) are ongoing.
- A large-scale lysimeter study at Hanford will generate valuable data to better predict the rate of oxygen ingress in grout waste forms.
- There remains uncertainty in the rate of reoxidation of grout waste forms within the IDF, but this can be handled by using sensitivity cases in PA modeling.



**Cross-section of Field Lysimeter Test
Facility Cell at Hanford**

Technical Updates Since 2017-NDAA-3134

- **2017-NDAA-3134 Ask:**

- “Use of new effective diffusion coefficients to update predictions of performance in an IDF environment”

- **Update**

- No updated efforts have directly carried out a PA for a primary LAW grouted waste form in the IDF.
- Recent modeling has identified performance targets within the IDF for a grouted waste form based on back calculations. (PNNL-28992).
- Summaries of the target performance of the major contaminants is provided in Volume II: Appendix A.
- The primary uncertainty is in the long-term maintenance of properties of the waste form but changing properties can be assessed in sensitivity cases in PA modeling.

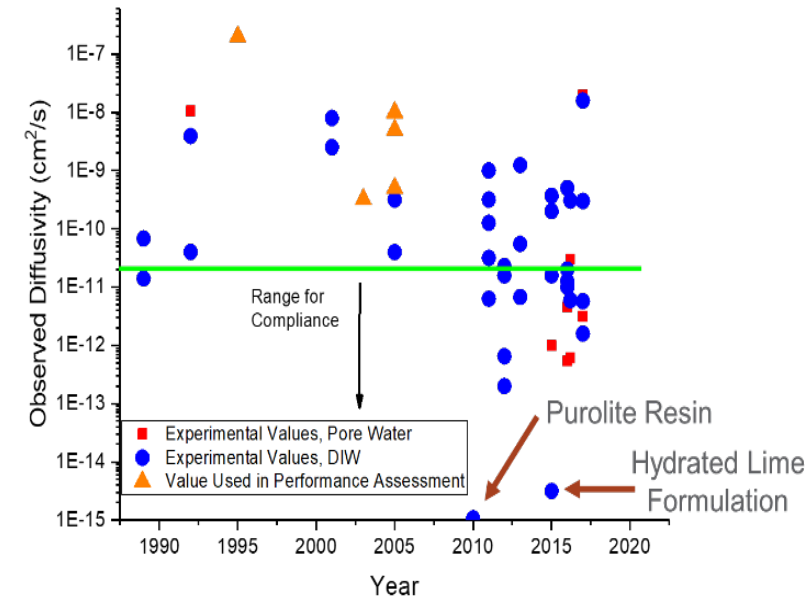


Figure A-1. Comparison of Historical Iodine Leach Test Data from Experimental Results (blue dots/red squares) and Those Used in Prior Performance/Risk Assessments (orange triangles). Adapted from PNNL-28992

Technical Updates Since 2017-NDAA-3134

- **2017-NDAA-3134 Ask:**

- *Testing to assess the effectiveness of iodine getters in conjunction with Cast Stone formulations over a comprehensive range in LAW chemistry consistent with ranges anticipated in the feed vector. Testing to identify other potential iodine getter formulations/materials (e.g., bismuth-based as Ag is a RCRA listed metal)."*

- **Update:**

- Data sets exist showing the efficacy of iodine getters in LAW Cast Stone.
- The most important factor in success of an iodine getter is the ratio of silver added to the total halides present and relevant examples are covered in the report.
- Alternatives to silver have been proposed and are currently under study (resins, Bi).

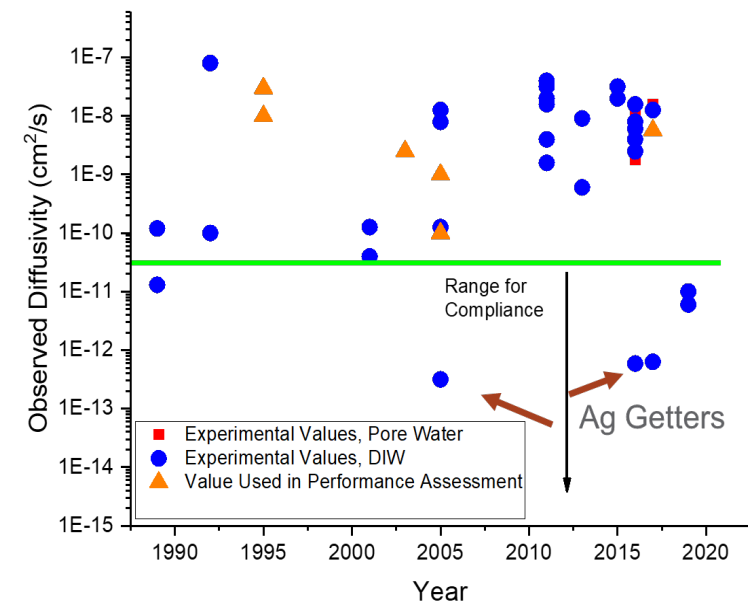


Figure A-3. Comparison of Historical Iodine Leach Test Data from Experimental Results (blue dots/red squares) and Those Used in Prior Performance/Risk Assessments (orange triangles). Adapted from PNNL-28992

- **2017-NDAA-3134 Ask:**

- *“Testing to assess the potential impact of the process to address LDR organics on the performance of the grouted waste form” and “The process to destroy LDR organics impacts the performance of the grouted waste form, which may be a particular concern for technetium. This risk is addressed above in the recommendations for additional testing in Section C.4.1 [of SRNL-RP-2018-00687]. This risk applies to IDF only.”*

- **Update**
- **Work has been ongoing to better predict or detect the presence of LDR organics within the Hanford tank wastes and ways to remediate organics present prior to immobilization (e.g., evaporation).**
- **The LDR organics, at the concentrations projected, are not anticipated to impact the properties of the grout.**
- **Disposal performance of a grouted waste form related to LDR organics is based on total concentration in the waste form. The main uncertainty around LDR organics remains in the quantification and potential need for treatment, but the knowledge base has grown since the NDAA17 report.**

Technical Updates Since 2017-NDAA-3134

- **2017-NDAA-3134 Ask:**

- “The potential improvements to the performance and economics (...of a GDU) would need to be evaluated quantitatively, which was beyond the scope of this assessment. A potential downside to SDUs is the inability to retrieve the waste form should an issue arise with the curing of a particular batch.”

- **Update**

- The use of a large vault isolates more of the waste from environmental exposure due to the large volume to surface area ratio.
- GDU geometry would provide longer transport pathways compared with containerized waste forms greatly slowing release from the GDU and slowing the ingress of reactive environmental species (e.g., oxygen, CO₂). The result would be that the GDU may maintain the initial conditions of a majority of the waste form for extended timeframes.
- The primary uncertainty is the lack of an updated performance assessment (PA) for a GDU geometry at Hanford but could be based off of the SRS PA. It is believed that the GDU system would perform much better versus the individual containerized disposal.
- Retrieving the GDU material for unforeseen reasons is also considered plausible but costly. The process could be analogous to the removal a nuclear reactor concrete biological shield.
- Recent computational analysis and experimental works relevant to the GDU concept are discussed in detail in Volume II Appendix C: Section C.14

Summary

- **Uncertainty drivers varied across the alternatives (Volume II: Appendix E)**

- Uncertainty around long-term effectiveness driven by disposal locations
- Risk associated with schedule implementation and operations was larger for high temperature alternatives due to process complexity, off-gas handling and consumable changeouts.
- High confidence around the assessments of likelihood of successful mission completion
- Similar range of cost uncertainty across alternatives

- **Updated Information from 2017-NDAA-3134 Report (Volume II: Appendix A)**

- New information and responses to unknowns listed in 2017-NDAA-3134 report are presented in Appendix II:A
- Continually reducing uncertainties associated with disposal of LAW waste forms.



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Alternative Analyses

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2021 NDAA-3125 Meeting #3

April 26-28, 2022

SRNL-STI-2022-00199



U.S. DEPARTMENT OF
ENERGY

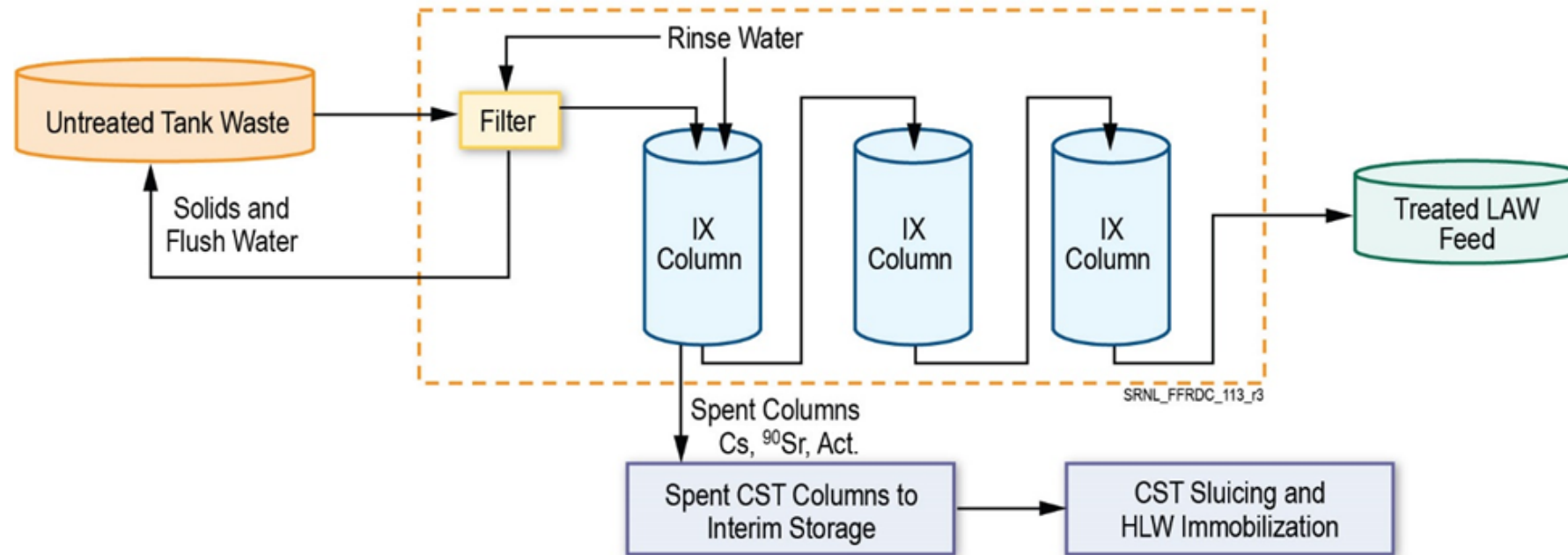
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Pretreatment

- Pretreatment of LAW assumed needed to remove ^{137}Cs equivalent to WTP LAW

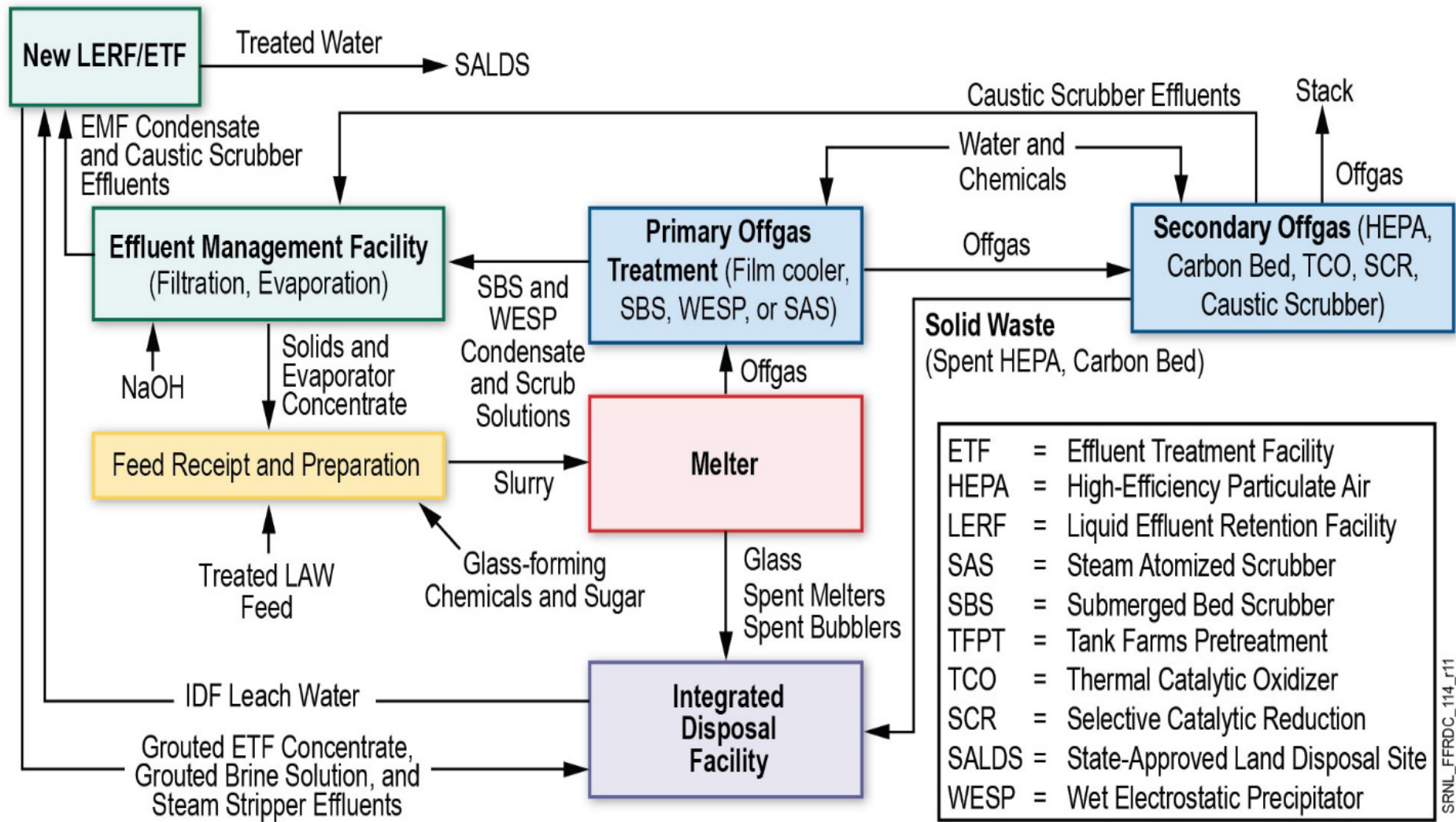
Vitrification Facility criteria ($<3.18\text{E-}5 \text{ Ci/mole Na}^+$)

- Assume Tank Farm Pretreatment (TFPT) using Crystalline Silicotitanate (CST)
 - *also removes $>99\%$ of ^{90}Sr from most LAW compositions ($\sim 90\%$ $<\text{Class A}$)*
- Does not preclude pretreatment in WTP – but may impact offsite disposal waste class

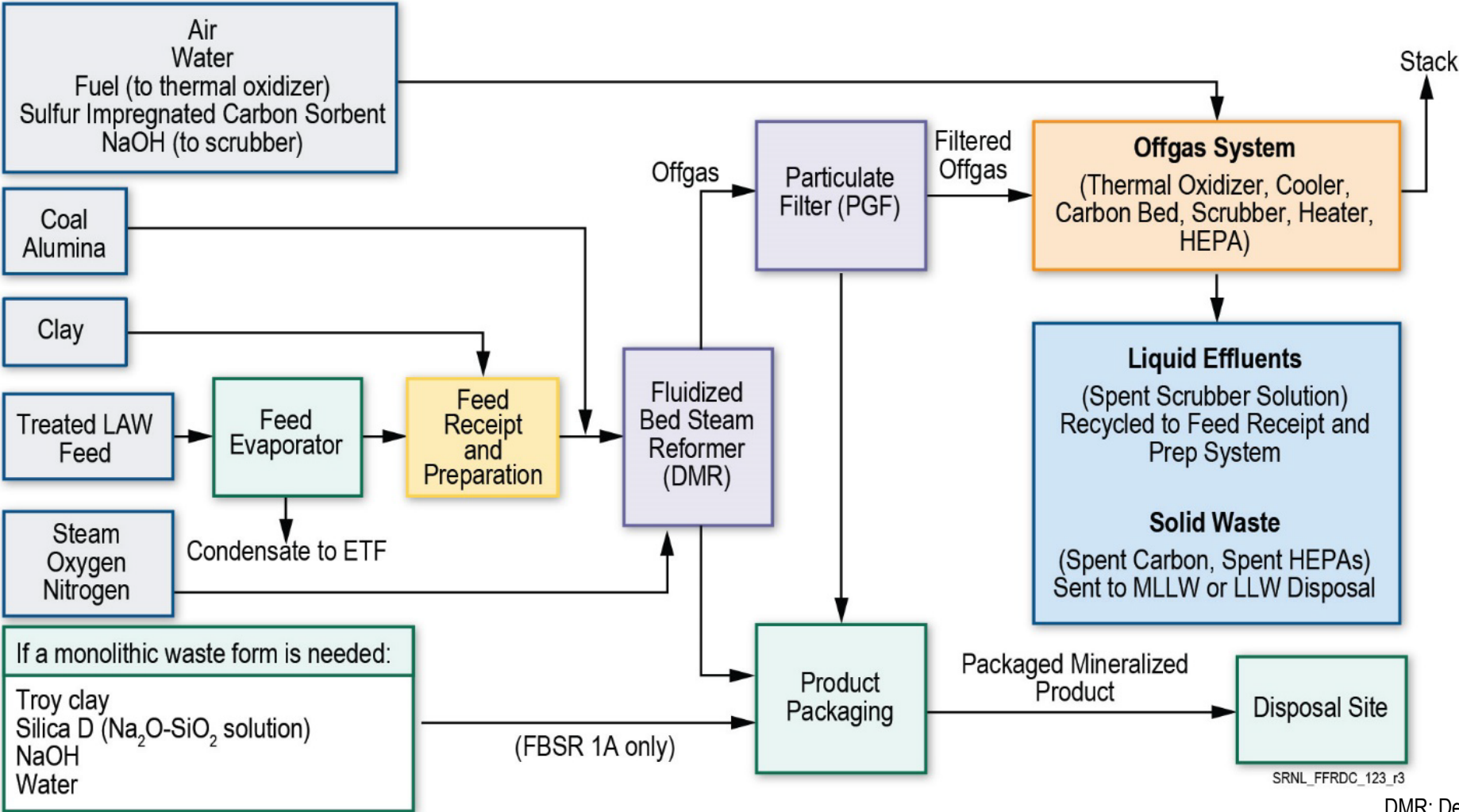


Tank Farms Pretreatment Process (TFPT) ~ Tank Side Cesium Removal (TSCR)

Alternative Vitrification 1 Simplified Flowsheet



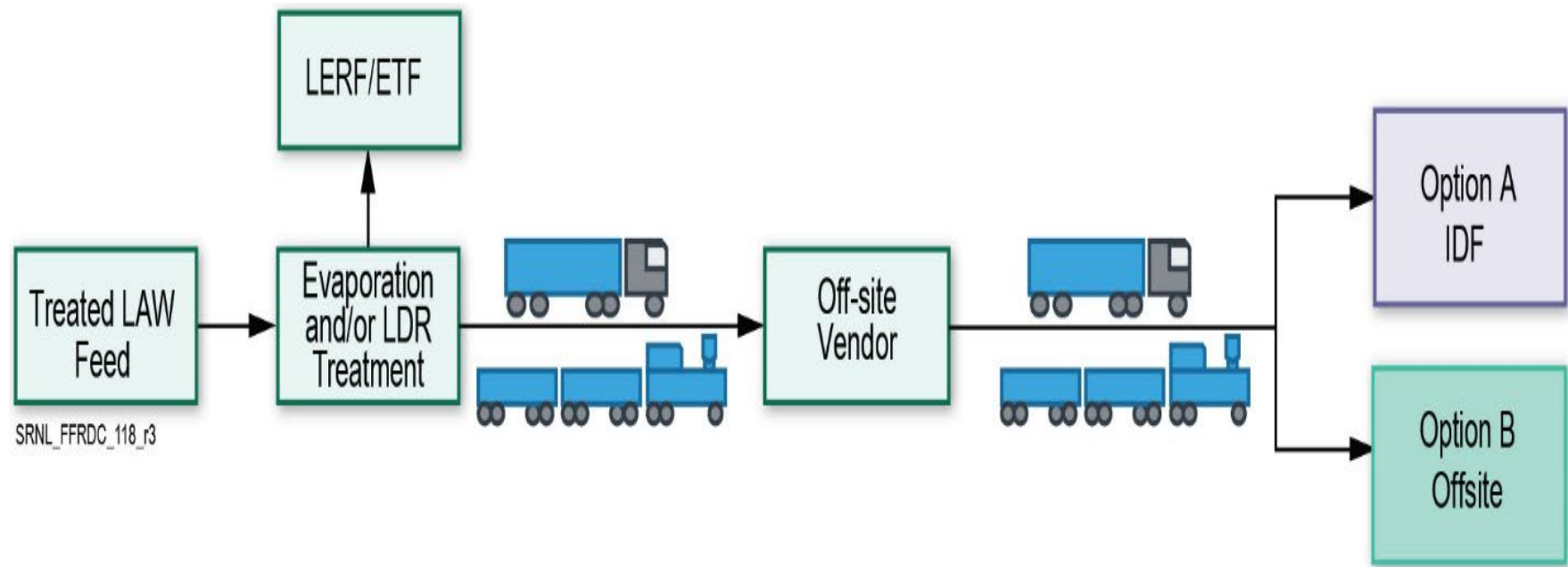
Alternative FBSR 1A Simplified Flowsheet



DMR: Denitration and Mineralizing Reformer
MLLW: Mixed Low Level Waste
LLW: Low Level Waste
HEPA: High Efficiency Particulate Air

Alternatives Grout 4A and 4B – Off-site Vendor – Simplified Flowsheet

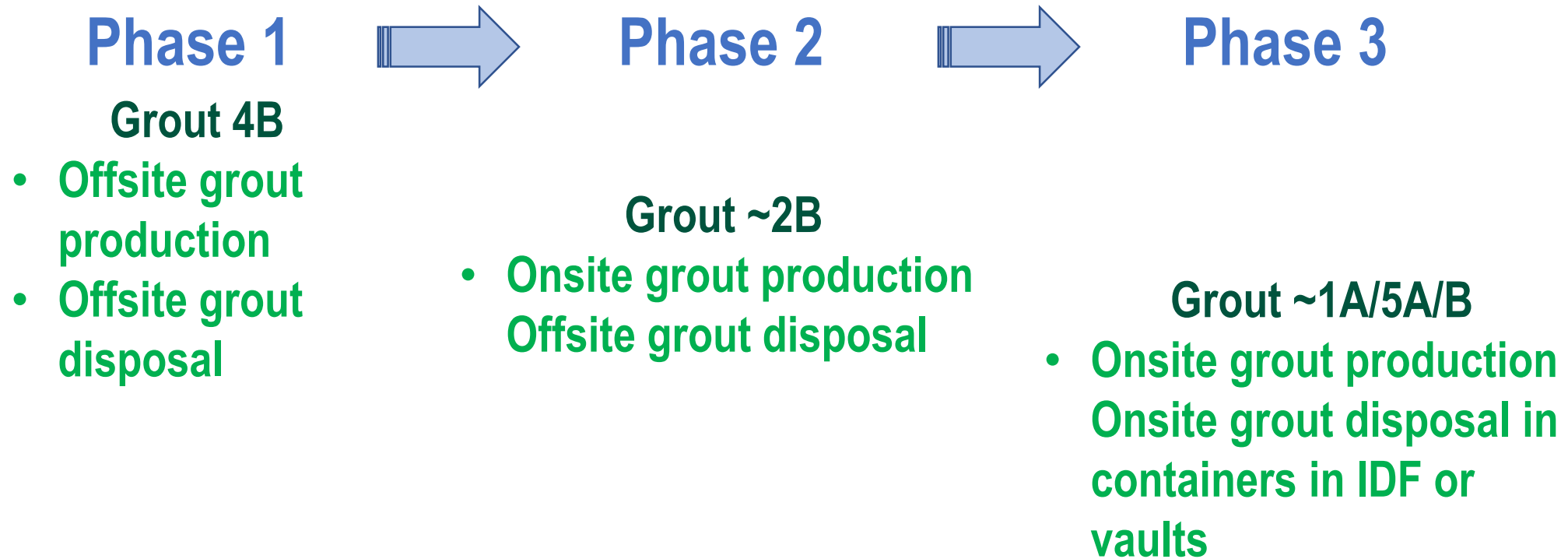
.....



Note: all grout options depict “LDR treatment”, although it may not be required for all feeds

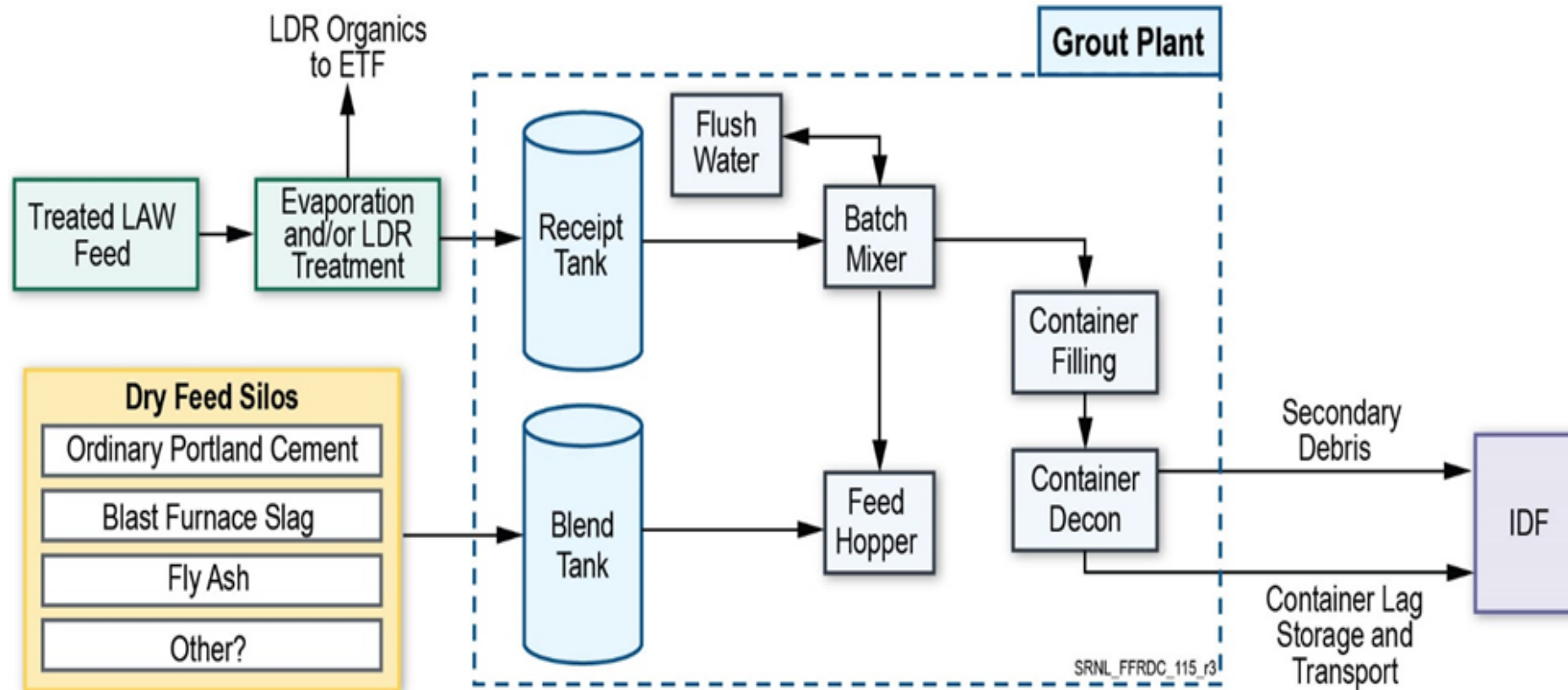
LERF: Liquid Effluent Retention Facility
ETF: Effluent Treatment Facility

Alternative Grout 6 – Hybrid Phased on-site/off-site Grout - Concept

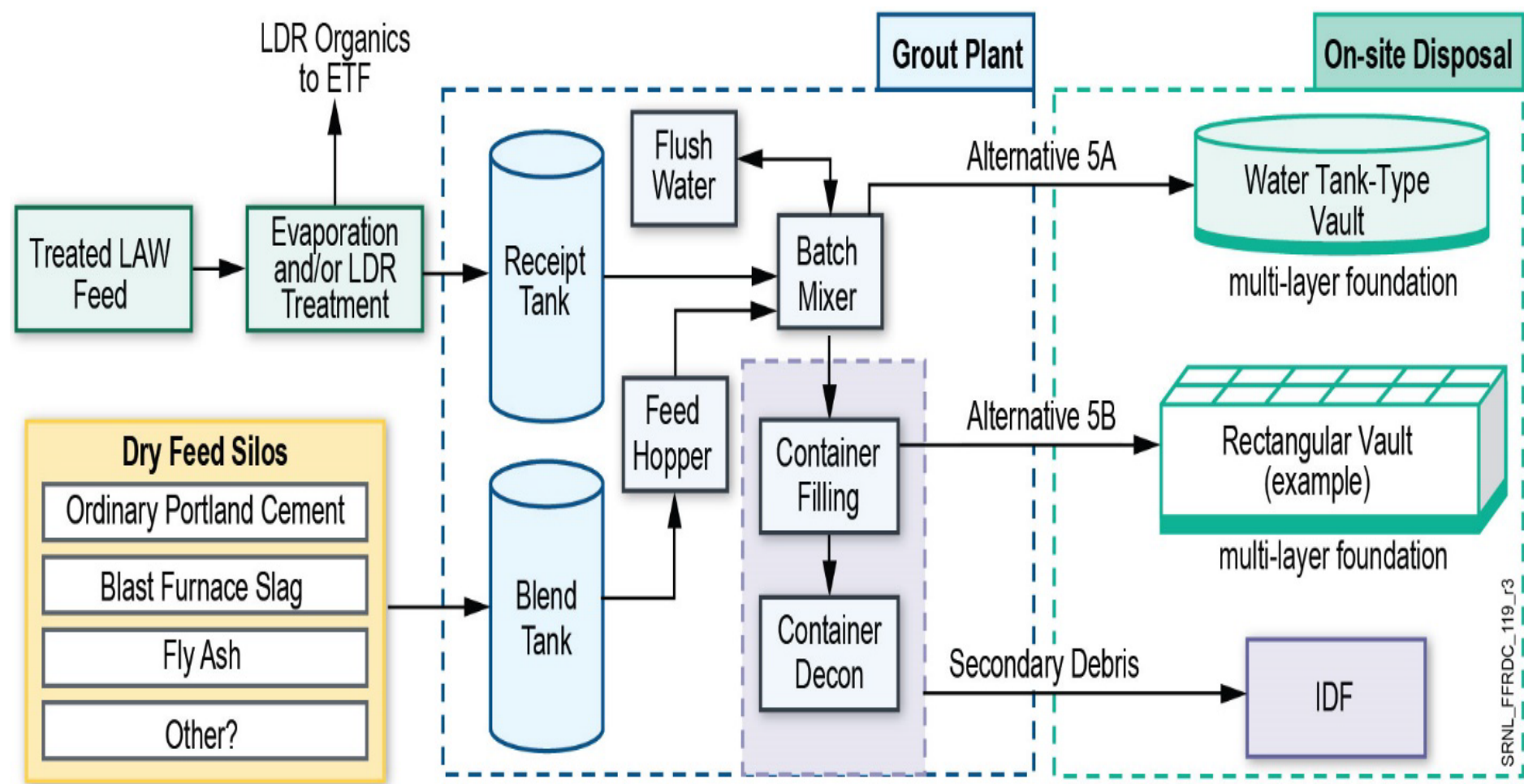


Maximum flexibility alternative

Alternative Grout 1A – Single grout plant – On-site disposal - Simplified Flowsheet



Alternatives Grout 5A and 5B Simplified Flowsheet



Vitrification 1 - Single Vitrification Plant - Selection Criteria Summary

1. Long-Term Effectiveness

- Residual threat to health and environment upon successful completion
 - + *Nitrates/nitrites and waste organics destroyed; low mobility of rads/metals that remain in glass*
 - *NH₃ and organics produced; NH₃, Hg are in secondary wastes; Some I-129 in secondary wastes - TBD*
- Long-term risks upon successful completion
 - + *High confidence in destruction of nitrates/nitrites, waste organics; long-term sequestration of rads/metals that remain in glass*
 - *Uncertainty in fate and partitioning of Hg, I-129, to secondary wastes, melter idling impact on Tc fate*

2. Implementation Schedule and Risk

- + *Low volume of primary waste; low transportation risk*
- *Delayed start-up increases risk of tank degradation; worker hazards; high greenhouse gas emissions, chemical and power use; high atmospheric vapor release and secondary liquid; extended duration of operations; risk of further delay*

3. Likelihood of Successful Mission Completion

- + *Replicates first LAW melter technology, reducing technology uncertainty*
- *Complex, integrated process with high maintenance needs; insufficient funds to start-up by need date*

4. Life Cycle Costs - (see later presentation)

FBSR 1A - Fluidized Bed Steam Reforming – On-site Disposal - Selection Criteria Summary

1. Long-Term Effectiveness

- Residual threat to health and environment upon successful completion
 - + *Nitrates/nitrites/waste organics destroyed; Tc sequestered in waste form; moderate volume of primary waste*
- Long-term risks upon successful completion
 - + *High confidence in destruction of nitrates/nitrites, waste organics, non-pertechnetate; long-term sequestration of rads that remain in granular product*

2. Implementation Schedule and Risk

- + *low transportation risk*
- *Intermediate delayed start-up has risk of tank degradation; worker hazards; high greenhouse gas emissions, chemical and power use; extended duration of operations; risk of further delay due to cost and technical issues*

3. Likelihood of Successful Mission Completion

- + *Similar to other equipment (but dissimilar feed waste stream); lessons learned from IWTU*
- *Very highly complex, integrated process with high maintenance and process control requirements; unique waste form; needs significant pilot-scale testing to reduce uncertainty; insufficient funds to start-up by need date*

4. Life Cycle Costs - (see later presentation)

Grout 4B - Off-site Vendor for Grouting – Off-site Disposal - Selection Criteria Summary

(assumes vendor flowsheet is identical to offsite Grout 1B)

1. Long-Term Effectiveness

- Residual threat to health and environment upon successful completion
 - + *Reduced long-term ammonia issue (WTP LAW continues); no rad impact to Hanford groundwater; Hg, Tc, & I in primary waste form offsite; minimal secondary waste*
 - *Nitrates/nitrites not destroyed (but no impact); 1.8X waste volume increase*
- Long-term risks upon successful completion
 - + *Minimal added impact of ammonia; high confidence in no impact to Hanford groundwater*
 - *Moderate confidence in LDR organic resolution*

2. Implementation Schedule and Risk

- + *On-time start-up decreases risk of tank degradation; minimal worker hazards; low greenhouse gas emissions, chemical and power use; minimal atmospheric discharges; minimal technical risk of waste form production issues*
- *Moderate transportation risk; high volume of primary waste; LDR organics not resolved*

3. Likelihood of Successful Mission Completion

- + *Similar to existing processes; robust/flexible; low complexity; commercially available equipment; demonstrated in TBI; adaptable; low likelihood of failure for technical reasons; sufficient funds to start-up by need date*
- *LDR organics may not be sufficiently resolved, requiring more to WTP LAW melters*

4. Life Cycle Costs - (see later presentation)

Grout 6 - Phased Off-site and On-site Grouting in Containers - Selection Criteria Summary

(assumes vendor flowsheet is identical to offsite Grout 1B)

1. Long-Term Effectiveness

- Residual threat to health and environment upon successful completion
 - + *Reduced long-term NH₃ issue (WTP LAW continues); low potential rad impact to Hanford groundwater; Hg, Tc, & I in primary waste form disposed offsite/onsite; minimal secondary waste*
 - *Nitrates/nitrites not destroyed (but limited impact); 1.8X waste volume increase*
- Long-term risks upon successful completion
 - + *Minimal added impact of ammonia; high confidence in limited potential impact to Hanford groundwater; lack of potential migration due to low water infiltration rates, vault barrier*
 - *Moderate confidence in LDR organic resolution; uncertainty in impact of non-pertechneate*

2. Implementation Schedule and Risk

- + *Early start-up minimizes risk of tank degradation; minimal worker hazards; low greenhouse gas emissions, chemical and power use; minimal atmospheric discharges; minimal technical risk*
- *Moderate transportation risk; high volume of primary waste; LDR organic resolution or LAW vit*

3. Likelihood of Successful Mission Completion

- + *Similar to existing processes; robust/flexible; low complexity; commercially available equipment; demonstrated in TBI; vault demonstrated (SRS); adaptable; low likelihood of failure for tech. reasons; sufficient funds to start-up by need date*
- *LDR organics may not be sufficiently resolved, requiring more to WTP LAW melters*

4. Life Cycle Costs - (see later presentation)

Summary

- **Considered 23 Alternatives**
- **Fully evaluated 15 Alternatives**
 - 4 key Alternatives described here
 - *Vitrification 1 - Single Vitrification Plant*
 - *FBSR 1A - Fluidized Bed Steam Reforming – On-site Disposal*
 - *Grout 4B - Off-site Vendor for Grouting – Off-site Disposal*
 - *Grout 6 - Phased Off-site and On-site Grouting in Containers*
- **Criteria evaluated technical parameters for long and short-term impacts**
- **Facility and operating cost projections to be provided in subsequent presentation**

Alternative No Action

- **Use WTP LAW melters only – no new facility or process**
 - 21 MT glass/day at 70% TOE
 - 64 years required to produce 489,000 MT of glass
 - *Extends mission by >22 years (no formal modeling)*
 - Impacts HLW mission completion
 - Lower TOE would extend mission further
- **Rejected as an alternative for full evaluation**

Alternative Vitrification 2 – Increased LAW Vitrification Rate

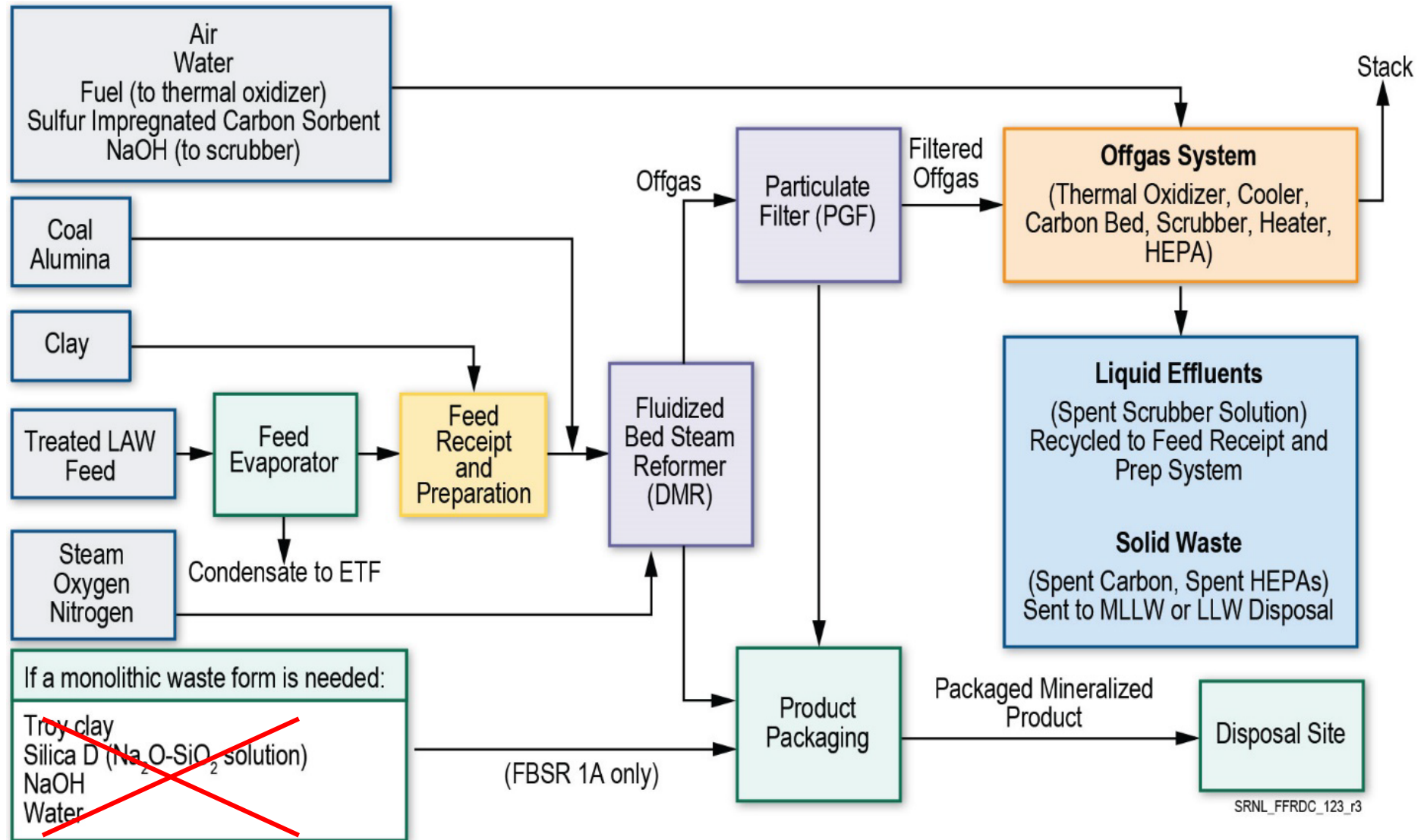
- **Increasing waste throughput would lessen need for additional melter capacity**
 - Need ~50% increase in throughput while maintaining 70% TOE
 - Increase waste loading
 - *Increased waste loading already accounted for and additional gains likely insufficient*
 - Increase throughput
 - *Reduce melter refractory thickness*
 - *Increase melt temperature*
 - Impacts on Tc & I & halide volatility; melter component life; limited feed, offgas and container decon/handling capacity
 - Add third melter
 - *Existing space in WTP LAW may not be available*
 - Increase TOE
 - *Other melter systems achieve 40-50%*
 - Increase feed lag storage capacity
 - *Reduces but does not eliminate additional capacity needed*
 - Break recycle loop
 - *Diverts most Tc and I to secondary grout*
 - Thorough engineering study and more R&D would be needed to fully assess
 - *Beyond scope of this study – rejected for full evaluation*

Alternative Vitrification 3 – Near Tank Vitrification

- **Multiple vitrification units at separate plants in East & West areas**
 - Avoids inter-area transfer line use
 - Immobilized glass and secondary wastes disposed onsite
 - Multiple possible melter configurations demonstrated at $\geq$ pilot scale including:
 - *GeoMelt® In-Container Vitrification™ (ICV)*
 - *Transportable Vitrification System*
 - *Dem&Melt*
 - ICV selected as reference technology due to maturity for Hanford applications
 - *Pretreated LAW mixed with glass formers*
 - *Dried in concentrator/dryer*
 - *Melter (single use) with graphite electrodes*
 - *Offgas system (filter; liquid condenser; thermal oxidizer; caustic venturi scrubber; HEPA; GAC)*
 - *Lid attached (Melter is disposal container)*
 - Projected to require up to 4 replicate melter processing lines for each East and West areas
 - Comparable to the Vit-1 alternative with similar offgas treatment complexity
 - Bounded by Vit-1 alternative so not fully evaluated

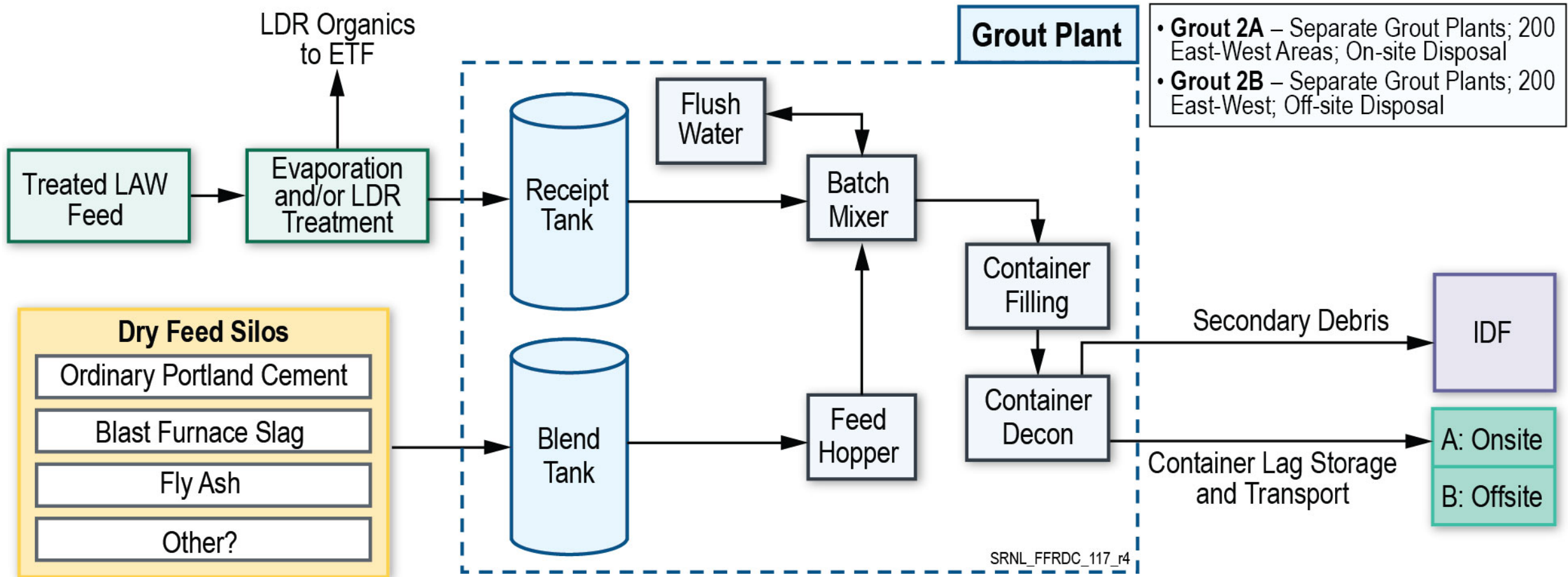
Alternative FBSR 1B - Fluidized Bed Steam Reforming – Off-site Disposal - Simplified Flowsheet

(same as FBSR 1A but no geopolimer needed)



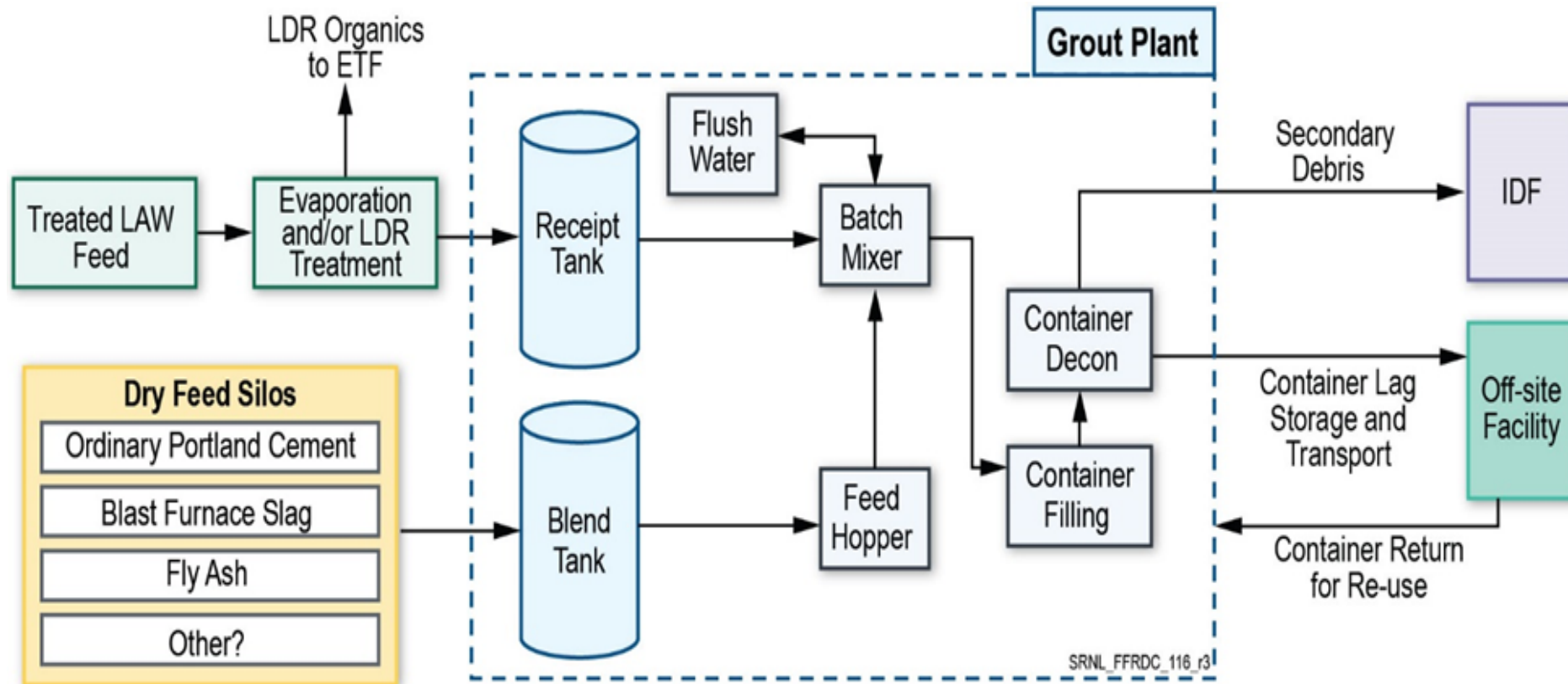
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Alternatives Grout 2A and 2B – Simplified Flowsheet

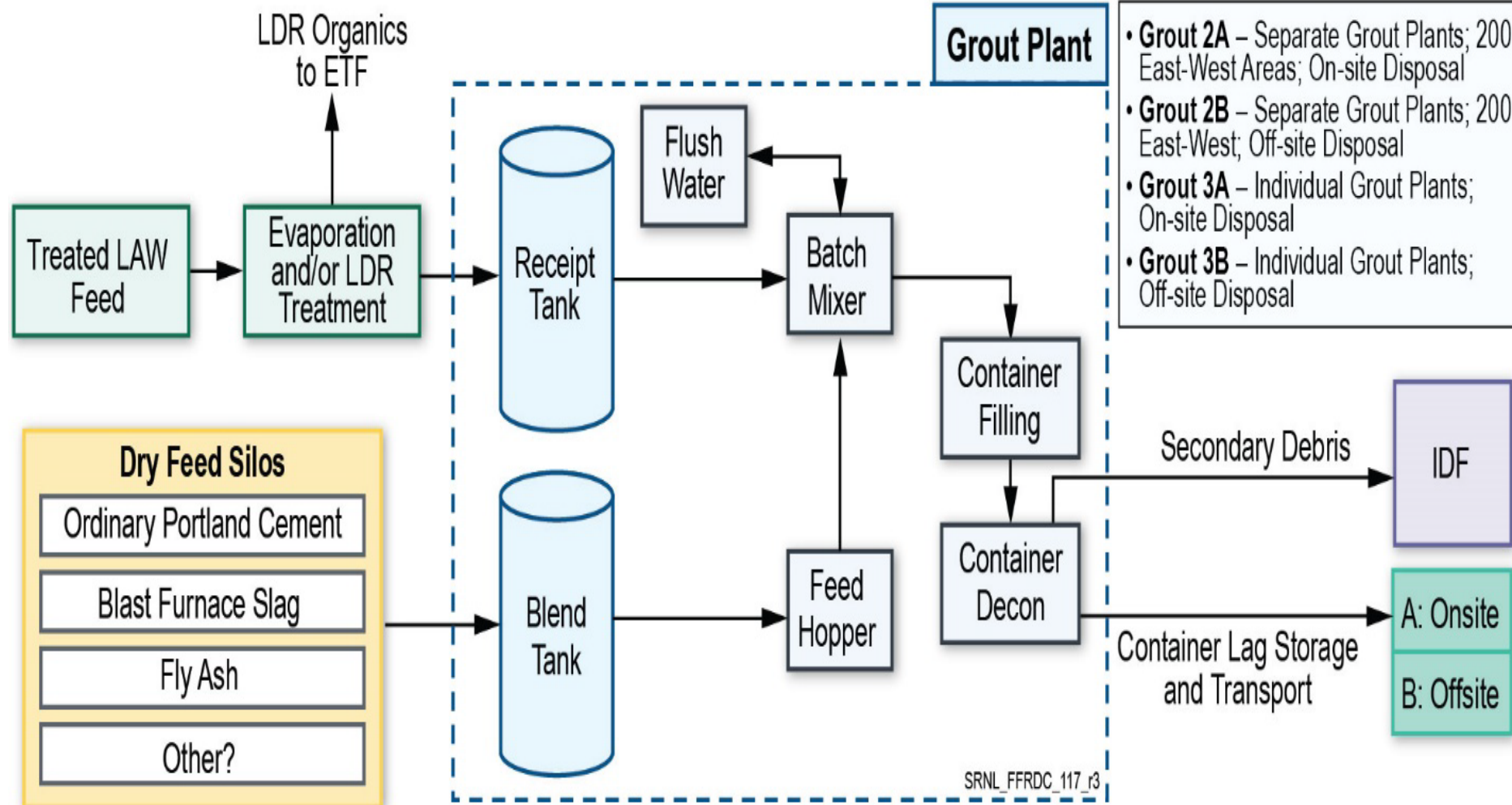


Note: All flowsheets for grout options include LDR Organic treatment although may be unnecessary for

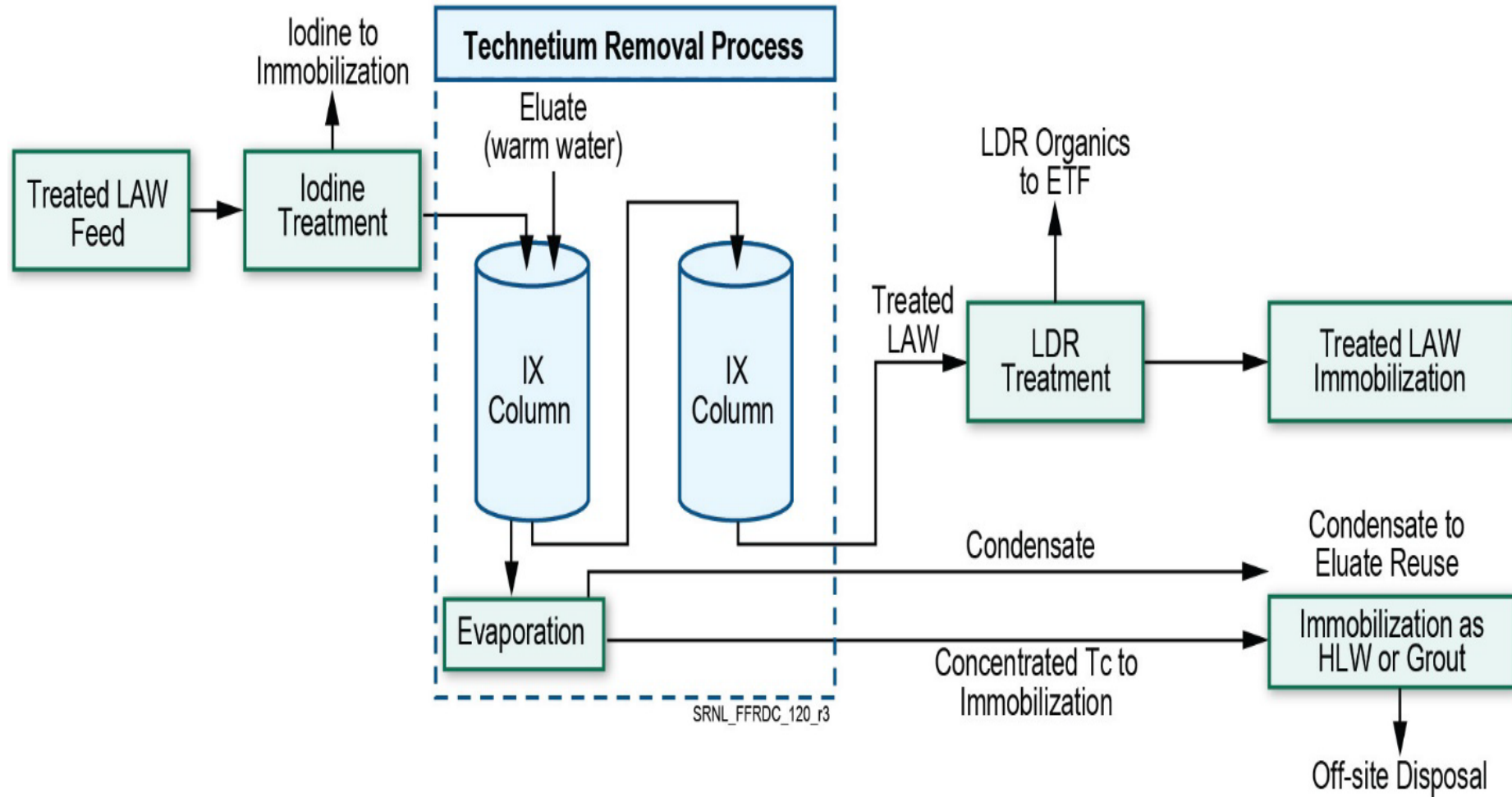
Alternative Grout 1B Single grout plant – off-site disposal - Simplified Flowsheet



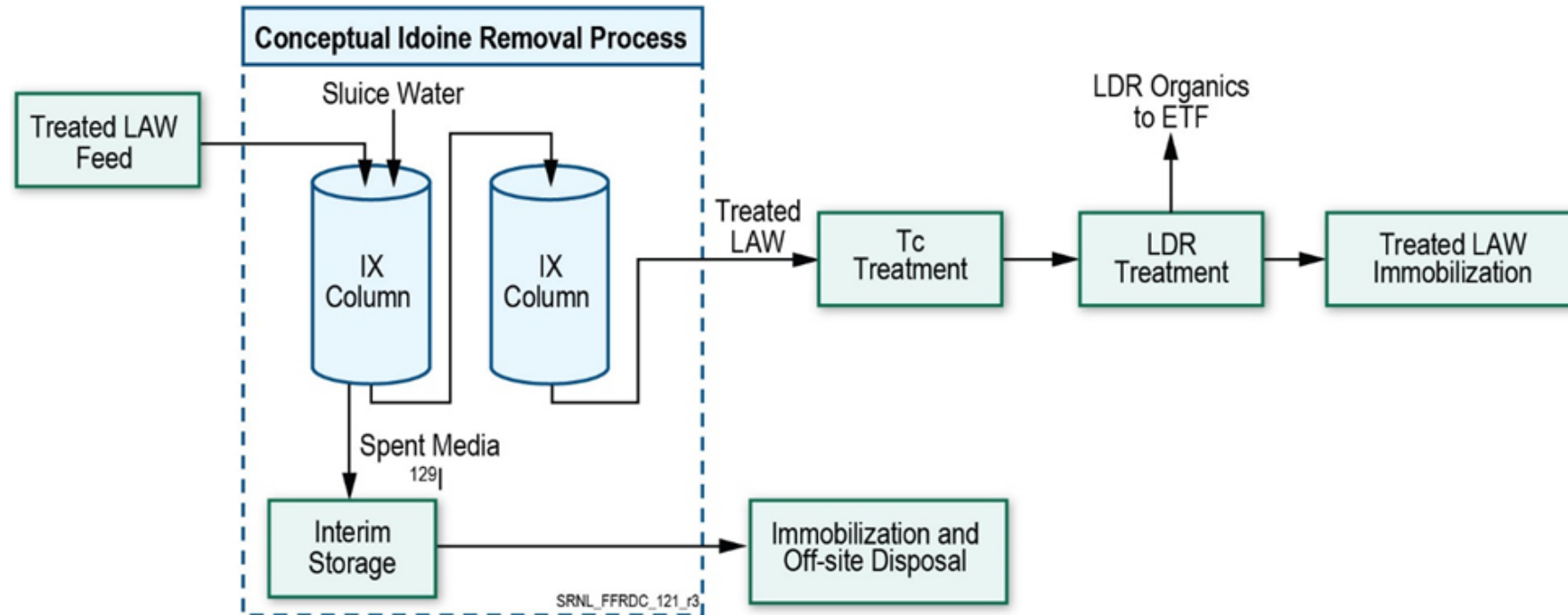
Alternative Grout 2A, 2B, 3A, 3B Simplified Flowsheet



Technetium Removal Conceptual Flowsheet



Iodine Removal Conceptual Flowsheet





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LAW Supplemental Treatment Alternatives

Cost and Schedule Methodology & Estimates

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Environmental and Legacy Mgmt., SRNL

Estimating Lead

2021 NDAA-3125 Meeting #3

April 26-28, 2022

SRNL-STI-2022-00199



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Presentation Outline

- 1) Introduction
- 2) Mission Construction
- 3) Methodology
- 4) Modeling Scenarios
 - Development
 - Results
- 5) Internal Analysis (Alternatives & Sensitivities)
 - Development
 - Results
- 6) Summary

Evaluation(s) of the Hanford Mission: Scope, Cost, and Schedule

- The Hanford clean-up program is a massive and complex undertaking.
- Federally Funded Research and Development Centers (FFRDC) studies per National Defense Authorization Act directives are running in parallel with other types of analyses, such as those by
*Government Accounting Office (GAO-17-306 & GAO-22-104365),
Office of River Protection (System Planning),
Corps of Engineers (WTP remaining capital facilities).*
- The various studies plus the *Tank Closure and Waste Management Environmental Impact Statement* provide different views of the mission.
- This presentation will summarize this FFRDC study – specific to LAW Supplemental Treatment – with consideration of implementation as per the above.

LAW Supplemental Treatment Capacity Decision(s)

Capital cost, mission progress, and risk reduction posture are derived from the technology selection, planning and execution. Several interrelated facets.....

How

- Processed technology selection
- Funded constrained / unconstrained
- Scheduled implementation

Where

- Treated onsite (Tank Farm Quadrants) / offsite
- Dispositioned onsite (IDF or Vault) / offsite

When

- w/r/to HLW mission efficiency
- w/r/to LAW risk reduction rate

Potential for Disparity Between the Alternatives

- **The facets which significantly differentiate options...**
- Capital cost is a primary issue for single, large facility (located near WTP / IDF)
 - Significant impact on potential starting date and full HLW support
 - Can drive overall mission completion (ex. Treat All Tank Waste)
 - SLAW annual operating cost factors with mission length
 - *Mission length is normally driven by HLW vitrification*
- Offsite disposition options may appear to increase operating costs – but should be evaluated in conjunction with capital cost and impact on total mission schedule...
 - Onsite grout options carry risk of schedule delay due to regulatory acceptance
 - *Accelerated feed and treatment start dates improve near-term risk reduction*
- Combining minimal capital cost options with offsite disposition appears viable for near-term start
 - *Can reduce total mission, life-cycle cost, and long-term risk*

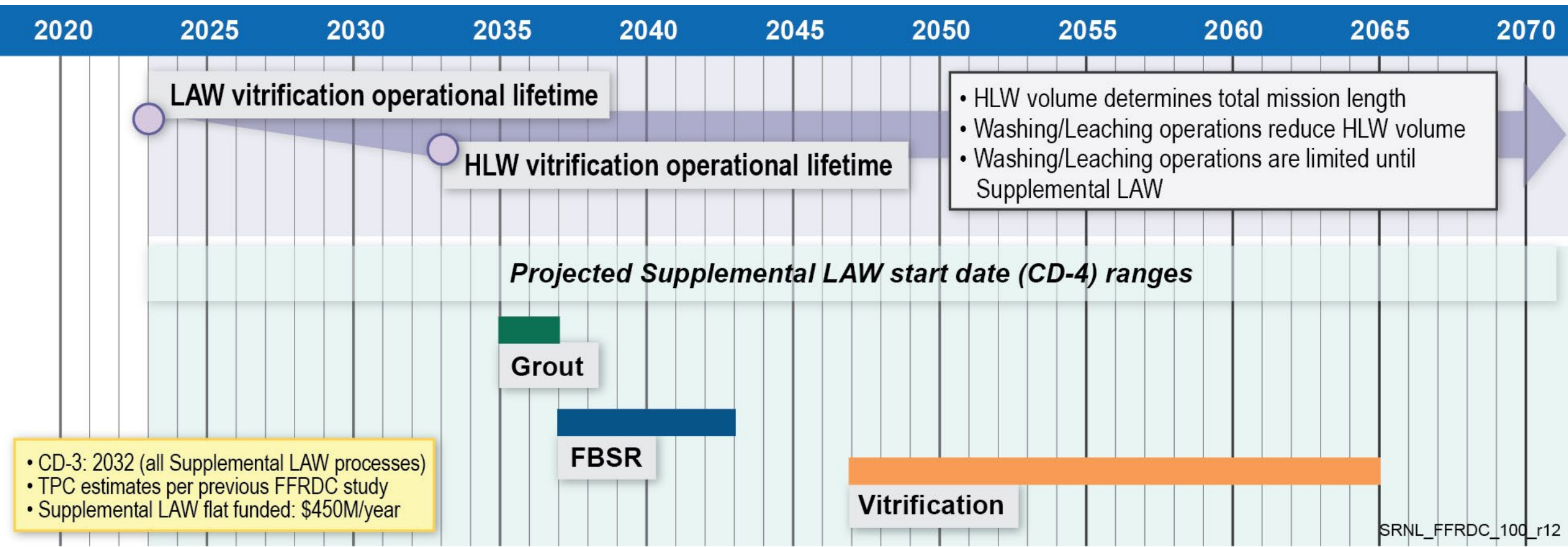
Mission Construction – Initial Bases and Metrics

- The previous FFRDC report and other publications (such as GAO 22-104365) describe costs of various process alternatives and disposition. This study more directly incorporates LAW supplemental treatment within the total mission - as the schedule is not constrained and System Planning tools could be incorporated alongside the Alternatives analysis.
 - Capital costs and onsite operating costs are derived from the previous FFRDC report (SRNL-RP-2018-00687)
 - Mission schedule reflects System Planning comparative results (Vitrification 1 versus Grout 4B) plus the Alternatives analysis (timing for the start of LAW Supplemental Treatment)
 - LAW & HLW feed generated by CST IX and HLW processing arrangements as per previous System Planning studies.
 - Offsite disposition costs reflect updated estimates of grouted waste classification and vendor pricing identified during this study.
 - Cost metrics are provided as per System Planning (unescalated \$) and for Criterion 4 (discounted, present value)
 - Vitrification and Offsite Grout are summarized per GAO-17-306 (Table 2)
 - *Technology alternative capital cost and/or avoidance*
 - *Short-term risk (\$/gal) and schedule reduction*
 - *Long-term risk (\$/Ci Tc) plus disposition*
 - *Total mission cost*

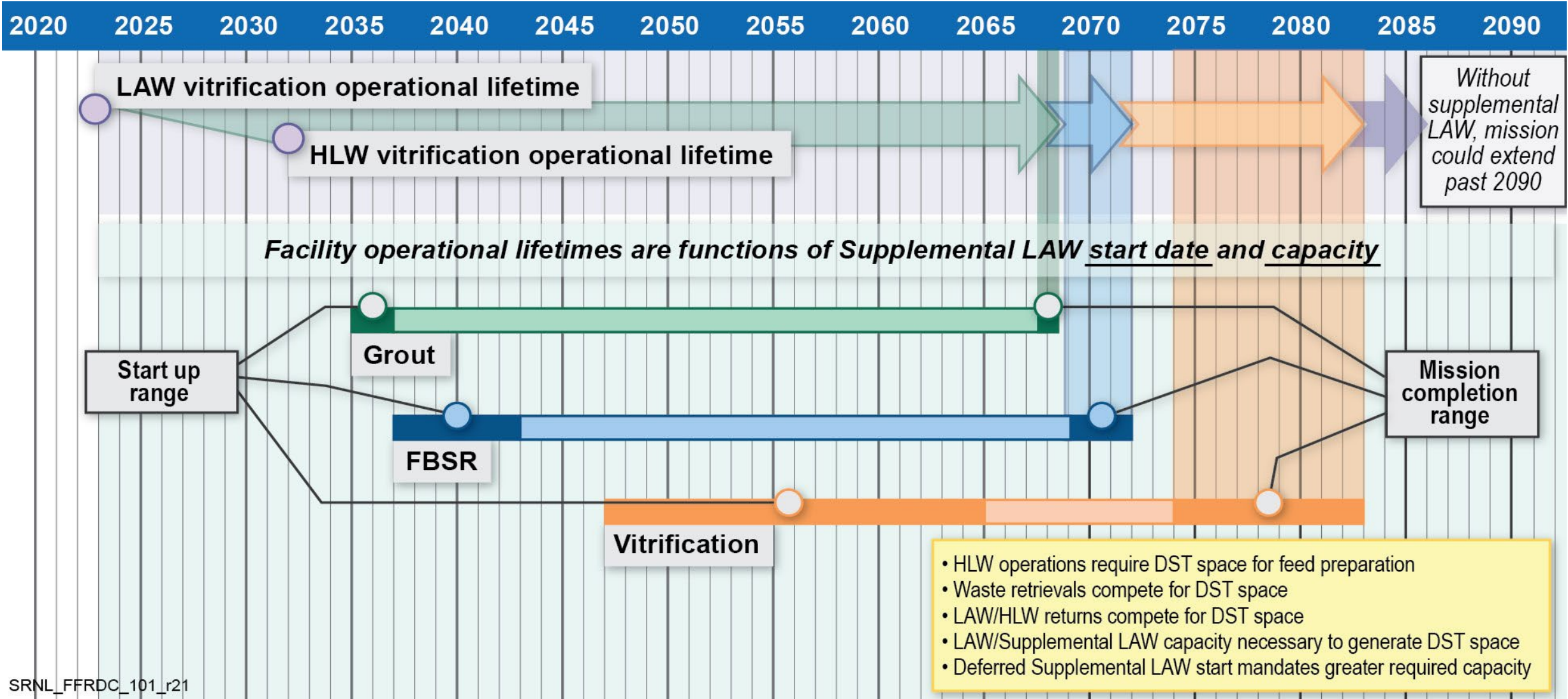
System Plan style process (TopSim) and cost modeling was performed to bound mission profiles.

Projected Supplemental LAW Facility Start Dates

Start dates greatly impact mission length and cost



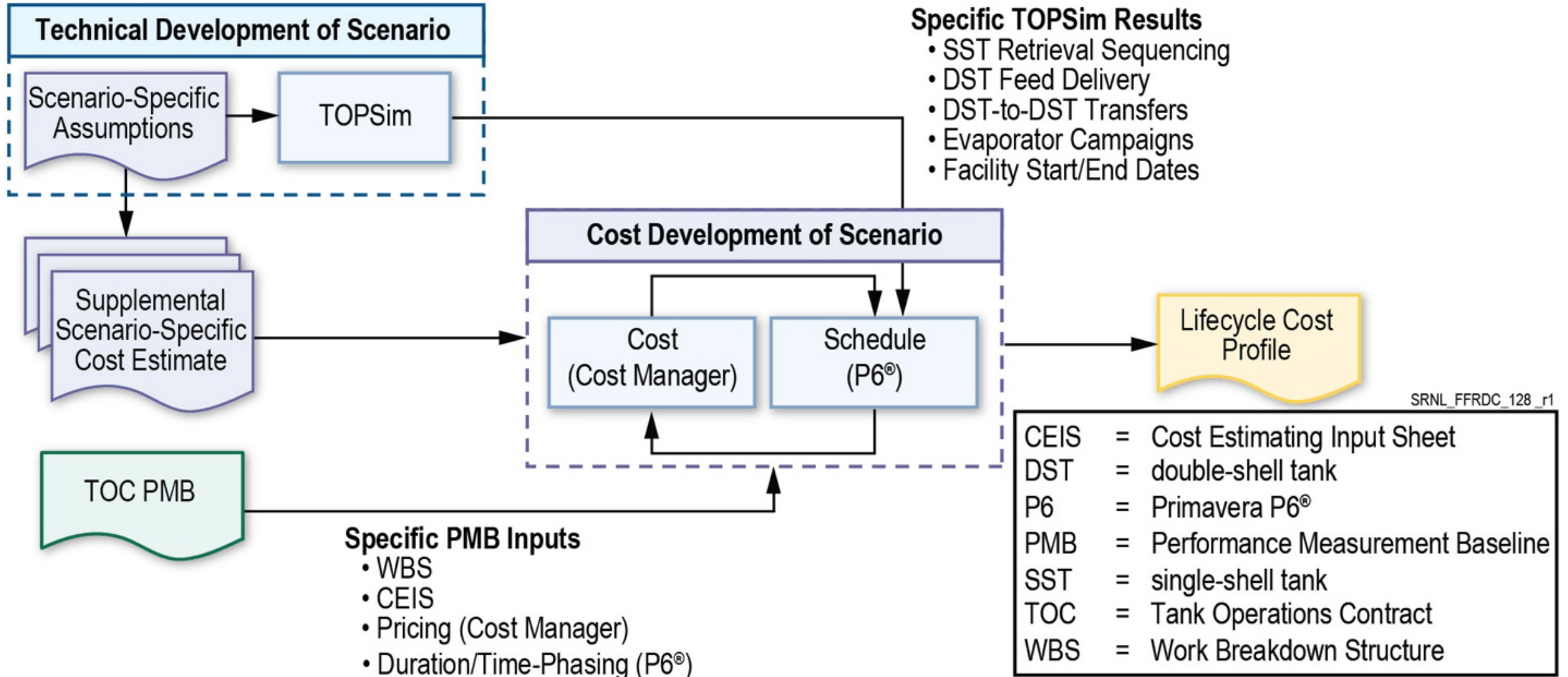
Projected Integrated Mission Completion Profiles



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For reference, WMEIS projected 2018 thru 2093 if no LAW Supplemental Treatment (EIS Alternative 2B)

System Planning Methodology - Life Cycle Cost Modeling



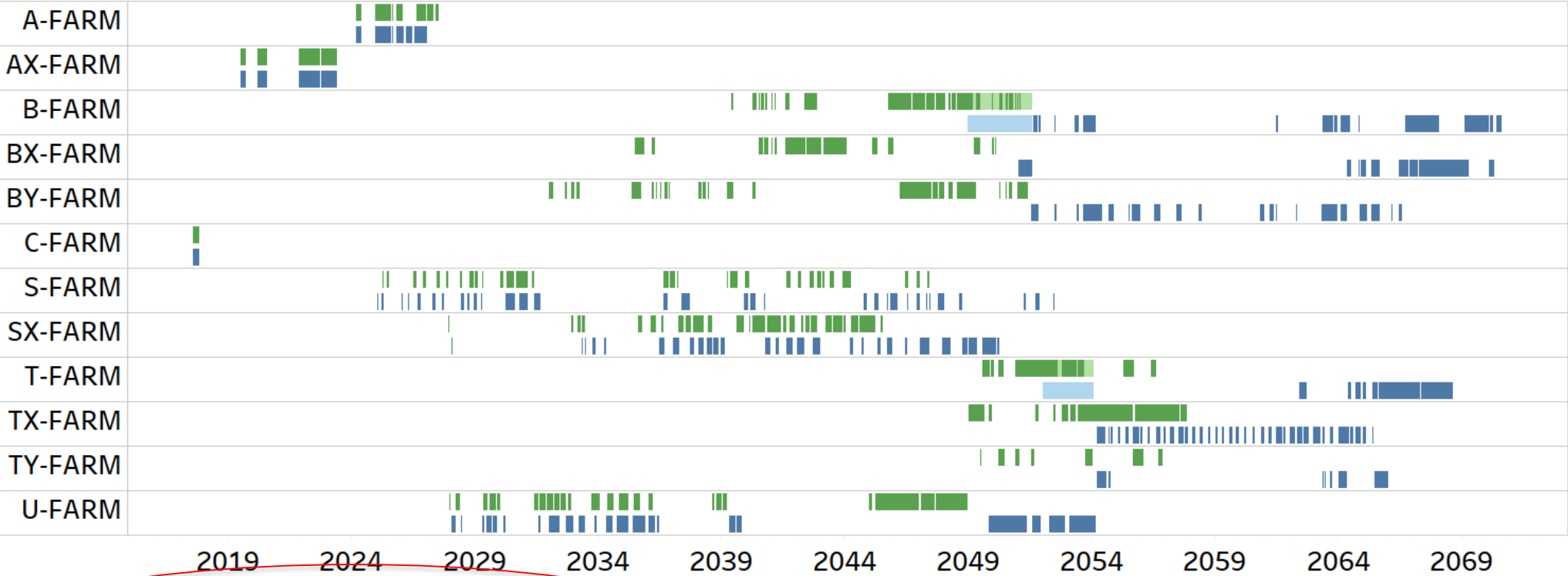
Alternative Grout 4B Scenario Overview – Highest Level Simulation Logic

LAW Phase	Start Year	End Year	Phase Overview
Phase 1	2023	2064	DFLAW process using SE TSCR facility to pretreat supernate in SE Quadrant (A/AX/C Farm SSTs & East Area DSTs) and send to WTP LAW Vit; continues through end of the mission
Phase 2	2026	2058	- New SW TSCR comes online to pretreat supernate in SW Quadrant (S/SX/U Farm SSTs & SY Farm DSTs) before sending for supplemental treatment - SW TSCR runs until all West Area SSTs have been retrieved
Phase 3	2028	2064	- SE TFPT (3x TSCR capacity) as well as LFEs for both SE and SW TSCRs come online; evaporators concentrate pre-treated feed to 7.5 M Na through end of the mission - Any LAW feed in excess of what can be treated by LAW Vit is now sent for supplemental treatment and continues through end of the mission (<i>versus 2050 for Vitrification 1</i>) - B-Complex retrievals begin as space opens in SE Quadrant (<i>versus 2050 for Vitrification 1</i>)
Phase 4	2036	2064	SE TFPT capacity and supplemental LAW treatment increase so HLW vitrification paces the mission (<i>common for all simulations, only need dates change</i>)

Mission Dates & Metrics: Vitrification (1) and Early Offsite Grout (4B)

Metric	Delayed LAW Supp. Vitrification (East Area 2050)	Grout 4B (East Area 2028)
Treat All Tank Waste	2075	2066
Complete all SST Retrievals	2070	2057
S/SX SSTs Retrieved During DFLAW	5	7
Cross-Site Slurry Line Activated	2039	2039
IHLW Glass Canisters	12,000	9,300
ILAW Glass Containers	67,500	26,600
West Area LAWST Feed (Post-Evaporation)	70.4 Mgal (N/A)	51.2 Mgal (23.7 Mgal)
East Area LAWST Feed	53.6 Mgal	75.6 Mgal
East Area LAW Vitrification Feed	50.5 Mgal	36.5 Mgal
Required SE TFPT Size (TSCR Unit Equivalents)	8	5
Life-Cycle Cost Unescalated	\$110B	\$79

SST Retrieval Gantt Chart – Comparative Dates to Consolidate Waste into Double Shell Tanks

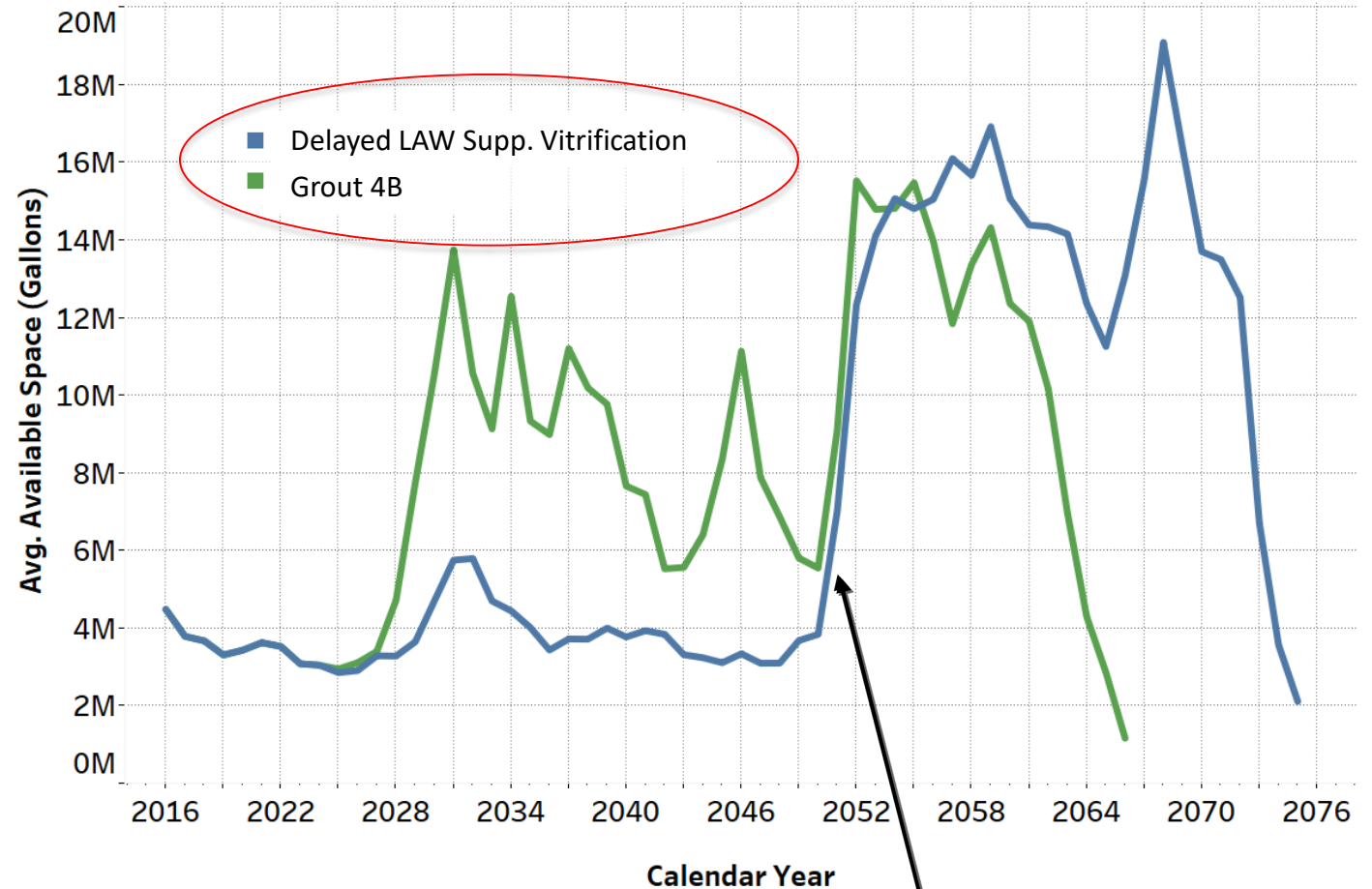


- Retrieved to DST's Grout 4B
- Retrieved to DST's, Delayed LAW Supplemental Vitrification

Double Shell Tank Space Utilization: Measure of Short-Term Risk

- Initially there's far more East Area DST space per Grout 4B due to increased East Area LAW treatment capacity versus Delayed SLAW Vit
- In the early 2050s as the HFPEM facility begins operations, significant DST space is gained as DSTs are no longer used for staging HLW feed prep & Vitrification effluents for evaporation

DST space generation (via LAW ST) improves risk reduction posture plus HLW feed preparation / support



HFPEM Facility operations begin, generating additional available space

Comparative Technetium Disposition: Measure of Long-Term Risk

Table F-1. Technetium-99 Curie Disposition – Alternatives 4B and Delayed Low-Activity Waste Supplemental Vitrification

Disposal	Waste Type	Treatment	Alternative 4B Ci Tc	Delayed Vitrification Ci Tc
Offsite	LAW	West TSCR	6,500	7,500
Offsite	LAW	East TSCRs	10,500	N/A
Onsite	LAW	LAW vitrification	6,800	11,900
Onsite	LAW	Supplemental LAW vitrification	N/A	4,400
Offsite	HLW	HLW vitrification	1,250	1,250
Total			25,050	25,050

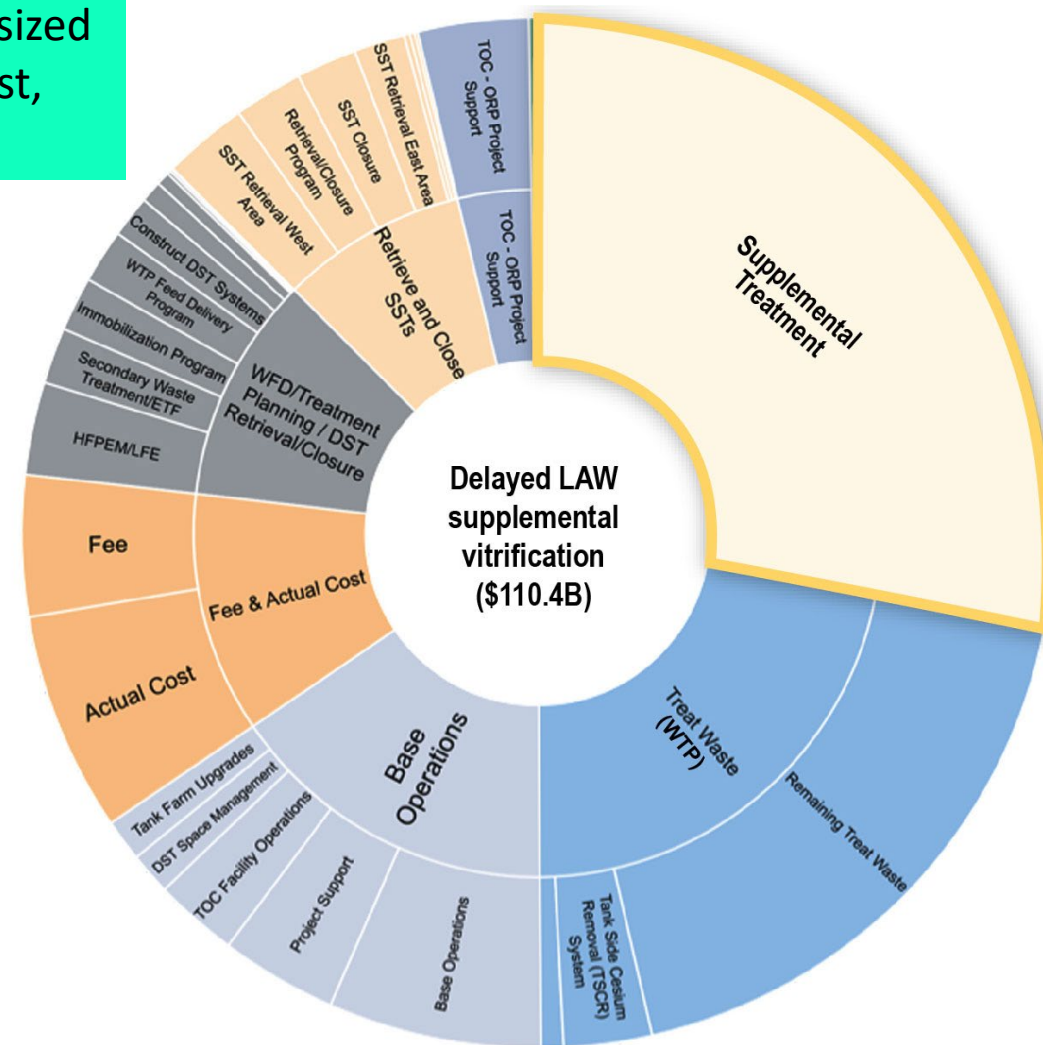
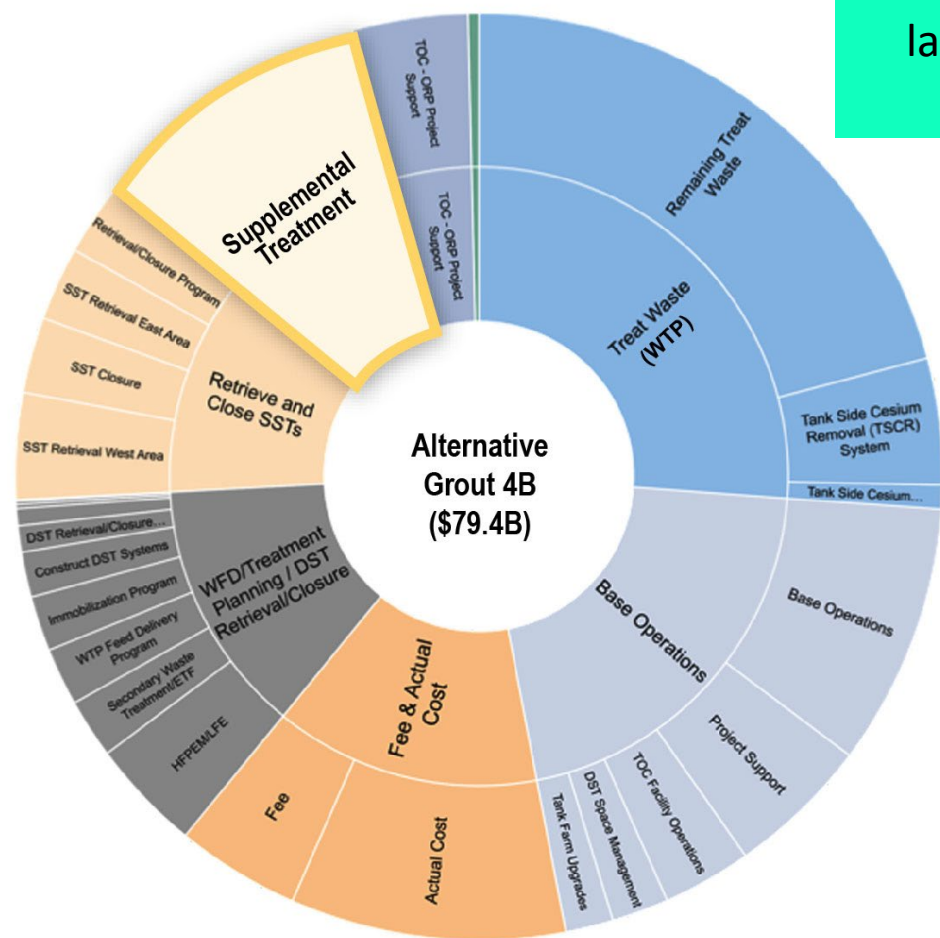
Notes: Tank farm inventory **25,000 Ci**
 Expected loss 1%
 HLW nominal content 5% (1,250 Ci)

HLW = high-level waste.
 IDF = Integrated Disposal Facility.
 LAW = low-activity waste.
 Tc = technetium.
 TSCR = tank-side cesium removal.

Summary Technetium Disposition		
Offsite Grout 4B		Delayed supplemental LAW vitrification
18,250	Total offsite (Ci)	8,750
6,800	Total on-site IDF (Ci)	16,300

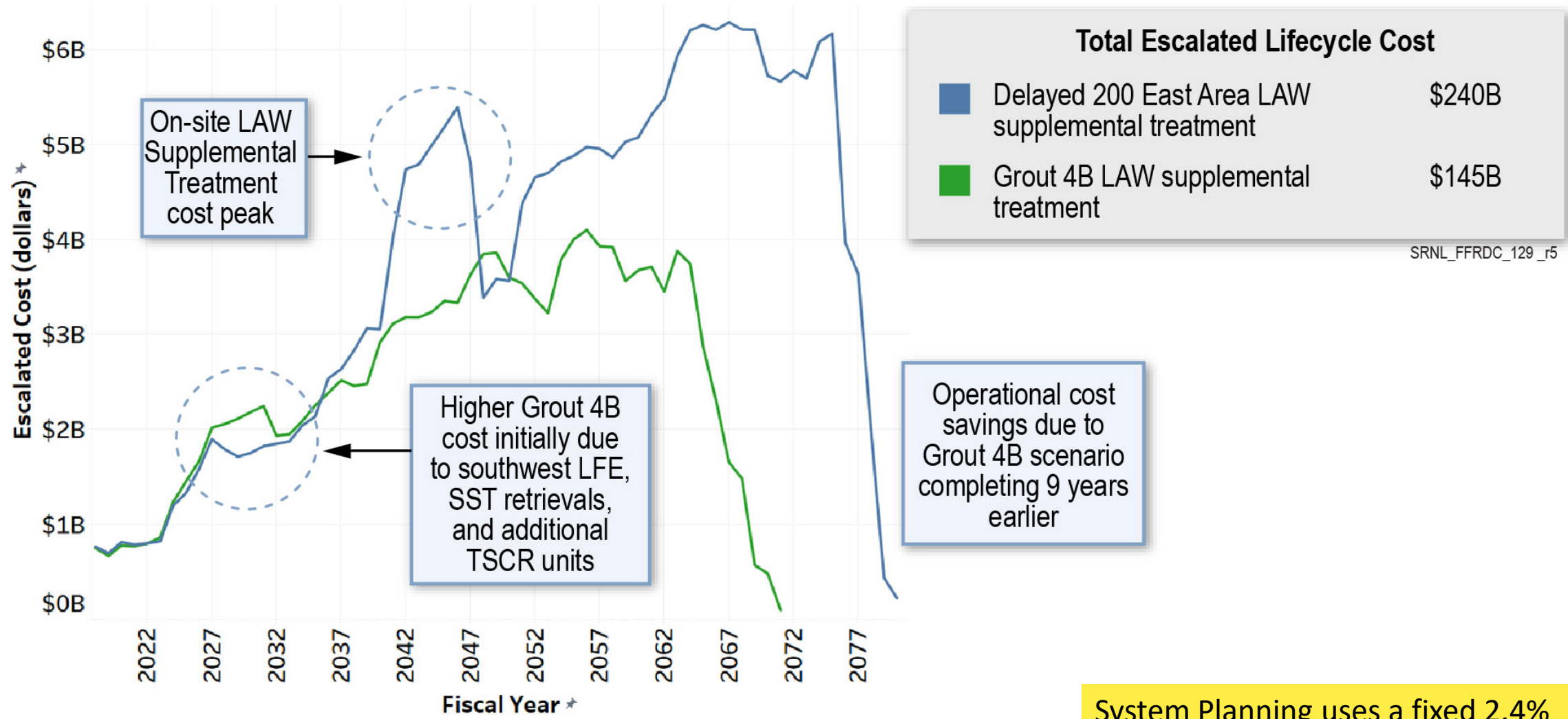
Mission Alternative Cost Comparison – by Work Breakdown Structure

WBS elements are sized largest to smallest, clockwise



LAW supplemental treatment accounts for \$21B of the \$31B cost delta – the additional \$10B is due to reduced mission length

Lifecycle Cost Profile (Escalated)



System Planning uses a fixed 2.4% Escalation factor for CAPEX and OPEX.

Key Results

- SE TFPT size equivalent to 5x TSCR units (Grout 4B) provided highest possible treatment capacity with least impact to mission cost/schedule (*Delayed LAW Supplemental Vitrification required 8x TSCR units*)
- B-Complex retrievals start earlier in the mission in 2032 (beginning with BY farm) to provide additional feed to supplemental LAW treatment (*versus 2050 for Delayed LAW Supplemental Vitrification*)
 - Even after re-ordering retrievals/introducing additional staging tanks, two feed outages in early 2030's (11/2031 – 11/2032 and 08/2034 – 06/2035) demonstrate that **waste can be pretreated faster than retrievals occur**
- SST Retrieval progress comparable to the Delayed LAW Supplemental scenario for first part of the mission, but retrieval rate increases significantly in the Grout 4B beginning mid 2030s
- Grout 4B completes in 2066, 9 years earlier than the Delayed LAW Supplemental Vitrification scenario, which completes in 2075

These results were used to bound Grout/FBSR/Vitrification alternative performance metrics, such as:

Required pre-treatment capacity

Volume processed (total and annual)

Tc Curies processed and disposition

LAW Supplemental Treatment “Mission Sheet:” Vitrification (sheet 1 of 3)

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
T&D Plus Pilot Activity funded with capital project	50	75	100	125	130	75	50								
Conceptual Planning / Approve Mission Need - CD-0	\$10														
Conceptual Design / Acquisition Strategy - CD-1		\$20	\$20												
Preliminary Design / Performance Baseline - CD-2				\$50	\$75	\$100									
Definitive Design / Approve Start of Construction - CD-3							\$150	\$175							
Procurement / Long-Lead Procurement						\$25	\$100	\$275	\$400	\$400	\$250	\$150	\$50		
Construction									\$100	\$150	\$300	\$450	\$450	\$450	\$400
Startup / Cold Commissioning - CD-4															
Hot Commissioning / Operations (OPEX)															
FY Cost (Unescalated)	\$60	\$95	\$120	\$175	\$205	\$200	\$300	\$450	\$500	\$550	\$550	\$600	\$500	\$450	\$400
Cum Cost (Unescalated)	\$60	\$155	\$275	\$450	\$655	\$855	\$1,155	\$1,605	\$2,105	\$2,655	\$3,205	\$3,805	\$4,305	\$4,755	\$5,155
Escalation Factor	1.08	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.48	1.54	1.60	1.67	1.73	1.80	1.87
FY Cost (Escalated @ 4%)	\$65	\$107	\$140	\$213	\$259	\$263	\$411	\$640	\$740	\$847	\$881	\$999	\$866	\$810	\$749
Cum Cost (Escalated)	\$65	\$172	\$312	\$525	\$784	\$1,048	\$1,458	\$2,099	\$2,839	\$3,686	\$4,566	\$5,565	\$6,431	\$7,241	\$7,991
Funding Level (Annual)	\$469	\$479	\$489	\$499	\$510	\$520	\$531	\$543	\$554	\$566	\$577	\$590	\$602	\$615	\$628
Cumulative Funding	\$469	\$948	\$1,437	\$1,936	\$2,446	\$2,967	\$3,498	\$4,041	\$4,594	\$5,160	\$5,738	\$6,327	\$6,929	\$7,544	\$8,171
Funding (Overage/Shortfall)	\$404	\$776	\$1,125	\$1,411	\$1,662	\$1,919	\$2,040	\$1,942	\$1,756	\$1,475	\$1,171	\$762	\$498	\$302	\$181
2nd LAW Vit Cost - \$7.5B in FY23 \$	Region of DFLAW plus HLW Completion and Start-Up														

Mission escalated at 4% through capital project (2050) and 2.4% OPEX – as per DOE PM guidance. Full carry over allowed throughout mission. Flat funding (\$450M) inflated at 2.1% annually. Sensitivity analyses used 8% for capital project. Yellow highlights relate to funding set aside or consumed at key mission dates – such as HLW CD-4 or other LAW Supplemental Alternative CD-4.

LAW Supplemental Treatment “Mission Sheet:” Vitrification (sheet 2 of 3)

	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056
T&D Plus Pilot Activity funded with capital project																	
Conceptual Planning / Approve Mission Need - CD-0																	
Conceptual Design / Acquisition Strategy - CD-1																	
Preliminary Design / Performance Baseline - CD-2																	
Definitive Design / Approve Start of Construction - CD-3																	
Procurement / Long-Lead Procurement																	
Construction	\$350	\$350	\$300	\$300	\$300	\$300	\$250										
Startup / Cold Commissioning - CD-4							50	\$175	\$225	\$350							
Hot Commissioning / Operations (OPEX)											\$515	\$530	\$545	\$560	\$575	\$590	\$590
FY Cost (Unescalated)	\$350	\$350	\$300	\$300	\$300	\$300	\$300	\$175	\$225	\$350	\$515	\$530	\$545	\$560	\$575	\$590	\$590
Cum Cost (Unescalated)	\$5,505	\$5,855	\$6,155	\$6,455	\$6,755	\$7,055	\$7,355	\$7,530	\$7,755	\$8,105	\$8,620	\$9,150	\$9,695	\$10,255	\$10,830	\$11,420	\$12,010
Escalation Factor	1.95	2.03	2.11	2.19	2.28	2.37	2.46	2.56	2.67	2.77	1.90	1.94	1.99	2.04	2.09	2.14	2.19
FY Cost (Escalated @ 4%)	\$682	\$709	\$632	\$657	\$684	\$711	\$739	\$449	\$600	\$970	\$977	\$1,030	\$1,084	\$1,141	\$1,199	\$1,260	\$1,290
Cum Cost (Escalated)	\$8,672	\$9,381	\$10,013	\$10,671	\$11,354	\$12,065	\$12,805	\$13,253	\$13,853	\$14,824	\$15,801	\$16,830	\$17,914	\$19,055	\$20,255	\$21,515	\$22,805
Funding Level (Annual)	\$641	\$654	\$668	\$682	\$696	\$711	\$726	\$741	\$757	\$772	\$789	\$805	\$822	\$839	\$857	\$875	\$893
Cumulative Funding	\$8,812	\$9,466	\$10,134	\$10,816	\$11,512	\$12,223	\$12,949	\$13,690	\$14,446	\$15,219	\$16,007	\$16,813	\$17,635	\$18,474	\$19,331	\$20,206	\$21,100
Funding (Overage/Shortfall)	\$140	\$85	\$120	\$145	\$158	\$158	\$144	\$436	\$593	\$395	\$207	(\$17)	(\$279)	(\$581)	(\$923)	(\$1,308)	(\$1,705)
								annual overage / underage			(\$188)	(\$224)	(\$262)	(\$301)	(\$342)	(\$385)	(\$397)
2nd LAW Vit Cost - \$7.5B in FY23 \$																	

Mission operations start in 2050. Funding shortfalls are captured so as to determine project cost. OPEX estimate is based on nominal 1.4X WTP LAW cost versus the 3X increase in processing rate. Mission is carried thru 2075 as per WRPS System Planning simulation – Delayed LAW Supplemental Vitrification

LAW Supplemental Treatment “Mission Sheet:” Vitrification (sheet 3 of 3)

	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075
T&D Plus Pilot Activity funded with capital project																			
Conceptual Planning / Approve Mission Need - CD-0																			
Conceptual Design / Acquisition Strategy - CD-1																			
Preliminary Design / Performance Baseline - CD-2																			
Definitive Design / Approve Start of Construction - CD-3																			
Procurement / Long-Lead Procurement																			
Construction																			
Startup / Cold Commissioning - CD-4																			
Hot Commissioning / Operations (OPEX)	\$590	\$560	\$560	\$560	\$545	\$545	\$545	\$545	\$545	\$545	\$545	\$545	\$530	\$530	\$530	\$530	\$530	\$530	\$530
FY Cost (Unescalated)	\$590	\$560	\$560	\$560	\$545	\$545	\$545	\$545	\$545	\$545	\$545	\$545	\$530	\$530	\$530	\$530	\$530	\$530	\$530
Cum Cost (Unescalated)	\$12,600	\$13,160	\$13,720	\$14,280	\$14,825	\$15,370	\$15,915	\$16,460	\$17,005	\$17,550	\$18,095	\$18,640	\$19,170	\$19,700	\$20,230	\$20,760	\$21,290	\$21,820	\$22,350
Escalation Factor	2.24	2.29	2.35	2.40	2.46	2.52	2.58	2.64	2.71	2.77	2.84	2.91	2.98	3.05	3.12	3.20	3.27	3.35	3.43
FY Cost (Escalated @ 4%)	\$1,321	\$1,284	\$1,315	\$1,347	\$1,342	\$1,374	\$1,407	\$1,441	\$1,476	\$1,511	\$1,547	\$1,585	\$1,578	\$1,616	\$1,655	\$1,694	\$1,735	\$1,777	\$1,819
Cum Cost (Escalated)	\$24,127	\$25,411	\$26,726	\$28,073	\$29,415	\$30,789	\$32,197	\$33,638	\$35,114	\$36,625	\$38,172	\$39,757	\$41,334	\$42,950	\$44,605	\$46,299	\$48,034	\$49,810	\$51,630
Funding Level (Annual)	\$912	\$931	\$951	\$971	\$991	\$1,012	\$1,033	\$1,055	\$1,077	\$1,100	\$1,123	\$1,146	\$1,171	\$1,195	\$1,220	\$1,246	\$1,272	\$1,299	\$1,326
Cumulative Funding	\$22,012	\$22,943	\$23,894	\$24,865	\$25,856	\$26,869	\$27,902	\$28,957	\$30,034	\$31,134	\$32,257	\$33,403	\$34,574	\$35,769	\$36,989	\$38,235	\$39,507	\$40,806	\$42,132
Funding (Overage/Shortfall)	(\$2,115)	(\$2,468)	(\$2,832)	(\$3,208)	(\$3,559)	(\$3,921)	(\$4,295)	(\$4,681)	(\$5,079)	(\$5,491)	(\$5,915)	(\$6,353)	(\$6,761)	(\$7,181)	(\$7,615)	(\$8,064)	(\$8,527)	(\$9,004)	(\$9,498)
	(\$409)	(\$353)	(\$364)	(\$376)	(\$351)	(\$362)	(\$374)	(\$386)	(\$398)	(\$411)	(\$424)	(\$438)	(\$407)	(\$421)	(\$434)	(\$448)	(\$463)	(\$478)	(\$493)
2nd LAW Vit Cost - \$7.5B in FY23 \$																			

Mission operations complete in 2075. Final cost is calculated to be slightly over \$22B (unescalated). For reference, the independent System Planning mission analysis determined LAW supplemental vitrification to cost \$24B (unescalated). No cost elements were common between the studies.

LAW Supplemental Treatment “Mission Sheet:” Vitrification Sensitivity (sheet 1 of 2)

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
T&D Plus Pilot Activity funded with capital project	50	75	100	125	130	75	50								
Conceptual Planning /Approve Mission Need - CD-0	\$20														
Conceptual Design / Acquisition Strategy - CD-1		\$40	\$40												
Preliminary Design / Performance Baseline - CD-2				\$100	\$150	\$200									
Definitive Design / Approve Start of Construction - CD-3							\$300	\$350							
Procurement / Long-Lead Procurement						\$50	\$200	\$550	\$400	\$200	\$200	\$300	\$100	\$200	\$100
Construction									\$100	\$200	\$200	\$200	\$200	\$200	\$200
Startup / Cold Commissioning - CD-4															
Hot Commissioning / Operations (OPEX)															
FY Cost (Unescalated)	\$70	\$115	\$140	\$225	\$280	\$325	\$550	\$900	\$500	\$400	\$400	\$500	\$300	\$400	\$300
Cum Cost (Unescalated)	\$70	\$185	\$325	\$550	\$830	\$1,155	\$1,705	\$2,605	\$3,105	\$3,505	\$3,905	\$4,405	\$4,705	\$5,105	\$5,405
Escalation Factor	1.08	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.48	1.54	1.60	1.67	1.73	1.80	1.87
FY Cost (Escalated @ 4%)	\$76	\$129	\$164	\$274	\$354	\$428	\$753	\$1,281	\$740	\$616	\$640	\$833	\$520	\$720	\$562
Cum Cost (Escalated)	\$76	\$205	\$369	\$643	\$997	\$1,425	\$2,177	\$3,458	\$4,198	\$4,814	\$5,455	\$6,287	\$6,807	\$7,527	\$8,089
Funding Level (Annual)	\$469	\$479	\$489	\$499	\$510	\$520	\$531	\$543	\$554	\$566	\$577	\$590	\$602	\$615	\$628
Cumulative Funding	\$469	\$948	\$1,437	\$1,936	\$2,446	\$2,967	\$3,498	\$4,041	\$4,594	\$5,160	\$5,738	\$6,327	\$6,929	\$7,544	\$8,171
Funding (Overage/Shortfall)	\$393	\$743	\$1,068	\$1,294	\$1,449	\$1,542	\$1,321	\$582	\$396	\$346	\$283	\$40	\$122	\$17	\$82
2nd LAW Vit Cost - \$7.5B in FY23 \$	Region of DFLAW plus HLW Completion and Start-Up														

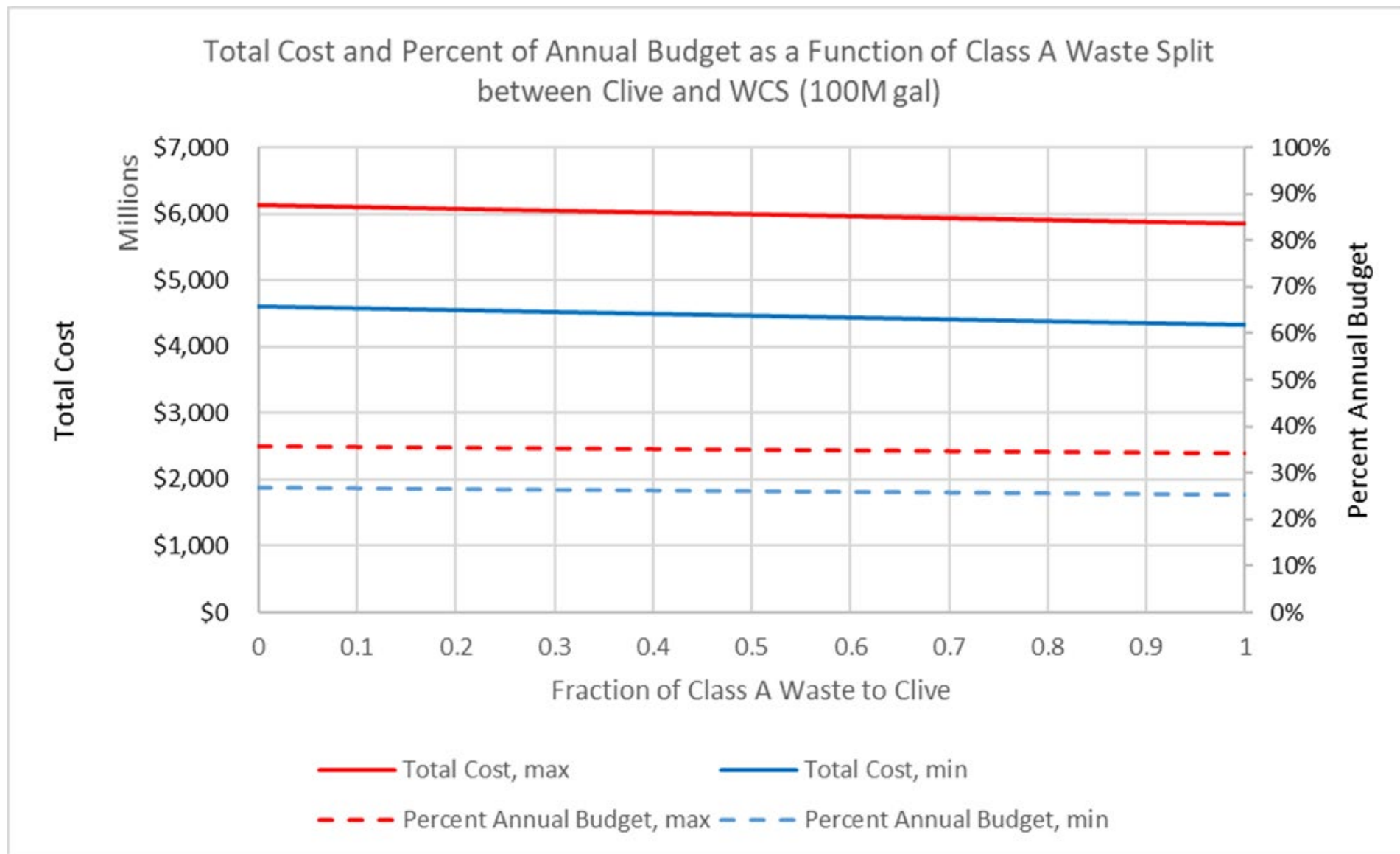
Project cost reflects +100% (\$15B). Construction and long-lead procurements are funding limited, resulting in significant schedule impacts.

LAW Supplemental Treatment “Mission Sheet:” Vitrification Sensitivity (sheet 2 of 2)

	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078
T&D Plus Pilot Activity funded with capital project														
Conceptual Planning / Approve Mission Need - CD-0														
Conceptual Design / Acquisition Strategy - CD-1						Note: 2070 is nominal date for Treat all Tank Waste for FBSR applications.								
Preliminary Design / Performance Baseline - CD-2														
Definitive Design / Approve Start of Construction - CD-3														
Procurement / Long-Lead Procurement														
Construction	\$200	\$200	\$200	\$200	\$200	\$175	\$175	\$175	\$200	\$175	\$50			
Startup / Cold Commissioning - CD-4											100	\$350	\$450	\$700
Hot Commissioning / Operations (OPEX)														
FY Cost (Unescalated)	\$200	\$200	\$200	\$200	\$200	\$175	\$175	\$175	\$200	\$175	\$150	\$350	\$450	\$700
Cum Cost (Unescalated)	\$12,255	\$12,455	\$12,655	\$12,855	\$13,055	\$13,230	\$13,405	\$13,580	\$13,780	\$13,955	\$14,105	\$14,455	\$14,905	\$15,605
Escalation Factor	5.19	5.40	5.62	5.84	6.07	6.32	6.57	6.83	7.11	7.39	7.69	7.99	8.31	8.65
FY Cost (Escalated @ 4%)	\$1,039	\$1,080	\$1,123	\$1,168	\$1,215	\$1,106	\$1,150	\$1,196	\$1,421	\$1,293	\$1,153	\$2,798	\$3,741	\$6,052
Cum Cost (Escalated)	\$29,929	\$31,009	\$32,132	\$33,300	\$34,515	\$35,621	\$36,771	\$37,967	\$39,388	\$40,681	\$41,834	\$44,632	\$48,373	\$54,426
Funding Level (Annual)	\$1,077	\$1,100	\$1,123	\$1,146	\$1,171	\$1,195	\$1,220	\$1,246	\$1,272	\$1,299	\$1,326	\$1,354	\$1,382	\$1,411
Cumulative Funding	\$30,034	\$31,134	\$32,257	\$33,403	\$34,574	\$35,769	\$36,989	\$38,235	\$39,507	\$40,806	\$42,132	\$43,486	\$44,868	\$46,279
Funding (Overage/Shortfall)	\$105	\$125	\$125	\$103	\$59	\$148	\$219	\$269	\$119	\$125	\$298	(\$1,146)	(\$3,505)	(\$8,146)
	\$39	\$20	(\$0)	(\$22)	(\$44)	\$90	\$70	\$50	(\$149)	\$5	\$173	(\$1,444)	(\$2,359)	(\$4,641)
2nd LAW Vit Cost - \$7.5B in FY23 \$														

The extension required for construction indicates start-up will not commence prior to 2075, post mission completion for other alternatives.

Example Offsite Grout Cost Projection: Grouting plus Transportation and Disposal



Grouting Cost
\$30 - \$45 / gal
is major factor

≈90/10 A/B split
All Class B to WCS

Base assumption:
50/50 split Class A

LAW Supplemental Alternatives: Total Discounted Cost and OPEX Cost

	Hot Operations	LAW Supplemental Operations Complete	Total Cost (M) Discounted (3% basis)	Total OPEX Cost (M) Discounted (3% basis)
Vitrification 1	2050	2075	\$12,700	\$5,090
FBSR 1A	2040	2070	\$5,530	\$2,150
FBSR 1B	2040	2070	\$6,280	\$2,910
Grout 1A	2036	2068	\$2,730	\$1,620
Grout 1B	2036	2068	\$3,410	\$2,310
Grout 1C	2036	2068	\$3,120	\$1,920
Grout 2A	2036	2068	\$3,400	\$1,850
Grout 2B	2036	2068	\$4,320	\$2,770
Grout 2C	2036	2068	\$3,850	\$2,210
Grout 4A	2027	2065	\$3,340	\$2,930
Grout 4B	2027	2065	\$3,850	\$3,440
Grout 5A	2036	2068	\$3,350	\$1,610
Grout 6	2027	2065	\$4,130	\$2,730

Near-Term Views of Cost of Alternatives

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Vitrification 1	\$ 424	\$ 412	\$ 400	\$ 388	\$ 377	\$ 366	\$ 355	\$ 345	\$ 335	\$ 325
FBSR 1A	\$ 49	\$ 77	\$ 115	\$ 237	\$ 263	\$ 176	\$ 225	\$ 226	\$ 335	\$ 332
GROUT 4B	\$ 130	\$ 130	\$ 135	\$ 145	\$ 119	\$ 108	\$ 125	\$ 118	\$ 115	\$ 134
GROUT 6	\$ 130	\$ 130	\$ 135	\$ 150	\$ 133	\$ 120	\$ 152	\$ 168	\$ 176	\$ 250
Present Value (3% discount basis)										
Vitrification 1	\$ 60	\$ 155	\$ 275	\$ 450	\$ 655	\$ 830	\$ 1,155	\$ 1,605	\$ 2,105	\$ 2,605
FBSR 1A	\$ 50	\$ 130	\$ 250	\$ 501	\$ 782	\$ 972	\$ 1,218	\$ 1,468	\$ 1,593	\$ 1,968
GROUT 4B	\$ 137	\$ 278	\$ 428	\$ 594	\$ 734	\$ 864	\$ 1,019	\$ 1,169	\$ 1,319	\$ 1,499
GROUT 6	\$ 137	\$ 278	\$ 428	\$ 599	\$ 749	\$ 878	\$ 1,050	\$ 1,239	\$ 1,434	\$ 1,734
Cumulative Cost (unescalated)										

Annual discounted costs show impact of flat funding across mission- more expensive capital projects will require significant carry-over.

Cumulative (unescalated) costs provided to evaluate applied funding requirements thru HLW hot operations (CD-4)

Cost and Performance Metrics for Selected LAW Supplemental Treatment Alternatives

Comparison of Cost and Projected Performance of Low-Activity Waste Supplemental Treatment Alternatives

LAW Supplemental Treatment Alternative	Cumulative unescalated cost (\$M)				Cumulative gallons of supplemental LAW feed treated (Mgal)				Cumulative curies of technetium treated (Ci)			
	2033 ^a	2039 ^b	2047 ^c	At Treatment Alternative Mission End ^d	2033 ^a	2039 ^b	2047 ^c	At Treatment Alternative Mission End ^d	2033 ^a	2039 ^b	2047 ^c	At Treatment Alternative Mission End ^d (percent of technetium treated)
Vitrification 1 (on-site facility with IDF disposition)	2,205	5,605	8,105	23,400 (2075)	-	-	-	83 ^e	-	-	-	6,640 (27%)
FBSR 1A (on-site facility with IDF disposition)	1,593	3,523	4,789	8,417 (2070)	-	-	25	86 ^e	-	-	5,700	10,210 (41%)
Grout 5A (on-site facility with GDU disposition)	1,118	1,630	2,490	5,316 (2068)	-	13	37	92 ^e	-	4,500	11,000	15,100 (62%)
Grout 4B (off-site grout with off-site disposition)	1,319	2,489	3,959	6,449 (2066)	14	34	58	97	6,900	10,100	12,600	15,600 (64%)
Grout 6 (off-site grout with off-site disposition through 2039; on-site facility with GDU disposition 2040 on)	1,434	3,240	3,361	5,039 (2066)	14	34	58	97	6,900	10,100	12,600	15,600 (64%)

^a Key mission activity: 2033 – Start of HLW vitrification.
^b Key mission activity: 2039 – Start of FBSR for supplemental LAW.
^c Key mission activity: 2047 – Start of vitrification for supplemental LAW.
^d The mission end date varies by treatment technology.
^e Interpolation between model runs. Gallons processed assumes that all feed not delivered to LAW vitrification is processed via supplemental LAW technology, indicative of scale as a function of mission duration. HLW vitrification will immobilize about 1,250 Ci Tc. LAW vitrification will immobilize (for on-site disposition) 6,800 to 11,900+Ci Tc, depending on mission duration and start of supplemental LAW processing. The tank farms inventory of ≈25,000 Ci Tc implies that all non-HLW immobilized Tc (plus about 1% residual) would be dispositioned onsite as immobilized supplemental LAW with ≈23,500 Ci Tc. The model run provided for supplemental LAW vitrification did include partial off-site disposition (7,500 Ci Tc) so as to allow for accelerated mission completion – 2075 as shown above per Note d. Offsite grouting cost per gallon (Alt's 4B and 6) set at \$45.

GDU

=

grout disposal unit.

HLW

=

high-level waste.

IDF

=

Integrated Disposal Facility.

LAW

=

low-activity waste.

MCi

=

million curies.

Mgal

=

million gallons.

Tc

=

technetium.

Summary Chart: Alternative Vitrification 1 and Alternative Grout 4B (Offsite Grout and Disposition)

	Supplemental LAW		
	Vitrification	Early Start <i>All Offsite Grout</i>	<u>Mission Impacts</u>
Estimated cost to construct treatment facilities [unescalated]	\$6.8 - \$15B	<\$0.35B	Capital avoidance: \$6-15 Billion
Short Term Risk - SST Retrievals Complete - <i>Cost (present value)</i>	2070 (\$150/gal)	2057 (\$40/gal)	Equivalent to the contents of ~7 AP-Farm DSTs disposed safely out of Washington State prior to HLW start-up
Long Term Risk - Tc Disposition - <i>Cost (present value)</i>	8,800Ci offsite 16,000Ci onsite (\$2,000,000/Ci)	18,000Ci offsite 6,800Ci onsite (\$250,000/Ci)	70% removed from Washington
Total Mission Cost [unescalated]	\$110B	\$80B	25% cost reduction

Back-Up Slides

Brief Overview of EIS – Mission Impacts of Facilities and Constrained Schedule

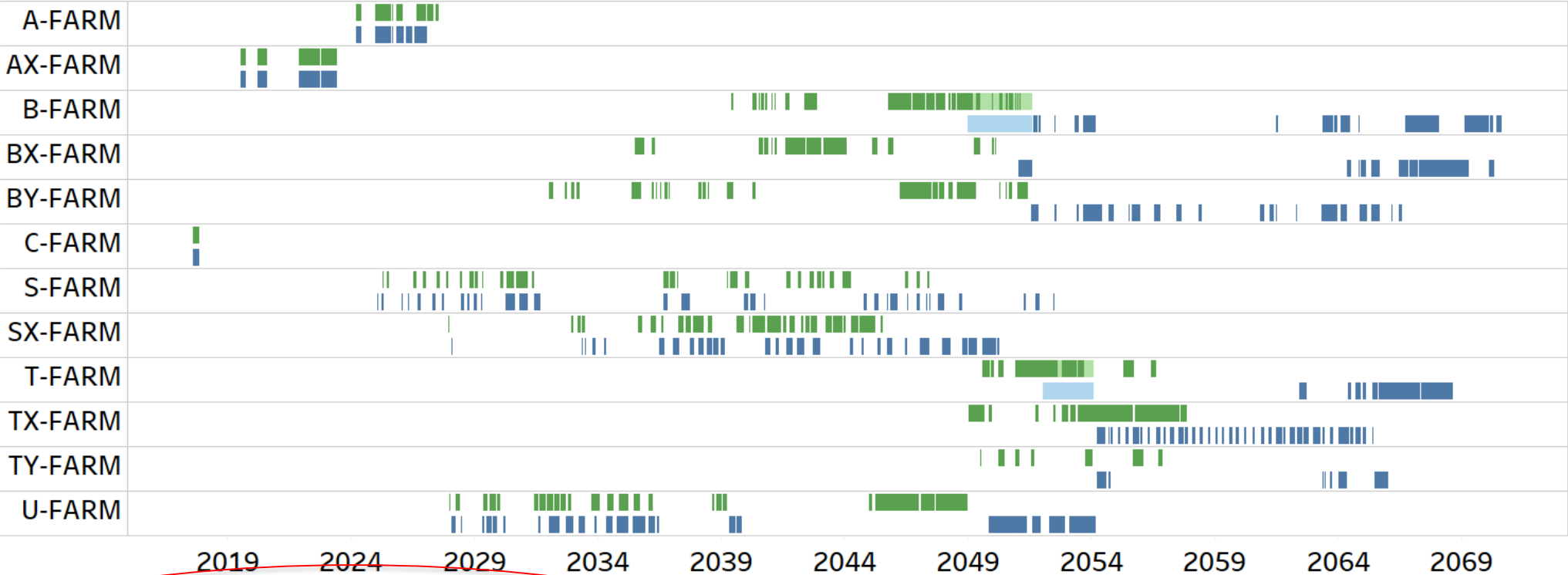
	Expanded Vitrification (EIS 2B)	WTP + Non-Thermal (EIS 3B)
WTP (HLW and LAW) ¹	HLW 2018-2040 LAW 2018-2043	HLW 2018-2040 LAW 2018-2040
Expanded Vitrification (2X LAW)	2022-2043	
Containerized Grout (East)		2018-2040
Containerized Grout (West)		2018-2040
TRU Waste Supp. Treatment (CH-TRU & RH-TRU)		3.1 Mgal ¼ Tank Waste Sludge
West Area Sol/Liq Sep's Facility		2018-2040
Construction / Op's, 2008 \$	8.7B / 11.3B	7.9B / 11.2B
Total Cost (w/disposal), 2008 \$	40.9B	39.9B

Schedule slip, WTP scope changes and cost growth make direct comparisons against constrained HLW schedule challenging

1. EIS Alternative 2A (no LAW Supplemental Treatment) projected WTP op's 2018 thru 2093

WMEIS
Readers Guide (Table 1&4)
Summary (pg. S 41-42,
Summary (Table S-29,-30)
Cost Volume (Section 2&3)

SST Retrieval Gantt Chart – Comparative Dates to Consolidate Waste into Double Shell Tanks

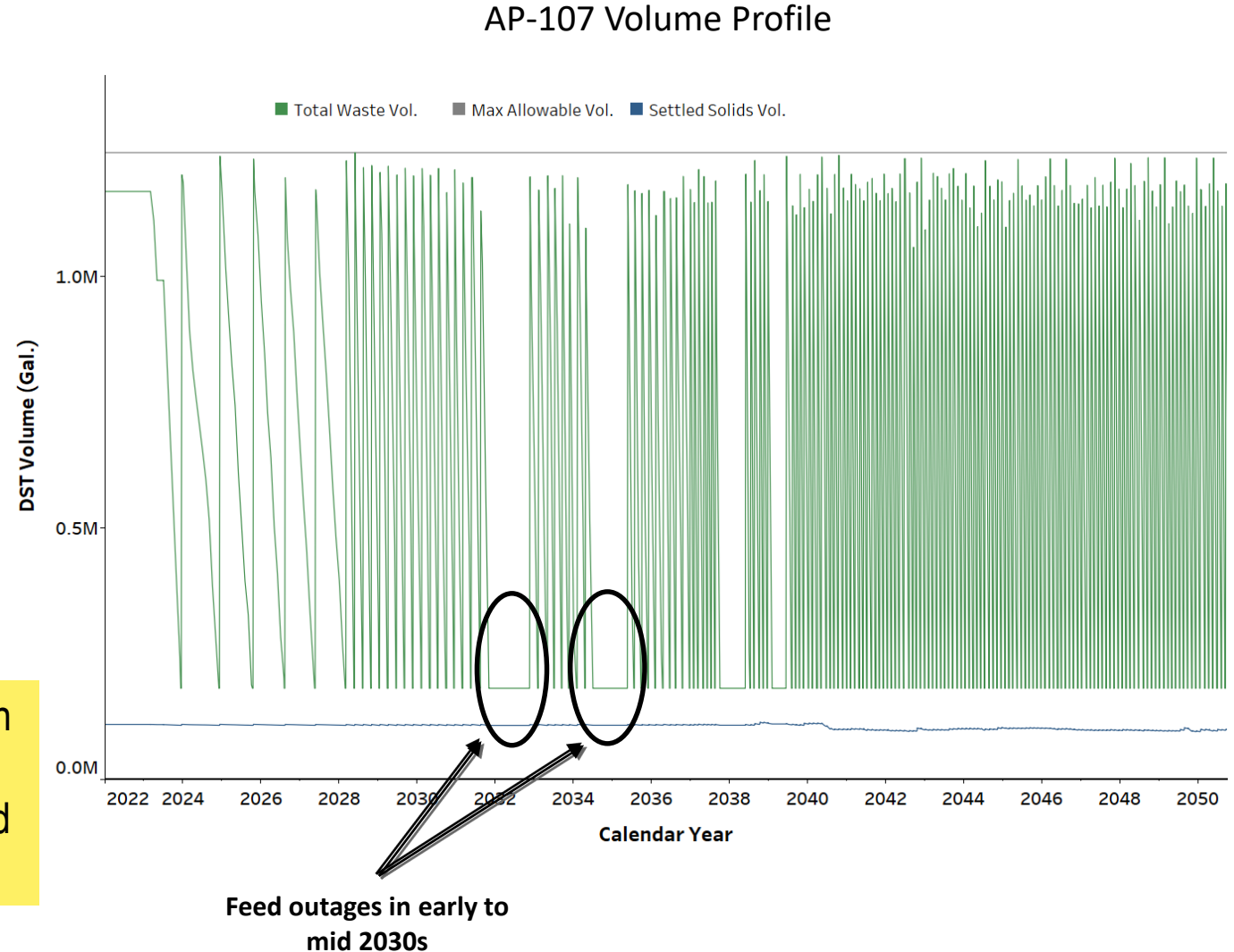


- Retrieved to DST's Grout 4B
- Retrieved to DST's, Delayed LAW Supplemental Vitrification

LAW Feed Availability: Alternative Grout 4B

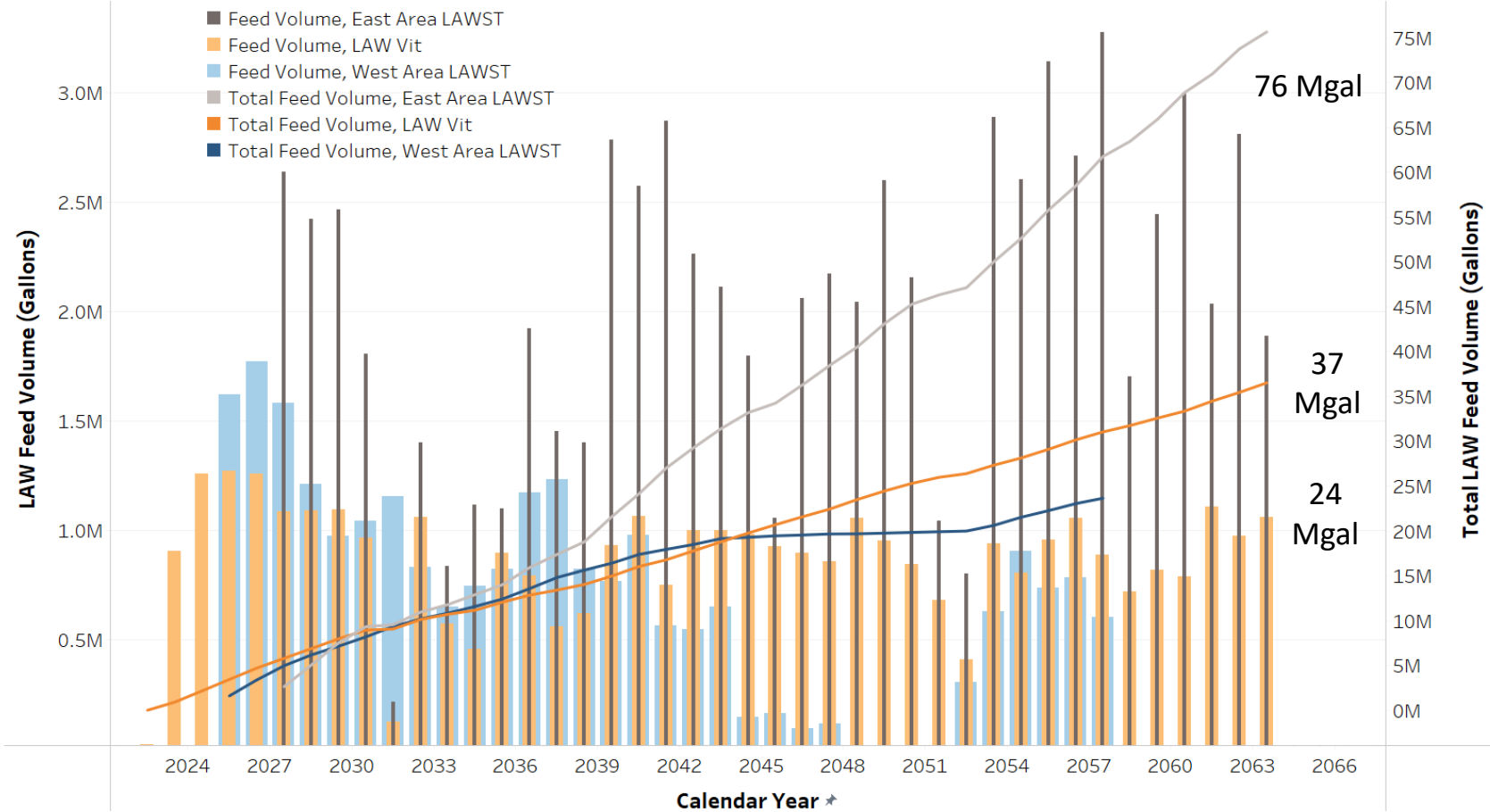
- Two year-long feed outages in East Area in the early 2030s demonstrate how the LAW processing rate initially outpaces retrievals
- LAW feed is diverted from West Area to supplement East Area LAW when needed starting in 2039, enabling a higher rate of West Area SST retrievals
- If this scenario were to be implemented, feed to LAW supplemental treatment from the SE TFPT would need to be throttled to ensure continued feed availability for WTP LAW Vitrification

The Grout 4B TopSim run indicates maximum DST space can be derived prior to WTP HLW hot operations. No “optimization” by either increasing retrievals or balancing feed rates was attempted.



LAW/LAWST Feed Volumes by Source

- Volume of waste designated as East Area LAWST is significantly higher, as West Area lacks sufficient tankage and pretreatment capacity to enable West Area retrievals to keep pace with East Area.



LAW Supplemental Treatment Cost Comparison

	Supplemental Pretreatment (PT) Area	Supplemental Pretreatment Cost Item	Unescalated Cost	Total Unescalated Cost
Grout 4B	East Area	East LFE Capital/Operations	\$330.6M	\$12.4B
		SE TSCR/TFPT	\$3.5B	
		East Load-Out Station	\$8.0M	
		Treatment/Disposal of Pretreated Supernate	\$5.7B	
	West Area	West LFE Capital/Operations	\$259.6M	
		SW TSCR	\$659.3M	
		West Load-Out Station	\$8.0M	
		Treatment/Disposal of Pretreated Supernate	\$1.8B	
Delayed LAW Supplemental Vitrification	East Area	East LFE Capital/Operations	\$779.2M	\$33.9B
		SE TSCR/TFPT	\$3.0B	
		LAWST Vit Facility	\$24.1B	
	West Area	SW TSCR	\$771.0M	
		West Load-Out Station	\$8.0M	
		Treatment/Disposal of Pretreated Supernate	\$5.3B	

LAW supplemental treatment accounts for \$21B of the \$31B cost delta – the additional \$10B is due to reduced mission length



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Assessment Summary and Results

Matt Champagney, PMP

Vice President – Engineering and
Planning Sector, Parsons

Decision Framework & Analysis SME

2021 NDAA-3125 Meeting #3

April 26-28, 2022

SRNL-STI-2022-00199



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Analysis Summary Methodology – Criteria Identification and Decomposition

- **“Decision-Informing Criteria” (taxonomy) developed to evaluate the effectiveness of each alternative**
 - e.g. “Long Term Effectiveness” which assesses factors such as waste form performance
- **Analytical Approach: Hierarchical Decomposition and Recomposition**
- **Six “top-level” or “tier 1” criteria defined by the FFRDC team**
 - Patterned After NEPA / RCRA / CERCLA / AEA (DOE 435.1) Decision Factors
- **Tier 1 criteria decomposed to identify underlying factors affecting the criteria; additional decomposition performed to capture all relevant factors**
 - Example: Criterion 1, Long-term effectiveness was broken down as far as tier 5
- **Established “Measures of Effectiveness” (MOE) to evaluate each criterion at the lowest tiers of the taxonomy and included an explanation of each parameter**

Analysis Summary Methodology – Criteria Recomposition, Alternative Analysis

- **23 Alternatives defined by team; 8 alternatives screened for being redundant or clearly dominated by other alternatives**
- **Evaluations performed at lowest tiers of taxonomy using established MOEs for remaining 15 alternatives**
- **Lowest-tier criteria “rolled up” to the next tiers in the taxonomy, with key drivers identified and documented at every subsequent step in the recomposition**
- **Chose representative alternatives for each technology – Vitrification 1, FBSR 1A, Grout 4B – and a hybrid, phased alternative (Grout 6) for the summary presentation**

Drivers of Top-Level Evaluation

1. Long-Term Effectiveness (environmental and safety risk after disposal)

1. Residual threat to health and environment upon successful completion – potential for mobility of nitrates/nitrites, organics, radionuclides, metals
2. Long-term risks upon successful completion – confidence in process or technology and waste performance in disposal facility

Note: Only alternatives assessed as likely to comply with anticipated regulations and applicable standards for mobility and toxicity of wastes at project completion were evaluated in the Report. Alternatives unlikely to comply were screened out.

2. Implementation Schedule and Risk (environmental and safety risks prior to completion, including risks driven by waste tank storage duration)

1. Specific risks or benefits related to ongoing tank degradation – driven by duration to start treatment as well as overall mission duration
2. Risks to humans (other than tank degradation) – worker hazards
3. Risks to the environment (other than tank degradation) – greenhouse gas emissions, chemical and power usage, transportation risks
4. Duration – risk of further delay due to cost and technical issues that extend mission exacerbate previously stated risks

3. Likelihood of Successful Mission Completion (including affordability and robustness to technical risks)

1. Likelihood and consequences of failing to complete due to technical problems – technology maturity, process complexity, adaptability
2. Likelihood and consequences of failing to complete due to resource shortfall – equipment availability, funding

High-Level Comparison of the Four Representative Alternatives

Vitrification 1: Disposal onsite at Hanford	FBSR 1A: Solid monolith product disposal onsite at Hanford	Grout 4B: Off-site grouting/disposal	Grout 6: Phased Approach Off-site grouting/disposal, then on-site grouting/disposal
Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)			
Highly effective for primary waste; moderately effective for secondary waste. Medium confidence in the assessment.	Effective. Medium confidence in the assessment, due to technology immaturity.	Highly effective. High confidence in the assessment.	Highly effective. Good to high confidence in the assessment.
Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)			
High risk due to significant cost-based startup delays and operations limits. Moderate technical implementation risk. Construction finishes 2049, mission does not complete without significant additional annual budget.	High risk due to construction time required and technical execution risk. Construction finishes 2039; mission completes 2070.	Low risk due to immediate start, minimal construction, low-temperature process, likely capacity, and modest transportation and operations costs. Limited facilities (e.g., evaporator and load-out station) needed; mission completes 2065.	Very low risk due to immediate start, flexible timing of conversion to on-site low-temperature process, and inexpensive operations. Grout plant construction finishes 2039; mission completes 2065.
Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)			
Very low probability of successful completion due to affordability.	Low probability of successful completion due to technical risk.	Very high likelihood of successful completion.	High likelihood of successful completion.
Criterion 4: Lifecycle cost (discounted lifecycle costs)			
\$7.6B construction; \$5.1B operations (unaffordable, \$1.36B shortfall)	\$3.4B construction; \$2.2B operations	\$0.4B construction; \$3.4B operations	\$1.4B construction; \$2.7B operations

Assessment Rationale – Vitrification 1

Vitrification 1: Disposal onsite at Hanford

Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)

Highly effective for primary waste; moderately effective for secondary waste. Medium confidence in the assessment.

Residual threat to health and environment upon successful completion

+ **Nitrates/nitrites and waste organics destroyed; low mobility of rads/metals that remain in glass**

- **NH₃ and organics produced; NH₃, Hg are in secondary wastes; Some I-129 in secondary wastes - TBD**

Long-term risks upon successful completion

+ **High confidence in destruction of nitrates/nitrites, waste organics; long-term sequestration of rads/metals that remain in glass**

- **Uncertainty in fate and partitioning of Hg, I-129, to secondary wastes, melter idling impact on Tc fate**

Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)

High risk due to significant cost-based startup delays and operations limits. Moderate technical implementation risk. Construction finishes 2049, mission does not complete without significant additional annual budget.

+ **Low volume of primary waste; low transportation risk**

- **Delayed start-up increases risk of tank degradation; worker hazards; high greenhouse gas emissions, chemical and power use; high atmospheric vapor release and secondary liquid; extended duration of operations; risk of further delay**

Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)

Very low probability of successful completion due to affordability.

+ **Replicates first LAW melter technology, reducing technology uncertainty**

- **Complex, integrated process with high maintenance needs; insufficient funds to start-up by need date**

Criterion 4: Lifecycle cost (discounted lifecycle costs)

\$7.6B construction;
\$5.1B operations
(unaffordable, \$1.36B shortfall)

- **Capital costs extend the duration to startup**

- **Annual operating costs exceed annual budget**

Assessment Rationale – FBSR 1A

FBSR 1A: Solid monolith product disposal onsite at Hanford

Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)

Effective. Medium confidence in the assessment, due to technology immaturity.

Residual threat to health and environment upon successful completion

+ Nitrates/nitrites/waste organics destroyed; Tc sequestered in waste form; moderate volume of primary waste

Long-term risks upon successful completion

+ High confidence in destruction of nitrates/nitrites, waste organics, non-pertechnetate; long-term sequestration of rads that remain in granular product

- Uncertainties associated with shallow disposal at facility with pathway to potable water, smaller dataset for FBSR waste form performance

Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)

High risk due to construction time required and technical execution risk. Construction finishes 2039; mission completes 2070.

+ low transportation risk

- Intermediate delayed start-up has risk of tank degradation; worker hazards; high greenhouse gas emissions, chemical and power use; extended duration of operations; risk of further delay due to cost and technical issues

Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)

Low probability of successful completion due to technical risk.

+ Similar to other equipment (but dissimilar feed waste stream); lessons learned from IWTU

- Complex, integrated process with high maintenance needs; insufficient funds to start-up by need date

Criterion 4: Lifecycle cost (discounted lifecycle costs)

\$3.4B construction;
\$2.2B operations

+ Alternative is eventually achievable at the point estimate for the assumed annual funding constraint

- Technical uncertainty and process complexity result in greater cost uncertainty

Assessment Rationale – Grout 4B

Grout 4B: Off-site grouting/disposal

Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)

Highly effective. High confidence in the assessment.

Residual threat to health and environment upon successful completion

+ Reduced long-term ammonia issue (WTP LAW continues); no rad impact to Hanford groundwater; Hg, Tc, & I in primary waste form offsite; minimal secondary waste

- Nitrates/nitrites not destroyed (but no impact); 1.8X waste volume increase

Long-term risks upon successful completion

+ Minimal added impact of ammonia; high confidence in no impact to Hanford groundwater

- Moderate confidence in LDR organic resolution

Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)

Low risk due to immediate start, minimal construction, low-temperature process, likely capacity, and modest transportation and operations costs. Limited facilities (e.g., evaporator and load-out station) needed; mission completes 2065.

+ On-time start-up decreases risk of tank degradation; minimal worker hazards; low greenhouse gas emissions, chemical and power use; minimal atmospheric discharges; minimal technical risk of waste form production issues

- Moderate transportation risk; high volume of primary waste; LDR organics not resolved

Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)

Very high likelihood of successful completion.

+ Similar to existing processes; robust/flexible; low complexity; commercially available equipment; demonstrated in TBI; adaptable; low likelihood of failure for technical reasons; sufficient funds to start-up by need date

- LDR organics may not be sufficiently resolved, requiring more to WTP LAW melters

Criterion 4: Lifecycle cost (discounted lifecycle costs)

\$0.4B construction;
\$3.4B operations

Assessment Rationale – Grout 6

Grout 6: Phased Approach, Off-site grouting/disposal, then on-site grouting/disposal

Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)

Highly effective. Good to high confidence in the assessment.

Residual threat to health and environment upon successful completion

+ Reduced long-term NH₃ issue (WTP LAW continues); low potential rad impact to Hanford groundwater; Hg, Tc, & I in primary waste form disposed offsite/onsite; minimal secondary waste

- Nitrates/nitrites not destroyed (but limited impact); 1.8X waste volume increase

Long-term risks upon successful completion

+ Minimal added impact of ammonia; high confidence in limited potential impact to Hanford groundwater; lack of potential migration due to low water infiltration rates, vault barrier

- Moderate confidence in LDR organic resolution; uncertainty in impact of non-pertechetate

Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)

Very low risk due to immediate start, flexible timing of conversion to on-site low-temperature process, and inexpensive operations. Grout plant construction finishes 2039; mission completes 2065.

+ Early start-up minimizes risk of tank degradation; minimal worker hazards; low greenhouse gas emissions, chemical and power use; minimal atmospheric discharges; minimal technical risk

- Moderate transportation risk; high volume of primary waste; LDR organic resolution or LAW vit

Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)

High likelihood of successful completion.

+ Similar to existing processes; robust/flexible; low complexity; commercially available equipment; demonstrated in TBI; vault demonstrated (SRS); adaptable; low likelihood of failure for tech. reasons; sufficient funds to start-up by need date

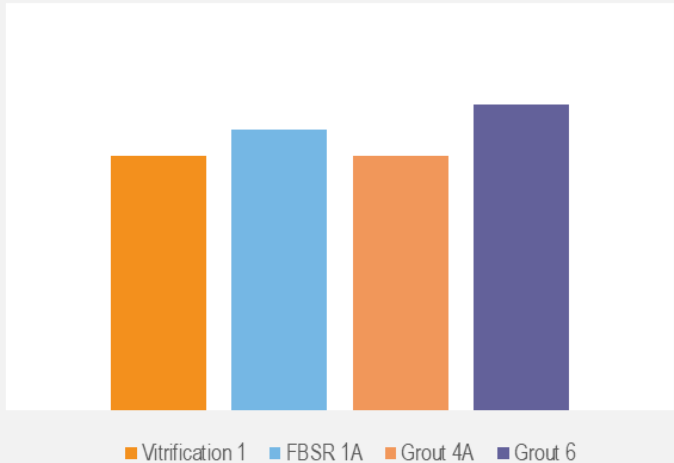
- LDR organics may not be sufficiently resolved, requiring more to WTP LAW melters

Criterion 4: Lifecycle cost (discounted lifecycle costs)

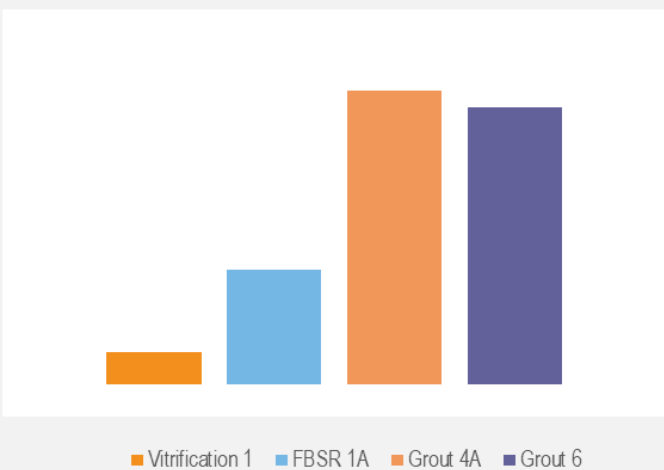
\$1.4B construction;
\$2.7B operations

Assessment Summary

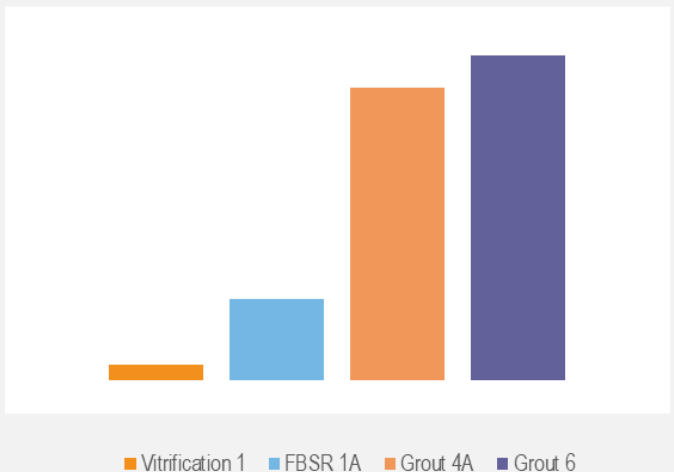
Criterion 1 – Long-term Effectiveness



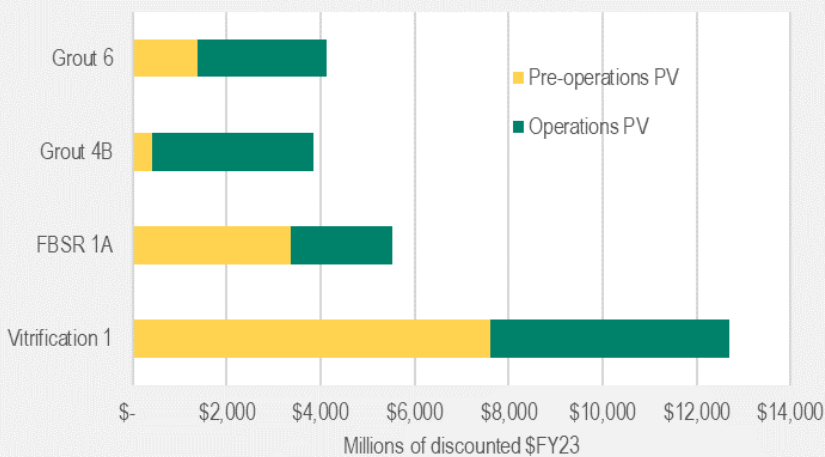
Criterion 3 – Likelihood of Successful Project Completion



Criterion 2 – Implementation Schedule and Risk

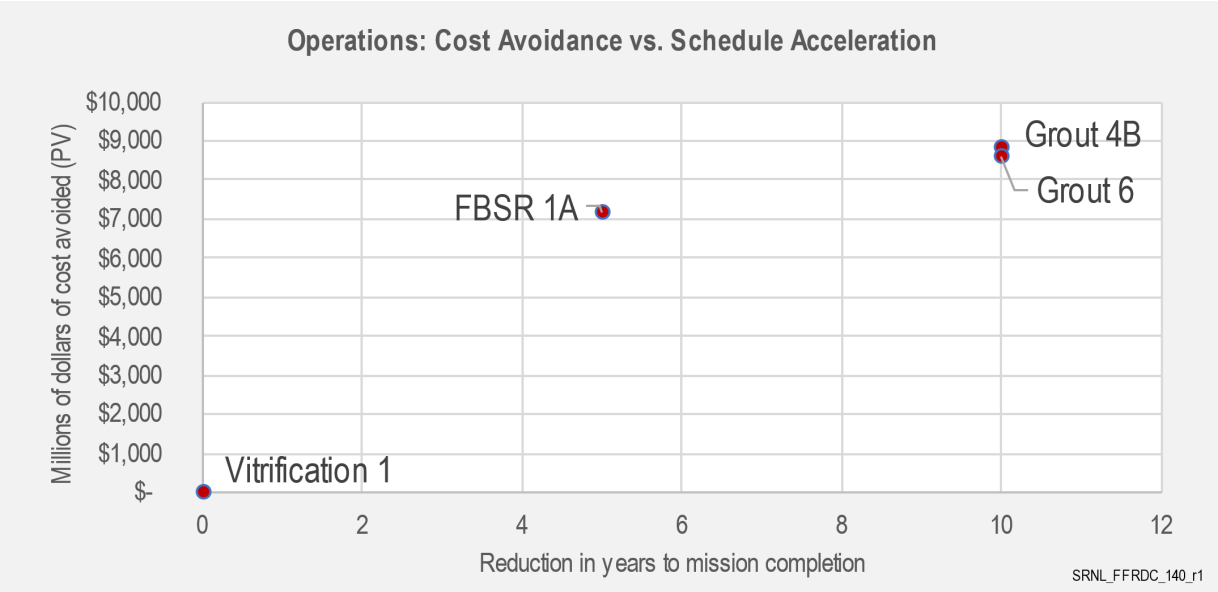
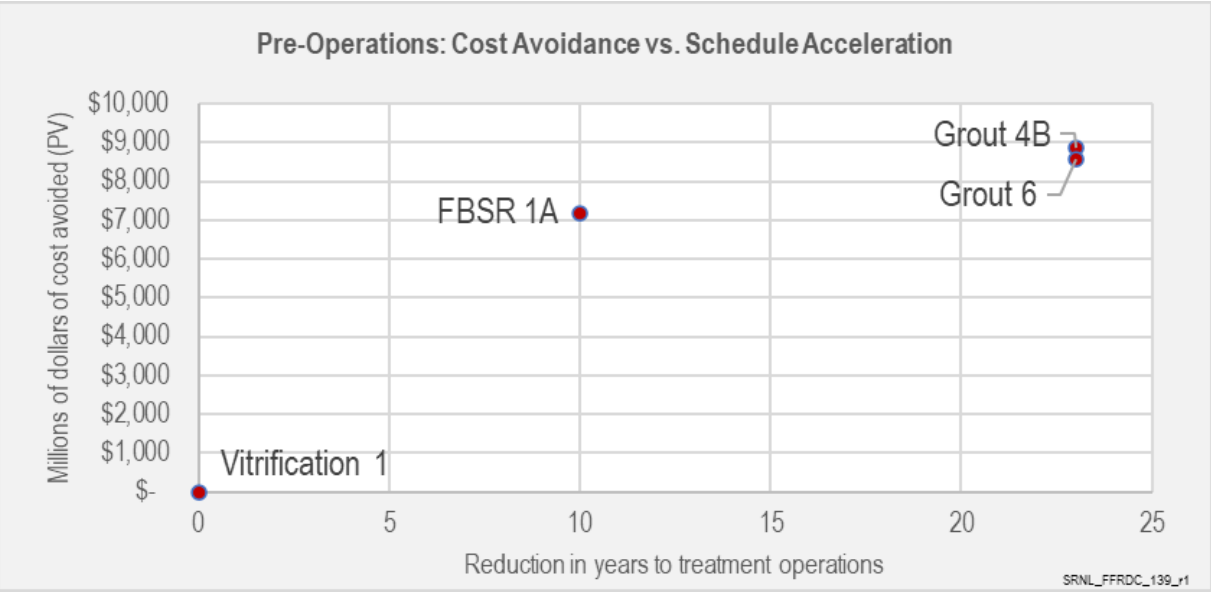


Criterion 4: Life Cycle Costs



Cost and Schedule Comparisons

Alternative	Pre-					Cost Avoidance	Pre-Ops Cost Avoided	Ops Cost Avoided	Start Acceleration	Completion Acceleration	% cost avoided (PV)	% start acceleration	% mission acceleration
	Present value (PV)	operations PV	Operations PV	Begin Ops	Mission Complete								
Vitrification 1	● \$ 12,700	● \$ 7,608	● \$ 5,092	2050	2075	\$ -	\$ -	\$ -	0	0	○ 0%	○ 0%	○ 0%
FBSR 1A	○ \$ 5,527	● \$ 3,375	● \$ 2,152	2040	2070	\$ 7,174	\$ 2,940	\$ 2,940	10	5	● 56%	● 37%	○ 10%
Grout 4B	○ \$ 3,854	○ \$ 410	● \$ 3,444	2027	2065	\$ 8,846	\$ 1,648	\$ 1,648	23	10	● 70%	● 85%	● 19%
Grout 6	○ \$ 4,127	○ \$ 1,393	● \$ 2,734	2027	2065	\$ 8,574	\$ 2,358	\$ 2,358	23	10	● 68%	● 85%	● 19%





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Wrap Up — Summary & Conclusions

Bill Bates

Dep. Associate Laboratory Director,
Environmental and Legacy Mgt., SRNL
FFRDC Team Lead

2021 NDAA-3125 Public Meeting #3

April 26-28, 2022

SRNL-STI-2022-00199



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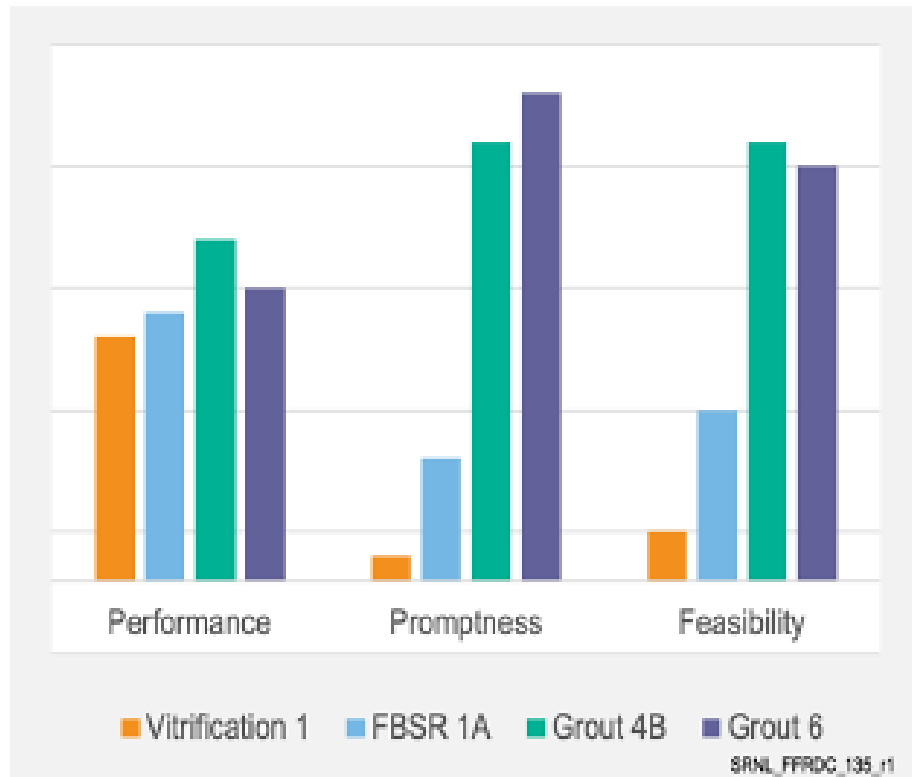
Comparative Analysis

Table 5-1. High-Level Comparison of the Four Consolidated Alternatives for Supplemental Treatment of Low-Activity Waste

Alternative			
Vitrification 1: Disposal onsite at Hanford	FBSR 1A: Solid monolith product disposal onsite at Hanford	Grout 4B: Off-site grouting/disposal	Grout 6: Phased Approach Off-site grouting/disposal, then on-site grouting/disposal
Criterion 1: Long-term effectiveness (environmental and safety risk after disposal)			
Highly effective for primary waste; moderately effective for secondary waste. Medium confidence in the assessment.	Effective. Medium confidence in the assessment, due to technology immaturity.	Highly effective. High confidence in the assessment.	Highly effective. Good to high confidence in the assessment.
Criterion 2: Implementation schedule and risk (environmental and safety risks prior to mission completion, including risks driven by implementation and waste tank storage duration)			
High risk due to significant cost-based startup delays and operations limits. Moderate technical implementation risk. Construction finishes 2049, mission does not complete without significant additional annual budget.	High risk due to construction time required and technical execution risk. Construction finishes 2039; mission completes 2070.	Low risk due to immediate start, minimal construction, low-temperature process, likely capacity, and modest transportation and operations costs. Limited facilities (e.g., evaporator and load-out station) needed; mission completes 2065.	Very low risk due to immediate start, flexible timing of conversion to on-site low-temperature process, and inexpensive operations. Grout plant construction finishes 2039; mission completes 2065.
Criterion 3: Likelihood of successful mission completion (including affordability and robustness to technical risks)			
Very low probability of successful completion due to affordability.	Low probability of successful completion, due to technical risk.	Very high likelihood of successful completion.	High likelihood of successful completion.
Criterion 4: Lifecycle cost (discounted lifecycle costs)			
\$7.6B construction; \$5.1B operations (unaffordable, \$1.36B shortfall)	\$3.4B construction; \$2.2B operations	\$0.4B construction; \$3.4B operations	\$1.4B construction; \$2.7B operations

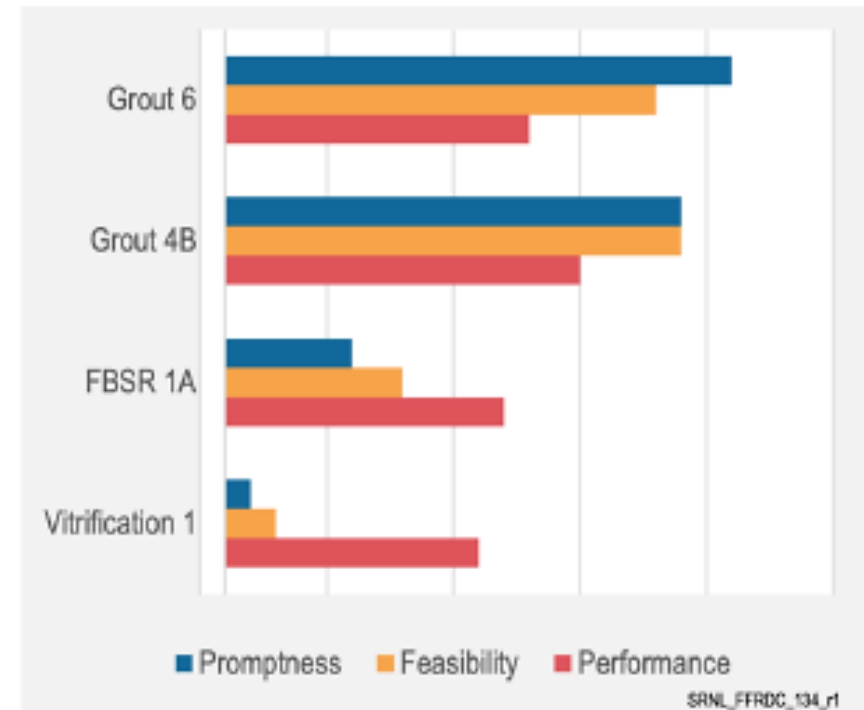
FBSR = fluidized bed steam reforming.

Comparison by Criteria



Performance = Criterion 1, Promptness = Criterion 2, and Feasibility = Criterion 3.

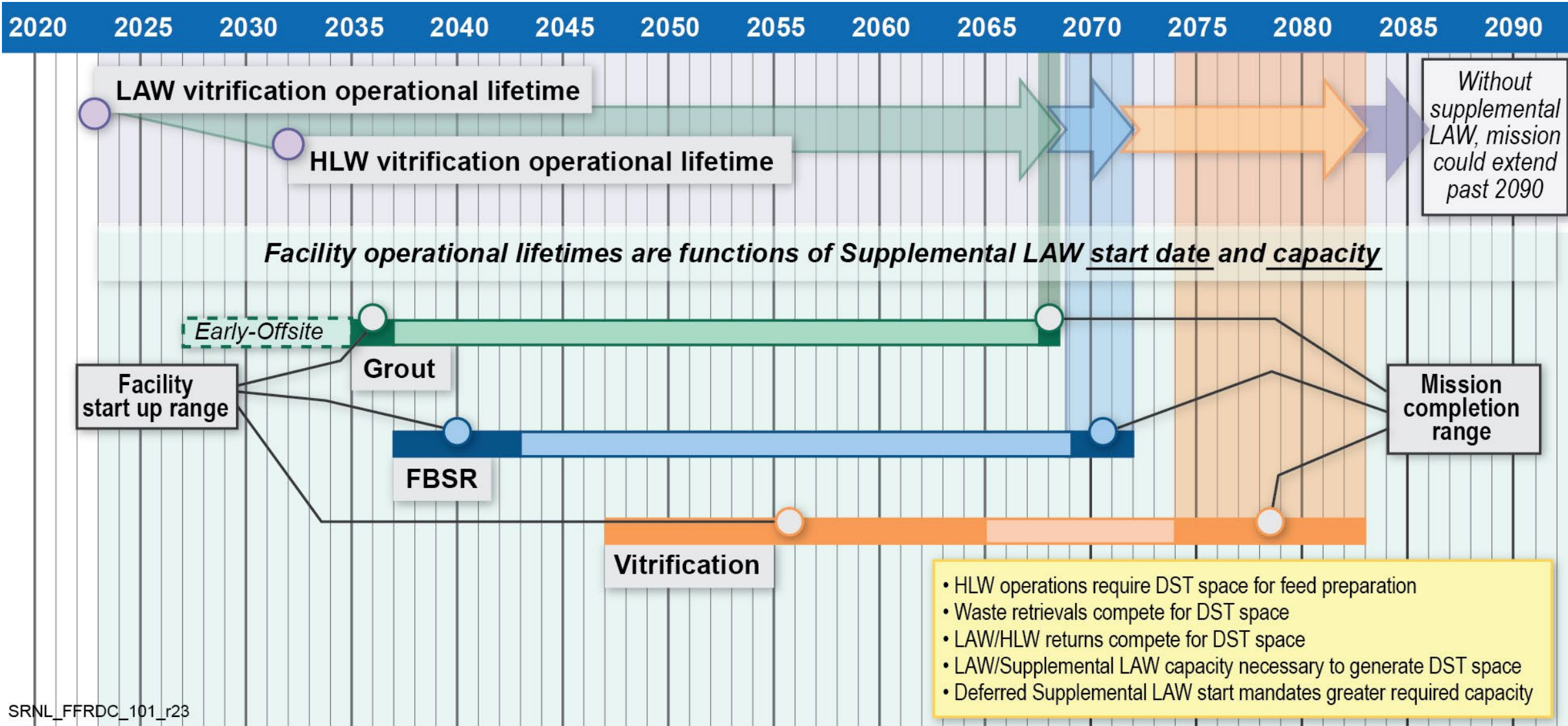
Figure 4-3. Comparison by Criterion



Performance = Criterion 1, Promptness = Criterion 2, and Feasibility = Criterion 3.

Figure 4-2. Qualitative Alternatives Comparison of Four Representative Alternatives

Schedule Durations



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For reference, WMEIS projected 2018 thru 2093 if no LAW Supplemental Treatment (EIS Alternative 2B)

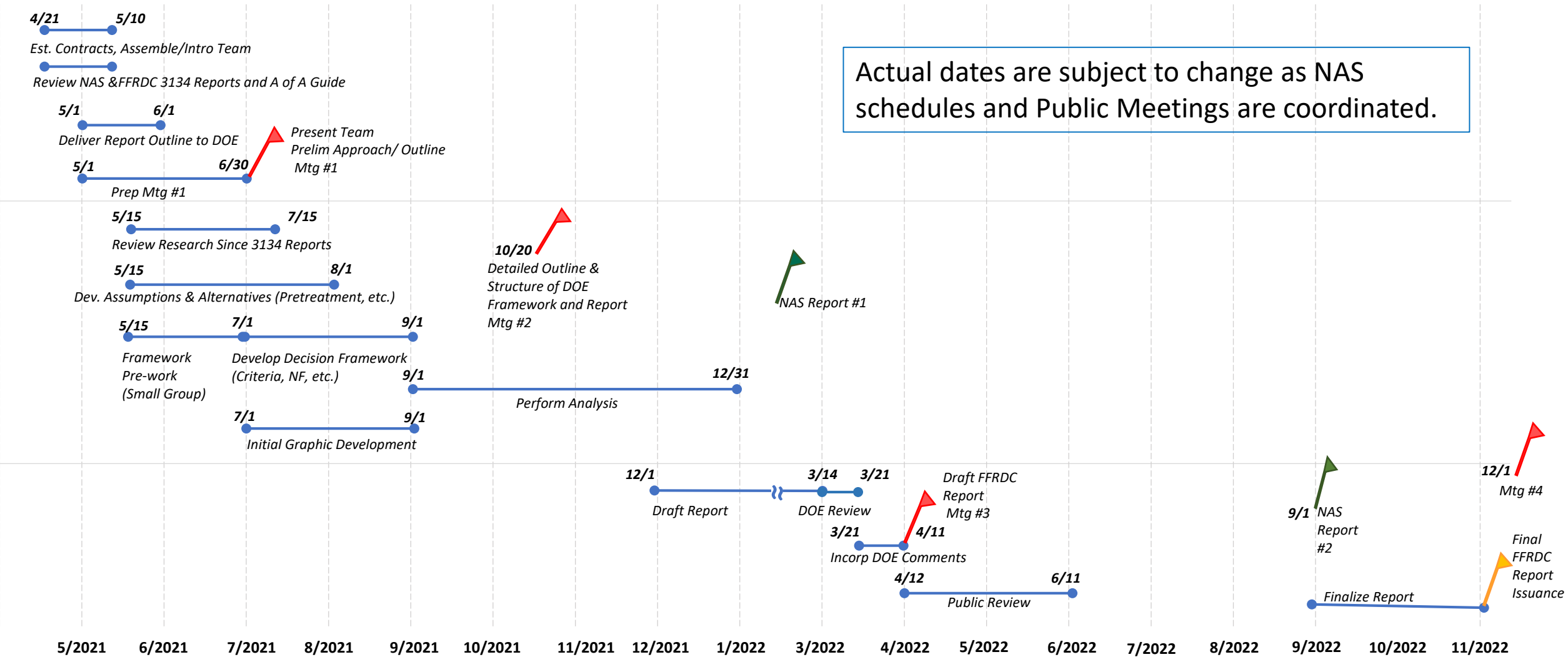
Conclusions

- **Only Grout-Based Alternatives are Likely to be Affordable and Readily Implemented**
- **Processing Flexibility is an Important Consideration**
- **Vitrification & Grout Waste Forms can Provide Long-Term Protectiveness**
- **FBSR is Considered “First-of-a-Kind” for Hanford LAW**
- **Cost is the Primary Constraint on Duration—Particularly Capital Cost**
- **Off-Site Disposal Removes Tc and I from Hanford and Most Would Be Class A/B**
- **DFLAW Would Run Concurrent with Supplemental Treatment**

Recommendation

- ***DOE should expeditiously secure and implement multiple pathways for off-site grout solidification/immobilization and disposal of LAW in parallel with the DFLAW vitrification process.***
 - **Rapid Risk Reduction** – DST Space, Accelerate Waste Retrievals, Waste Stabilized
 - **Environmental Protection** – Reduce Onsite Disposal Inventory, Offsite Disposal with No Credible Pathway to Potable Water
 - **Flexibility** – Can Route LAW Selectively
 - **Time to Enable Transition(s)** – If On-Site Treatment and/or Disposal are Pursued, Benefit from Operating Experience
 - **Reduction or Elimination of Need for Future Capabilities**
 - **Minimized Financial Demands** – Closest to Current Funding Levels
 - **Most Likely to be Successfully Implemented**

FFRDC Team Schedule



Actual dates are subject to change as NAS schedules and Public Meetings are coordinated.