Table 4-9. Regulatory compliance evaluation summary for the In Situ Grouting alternative.

ARAR or TBC	Type	Relevancy[a]	Citation	Meets Evaluation?
Idaho groundwater quality rule	Chemical	A	IDAPA 58.01.11.200	Yes[b]
National primary drinking water standards	Chemical	RA	40 CFR 141 MCLs and MCLGs	Yes[b]
Radiation protection of the public and the environment	Chemical Action	TBC	DOE Order 5400.5	Yes
Idaho toxic air pollutants	Chemical	A	IDAPA 58.01.01.585 and .586	Yes
Idaho ambient air quality standards for specific air pollutants	Chemical	A	IDAPA 58.01.01.577	Yes
National emission standards for hazardous air pollutants	Chemical	A	40 CFR 61	Yes
Native American graves protection and repatriation regulations	Location	A	43 CFR 10	Yes—if encountered
Preservation of historic, prehistoric, and archeological data	Location	A	36 CFR 800 and 40 FR 6.301(b) and (c)	Yes—if encountered
Protection of archaeological resources	Location	A	43 CFR 7	Yes—if encountered
Preservation of historical sites	Location	A	Idaho Statute 67-4601 et seq. and Idaho State Historical Statute 67-4101 et seq.	Yes—if encountered
Compliance with environmental review requirements for floodplains and wetlands	Location	A	10 CFR 1022	Yes
Protection of floodplains	Location	RA	Executive Order 11988; 40 CFR 6.302(b); 40 CFR 6 Appendix A	Yes
Remediation waste management sites located within floodplains	Location	A	40 CFR 264.18(b)	Yes
Location standards for TSD facilities located within floodplains	Location	A	40 CFR 264.1(j)(7)	Yes
Idaho groundwater quality rule	Action	A	IDAPA 58.01.11.006	Yes[b]
Standards for owners and operators of TSD facilities—general groundwater monitoring requirements	Action	A	40 CFR 264.97	Yes[b]
National ambient air quality standards	Action	A	40 CFR 50	Yes
Idaho control of fugitive dust emissions	Action	A	IDAPA 58.01.01.650 and .651	Yes
Idaho fuel burning equipment—particulate matter	Action	A	IDAPA 58.01.01.675 through 681	Yes
Idaho particulate matter—process equipment emission limitations on or after July 2, 2000	Action	A	IDAPA 58.01.01.710	Yes
Identification and listing of hazardous waste	Action	A	40 CFR 261	Yes

Table 4-9. (continued).

ARAR or TBC	Type	Relevancy[a]	Citation	Meets Evaluation?
Hazardous waste determination	Action	A	IDAPA 58.01.05.006 (40 CFR 262.11)	Yes
Standards for owners and operators of TSD facilities—closure and postclosure requirements	Action	RA	IDAPA 58.01.05 (40 CFR 264 Subpart G)	Yes
Standards for owners and operators of TSD facilities—landfills	Action	RA	IDAPA 58.01.05 (40 CFR 264 Subpart N)	Yes
Standards for owners and operators of TSD facilities—use and management of containers	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart I)	Yes
Standards for owners and operators of TSD facilities—tank systems	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart J)	Yes
Standards for owners and operators of TSD facilities—surface impoundment	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart K)	Yes
Standards for owners and operators of TSD facilities—air emission standards for process vents	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart AA)	Yes
Standards for owners and operators of TSD facilities—equipment leaks	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart BB)	Yes
Standards for owners and operators of TSD facilities—tanks, surface impoundments, and containers	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart CC)	Yes
Standards for owners and operators of TSD facilities—containment buildings	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart DD)	Yes
Standards for owners and operators of TSD facilities—remediation waste management rules	Action	A	IDAPA 58.01.05 (40 CFR 264.1[j] [1] through [13])	Yes
LDRs	Action	A	IDAPA 58.01.05.011 (40 CFR 268)	Yes
National pollutant discharge elimination system	Action	RA	40 CFR 122.26	Yes
Radioactive waste management	Action	TBC	Order DOE 435.1	Yes

a. A = applicable requirement, RA = relevant and appropriate requirement, TBC = to-be-considered requirement
b. Evaluation criteria met not including the potential vadose zone contribution.
ARAR = applicable or relevant and appropriate requirements
CFR = *Code of Federal Regulations*
DOE = U.S. Department of Energy
IDAPA = Idaho Administrative Procedures Act
TSD = treatment, storage, and disposal

4.4.2.3 Chemical-Specific (Applicable or Relevant and Appropriate Requirements). The ISG alternative would meet RAOs for direct contact because the stabilized waste and its overlying low-permeability barrier cover system would prevent human and ecological receptors from direct exposure. This alternative also would reduce mobility of COCs and reduce infiltration. Not including contaminants presently in the vadose zone, the ISG alternative would inhibit COC migration from buried waste to underlying groundwater. Application of this alternative would meet the RAOs and related PRGs identified for groundwater (IDAPA 58.01.11; 40 CFR 141) if the potential vadose zone contribution is excluded.

The chemical-specific requirements of state and federal air quality standards would be met during both construction and remediation action implementation. Idaho state requirements include controlling toxic air pollutants (IDAPA 58.01.01.585 and .586), ambient air quality standards for specific air pollutants (e.g., particulate matter [IDAPA 58.01.01.577]), and emission of fugitive dusts (IDAPA 58.01.01.650). Federal requirements include NESHAPs (e.g., radionuclides) (40 CFR 61) and NAAQS (e.g., particulate matter) (40 CFR 50).

4.4.2.4 Location-Specific (Applicable or Relevant and Appropriate Requirements).

Location-specific ARARs for the ISG alternative are the same as those for the Surface Barrier alternative (see Section 4.2.4.2).

4.4.2.5 Action-Specific (Applicable or Relevant and Appropriate Requirements).

Because the ISG alternative leaves waste in place, RCRA Subtitle C requirements for closure and postclosure (40 CFR 264 Subpart G) and landfills (40 CFR 264 Subpart N), as adopted by reference in the State of Idaho's Rules and Standards for Hazardous Waste (IDAPA 58.01.05), may be relevant and appropriate because the SDA is not a new or existing RCRA-regulated unit. Design and operation of the surface barrier would meet the RCRA substantive requirements for a top liner. The RCRA Subtitle C requirements for air emission standards for process vents (40 CFR 264 Subpart AA) and equipment leaks (40 CFR 264 Subpart BB) may be applicable for some equipment used during in situ thermal desorption operations, if emissions contain levels of restricted hazardous volatile waste above established thresholds. If applicable, these requirements would be met by using appropriate engineering controls. In addition, RCRA Subtitle C requirements for air emission standards for tanks, surface impoundments, and containers (40 CFR 264 Subpart CC) and treatment of hazardous waste using containers, tanks, surface impoundments, and waste piles (40 CFR 264 Subparts I, J, K, and L) may be applicable to Pad A waste if hazardous waste is encountered and treated onsite. RCRA general groundwater monitoring requirements (40 CFR 264.97) that use monitoring wells to detect COCs in the underlying aquifer are applicable to the ISG alternative. Provisions for groundwater monitoring are included in this alternative.

Furthermore, substantive RCRA generator requirements for hazardous waste identification and management (40 CFR Parts 261 and 262) would be applicable to this alternative if hazardous waste were generated during these activities. Also, the substantive portions of 40 CFR 268, including applicable LDRs and requirements for generators that treat hazardous waste, would apply to activities at Pad A if hazardous waste were treated onsite before disposal. Special rules for treating characteristic hazardous waste (40 CFR 268.9) would apply, if stored nitrate salt identified as an oxidizer (D001) is treated.

Implementing institutional controls (e.g., security and access) identified for this alternative would prevent possible exposure to waste by human intruders and biota. The controls would also meet applicable DOE requirements for residual radioactivity left in place, including related provisions of DOE Order No. 5400.5.

Construction and remediation would meet state and federal air quality standards requirements. Idaho state requirements include controlling toxic air pollutants (IDAPA 58.01.01.585 and .586), ambient air quality standards for specific air pollutants (e.g., particulate matter [IDAPA 58.01.01.577]), emission of fugitive dusts (IDAPA 58.01.01.650), particulate matter emission standards for fuel burning equipment (IDAPA 58.01.01.675 through 681), and process equipment emission limitations (IDAPA 58.01.01.710). Federal requirements include NESHAPs (e.g., radionuclides) 40 CFR 61 and NAAQS (e.g., particulate matter) 40 CFR 50. These requirements would be met by using appropriate engineering controls. Organic vapors that may accumulate beneath the biotic barrier following remediation would be collected, removed, and treated by the active OCVZ treatment system (OU 7-08) and the designed passive gas collection layer operating in the modified RCRA Subtitle C cap. The EPA Office of Air Quality Planning and Standards is developing a new MACT for the remediation site source category. This MACT, projected to be effective after 2002, would apply to remediation sites that are major sources of organic hazardous air pollutants during site remediation activities. If applicable to CERCLA sites, all vents, remedial material management units, and associated equipment components involved in the remedial activity could require emission controls.

As required, NPDES storm water discharge protective measures and best management practices would be implemented for storm water controls, road building, waste management, and other related remedial activities as appropriate. Applicable DOE TBC requirements for protection of human health also would be met during remedial activities.

Requirements of DOE Order 435.1, which specifies that all DOE radioactive waste is to be managed in a manner protective of worker and public health and safety and the environment, would be met.

4.4.2.6 Long-Term Effectiveness and Permanence (Balancing Criterion). The ISG waste form would be physically and chemically stable over geologic time. The most significant mechanism causing grout degradation is dissolution of grout materials by slowly infiltrating water. However, as discussed in the supporting report, grout waste forms are chemically compatible with the natural SDA environment. Recent grout testing has demonstrated that dissolution of grout materials, even in saturated conditions, would occur only at extremely low rates (Armstrong, Arrenholz, Weidner 2002).

If ISTD is performed, VOCs in treated areas would be permanently removed and destroyed. This would eliminate future risk associated with COCs (e.g., CCl_4, methylene chloride, and tetrachloroethylene). The surface barrier would further reduce risk by inhibiting infiltration of water through the grouted waste, thereby impeding further release of contamination to the aquifer.

Though this alternative would be effective at minimizing future risk, some COCs presumably would have been released before remediation could take place. The amount that has been released to date and current rates of release are not known with certainty. However, conservative estimates are that the preremediation release may result in groundwater contamination posing a risk above 1E-04. Modeling indicates that this risk would peak by 2110 and could extend beyond the boundary of the SDA for a distance of approximately 1,500 to 2,000 ft. Therefore, this alternative could require institutional controls that prohibit using groundwater within this buffer zone.

In addition to prohibiting groundwater use within the buffer zone around the SDA, other institutional controls would be required to ensure RAOs are met and maintained. Land-use restrictions would be required to prevent development, excavation, or drilling on and near the SDA. Frequent inspection and maintenance of the surface barrier would be required. In addition, the barrier would have to be reconstructed every 500 years. Groundwater monitoring would be required to ensure contamination does not exceed acceptable levels beyond the institutional control boundary.

Assuming contamination in the vadose zone is ignored, long-term (10,000-year) modeling performed for this alternative provides an indication of effectiveness of the ISG technology and surface barrier in preventing migration of COCs remaining in the burial zone of the SDA. Simulations indicate that this alternative would effectively reduce contaminant migration and control groundwater ingestion risk from COCs in the burial zone to acceptable levels.

4.4.2.6.1 Risk Modeling Assumptions—Water was assumed to infiltrate the modified RCRA Subtitle C Barrier at a rate of 0.114 cm/year. Contaminant releases from the grout were conservatively assumed to occur by diffusion from within 2-ft-diameter grout columns. These columns would be formed by injecting grout into the waste site to create interlocking columnar monoliths. This is based on a conservative assumption that the points of contact between columns may be a zone of weakness where cracks can form. For modeling purposes, the surface available for leaching was assumed to be the outside surface of the 2-ft-diameter columns. Realistically, surface area available for leaching is would be much lower, but few applicable data are available to develop accurate prediction of cracking in grouted waste over long periods.

The DUST-MS model assumed that infiltrating water flows through the columnar joints in the grout at volumetric rates equal to the surface area of the treated region multiplied by the infiltration rate. The volumes of water contacting the waste in a given period were assumed to dissolve the contaminants released in the same period, up to their solubility limits. Modeling limitations precluded chemical alteration of infiltrating water as it passes through the grouted waste in the simulations. As a result, release rates in the model might be biased high. The concentrations of contaminants released from the source term were input to the TETRAD model to estimate groundwater concentrations and drinking water risk.

4.4.2.6.2 Magnitude of Residual Risk—The magnitude of residual risk associated with this alternative is illustrated in Figure 4-7. This figure shows the cumulative carcinogenic risk over time caused by ingestion of groundwater impacted by release of residual contaminants in grouted TRU pits and trenches and grouted SVRs.

The figure presents two risk projections: (1) risk associated with postremediation release from the residual source term in the SDA only, and (2) total risk represented by release of residual source-term contaminants plus postulated contamination in the vadose zone before application of ISG in the SDA. The risks represent exposure at the point of maximum groundwater contamination; for results that include potential COCs in the vadose zone, this location lies at the southern edge of the SDA. Modeling results show that the near-term risks are dominated by COCs that may have been released before the remedial action. However, considerable uncertainty is in the assumptions used in the risk modeling, because the mass of potential COCs in the vadose zone and the rates of release from the SDA are unknown.

As shown in the figure, carcinogenic risk associated only with postremediation release of contaminants reaches approximately 4E-06 in 2,000 years and then decreases to approximately 2E-07 in 10,000 years. Carbon-14 accounts for approximately 80% of the risk in 1,000 years. Technetium-99 and I-129 are other significant contributors. After 1,000 years, uranium isotopes dominate risk.

The residual hazard index for this alternative is assumed less than 1.0. As stated previously, risk modeling indicates that the hazard index attributable to postremediation contaminant release under the Surface Barrier alternative would be less than 1.0. It is assumed that, given the treatment provided by ISG, the residual hazard index for the ISG alternative would be lower than that for the Surface Barrier alternative.

In the carcinogenic risk curve shown in Figure 4-7, the potential influence on risk levels caused by contaminants previously released from the source term to the underlying vadose zone are presented. Model results show that contaminants released to the vadose zone before remediation result in cumulative risks in groundwater greater than the 1E-04 levels for a zone that extends 1,500 ft beyond the SDA boundary.

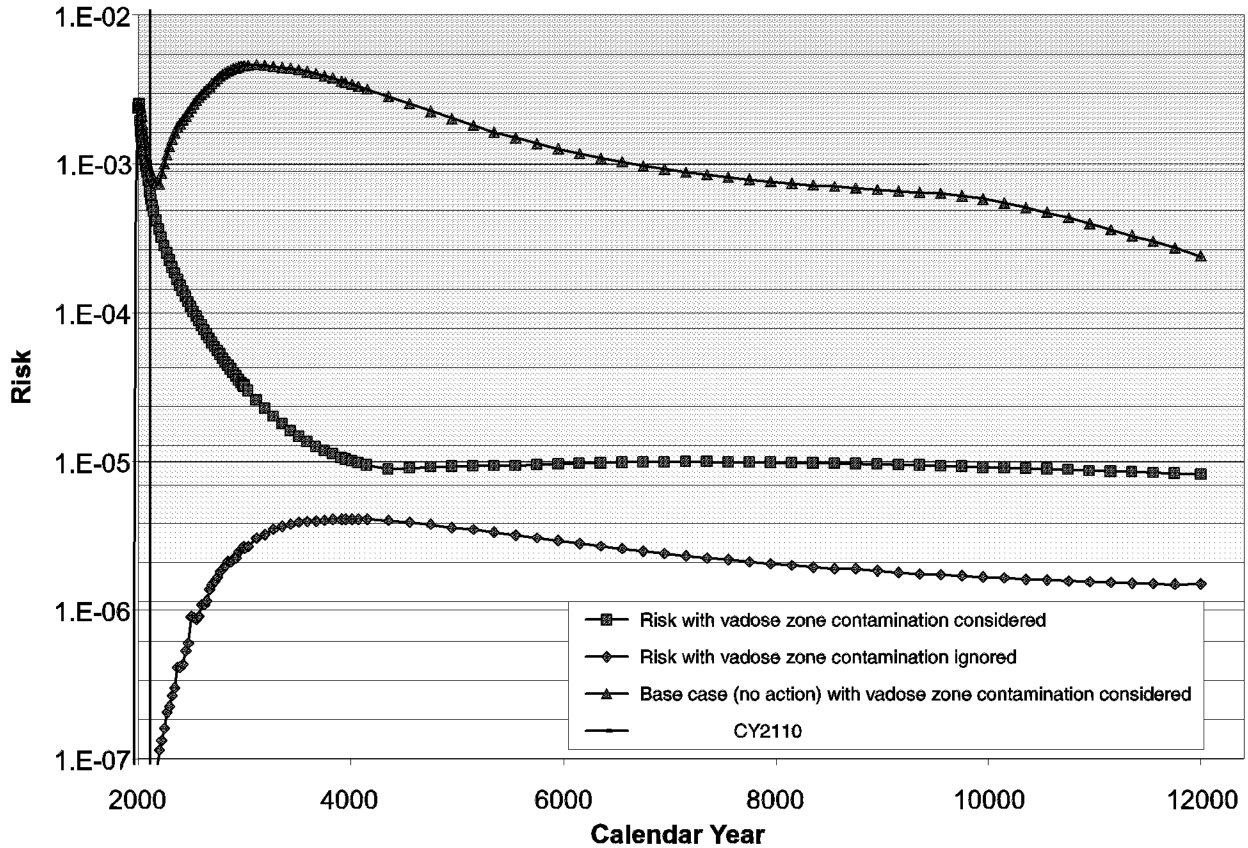

Figure 4-7. Residual groundwater risk for the In Situ Grouting alternative.

4.4.2.6.3 Adequacy of Reliability and Controls—Monitoring the treated waste and maintaining the barrier would be required in perpetuity to ensure effectiveness and permanence of the remedy. Regular monitoring (e.g., visual inspections and surface-elevation surveys) would be performed to detect compromises in the barrier's integrity or effectiveness. The barrier would be maintained and repaired as required to achieve original performance standards. Because of the required life span of the remedy, portions of the barrier likely would need to be repaired or reconstructed periodically and the entire barrier likely would need to be replaced once every 500 years.

Long-term reliability and performance of the ISG remedy would be assessed through monitoring of groundwater, the vadose zone, air, fauna, and surface vegetation. In addition, a network of monitoring probes would be installed throughout the monolith before the grout cures, to collect moisture and vapor samples and monitor temperature, redox, and pH conditions over time.

To ensure protectiveness, active institutional controls would be required to limit land-use activities near the SDA. A prohibition on drilling and using groundwater within a buffer zone around the SDA would have to be enforced. Access controls would have to be implemented and maintained in perpetuity to prevent intrusion into the waste.

4.4.2.6.4 Summary of Long-Term Effectiveness—Fate and transport modeling indicates that the postremediation peak carcinogenic risk would be less than 1E-04 and the hazard index would be less than 1.0 for the groundwater ingestion pathway, when postulated contamination in the vadose zone is not included. The grout monolith would be chemically and physically stable over geologic time. Appropriate institutional controls and operation and maintenance programs, plus periodic barrier repair and replacement, would provide additional long-term control for the stabilized waste. Should the potential COCs in the vadose zone at the time of remediation cause groundwater contamination to exceed health-based levels in a zone beyond the SDA boundary, institutional controls would be required to prevent access to, and use of, any contaminated groundwater. Therefore, the ISG alternative is an effective and permanent remedy.

4.4.2.7 Reducing Toxicity, Mobility, or Volume Through Treatment (Balancing Criterion). This alternative would encapsulate all waste sites contributing to the potential risk to human health and the environment with ISG technology. Pretreating some high-organic areas may be required to ensure adequate grouting. Because all waste is encapsulated in the grout mixture rather than destroyed or reduced, contaminants present in the encapsulated form would be immobilized significantly but would remain onsite.

4.4.2.8 Short-Term Effectiveness (Balancing Criterion). Components of the ISG alternative's short-term effectiveness entail the following:

4.4.2.8.1 Protecting the Community During Remedial Actions—The ISG alternative could be readily implemented with minimal risk and impact to the public and INEEL workers. Increased traffic on the INEEL during borrow-material acquisition is anticipated. And if borrow material is obtained from sources off the INEEL, increased traffic would affect communities near the INEEL. Therefore, traffic control plans would be developed to minimize the impact and potential increase in transportation risk to communities both the on and off the INEEL.

4.4.2.8.2 Protecting Workers During Remedial Action—This alternative could be implemented with moderate risk and impact to remediation workers. As with all alternatives that disturb buried waste, the potential exists for worker exposure to direct ionizing radiation and other chemical hazards. Because the ISG technique involves repeatedly inserting steel lances into the waste and injecting grout under high pressures, contamination potentially could be brought to the surface, adhered to the injection equipment or imbedded in grout returns. Past ISG work at the INEEL has experienced minor to large amounts of grout returns (wet grout forced to the surface during injection operations) (Armstrong, Arrenholz, Weidner 2002).

The OU 7-13/14 Preliminary Safety Analysis predicts that the potential amount of contamination brought to the surface would be minimal (Peatross 2001). Furthermore, because of the encapsulating properties of grout, the contamination would not become easily airborne. Based on results of the analysis, unmitigated hazards would not exceed dose evaluation guidelines established in DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis." The ISG operation would not be classified as a nuclear operation in accordance with DOE Standard (STD) DOE-STD-1027-92 "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Report." Using the process established in DOE Standard DOE-STD-5502-94, "Hazard Baseline Documentation," and DOE-ID Order 420.D, the ISG operation would be classified as a low radiological hazard.

Because of these analyses, ISG is not subject to many of the difficult controls and processes associated with nuclear operations as some other remedial alternatives. Worker safety aspects of ISG would be governed under an extensive health and safety plan prepared in accordance with 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response," and 20 CFR 1926.65, "Safety and Health Regulations for Construction." The health and safety plan would include a detailed hazards analysis and identify engineering and administrative controls to ensure protection of workers.

The ISG operation would be conducted inside a negative-pressure radiological confinement building. In addition, using a wheeled gantry crane platform would allow workers to remain outside the building during grouting operations. The confinement building and remote operations would be implemented to provide a defense in depth approach to worker safety.

The confinement building structure would be maintained under negative pressure and ventilated through a HEPA filter system. The structure would be continually disassembled and moved as the ISG operation progresses across the SDA. The OU 7-13/14 Preliminary Safety Analysis (Peatross 2001) predicted that the potential for airborne contamination is very low, so it is anticipated that the building would not become highly contaminated. A robust system of radiation monitors inside the structure would be used to verify that contamination is maintained at acceptable levels. Workers would enter the building periodically to monitor contamination levels or to repair equipment but would not be allowed inside during operations when the potential for surface contamination is highest.

Though worker risks in terms of evaluation guidelines are relatively low, the practical issue of controlling the spread of radioactive contaminants during and after the grouting operation remains. Some form of surface contamination control would be required to prevent spread of surface contamination across the SDA and neighboring facilities.

Previous INEEL tests on simulated waste have used concrete or steel platforms, referred to as thrust blocks, to cover the ground and contain grout returns. A flexible plastic bag or shroud, referred to as a drill-string enclosure, also has been tested to encase the drill string itself in an effort to minimize the potential for contamination spread. While the system of thrust blocks and drill-string enclosure may be a viable approach, a number of operational problems have precluded a successful demonstration.

Another approach that has been suggested has been to cover postoperational grout returns with a 3-ft layer of soil. The soil would preclude erosion and possible airborne suspension of contaminants in the interim period before construction of the cap. Because of results of the OU 7-13/14 Preliminary Safety Analysis, and considering the protection offered by remote operations and a confinement building, the simpler contamination-control approach may be preferred. Because the contamination-control techniques have not yet been designed and demonstrated, some uncertainties would need to be resolved during the remedial design.

In addition to the radiological and chemical hazards posed by the waste, the heavy equipment used during implementation of the ISG alternative (e.g., drill rigs, cranes, high pressure pumps, batch plant equipment, trucks, and loaders) pose significant industrial hazards. During the remedial design and subsequent readiness activities, remediation workers would need to ensure that all systems are properly designed and meet the appropriate engineering specifications and standards. Operations would need to be conducted in a planned and controlled manner with adequate procedures and trained crews to ensure the safety of workers.

Retrieving and treating Pad A waste presents additional hazards. Retrieving low-level radiological waste presents inherent risks to workers, but the risk is substantially less than that posed by retrieval of waste from TRU areas. Notably, several drums were retrieved previously from Pad A for experimental purposes (early 1990s) without using a radiological confinement building. A thorough hazard analysis is needed to determine worker risk posed by the Pad A operation and to establish requirements for confinement systems and other safety systems.

The report prepared in support of this PERA (Schofield 2002) estimated the risk to workers associated with implementing this alternative. The evaluation considered direct external radiation exposure and exposure to mechanical injuries for remediation workers. No risks to the public were projected for this alternative because no off-INEEL transportation of hazardous materials would occur. Engineering controls during implementation would preclude the release of particulate radioactive materials. Risk results of that evaluation are these:

- Cancer = 1.07
- Injury = 74.5
- Fatality = 0.17.

As shown, the evaluation predicts that during implementation, one person would develop cancer because of exposure to hazardous substances, including radioactive material and radiation fields. Approximately 75 injury accidents would occur during implementation, and the projection for fatality accidents is less than one.

4.4.2.8.3 Environmental Impacts Associated with Construction—Environmental impacts associated with the ISG alternative include potential particulate emissions resulting from construction activities and increased construction-related traffic. Particulate emissions would be controlled with applicable dust suppression techniques, as necessary, to ensure that exposure to off-INEEL receptors does not exceed either 25 mrem/year total effective dose equivalent from all exposure pathways or the 10 mrem/year total effective dose equivalent through the air pathway (in accordance with DOE Manual 435.1-1, "Radioactive Waste Management Manual").

4.4.2.8.4 Time Until Remedial Action Objectives Are Achieved—Preliminary project schedules project that the ISG alternative could be fully completed within 12 years of an approved ROD. The alternative would meet all RAOs, but ultimate effectiveness of the ISG alternative would not be confirmed until the cap is constructed, operated, and monitored for some time.

4.4.2.9 Implementability (Balancing Criterion). This alternative is implementable. In situ grouting has been widely tested as either CERCLA treatability studies or small remedial actions. Information provided by past testing demonstrates that ISG is an effective technology with applications for the SDA (Armstrong, Arrenholz, Weidner 2002). However, ISG has not yet been implemented at the scale that would be required for OU 7-13/14. As with all intrusive alternatives for the SDA, significant technical risks are associated with treating the buried waste. Estimates of production rates and costs for this alternative have significant uncertainty because buried waste sites as large and complex as the SDA have not been treated before with this technology.

4.4.2.9.1 Technical Feasibility—Results of past field trials at the INEEL and other DOE sites show that injection grouting is clearly implementable at the SDA. The actual deployment system used to inject the grout would need to be evaluated during remedial design and optimized for specific waste streams. However, for this evaluation it is clear that rotary point injection would be technically feasible for use in pits and trenches where intimate mixing of waste and grout is desired.

The necessary equipment is commercially available and commonly used. The primary components of the ISG system (i.e., batch plants, cranes, drill rigs, and positive displacement pumps) are all commonly used and reliable. Though some equipment modifications would be necessary, no further development or testing (other than acceptance testing) is envisioned.

Treating the SDA with ISG would require hundreds of thousands of individual injections. The sheer number of injections required is challenging and the heterogeneous nature of the subsurface treatment zone would complicate operations. However, considering past field trials, and assuming that a crane-mounted system would be used, the time estimated for treating the SDA is reasonable.

Treating the SDA would require a large volume of grout, more than 200,000 yd^3. However, producing the grout is technically feasible. A single, moderately sized batch plant can produce 500 yd^3 each day, more than enough to support the injection operations.

Retrieving and treating Pad A waste is technically feasible. The waste is primarily low-level with a few drums of TRU waste. No hazards (e.g., explosives or highly flammable materials) have been identified. Stabilization and macroencapsulation processes are used commercially to treat radioactively contaminated waste. Again, specific constituents of the waste would need to be evaluated and stabilizing agents tested to ensure applicable requirements are met, but the process is technically feasible.

Technical difficulties with the ISG process encountered during past field tests included excessive grout returns, inadequate permeation with low-pressure systems, and clogging of injection nozzles. Those difficulties have been largely resolved through subsequent design and testing (Armstrong, Arrenholz, Weidner 2002). However, several waste streams may pose potential problems for implementing ISG and must be considered in this evaluation and addressed in detail during remedial design. The ISG technology is relatively robust and this evaluation assumes that ISG could be applied effectively to most waste streams found in the SDA. However, ISG performance for several waste types, depending on concentration and aerial extent, is unknown. These waste types include:

- Organic oil—Series 743 organic sludge originating from the RFP has high oil content (averaging 37 gal/drum) and a grease-like consistency (Clements 1982). In previous tests with simulated oil waste streams, researchers have had difficulty grouting oil-based waste streams (Loomis and Thompson 1995). However, more recent bench-scale testing indicates that waste streams with 10 to 12 wt% oil could be effectively treated with a wide range of grout types. Waste with significantly higher organic loadings could be effectively treated using specialized grouts, such as blast furnace slag grouts, hydrocarbon-based grouts, or other grouts. Areas in the SDA with intermittent or scattered drums of organic oil waste should are not problem areas because the oily mixture would be encapsulated on all sides by competent grout. However, grout performance data are not readily available for areas with many oil drums. Pretreatment by ISTD would be required before ISG could be applied to areas with high numbers of Series 743 sludge drums. Previous analysis of the distribution of Series 743 sludge (Miller and Varvel 2001) estimated that a total area of less than 1 acre may have such high concentrations. These areas are located in Pits 4, 6, 9, and 10.

- Nitrate salt—745 Series nitrate sludge waste is comprised primarily of dried sodium nitrate and potassium nitrate salt that originated from evaporation ponds at RFP. High concentrations of salt compounds interfere with the curing of many cementitious grouts. However, recent bench tests have demonstrated that waste loadings up to 12-wt% nitrate have no effect on the grout leach resistance (Armstrong, Arrenholz, Weidner 2002). Furthermore, past work demonstrated that, with certain grout formulations, competent waste forms could be achieved with waste loadings approaching 50-wt% nitrate salt. Research also found many grouts that failed when mixed with high concentrations of nitrate salt. The researchers recommended that results not be extrapolated from one waste to another, but tests on actual waste should be used to select a grout formulation (Loomis, Miller and Prewett 1997; Spence et al. 1999).

  As with the oil-based sludge drums, intermittent nitrate waste drums would not significantly affect the performance of the ISG monolith. However, areas with high densities of nitrate drums with waste loadings exceeding 50 wt% could preclude effective curing of cementitious grouts. Areas with nitrate salt waste in concentrations exceeding 50 wt% would be identified as interference areas that could not be effectively grouted without further development and testing of grout formulations. A paraffin- or polyethylene-based grout would be effective, but performance data specific to nitrate salt have not been developed. Pad A, with its high concentration of nitrates, would be retrieved and the waste stabilized in an ex situ treatment system to ensure performance standards are met.

- Large objects—Jet injection grouting relies on advancing an injection lance through the waste with rotary-percussion action. SDA waste includes construction debris (e.g., concrete, steel, and pipes) and large objects (e.g., trucks, tanks, reactor-vessel pieces). Intersecting such objects would prevent fully advancing the injection lance and prevent grouting at that spot. If drill refusal is an isolated event, the offending object may be sufficiently encased with grout through adjacent holes. However, an area may become impossible to grout successfully if a large cache of steel or other such debris is encountered. Presently, maps of large-object areas are unavailable, so it is difficult to predict to what extent drill refusal would be a problem. Many of the COCs are associated with drummed waste (sludge) that, as demonstrated by recent probing, is easily penetrated. Areas containing large caches of demolition debris, vehicles, or other large objects could pose a challenge for drilling and may preclude grouting of those areas.

4.4.2.9.2 Administrative Feasibility—Though the actions under the ISG alternative are implemented under CERCLA and do not require permits, the substantive provisions of permits that would otherwise be required are considered to be ARARs. Any selected remedial alternative would be required to demonstrate ARAR compliance. Because the ISG alternative would adequately address identified ARARs, no known administrative barriers would exist to prohibit implementation.

Safety disciplines (e.g., radiation safety, industrial hygiene, and construction safety) are readily available at the INEEL. Regulatory compliance support, including permitting required for construction activities, also is available. Changes to the storm water or Big Lost River systems may require assessing wetlands and associated environmental receptors or habitats, but this issue is not anticipated to adversely affect the administrative implementability of this alternative. Previous implementations of ISG at the INEEL and other DOE sites did not encounter any administrative barriers.

Though this alternative's activities do not expose buried waste or provide a way to bring any substantial contamination to the surface, the act of puncturing through and pressure-grouting waste would generate some level of radiological and nuclear material hazard. The process of safety analysis, design, and operational readiness for systems and techniques to treat the waste would be difficult. However, preliminary safety analysis and design work completed for ISG, coupled with the success of past technology performance tests, show that these issues could be adequately mitigated with proper design and operations. While long-term monitoring activities, cover maintenance, and 5-year site reviews would require long-term coordination, these activities would not present significant administrative difficulties.

4.4.2.9.3 Availability of Services and Materials—Services and materials required include mechanical hauling and grading, construction of a grout batch plant, hauling grout materials, in situ nonreplacement jet grouting of the subsurface, hauling and placing materials to construct a multilayered cover, installing storm flow diversions, constructing fences and other access controls, and site restoration including grading and reseeding.

All earthwork under this alternative would involve using readily available standard construction equipment, trades, and materials. Soil and rock could be borrowed or quarried if needed from regional sources. Services and infrastructure for construction activities are readily available in the local region, and services and materials for the jet grouting are available from a number of commercial vendors. At least two vendors have provided ISG services to the INEEL in the past.

A number of commercial firms specializing in formulating and producing many types of grout are available. While some specific, experimental grout types may not available on a large scale, all of the candidate grouts tested and proposed for this application are thought to be available on a production scale. The multiple vendors have extensive experience formulating specific grouts with additives to suit individual remediation goals and deployment mechanisms. For example, additives have been shown to reduce leachability of heavy metals to below instrument detection limits. Other additives increase set time and reduce viscosity to facilitate handling and injecting grout into the waste seam. Many grouts could be readily mixed onsite in a batch plant similar to the cement batch plants commonly found near large construction sites. Raw materials could be brought in readily by truck or rail and staged onsite.

4.4.2.10 Cost (Balancing Criterion). The net present value of the ISG alternative is estimated at $823 million, as shown in Table 4-10. The net present value estimate includes $815 million for capital and $8 million for O&M costs. Primary capital costs are associated with the primary waste sites. The primary O&M costs are associated with environmental monitoring and cap maintenance. The costs include an estimated average 33% contingency.

Table 4-10. Total estimated costs for the In Situ Grouting alternative with contingency.

Activity	Total Costs ($M)	Net Present Value ($M)
Capital costs		
Surface barrier	70.9	—
In situ grouting and foundation grouting	576.2	—
Volatile organic contaminant treatment using ISTD	52.2	—
Pad A retrieval and reconfiguration	201.9	—
Testing	23.7	—
Management, design, and reporting	147.7	—
Total capital costs	1,072.6	814.5
Operating and maintenance		
Monitoring and surveillance	31.5	—
Cover maintenance	9.0	—
Fencing and signage	0.3	—
Management	4.9	—
Total operating and maintenance costs	45.7	8.1
Total	**1,118.3**	**822.6**

ISTD = in situ thermal desorption

A cost evaluation has been performed to show the sensitivity of the total capital cost for the ISG alternative when production rates are varied. Figure 4-8 shows the projected cost increase if grouting time were increased from 4 minutes per grout hole. As shown, if grouting production rates were to slow from 4 minutes per grout hole to 8 minutes per hole, the total project costs estimates would increase from approximately $1.1 to $1.4 million. While the costs increase in a nearly linear fashion, they do not double when the ISG production rate doubles. This demonstrates that while production rates are a significant cost factor for the ISG alternative, other substantial costs could be incurred independent of production rate.

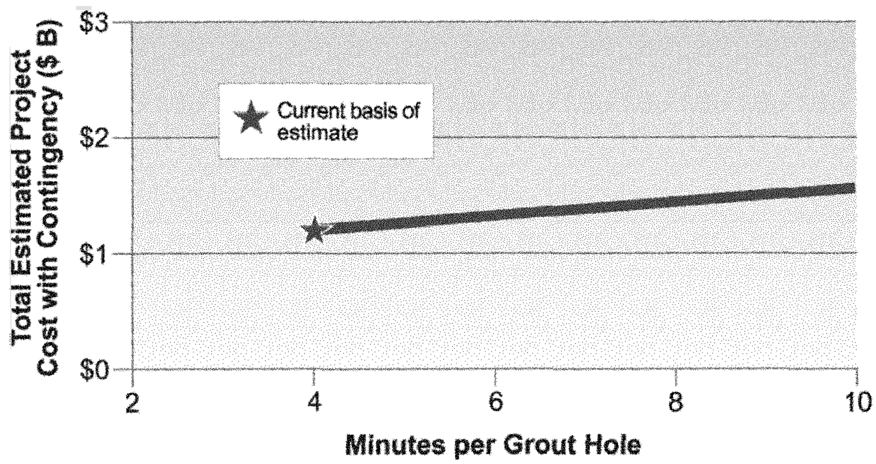

Figure 4-8. Sensitivity analysis for In Situ Grouting alternative production rates and total capital costs.

4.5 Alternative 4—In Situ Vitrification

4.5.1 Alternative Description

This alternative relies on in situ vitrification (ISV) as the primary technology to treat the COC-bearing waste streams within the SDA. The technology would be applied to the TRU Pits 1 through 6 and 9 through 12, and the TRU Trenches 1 through 10. Waste on Pad A would be reconfigured and treated with ISV. To minimize potential occurrence of melt expulsion event during ISV processing, ISTD would be used in the waste areas as a pretreatment. Vitrified waste materials would then be further isolated from potential future human or ecological receptors through construction of a low-permeability biotic barrier cover system.

> **In Situ Vitrification Alternative Remediation Strategy**
>
> Stabilizing and treating buried waste with in situ vitrification (ISV) and selective in situ grouting. Contaminants would either be destroyed or immobilized in glass-like monoliths (and grout monoliths) reducing migration to adjacent media to acceptable levels. Future exposure to the stabilized waste would be prevented through implementing administrative and physical land-use restrictions and would include placement of a low-permeability and biotic barrier cover system.
>
> **Key Elements:**
>
> (1) In situ vitrification with in situ thermal desorption pretreatment
> (2) Reconfiguration of the Pad A waste for ISV treatment
> (3) Selective in situ grouting of buried waste
> (4) Foundation grouting
> (5) Placement of low-permeability cover system
> (6) Physical and administrative land-use restrictions
> (7) Long-term monitoring and maintenance.

The ISV technology would remove and destroy organic constituents of waste and encapsulate most inorganic constituents within a durable, glass-like monolith. This stable waste form would reduce the potential for migration of identified COCs to adjacent media. The exceptions are C-14, I-129, Nb-94, and Tc-99 in activated metal, which are not likely to be incorporated into the melt, but instead would remain in association with the metal that would pool at the base of the melt (Thomas and Treat 2002). The activated metal waste streams containing C-14, I-129, Nb-94, and Tc-99 are located primarily in the SVRs and in isolated areas in the non-TRU trenches. Because the activated metal is remote-handled with very high gamma radiation, significant safety issues are associated with retrieving this waste. Furthermore, there would be no disposal option for this waste if it was retrieved. Therefore, to ensure compliance with the RAOs, in situ encapsulation using ISG technology would be performed.

4.5.1.1 Primary Technology—In Situ Vitrification. The ISV components of the alternative, summarized in following subsections, include readiness activities, treatment, capping, access restrictions, and long-term monitoring and maintenance. ISV treatment activities in this alternative include moving the waste on Pad A to a new adjacent pit while adding more soil to ensure a mixture suitable for vitrification, placing a layer of soil over the areas to be vitrified to meet the 10-ft cover objective, preconditioning the waste using ISTD, vitrifying the waste using ISV, treating off-gases generated during ISTD and ISV processing, and treating secondary waste produced during off-gas processing.

4.5.1.1.1 Readiness Activities—Readiness activities include further site characterization and analysis of waste generation and disposal records, testing, design, construction, permitting, authorization-basis analysis, and operational readiness reviews.

Further characterization and analysis of records are needed to better establish bounding conditions for safe and effective operations at individual ISV melt settings. A preliminary review of data indicates that the potential exists for excessive levels of combustible and alkaline materials and perhaps inadequate soil at some melt settings. The potential for encountering spent fuel and high radiation sources also exists. These issues need improved bases for planning tests and developing the authorization basis and design for safe operations.

A significant level of nonradioactive and radioactive testing would be required in this alternative. This alternative would employ ISV and ISTD in unproven applications. Unique conditions for these technologies include high concentrations of potentially respirable plutonium powders in some waste containers and the possible presence of spent fuel, high-gamma-radiation sources, and gas cylinders. In addition, it is imperative that large melt expulsion events be precluded because of severe burn hazards and inhalation risks created when airborne plutonium powder escapes a gas containment system under pressure. Including ISTD in the alternative and maintaining a minimum of 10 ft of soil cover over the molten glass at all times have potential to preclude melt expulsion events. Testing under bounding conditions would be required to prove that these features would ensure safety and effectiveness. Tests of ISV and ISTD off-gas and secondary waste treatment systems also would be required to support the design of systems capable of meeting safe operating limits and complying with regulatory permit conditions.

4.5.1.1.2 Restaging Pad A Waste in Adjacent Pit—Waste on Pad A consists largely of closely spaced drums stacked 11-high and wooden waste boxes on an asphalt pad installed at grade. The drums cover an area of approximately 33,000 ft^2. Soil covers the stacked drums and is bermed around the site at about a 4:1 slope. The amount of interstitial soil between drums is deemed insufficient to ensure effective vitrification, especially in consideration of the large fraction of high-alkali waste placed in some areas on Pad A. Therefore, the waste would be restaged with an equal volume of soil in a 150 × 240 × 25-ft-deep pit constructed adjacent to Pad A. Contaminated overburden, underburden, and berm soil would be used as the source of soil added to the waste. The waste and soil mixture would fill the pit to within 5 ft of the top. A 5-ft layer of clean soil would be placed on top of the waste and soil mixture before the building was decontaminated and removed.

The restaging building would encompass the entire Pad A and the new disposal pit. A central wall would divide the building into two nearly equal areas. The plan dimensions of the building would be approximately 300 × 300 ft. The height of the building would be approximately 35 ft abovegrade in the Pad A area and 20 ft abovegrade in the new pit area. In the Pad A and new pit area, remotely operated bridge cranes equipped with clam shovels would be used to move the waste and soil to the pit. Transfer carts would be used to move waste in bins from the Pad A area to the pit area. The building would be constructed to Seismic Category II requirements, ensuring seismic stability while restaging activities are conducted. Water fogs would be employed to minimize airborne particulates. The building would be maintained under a negative pressure of about –4 in. water gauge to ensure containment of airborne contamination. Air in the building would be exhausted through HEPA filters and a stack after heating the air to above dew point temperature. Two 100% blowers would provide for exhausting the facility. A separate diesel-powered blower would provide ventilation in the event of loss of line power.

4.5.1.1.3 Addition of Soil to Protect Against Melt Expulsion Events—A large release of pressurized steam or other gas beneath the glass pool can cause a melt expulsion event. Soil would be added to the top of the designated pits and trenches to meet the objective of a minimum of 10 ft of soil over zones undergoing vitrification. The soil cover would provide a barrier to prevent expulsion of molten glass. Approximately 5 ft of soil covers the waste sites at present. A total of 12 ft of soil would be needed to allow for safely emplacing ISV starter path material between electrodes at a depth of 10 ft. This would ensure a 2-ft buffer of clean soil above the waste level at startup. As the melt grows and deepens, additional soil would be added to fill the hole created by subsidence, resulting in a soil cover of about 17 ft at completion of the melt.

The soil cover also must support the heavy equipment used during ISV, including 20-yd^3 dump trucks, boom cranes, and ISV off-gas hoods weighing more than 50 tons. Local soil contains sufficient clay to render the soil unsuitable for road use under rainy conditions. Thus, the upper 3 ft of soil would consist of a suitable road ballast material, compacted to meet vehicle load-bearing requirements. A 4-ft soil layer emplaced below the ballast would provide the remaining soil height to satisfy the minimum 10-ft cover requirement at startup.

The soil and ballast cover would be flat and extend 20 ft beyond footprints of the trenches and pits. These features would ensure a suitable surface for centering the ISV off-gas hoods over edges of the waste zone to be vitrified and then sealing the hoods to the ground. The cover would span the entire area that contains the designated trenches because the spacing between trenches averages only about 20 ft. Some contiguous pits also would be combined under the same soil and ballast cover to facilitate moving ISTD and ISV equipment. Specific groupings of pits and trenches under the same soil and ballast cover would include (1) all designated trenches and Pits 1 and 2, (2) Pit 3, (3) Pits 4, 6, 10, 11, and 12, (4) Pit 5, (5) Pit 9, and (6) the reconfigured Pad A waste. The soil and ballast cover placed on each of the waste-site groupings would be encircled by bermed soil with side slopes of 3:1. The berms would be 7 ft high and their bases would extend 21 ft beyond the edge of the cover. The total quantity of soil that would be used in the cover and berms is approximately 250,000 yd^3. The total quantity of ballast that would be used in the covers is approximately 170,000 yd^3. The soil and ballast would cover a total area of about 32 acres, not including the area covered by the berms.

4.5.1.1.4 Preconditioning the Waste Using In Situ Thermal Desorption—The ISTD technology would be used to precondition the waste and at least 2 ft of the soil underburden, before the ISV application. Like ISV, ISTD heats the waste, but at slower rates and to lower temperatures. Waste and underburden would need to be preconditioned to preclude risk of melt expulsion events during ISV and provide a concentrated off-gas stream that is more amenable to treatment than the diluted ISV off-gas stream. Waste would be heated to a level sufficient to dry out the soil and waste sludge, vaporize volatile materials, and safely breach most remaining sealed containers by the internal pressure generated by the heated contents. The underburden would be heated to remove interstitial water as well as water perched on the underlying basalt.

Release of steam and other gases during ISTD would take place without incurring melt expulsion events because unmelted waste at ISTD operating temperatures contains substantial interconnected porosity. This allows any steam and other gases rapidly released belowground to compress safely into the interconnected void space in the waste zone and then migrate toward gas extraction pipes. Melt expulsion events have occurred during past ISV operations because molten glass is an incompressible, impermeable fluid that prevents dissipation of pressurized gas into void spaces in the surrounding unmelted waste and soil. Gases released within molten glass are buoyant, and thus are released at the glass surface, sometimes with forces sufficient to cause melt expulsion events. The maximum temperature reached during ISTD (800°C [1,472°F]) is well below the temperature at which soil and steel melt. The minimum temperature that would be reached (360°C [680°F]) is the temperature at which metallic mercury boils. Other major components of the waste are sodium nitrate and potassium nitrate, which decompose at 380° and 400°C (680° and 752°F), respectively, and could be destroyed largely during ISTD. Gas cylinders also should be safely breached because they are constructed with gas vent plugs designed to slowly relieve pressure at approximately 200°C (392°F).

The ISTD would employ an array of heated stainless steel pipe assemblies inserted into the ground on an 8 × 8-ft spacing to a depth of approximately 3 ft below the buried waste. Each assembly would include a sealed pipe that contains an electrical resistance-heating element, a vented pipe used to extract gases, and thermocouples. Each extraction pipe would be connected to a pipe manifold that conveys the gases to an off-gas treatment system. Because the height of the waste zone averages about 9 ft, and because a 12-ft-thick layer of soil would cover the waste, the average pipe assembly would be inserted to a depth of 24 ft.

The assemblies would be inserted into the ground with either vibratory or hydraulic techniques. The INEEL has demonstrated the effectiveness of the vibratory technique in penetrating the waste zone with rods and beams to mechanically breach sealed containers. However, the method of inserting pipes in previous applications of ISTD was to drill oversized holes into the ground and simply lower pipes into the holes. The advantage of this approach is that steam and other vapors can pass into the space between the waste and a pipe assembly and then freely enter the gas-extraction pipe. Driving the pipes into the ground as required in the SDA application could cause the gas-extraction holes to become caked with soil, thereby reducing the rate at which heating and extraction could occur. Therefore, a method of sealing the extraction holes with a material that can be melted out is being developed. This method should allow the extraction pipes to be inserted using vibratory or hydraulic techniques while ensuring acceptable heating and extraction rates. A method of filtering gas-entrained plutonium and cesium-137 (Cs-137) powders within the extraction pipes also would be needed to ensure worker safety. An internal sand filter may be an effective option.

The ISTD process occurs at a rate that is largely a function of spacing the heating pipes. Heat is transferred from the heating elements to the pipes and then to the waste at a nominal rate of 350 W per linear foot of heated pipe. Six ISTD systems would be used, each paired with an ISV system. Figure 4-9 shows a plan view of a paired ISTD and ISV system.

Four larger systems would be used when processing pits, and two smaller systems would be used when processing trenches. With the 8 × 8-ft spacing of the pipe assemblies, heating would occur over about a 90-day period. This is in contrast to the 18-day period estimated to complete an ISV cycle. Thus, each ISTD system must cover an area approximately five times larger than the area being vitrified to match the ISV processing rate. In pits where the largest glass melts would be created, 100 pipe assemblies would be employed in each ISTD system. The smallest melts would be created when vitrifying trenches; these would require about 60 assemblies per ISTD system.

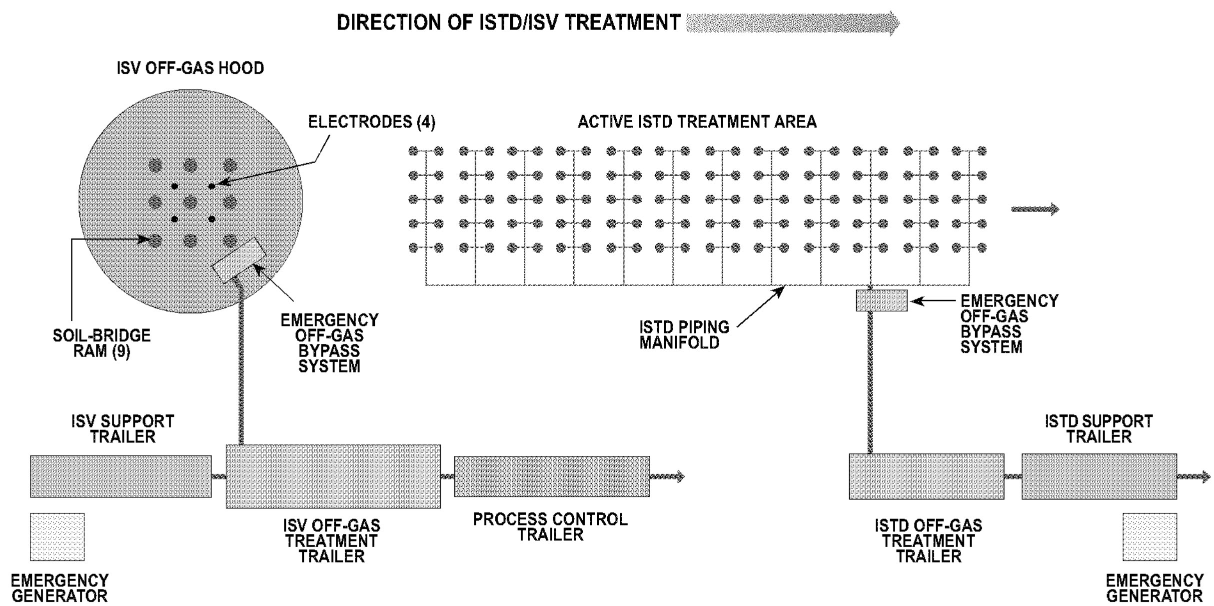

Figure 4-9. Plan view of paired in situ thermal desorption and in situ vitrification system.

Each of the larger ISTD systems would require about 330 kW of power. The smaller systems would require about 160 kW. Additional power would be required for off-gas processing. About 15 MW of installed power capability would be necessary to support all ISTD and ISV power needs in this alternative. Power would be distributed to the combined ISTD and ISV systems through power grid that would allow each paired ISTD and ISV system to draw a maximum of about 4 kW during nonroutine operations when high off-gas cooling demands are encountered. One power line at the OU 7-10 substation can currently provide 15 MW of power. However, for costing purposes for this alternative, it is assumed that an additional substation would need to be constructed to provide for long-term project-specific demands.

Each ISTD system would be operated as a single system or divided into five subsystems, each covering somewhat more than the area of a single melt. When a subsystem reaches its heating-temperature objectives, the pipe manifold that collects off-gases would be isolated from the rest of the off-gas manifold by closing valves. The 12 or 20 extraction pipes in the subsystem would be crimped closed; the manifold section would be disconnected and transported to the front of the advancing ISTD system and reconnected after gas purging at that location. ISTD processing at a given melt setting would be completed about a month ahead of the time at which ISV would begin. This approach would allow sufficient room for both ISV and ISTD operations while allowing both operations to be monitored and controlled from a single control trailer.

4.5.1.1.5 In Situ Vitrification—To raise the temperature of the ISTD-treated waste further (to approximately 1,500°C) to convert it to a glassy monolith, ISV would be used. The ISV application would complete the pyrolysis and decomposition of the waste constituents initiated by ISTD, then vitrify the waste and associated soil. Figures 4-10 and 4-11 depict application of planar ISV technology to pits.

The ISV process would heat soil and waste in the designated pits and trenches by passing current through the materials using four 12-in.-diameter graphite electrodes inserted into the ground. The amount of heat generated during ISV processing is a function of the electrical resistance of the soil and the current passed between electrodes. In situ vitrification is a much faster process than ISTD, which relies on conduction of heat outward into the waste from internally heated pipes. The insulating characteristics of soil and most waste materials limit the rate of heat transfer by conduction.

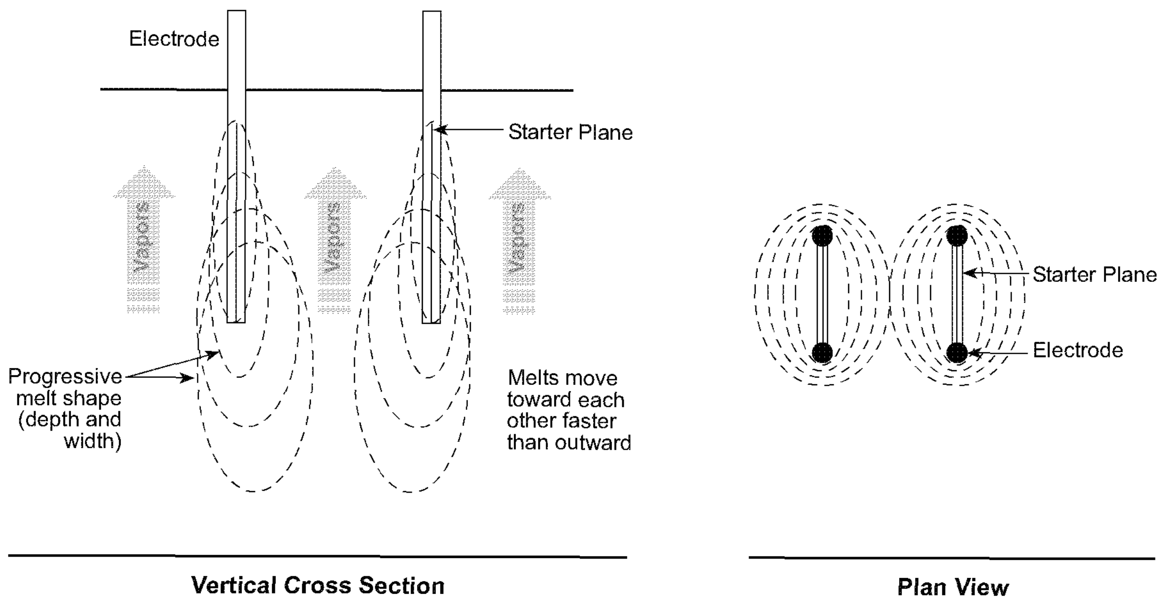

Figure 4-10. Cross-sectional and plan views of planar in situ vitrification melt progression (graphic adapted from LANL 2000).

As shown in Figure 4-11, electrodes used to vitrify pit waste would be installed in a square array on roughly 11-ft spacing. This configuration would create generally circular melts averaging about 35 ft in diameter. The shape of the melts in the trenches would be engineered to minimize melting into adjacent uncontaminated soil.

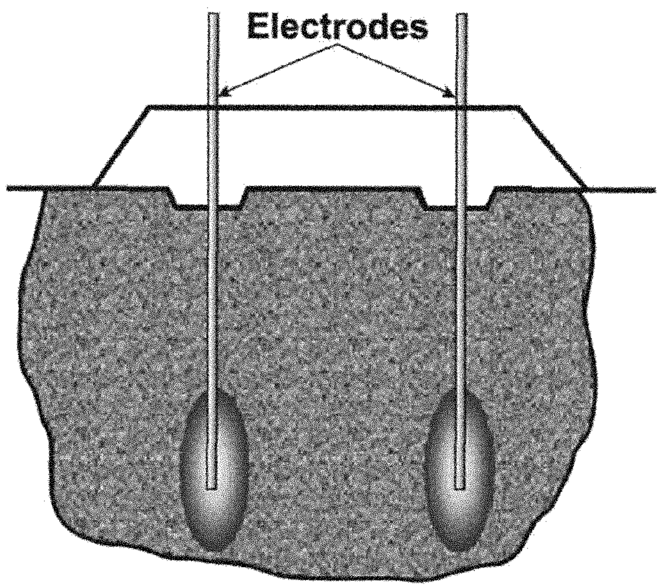

Figure 4-11. Subsurface planar in situ vitrification (graphic from LANL 2000).

Electrodes used to vitrify trench waste would be installed 11 ft apart in a line. This configuration would create oblong-shaped melts averaging approximately 35-ft long × 15-ft wide. Electrical current passed between pairs of electrodes would create generally planar melts (hence, the term planar ISV).

In the pit melting application, the planes would melt together and create circular-shaped melts. In the trench melting application, four electrodes would be installed along a line at points spaced 11 ft apart. Power would be supplied to each end electrode and the closest central electrode, causing two planar melts to form along the line. Power subsequently would be applied between the two central electrodes, causing the two planar melts to grow together into a longer planar melt.

When voltage is first applied to the electrodes in the ISV process, a flow of electrical current is established through an electrically conductive, buried starter path containing powdered graphite and glass frit. The resultant discharge of joule heat in the starter path raises starter-path temperatures to as high as 2,000°C. This temperature is well above the temperature required to melt soil (1,100 to 1,400°C). As the starter path melts, soil immediately adjacent to the starter path begins to melt and mix with the molten frit. These events increase both the electrical resistance of the molten frit and the amount of energy dissipated at a given amperage level (Buelt et al. 1987).

The starter path would be created using a backhoe to excavate trenches 2-ft wide × 10-ft deep (i.e., 2 ft above the buried waste level). A 1-ft-deep layer of the starter path material would be placed in each trench, followed by four 2-ft-diameter × 10-ft-long steel tubes inserted vertically on 11-ft centers. The trenches would then be backfilled with the excavated soil. The tubes would provide holes for guiding the electrodes to the desired starting elevation. If necessary, approximately 6 in. of electrically conductive grease would be added to the base of each tube to ensure adequate electrode-to-starter path conductivity.

When powered, the electrodes gradually would sink through the molten soil into the waste zone under their own weight, or, alternately, they would periodically be held at a selected depth using mechanical guides to help achieve greater melt widths. Thermocouples embedded in the waste at 30 and 35-ft-diameter locations would provide the capability to monitor the progression of the melt. The thermocouples would be connected electronically to a control trailer, where process operators could observe the waste temperatures in real time. The thermocouples would indicate progressively increasing temperatures as the melt grows, until burning out at approximately 1,400°C.

As the size of a melt increases, the surface area of the molten mass in contact with unmelted soil and waste also would increase until the amount of energy lost to cooling equals the amount added by joule heating. At this point, the melt would stop growing. The process would be engineered with sufficient capacity to ensure that desired melt parameters were achieved in the SDA application.

The volume of an ISV melt is usually much less than that of the original waste and soil. Densification of the waste and soil occurs because the glass usually contains few voids, and because the oxidation and pyrolysis that occur during melting largely eliminate organic materials. A volume reduction of 30 to 70% is typical. A 60% volume reduction would be expected in the designated pits and trenches at the SDA, resulting in melts averaging about 6 ft in height. The average depth of the base of a completed melt below the soil-cover surface would be about 24 ft.

On average, each melt setting would consume approximately 100,000 kWh, given an estimated power consumption rate of 300 kWh/ton of glass produced. The estimated time to provide power to a melt is 8 days, requiring delivery of 700 kW of power to the pit electrodes and 350 kW to the trench electrodes. The surface areas of the melts would overlap each other by 15%, and the melts would overlap into the soil that bounds the trenches and pits by an average of 6 ft, to ensure effective vitrification of contaminated areas. A total of 1,300 melts would be required over a 15-year operating period, necessitating four pit-ISV systems and two trench-ISV systems operating on an 18-day melt-to-melt cycle at a 70% total operating efficiency.

Gases produced at each ISV setting would be vented to a 70-ft-diameter off-gas hood centered over each melt zone. A pressure of about -1.3 cm or -0.5 in. water gauge would be maintained in the hood at all times using blowers to ensure containment of contaminants. About 99% of the total flow to the off-gas system would be air to ensure that the concentrations of flammable constituents of the off-gas would remain well below the lower flammability limit of the constituents. The hood would be substantially more robust than hoods used in earlier ISV applications. It would resist the highly corrosive effects of melt off-gases and effectively contain respirable TRU contaminants that may be emitted. High concentrations of hydrochloric acid in the off-gases suggests that construction using an expensive alloy (e.g., Hastalloy) may be required to ensure long life. The hood would be free-standing, circular in its plan dimensions, and capped with a rounded dome. Stress risers would be minimized in the design to enhance long life.

The heavy weight of this hood would require a tractor to move the hood to the next melt location. The free-standing hood would be hydraulically jacked 1 ft off the ground using an external frame and then driven 32 ft to the next melt setting, where it would be lowered to the ground. A boom crane with a minimum 60-ft reach and 5-ton capacity would be used to raise and move a hopper of dry sand around the boundary of the hood. An operator would direct the flow of sand from the hopper through a hose around the circumference of the hood to ensure that an adequate hood-to-ground seal is made.

The hood would be equipped with remote grapples to accept new electrode segments at the four electrode positions located near the center of the hood. The grapples would also screw the segments onto the electrodes and then lower the electrodes into the tube guides installed over the starter paths. The crane would lift and transfer 12 to 16 electrode segments to the grapple positions during each 8-day ISV power-on cycle. The crane used to seal the hood to the ground also would be used to lift electrode segments and perform several other functions including moving the ISTD pipe manifold. Thus, a crane would be dedicated to each of the six ISTD and ISV systems.

Additional hood equipment would include nine hydraulic rams capable of breaking down bridges of soil that may form over the melts as the waste undergoes volume reduction during melting. This step would ensure that the 10-ft protective soil cover would be maintained and not breached during a cave-in. The top of each ram would be equipped with a cyclone and star valve to aid in the receipt and delivery of washed, dry sand to the hood through a center-line hole in the ram. Washing the sand would be necessary to minimize the dust load on the off-gas treatment system and to minimize generation of secondary waste. Dry sand would be pneumatically delivered from a 20-yd^3 hopper truck each day to the cyclones and fed down the hollow core of the rams into the enclosed space of the hood. The addition of sand to the hood would compensate for the average 10 ft of subsidence expected during vitrification and provide insurance that the waste area would not become exposed to air. Exposure of the hot, dry waste to air could increase the risk of an underground fire. Adding sand to the melt area on a daily basis also would rejuvenate its filtering effect, helping to limit the upward migration of contaminants. This also would provide additional protection against a melt expulsion event.

Approximately 7 ft of sand would be added to the subsidence zone, leaving 3 ft to be filled with road ballast after the hood would be moved to the next location. Before the electrodes are powered, sand would be added through the center ram to establish a cone of sand 15 ft in diameter at its base. The flow of sand down the surface of the cone would result in filling the annular space between the electrodes and the electrode insertion tubes, thereby ensuring that a 10-ft cover of soil would be established in all areas before the electrodes are powered. Operating the rams would tend to flatten out the level of sand under the hood.

Approximately 300,000 yd^3 of sand would be delivered and placed to seal hoods to the ground and compensate for subsidence. Approximately 100,000 yd^3 of ballast would be delivered and placed to restore the load-bearing capability of the site to support future traffic. Approximately five 20-yd^3 truckloads of sand and ballast would be delivered each day to the six locations undergoing ISV.

4.5.1.1.6 Treating Off-Gases Generated During In Situ Thermal Desorption and In Situ Vitrification—Separate off-gas treatment systems would be used to treat off-gases generated by the paired ISTD and ISV systems for the following reasons:

- Off-gases generated by the ISTD system would be highly concentrated in flammable species, including hydrogen and carbon monoxide. This gas stream must not be mixed with air except when achieving controlled combustion. In contrast, the off-gases generated by the ISV system would be diluted with 100 parts of air to 1 part of melt gas in the off-gas hood, specifically to preclude the possibility of combustion or an explosion.

- Off-gases generated by the ISTD system would contain most of several volatile species that may not be as effectively treated in the highly diluted ISV off-gas stream. These species include volatile organic carbon compounds that escape pyrolysis, acidic halogens (notably hydrochloric acid) created during the hydrolysis of CCl_4 and other halogenated hydrocarbons, nitrogen oxides created during the dissociation and reaction of sodium and potassium nitrates, and mercury vapors.

- Off-gases generated by the ISTD system would be produced continuously, whereas off-gases generated by the ISV system would essentially cease several days after curtailing power to the electrodes.

Both off-gas systems would be subject to considerable variability in concentrations of off-gas streams because of high variability in compositions of buried waste. The five times larger area covered by the thermal desorption system and the leap-frog strategy of moving ISTD off-gas manifolds forward rather than thermally desorbing the same area all at once would dampen much of the gas variability in the ISTD process. Concentrations of semivolatile materials entering the ISV off-gas system would vary, but the sand layer maintained over the melt may be very effective in condensing semivolatile materials and filtering smoke and dust particles. Effective condensation of fission products having high gamma energies from spent fuel and radiation sources (especially Cs-137) and the filtration of TRU-contaminated particles would be critical to ensuring worker protection.

Additional definition of the compositions of buried waste within specific 1,000-ft^2 zones of the trenches and pits would be required to establish bounding conditions necessary for designing the off-gas systems and performing hazard analyses. (The average area of a pit melt is about 1,000 ft^2.) The limited analysis used as the basis for this PERA shows that the off-gas systems must protect against environmental releases of mercury, TRU-contaminated particles, acid gases (in particular nitrogen oxides, carbon monoxide, and hydrochloric acid), and volatile organic carbon compounds. Volatile and semivolatile radionuclides, (e.g., chlorine-36, Cs-137, I-129, and tritium), may be (1) present below levels of concern, (2) effectively condensed in the sand cover, or (3) effectively removed in the treatment train designed for the chemical COCs. Additional testing and analyses of the potential concentrations of these radionuclides in the off-gases would be necessary to determine if special removal processes must be incorporated into the off-gas systems.

The conceptual ISTD off-gas system would include traps to condense and collect elemental mercury as the off-gas exits the gas extraction pipes. Other trap locations also may be needed in the off-gas collection manifold to minimize corrosive damage to piping. The gas would then pass through a roughing filter and a metal HEPA filter designed to stop further entrainment of any TRU-contaminated particles that may be present. After filtration, the still-hot gases would be chilled to about 20°C (68°F) to condense and collect both water and mercury in a wet scrubber or demister. Elemental mercury would be collected in traps and condensed water would be passed through two activated carbon filters in series to remove organics and mercury in the +2 valance state. Feasibility of the wet carbon adsorption step would require further evaluation after bounding conditions for 1,000-ft^2 zones are established and off-gas treatment flow sheets are developed.

Water after adsorption would be neutralized with sodium hydroxide or lime and evaporated to a salt concentration of about 3 molar using primarily waste heat generated by the off-gas system. The concentrated salt solution would be transported in 1,000-gal tanker trucks to a Secondary Waste Treatment Facility (described in the following subsection) for further processing. One tanker truck would be transported every 5 days to the Secondary Waste Treatment Facility. Approximately 200,000 gal of 19-molar sodium hydroxide would be needed in ISTD and ISV off-gas neutralization processes over the 15-year period of operation. Two 5,000-gal steel tanks would be needed—one a heated tank for receipt of the 19-molar sodium hydroxide, and one for preparing dilute neutralization feed. Both tanks would be installed in a lined, bermed basin for protection of workers and the environment in the event of a leak.

Scrubbed but still-acidic off-gases would then be treated in a thermal oxidation unit using natural gas as the source of heat (when required) and controlled-air feed as the source of oxygen. Approximately 1 MW of natural gas would be used for thermal oxidation, evaporation, and other heating purposes. Thermal oxidation would effectively oxidize carbon monoxide and almost all of the volatile and semivolatile organic carbon materials. The presence of significant concentrations of certain acid gases (e.g., sulfur oxides) may prevent using catalysts, thereby requiring high-temperature oxidation and an increased cooling demand for subsequent gas treatment.

Resulting gas would be cooled and then passed through either a dry acid scrubber or a dry carbon adsorber, depending on whether the concentration of mercury would be high enough to contaminate the lime-based acid scrubbing medium. If so, two activated carbon adsorbers first would be used in series to remove mercury in the +2 valance and residual organic carbon. Removing mercury in the +2 valance state likely would be optimized in the presence of hydrochloric acid vapors. The acidic gases would then be passed through two bag houses or static lime-based dry scrubbers in series to remove acid halogens and sulfuric acid before being drawn into a blower. The blower would impel the gas forward to a selective catalyzed reactor (SCR) where anhydrous ammonia would be injected to chemically reduce the nitrogen oxides to nitrogen gas. A tanker truck would deliver ammonia to each of the six systems every few weeks. Approximately 200,000 gal of anhydrous ammonia would be consumed over the 15-year processing period. The fully treated gases would be discharged to the atmosphere through a stack. This conceptual off-gas treatment system would be included as part of the overall process-flow diagram for the ISV alternative shown in Figure 4-12.

The ISTD off-gas system would include two identical treatment trains, both designed for 100% capacity at approximately 100 ft^3/minute. Adsorber vessels would be mounted on skids. Both trains would operate simultaneously but one in standby mode to ensure readiness in case the other fails. Both trains would be installed in a single off-gas-processing trailer. The off-gas treatment process would be controlled from the same trailer used to control the thermal desorption, ISV, and ISV off-gas treatment processes. Two diesel generators designed to withstand the design-basis earthquake would provide emergency power to blowers in the event of loss of line power to ensure continued ventilation of the off-gas system.

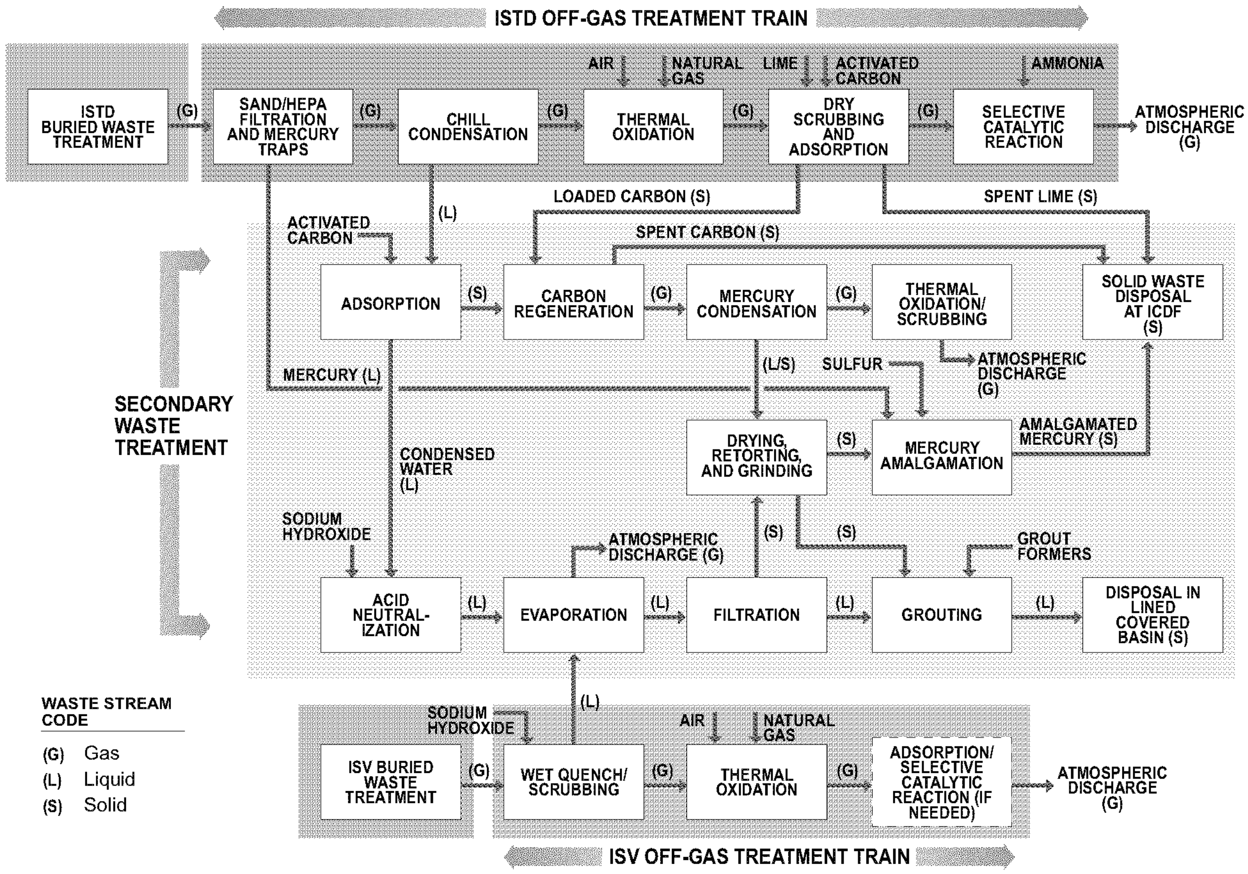

Figure 4-12. Process flow diagram for in situ vitrification.

The ISV off-gas system would be similar to the ISTD system, but would be nearly 100 times the capacity of the ISTD system to accommodate the dilution air added at the hood. The off-gas treatment train would begin with a roughing filter and HEPA filter, followed by a quencher and wet scrubber with a mercury trap and solids filter. Water recirculated through the scrubber would be neutralized with sodium hydroxide or lime to scrub acids from the off-gases. The scrub solution would be evaporated using primarily waste heat and then trucked to the Secondary Waste Treatment Facility for further processing. The scrubbed off-gases would be passed through banks of activated carbon adsorbers to remove trace organics and mercury. The fully treated gas would be drawn through two 100%-capacity blowers and discharged to the atmosphere through a stack. Like the ISTD system, the ISV system would include two identical off-gas treatment trains that would fit onto a single trailer (with the exception of the adsorber vessels).

Redundant ventilation systems provided for each ISV system are necessary to effectively contain airborne contaminants. Each redundant off-gas treatment train would be capable of drawing and treating about 3,000 ft^3/minute of gas. As a necessary precaution, an emergency backup ventilation system powered with the emergency diesel generators would automatically be activated during a large earthquake that might sever the duct connections between the hoods and off-gas trailers. A seismically qualified damper on the hood would be automatically opened to start emergency ventilation. Hood gases would be drawn by an emergency blower through a bank of metal HEPA filters and then discharged to the atmosphere from a short stack. The same system would be used in other emergencies and when moving the hoods. Similar but much smaller emergency systems would be employed in each of the ISTD systems to prevent explosion.

4.5.1.1.7 Secondary Waste Treatment—Secondary waste generated during ISTD and ISV operations would include flasks of elemental mercury; vessels containing saturated activated carbon and spent acid sorber materials; concentrated, neutralized scrubber solutions; and failed equipment. Failed equipment would include spent roughing filters and HEPA filters, and corroded or plugged pipes and off-gas processing vessels. Failed equipment potentially contaminated with TRU materials would be treated and disposed of by placing it on top of one of the trenches purposely not covered with soil and road ballast. The failed equipment would be covered with soil and ballast, and then vitrified with the waste beneath it. A small fraction of the failed equipment, particularly the filters, may be classified as TRU waste. Requirements for disposal of failed equipment would need to be specified in the ROD if this alternative were selected for implementation. Most of the remaining secondary waste would be classified as either LLW or MLLW.

The concentrated acid scrubber solutions would be transported from the ISTD and ISV off-gas systems in 1,000-gal batches and pumped into an agitated 10,000-gal steel tank. The solution would then be filtered or centrifuged to remove sludge, which would likely contain mercury and other heavy metals requiring treatment. The sludge would be dried and retorted to drive off mercury, which would be condensed and further treated. The filtered scrubber solution would be collected in one of two other 10,000-gal tanks in preparation for grouting, which would immobilize the solution and heavy metals it may contain.

Grouting would be accomplished on an 8,000-gal waste batch basis once every 40 days. A dry grout blend consisting of Portland cement and slurry-suspending clay would be mixed in a ratio of about 10 lb of blend per gal of waste solution. Volume of the resulting grout slurry would be about 50% greater than volume of the solution. The grout slurry would be pumped approximately 300 ft to a basin where it would flow to a low point and harden. The basin would be approximately 200 ft^2 at the surface, double-lined with polyethylene, and covered with floating polyethylene. It would be designed to contain about 2 million gal of grout. Dry grout blend material would be purchased premixed from a vendor, transported in 20-yd^3 hopper trucks, and unloaded using pneumatics into a 50-yd^3 grout-feed silo. Approximately 6,000 tons of dry blend material would be required over the 15-year operating period. Treatment and disposal requirements for the grout basin should be specified in the ROD if this alternative were selected for implementation.

Saturated activated carbon would be regenerated under elevated temperatures and chemically reducing conditions. This step would enable its reuse about 10 times by removing adsorbed mercury and organic compounds. The estimated quantity of spent activated carbon disposed of is 1,000 55-gal drums. Spent carbon would be disposed of at the ICDF. Organic materials desorbed from the carbon would be destroyed in the vapor form in a small thermal oxidation unit. Desorbed mercury would be reduced, condensed, and then amalgamated along with mercury collected in flasks during ISTD and ISV processing and with mercury condensed during retorting scrubber sludge.

Mercury amalgamation would occur by combining and mixing the mercury with elemental sulfur or proprietary chemicals at ambient temperature, then vigorously agitating the mixture to create the amalgam. Some scrubber sludge that resists retorting would be ground to a fine powder and amalgamated as well. Approximately 100 tons of sulfur would be needed in the amalgamation process. The estimated total quantity of amalgamated waste produced is 2,000 5-gal containers. Amalgamated waste would be disposed of at the ICDF.

Spent acid sorber material would be disposed of directly in its processing vessels at the ICDF. Approximately 500 500-gal vessels of spent acid sorber material would be disposed. A similar volume of waste would be produced if bag houses were used for dry acid scrubbing.

The Secondary Waste Disposal Facility would be a metal-frame building that provides approximately 10,000 ft^2 of floor space. The building would have about 20 ft of headroom and would also house a small laboratory for analyzing secondary waste and treated products, in addition to the secondary waste treatment processes previously described. A maintenance and storage building would be located nearby, as would an office trailer with a lunchroom, and another trailer with a change room.

4.5.1.2 Supplemental Technologies. To provide compliance with the RAOs, this alternative requires implementing a number of supplemental technologies within the SDA to address contaminant-specific concerns and provide for long-term stability of the cover system.

4.5.1.2.1 Grouting—The ISV technology would adequately treat identified COCs, with the exception of C-14, I-129, Nb-94, and Tc-99 associated with activated metal waste. These contaminants might not be incorporated in the melt, and would remain with metal that would pool at the base of the melt (Thomas and Treat 2002). The metal would leach at a higher rate than glass, thereby releasing the C-14, I-129, Nb-94, and Tc-99 and adversely affecting the quality of the underlying groundwater. The general distribution of the activated and fission product waste within the SDA is depicted in Section 2. As shown, the activated and fission product waste containing C-14, I-129, Nb-94, and Tc-99 are located primarily within the SVRs and isolated areas within the remaining low-level waste trenches. To address this issue, this alternative requires that the ISG technology be applied to these areas to immobilize C-14, I-129, Nb-94, and Tc-99.

Implementing ISG in these areas would follow the implementation presented previously for the ISG alternative in Section 4.4, and addressed in the accompanying technical report (Armstrong, Arrenholz, Weidner 2002).

4.5.1.2.2 Capping—To isolate treated waste and inhibit any future biotic intrusions, a low-permeability cap would be constructed over the entire SDA to limit infiltration of water and further reduce the mobility of waste. The proposed multilayer cap isa modified RCRA Subtitle C Cap, described previously for the ISG alternative. The cap consists of eight layers, including topsoil, sand filter, gravel filter, lateral drainage layer, asphalt, and a base course over grading fill. Before the cap is placed, subsurface stabilization with grout would be conducted to ensure foundation stability in nonvitrified areas and to minimize future subsidence-related maintenance requirements. These activities would be conducted when vitrification has been completed. Grading fill initially would be placed over the SDA where required to reduce surface undulations and crown the site before cap construction.

4.5.1.2.3 Access Restrictions—The land-use restrictions identified for this alternative would be similar to those discussed for the ISG alternative and primarily would involve controlling future access and developing the immediate site area.

4.5.1.2.4 Monitoring and Long-Term Maintenance—Groundwater, vadose-zone, and air-monitoring activities would be conducted as described for the ISG alternative. A review of the monitoring requirements, operations and maintenance activities, and trends in monitoring data would occur every 5 years to evaluate the effectiveness of the remedial action. Routine maintenance would be performed to repair monitoring wells and correct damage done by burrowing animals and erosion. For costing purposes, these activities are assumed to occur for 100 years. Because of the nature of the remedial actions associated with this alternative, it is assumed for costing purposes that monitoring requirements could be reduced after the initial 5-year review. The projected reduction would include 50% of the groundwater and lysimeter monitoring and elimination of the vapor port monitoring.

4.5.1.3 *Estimated Project Schedule.* Figure 4-13 shows the anticipated project schedule for implementing this alternative. Assuming a ROD signature date of 2005, the projected remedial activities would require approximately 24 years to implement, with completion in the year 2029.

As shown in Figure 4-13, it is projected that following completion of the ROD in 2005, approximately 8 years would be required for design and procurement, testing, and construction and testing of equipment. The ISTD and ISV waste treatment would begin in 2014.

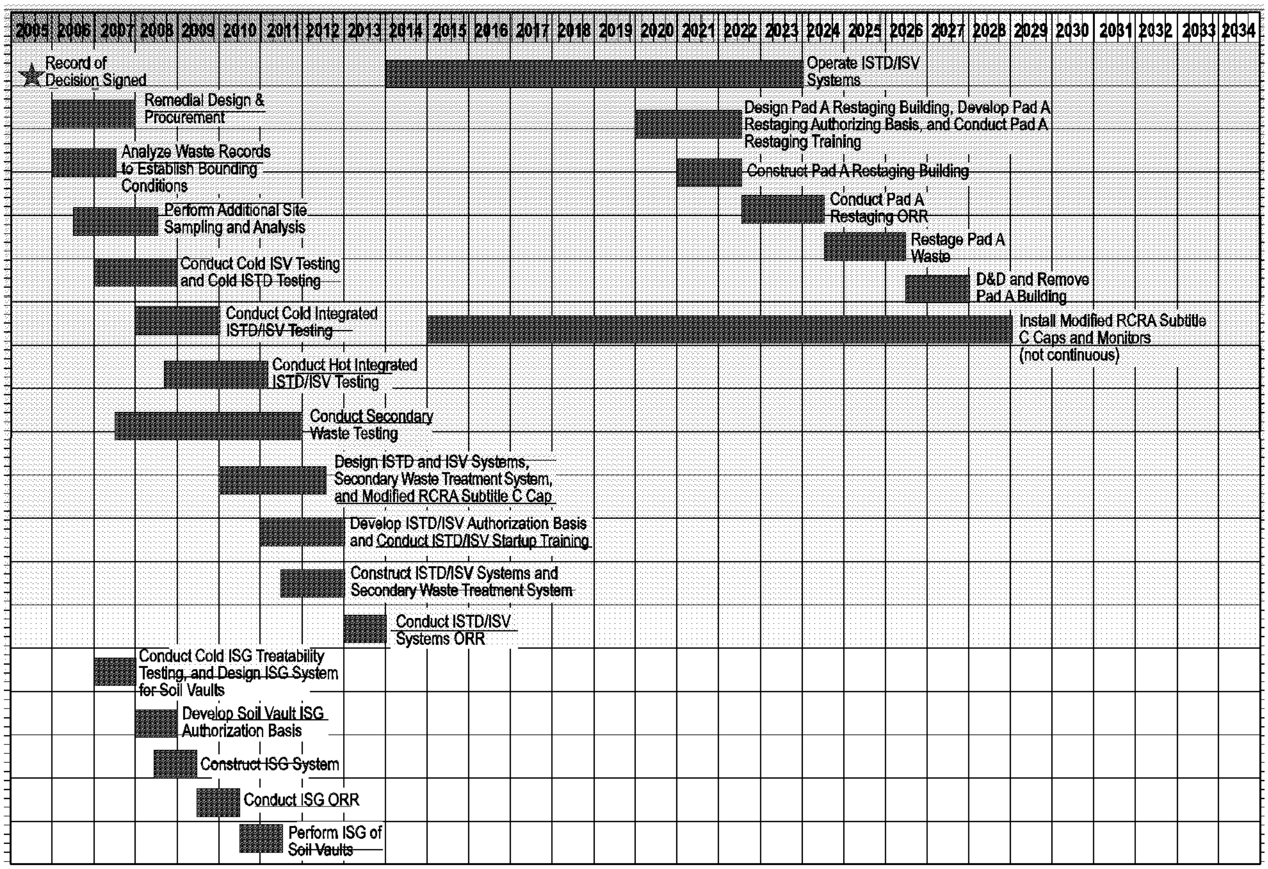

Figure 4-13. Schedule for the In Situ Vitrification alternative.

4.5.2 Screening Assessment

In the following sections, an assessment is provided of the ability of the In Situ Vitrification alternative to satisfy the two threshold criteria and the five balancing criteria described in Section 4.1.

4.5.2.1 *Overall Protection of Human Health and the Environment (Threshold Criterion).* The ISV alternative would be protective of human health and the environment and achieve the RAOs. Additionally, implementation of the alternative would reduce risks to an acceptable level. Preliminary schedules show that the alternative would be fully implemented by 2029, approximately 9 years following closure of the active pits. Because contaminants would remain at the site, monitoring would be continued through the 100-year institutional control period.

4.5.2.2 Compliance with Applicable or Relevant and Appropriate Requirements (Threshold Criterion).

This alternative involves the solidification of buried waste by the process of ISV and the construction of a low-permeability surface cover system. This alternative also involves treating selected areas with grout and restaging Pad A waste into a new pit to facilitate ISV of this waste. The key ARARs for the ISV alternative relate to containing buried waste over time. Under CERCLA, ARAR compliance would be addressed by considering chemical-, location-, and action-specific ARARs (and TBCs) independently. Appendix A presents a comprehensive summary of the potential ARARs that have been identified for this PERA. Table 4-11 provides the evaluation summary of the key ARARs for the ISV alternative.

Each requirement is identified by type (i.e., chemical-, location-, or action-specific), relevance (i.e., applicable, relevant and appropriate, or TBC), and regulatory source citation. The table also offers a conclusion as to whether the proposed alternative would meet a corresponding requirement. Detailed discussions of the significant requirements listed are presented in the following sections.

Table 4-11. Regulatory compliance evaluation summary for the In Situ Vitrification alternative.

ARAR or TBC	Type	Relevancy[a]	Citation	Meets Evaluation?
Radiation protection of the public and the environment	Chemical Action	TBC	DOE Order 5400.5	Yes
Idaho toxic air pollutants	Chemical	A	IDAPA 58.01.01.585 and .586	Yes
Idaho ambient air quality standards for specific air pollutants	Chemical	A	IDAPA 58.01.01.577	Yes
National emission standards for hazardous air pollutants	Chemical	A	40 CFR 61	Yes
Native American graves protection and repatriation regulations	Location	A	43 CFR 10	Yes—if encountered
Preservation of historic, prehistoric, and archeological data	Location	A	36 CFR 800 and 40 CFR 6.301(b) and (c)	Yes—if encountered
Protection of archaeological resources	Location	A	43 CFR 7	Yes—if encountered
Preservation of historical sites	Location	A	Idaho Statute 67-4601 et seq. and Idaho State Historical Statute 67-4101 et seq.	Yes—if encountered
Compliance with environmental review requirements for floodplains and wetlands	Location	A	10 CFR 1022	Yes
Protection of floodplains	Location	RA	Executive Order 11988; 40 CFR 6.302(b); 40 CFR 6 Appendix A	Yes
Remediation waste management sites located within floodplains	Location	A	40 CFR 264.18(b)	Yes
Location standards for TSD facilities located within floodplains	Location	A	40 CFR 264.1(j)(7)	Yes
Idaho groundwater quality rule	Action	A	IDAPA 58.01.11.006	Yes[b]

Table 4-11. (continued).

ARAR or TBC	Type	Relevancy[a]	Citation	Meets Evaluation?
Standards for owners and operators of TSD facilities—general groundwater monitoring requirements	Action	A	40 CFR 264.97	Yes[b]
National ambient air quality standards	Action	A	40 CFR 50	Yes
Idaho control of fugitive dust emissions	Action	A	IDAPA 58.01.01.650 and .651	Yes
Idaho fuel burning equipment—particulate matter	Action	A	IDAPA 58.01.01.675 through .681	Yes
Idaho particulate matter—process equipment emission limitations on or after July 2, 2000	Action	A	IDAPA 58.01.01.710	Yes
Standards for owners and operators of TSD facilities –closure and postclosure requirements	Action	RA	IDAPA 58.01.05 (40 CFR 264 Subpart G)	Yes
Standards for owners and operators of TSD facilities –landfills	Action	RA	IDAPA 58.01.05 (40 CFR 264 Subpart N)	Yes
Standards for owners and operators of TSD facilities—requirements for incinerators	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart O)	Yes
Standards for owners and operators of TSD facilities—remediation waste management rules	Action	A	IDAPA 58.01.05 (40 CFR 264.1[j][1] through [13])	Yes
Standards for owners and operators of TSD facilities—air emission standards for process vents	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart AA)	Yes
Standards for owners and operators of TSD facilities—air emission standards for equipment leaks	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart BB)	Yes
Land disposal restrictions	Action	A	IDAPA 58.01.05.011 (40 CFR 268)	Yes
Standards for hazardous air pollutants for source categories—waste combustors	Action	A	40 CFR 63 Subpart EEE	Yes
National Pollutant Discharge Elimination System	Action	RA	40 CFR 122.26	Yes
Radioactive waste management	Action	TBC	DOE Order 435.1	Yes

a. A = applicable requirement, RA = relevant and appropriate requirement, TBC = to-be-considered requirement
b. Evaluation criteria met not including the vadose zone contribution.
ARAR = applicable or relevant and appropriate requirements
CFR = *Code of Federal Regulations*
DOE = U.S. Department of Energy
IDAPA = Idaho Administrative Procedures Act
TSD = treatment, storage, and disposal

4.5.2.3 Chemical-Specific (Applicable or Relevant and Appropriate Requirements). The ISV alternative would meet RAOs for direct contact because the solidified, buried waste, and its overlying surface barrier would prevent human and ecological receptors from direct exposure. This alternative would also reduce or prevent mobility of COCs and reduce infiltration. Not including the contaminants presently in the vadose zone, the ISV alternative would inhibit COC migration from buried waste to underlying groundwater and meet the RAOs identified for groundwater.

Chemical-specific requirements of state and federal air quality standards would be met during construction and remediation. Idaho state requirements include controlling toxic air pollutants (IDAPA 58.01.01.585 and .586), ambient air quality standards for specific air pollutants such as particulate matter (IDAPA 58.01.01.577), and emission of fugitive dusts (IDAPA 58.01.01.650). Federal requirements include NESHAPs (e.g., radionuclides) (40 CFR 61) and NAAQS (e.g., particulate matter) (40 CFR 50).

4.5.2.4 Location-Specific (Applicable or Relevant and Appropriate Requirements). The location-specific ARARs for the ISV alternative are the same as those for the Surface Barrier alternative (see Section 4.2.4.2).

4.5.2.5 Action-Specific (Applicable or Relevant and Appropriate Requirements). The substantive portions of NESHAPs for hazardous waste combustors (40 CFR 63 Subpart EEE) are applicable for emission control of the ISV system if the system is defined as an incinerator in accordance with 40 CFR 260.10. The NESHAP establishes the MACT emission standards for constituents and destruction and removal efficiencies as well as RCRA requirements for incinerators (40 CFR 264 Subpart O), including design and operation. These requirements would be met through appropriate engineering controls.

Because ISV would leave waste in place, RCRA Subtitle C requirements for closure, postclosure, and landfills also may be relevant and appropriate because the SDA is not a new or existing RCRA-regulated unit (40 CFR 264 Subparts G and N, as adopted by reference in the State of Idaho "Rules and Standards for Hazardous Waste" [IDAPA 58.01.05]). Design and operation of the surface barrier would meet the RCRA substantive requirements for a top liner. In addition, the RCRA Subtitle C requirements for air emission standards for process vents (40 CFR 264 Subpart AA) and equipment leaks (40 CFR 264 Subpart BB) may be applicable for some equipment used during ISV and ISTD operations (e.g., if emission levels of restricted hazardous volatile waste are above established thresholds). If applicable, these requirements would be met by using appropriate engineering controls. In addition, RCRA general groundwater-monitoring requirements (40 CFR 264.97) using monitoring wells to detect the presence of COCs in the underlying aquifer would be applicable to the ISV alternative. Provisions for groundwater monitoring are included in this alternative.

Any organic vapors that may have accumulated beneath the biotic barrier following remediation would be collected, removed, and treated by the active OCVZ treatment system (OU 7-08) and the designed passive gas-collection layer operating in the modified RCRA Subtitle C cap. The EPA Office of Air Quality Planning and Standards is developing a new MACT for the remediation site source category. This MACT, projected to be effective after 2002, would apply to remediation sites that are major sources of organic hazardous air pollutants. If applicable to CERCLA sites, all vents, remedial material management units, and associated equipment components involved in the remedial activity could require emission controls. These requirements would be followed.

Vitrification of Pad A waste would require restaging the waste into a new deep pit. It is assumed that DOE would use the AOC concept described in *Management of Remediation Waste Under RCRA* (EPA 1998), and as allowed under CERCLA, to permit moving waste, including the hazardous waste associated with Pad A, without violating RCRA treatment, storage, and disposal requirements. The applicability of RCRA Subtitle C to move and consolidate previously disposed waste or contaminated media depends on whether these activities occur in the same AOC. Because the deep pit is proposed for construction next to Pad A, it is assumed that the transfer would occur within the same AOC.

Institutional controls are often included in remedies to enhance long-term management protection. These controls supplement engineered remedies (40 CFR 300.430[a][1]). Institutional controls including security measures, access controls, fencing, and land-use restrictions are components of this alternative. These controls would help prevent possible exposure to waste by human intruders and biota. The controls would also meet applicable DOE requirements for residual radioactivity left in place, including the related provisions of DOE Order No. 5400.5.

As required, NPDES storm water discharge protections and best management practices would be implemented for storm water controls, road building, waste management, and other related remedial activities as appropriate. Applicable DOE TBC requirements for protection of human health would be met during remedial activities.

Requirements of DOE Order 435.1 would be met. This order specifies that all DOE radioactive waste is to be managed in a manner that is protective of worker and public health and safety and the environment.

4.5.2.6 Long-Term Effectiveness and Permanence (Balancing Criterion). Implementation of this alternative would provide for reliable long-term protection. Applying ISV to waste in the TRU pits and trenches would produce a stable, leach-resistant waste form. The VOC constituents would be destroyed through the ISV treatment process or pretreatment by ISTD, wherever it is applied. Most inorganic constituents, including most radionuclides, would be encapsulated in a glass-like matrix. Some SVOCs (i.e., VOCs with low boiling points, and volatile radionuclides and metals [e.g., cadmium, Cs-137, lead, and mercury])would evaporate and condense on adjacent soil. In this event, these constituents may not be immobilized in the glass-phase of the final waste form. However, with construction of the surface barrier, any contamination that condenses on the overburden soil would be effectively isolated and contained, preventing human and ecological exposure.

Salt known to be present in the waste may also melt and migrate away from the melt zone well before the melting temperature of the soil is reached. Molten salt can wick into pores of the soil and may entrain other alkalis (e.g., Cs-137 and dissolved heavy metals) as they migrate. Therefore, a salt zone, if created, may have higher potential for leaching any entrained COCs than the more stable glass-like matrix. ISV testing would be required to determine if a salt zone would be formed, to identify the types and amounts of COCs that would partition into this phase, and to assess the long-term durability of a salt phase. Grouting the SVRs and trenches with high concentrations of the fission and activation products C-14, I-129, Nb-94, and Tc-99, which are in metallic form, immobilizes these contaminants and minimizes potential for migration.

Though this alternative would be effective at minimizing future risk, it is assumed that some COCs would have been released before remedial action could take place. The amount released to date and current release rates are not known with certainty. However, conservative estimates indicate that preremediation release may result in groundwater contamination posing a risk greater than 1E-04. Modeling indicates that this risk would peak by 2110 and would extend beyond the boundary of the SDA for a distance of approximately 460 to 600 m (1,500 to 2,000 ft). Therefore, this alternative could require institutional controls that prohibit using groundwater within this buffer zone.

The key components of the ISV alternative's long-term effectiveness and permanence include residual risk, the reliability of the treated waste system over the long term, and the effectiveness of controls.

4.5.2.6.1 Risk Modeling Assumptions—Simulations show groundwater ingestion risks where the highest concentrations occur in the model. Releases of COCs from vitrified waste were assumed to occur by corroding the surface of vitrified HLW glass. The rate used was 1E-05 gm/cm^2-d, which is based on results from an ISV demonstration at the INEEL in 1990 (Callow 1991); this value is equivalent to the established corrosion rate for vitrified HLW. The demonstration was a reliable indication of long-term durability at the time the test was performed, but it is now believed the vapor hydration test should also be performed to estimate long-term durability of vitrified radioactive waste (McGrail 2000). Therefore, significant uncertainty exists in assigning a corrosion rate to vitrified waste in the SDA. Though the corrosion rate is expected to be much lower than indicated by results from the demonstration, data to improve predictions of the long-term durability of vitrified SDA waste and soil are not available.

Releases from melted metal occur by corroding the surface of metal, which is assumed to have the same surface area as untreated waste metals. Using unchanged waste geometry coupled with a metal corrosion rate of 2.2E-04 mm/year (the expected rate of corrosion of stainless steel in a weak salt brine) (Adler-Flitton, Nagata, and Norby 2001) is a very conservative assumption. Realistically, the surface area available for corrosion would be greatly reduced and a large portion would be protected from corrosion by the vitrified matrix above the metal phase. However, data are not presently available to refine these modeling assumptions. Other factors, such as impurities in the metal, also could modify the effective corrosion rate.

For types of waste treated by ISG, contaminant releases from the grout were conservatively assumed to occur by diffusion from within 2-ft-diameter grout columns. These columns would be formed by the injection of grout into the waste to create interlocking columnar monoliths (see Section 4.2.5.1). For modeling purposes, the surface available for leaching was assumed to be the outside surface of the 2-ft-diameter columns. This is based on a conservative assumption that the points of contact between columns may be a zone of weakness where cracks could form. In reality, the surface area available for leaching would be much lower, but few applicable data are available to support improved predictions for grouted waste over long periods.

Certain COCs with carcinogenic risks greater than 1E-06 and unacceptable noncarcinogenic hazards (hazard indexes greater than 1.0) are assumed to be destroyed or partially removed by treatment in this alternative. These COCs include nitrates and all VOCs, including CCl_4, methylene chloride, and tetrachloroethylene. Nitrates and VOCs were assumed fully removed at the TRU pits and trenches during the application of ISTD and ISV.

Water was assumed to infiltrate the modified RCRA Subtitle C Barrier at a rate of 0.114 cm/year. Using the DUST-MS model, the infiltrating water was assumed to flow through the columnar joints in the grout and around the glass monolith at volumetric rates equal to the surface area of the waste sites times the infiltration rate. The volumes of water contacting treated waste in a given period were assumed to dissolve contaminants released in the same period, up to their solubility limits in water. Because of modeling limitations, the chemical alteration of infiltrating water as it passes through the grouted and vitrified waste could not be represented; hence, rates of release modeled may be higher or lower than would be expected. The concentrations of contaminants released from the source term were input to the TETRAD model for estimating groundwater concentrations and drinking-water risk. In addition, the cap and its integral biotic barrier were assumed effective in preventing the intrusion of plant roots into the soil above the melt where SVOCs would have condensed. Testing and further analysis would be necessary to quantify the amounts of condensed SVOCs and their potential impact to risk through the groundwater pathway.

4.5.2.6.2 Magnitude of Residual Risk—The magnitude of residual risk associated with the ISV alternative is illustrated in Figure 4-13. This figure shows the cumulative carcinogenic risk over time caused by ingestion of groundwater impacted by release of residual contaminants in the vitrified TRU pits and trenches and grouted SVRs. The figure provides two risk projections: (1) risk associated with postremediation release from the residual source term in the SDA only, and (2) total risk represented by release of residual source-term contaminants plus postulated contamination in the vadose zone before the application of ISV in the SDA. The risks represent exposure at the point of maximum groundwater contamination; the simulated location associated with potential COCs in the vadose zone lies at the southern edge of the SDA. Modeling results are that the near-term risks are dominated by contamination that may have been released to the vadose zone before ISV. However, high uncertainty exists in assumptions used in the risk modeling, as the mass of COCs in the vadose zone and the rates of release from the SDA are unknown.

As shown in the figure, carcinogenic risk associated only with postremediation release of residual SDA contaminants would reach approximately 4E-06 in 2,000 years and then stabilize between approximately 2E-06 and 5E-06 in 2,000 to 10,000. Carbon-14 accounts for approximately 80% of the risk 2,000 years. Technetium-99 and I-129 are other significant contributors. After 2,000 years, uranium isotopes dominate risk.

In the carcinogenic risk curve shown in Figure 4-14, the potential influence on risk levels because of contaminants previously released from the source term to the underlying vadose zone are presented.

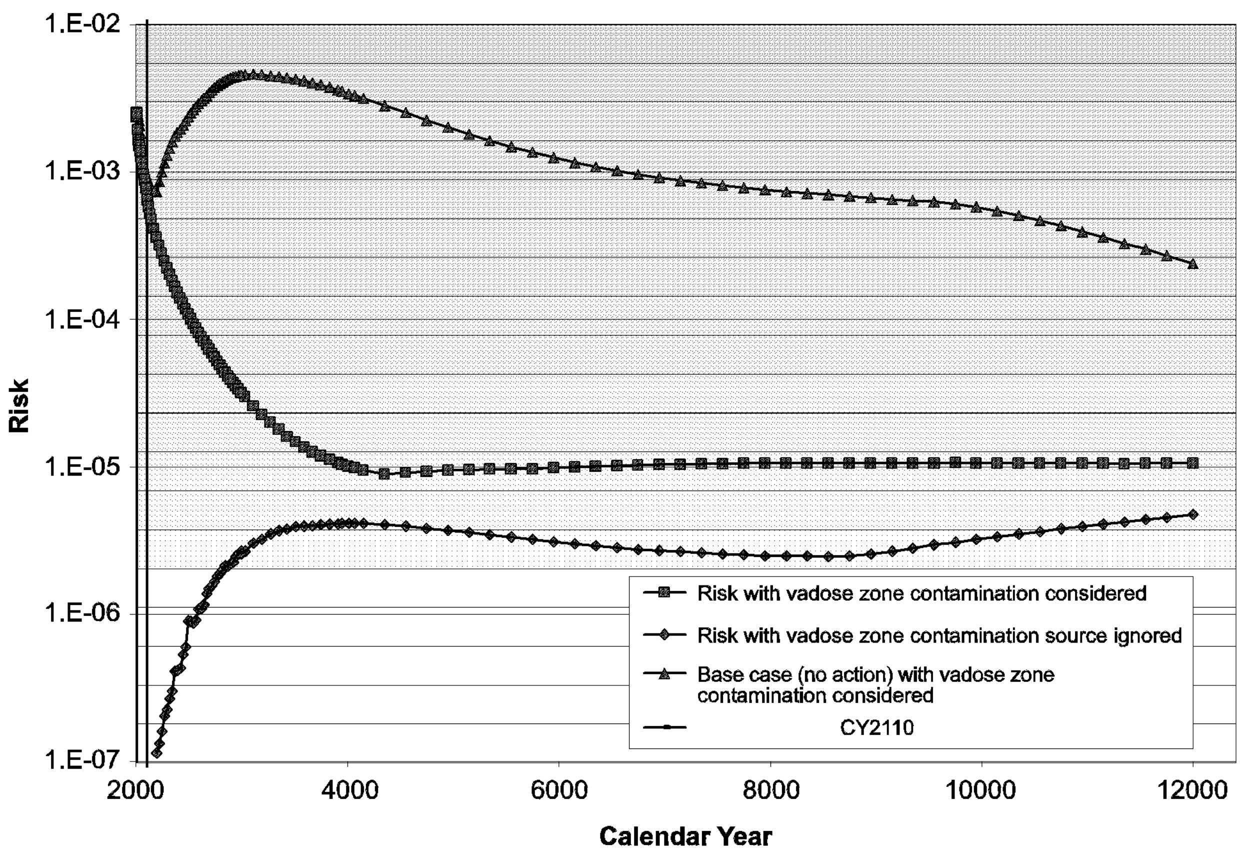

Figure 4-14. Carcinogenic risk for the In Situ Vitrification alternative.

Model results indicate that contaminants released to the vadose zone before implementing the remedial action may pose cumulative groundwater risk higher than 1E-04 for a zone that extends 1,500 ft beyond the SDA boundary. The residential hazard index for the ISV alternative is assumed less than 1.0. As stated previously, risk modeling indicates that the hazard index attributable to postremediation contaminant release under the Surface Barrier alternative would be less than 1.0. With treatment provided by ISV, the residual hazard index for the ISV alternative would be lower than that for the Surface Barrier alternative.

4.5.2.6.3 Adequacy of Reliability and Controls—The ISV and ISG waste forms would be physically and chemically stable over geologic time. Little or no long-term operational requirements for the treated waste forms are envisioned other than monitoring.

In addition to the physical chemical stability of the glass monolith and grouted matrix, the multilayered barrier would provide additional protection of human health and the environment by reducing infiltration and inhibiting biotic intrusion from the surface. The barrier also would minimize precipitation that reaches the glass and grouted waste forms, thereby further reducing leaching of the waste.

Monitoring treated waste and maintaining the barrier would be required in perpetuity to ensure effectiveness and permanence of the remedy. Regular monitoring (e.g., visual inspections, surface-elevation surveys) would be performed to detect compromises in the integrity or effectiveness of the barrier. The barrier would be maintained and repaired as required to achieve the original performance standards. Because of the required life span of the remedy, it is assumed that portions of the barrier would need to be repaired or reconstructed periodically and that the entire barrier would need to be replaced once every 500 years.

The long-term reliability and performance of the ISV and ISG treatment would be assessed through monitoring of groundwater, the vadose zone, air, fauna, and surface vegetation. In addition, a network of monitoring probes would be installed throughout the grout monolith before the grout cures, to collect moisture and vapor samples and monitor temperature, redox, and pH conditions over time.

To ensure protectiveness, active institutional controls would be required to limit land use near the SDA. A prohibition on drilling and using groundwater within a buffer zone around the SDA would be necessary. Access controls would be implemented and maintained in perpetuity to prevent intrusion into the waste.

4.5.2.6.4 Summary of Long-Term Effectiveness—Fate and transport modeling indicates that the postremediation peak carcinogenic risk would be less than 1E-04 and the hazard index would be less than 1.0 for the groundwater ingestion pathway, when the postulated contamination in the vadose zone is not included. The ISV and grout monoliths would be chemically and physically stable over geologic time. Appropriate institutional controls and operation and maintenance programs, plus periodic barrier repair and replacement, would provide additional long-term control for the vitrified and stabilized waste. Should the potential COCs in the vadose zone at the time of remediation cause groundwater contamination to exceed health-based levels in a zone beyond the boundary of the SDA, institutional controls would be required to prevent access to, and use of, any contaminated groundwater. Therefore, the ISV alternative could be an effective and permanent remedy.

4.5.2.7 Reduction in Toxicity, Mobility, or Volume Through Treatment (Balancing Criterion). As indicated, selected waste sites contributing to the potential risk to human health and the environment would be treated in place with ISV. Organic waste contaminants at the ISV sites would be destroyed or their masses reduced significantly. Most inorganic contaminants would be immobilized in glass, but some would be concentrated in the less leach-resistant metal zone at the base of glass melts. ISG applied to other selected waste sites would be effective in treating specific COCs (e.g., C-14). Off-gas treatment would be required in the ISV application to destroy or capture and treat volatile and airborne contaminants. The captured and treated off-gas contaminants would meet requirements for disposal at the INEEL. Further discussion on the quality and durability of the vitrified waste form is presented by Thomas and Treat (2002).

4.5.2.8 Short-Term Effectiveness (Balancing Criterion). Key components of the ISV alternative's short-term effectiveness entail protecting the public, workers, and environment as it is implemented.

4.5.2.8.1 Protecting the Community During Remedial Actions—Significant uncertainties exist about implementation of ISV at the SDA. However, advancements in ISV technology and results from cold testing would allow appropriate engineering and administrative controls to be developed to ensure safe implementation. At a minimum, traffic within the INEEL during the acquisition of borrow material would increase. If borrow material was obtained from off-INEEL sources, increased traffic would affect communities on and off of the INEEL. Traffic control plans to minimize the increase in transportation risk to both the on- and off-INEEL communities would be .

4.5.2.8.2 Protecting Workers During Remedial Actions—Remediation workers could be exposed to radionuclides in the surface soil during placing of the 10-ft-thick soil cover to protect against melt expulsion events. Conversely, the 1- to 2-m (3- to 6-ft) overburden soil present over the SDA makes significant exposure unlikely. If a release of contamination to the environment were to occur during ISTD or ISV, PPE and vehicles modified with positive-pressure ventilation system cabs and HEPA filters could be used to minimize exposure to residual radioactive contamination. Equipment modified for use in radioactively contaminated environments is available at the INEEL from previous remedial actions.

Other risks to workers would result from routine physical hazards, such as moving heavy equipment, including cranes, trucks, off-gas hoods, trailers, electrodes, and piping manifolds, during construction and operations. The risk of melt expulsion events, thermal hazards, and electrical hazards also would be elements of the ISV alternative. Including ISTD as a pretreatment and placing additional overburden soil would mitigate melt expulsion events. Training and using PPE would reduce thermal and electrical risks. Potential exposure to VOCs and other off-gas components would be limited through using hoods and off-gas treatment systems. Additionally, an explosion involving nitrate salt and reducing agents present in some of the waste streams is a potential chemical and physical hazard associated with ISV. Mitigation would be achieved by placing at least 3 m (10 ft) of overburden over the area to be vitrified.

A report prepared in support of this PERA (Schofield 2002) estimated risks to workers who are implementing this alternative. The evaluation considered direct external radiation exposure and exposure to mechanical injuries for remediation workers. No risks to the public were projected for this alternative because no off-INEEL transportation of hazardous materials would occur. Engineering controls during implementation would preclude the release of particulate radioactive materials. Estimated risks are:

- Cancer = 10.5
- Injury = 278.0
- Fatality = 0.62.

The evaluation predicts that during implementation of the ISV alternative, approximately 10 people would develop cancer because of exposure to hazardous substances, including radioactive material and radiation fields. Approximately 278 injury accidents with less than one fatality are estimated to occur during implementation.

Short-term risks were also quantified for off-normal occurrences (accidents) during implementation of the remedial action (Schofield 2002). These risks are portrayed in terms of the effects on a maximally exposed individual. The worst-case unmitigated accident scenario established for the ISV alternative was a melt expulsion event scenario. For this event, the unmitigated dose was reported at 37,000 rem, 50-year committed effective dose equivalent. However, for the subsurface planar ISV approach, as described in this report, the mitigating controls would reduce the maximally exposed individual exposure by a minimum of 1/10,000 or 3.7 rem, 50-year committed effective dose equivalent. The estimated lifetime cancer risk for the potential receptor is 2.33E-03.

Criticality is not an issue with respect to implementing ISV in the SDA for several reasons, but primarily because fissile isotopes would be dispersed (rather than concentrated) throughout the vitrified mass (Thomas and Treat 2002).

Occupational exposures would be kept ALARA and below the limits set forth in 10 CFR 835.202, "Occupational Dose Limits for General Employees." Radiological occupational exposures also would be kept ALARA and below the limits set forth in 10 CFR 835.202 of less than 5 rem/year.

The environmental monitoring component of this alternative is based on existing procedures that incorporate engineering, administrative, and PPE measures to ensure worker protection during monitoring activities.

4.5.2.8.3 Environmental Impacts Associated with Construction—Appropriate engineering and administrative controls would be developed to ensure safe implementation with minimal risk to the environment. Other environmental impacts include potential particulate emissions associated with construction activities and increased construction-related traffic. Particulate emissions would be controlled using dust-suppression techniques to ensure that exposure to off-INEEL receptors does not exceed 25 mrem/year total effective dose equivalent from all exposure pathways and does not exceed 10 mrem/year total effective dose equivalent through the air pathway in accordance with DOE Manual 435.1-1.

4.5.2.8.4 Time Until Remedial Action Objectives Are Achieved—Preliminary schedules project that the alternative could be completed within 24 years of an approved ROD. The ISV alternative would satisfy all RAOs, with the ultimate effectiveness of this alternative verified after the cap is constructed, operated, and monitored for some time.

4.5.2.9 Implementability (Balancing Criterion). Key components of the ISV alternative's implementability are technical and administrative feasibility and availability of services and materials.

4.5.2.9.1 Technical Feasibility—The ISV process, in particular the Subsurface Planar approach, is capable of processing selected SDA waste and producing a high quality glass waste form that is resistant to leaching over geologic time periods. The average size and depth of the waste appears amenable to applying subsurface planar ISV. The composition of the INEEL soil, the soil-to-waste ratio, and temperature and size of the melt appear to favor formation of a high-quality waste form.

However, certain waste conditions, including sealed, buried drums, large voids, and large metal forms have the potential to impede ISV processing. Remedial designers may require additional pretreatment beyond that planned or may exclude certain areas to avoid processing problems. In the past, these problems have included fires in the off-gas hood, explosions, and other violent melt expulsion events. Five of the 100 full-scale melts experienced at least one of these events while melting, resulting in damage to the equipment and termination of the project. The engineering study developed in support of the PERA describes the problems in detail and contains descriptions of two of the projects in which melt expulsion events occurred (Thomas and Treat 2002).

The wide range of hazardous constituents, and the uncertainty of their concentration and distribution, also presents a challenge for the design of the off-gas treatment system. The list of contaminants present at the SDA is extensive and complex, ranging from heavy metals and radionuclides to VOCs. Volatile and semivolatile metals, particulates, and products of pyrolysis of organics would be generated from an ISV melt. Examples of hazardous off-gas components include chloroform, I-129, benzene, cadmium, methylene chloride, tritium, nitrous oxides, and mercury. The technical feasibility of treating such constituents would depend on regulatory limits and the emission quantities and rates of emission derived from a more complete characterization of the waste streams.

While the ISV technology has been applied successfully in more than 100 melts over a period of about 10 years, the majority of the applications have been implemented at chemically contaminated soil sites. The technology has never been applied at a site where the amount of radiological material posed such a significant hazard as at the SDA. The presence of combustible, liquid, and reactive materials further complicates applying ISV at the SDA. Currently, it is unclear what measures would be required to adequately protect workers during ISV processing. Though a detailed safety analysis has not been completed, the potential for melt expulsion events and underground fires to expose workers to thermal, chemical, and radiological hazards remains despite mitigative features included in the alternative. The subsurface approach of planar ISV melting would significantly improve safety operations, but additional testing would be needed before requirements could be established for systems, structures, and components important to safety. Until these requirements have been defined, complications of this alternative are difficult to fully assess.

The implementability is rated low at this point because of the unresolved uncertainties about the potential for melt expulsion event, underground fires, and off-gas treatment. While researchers believe that new designs, in particular the subsurface planar ISV, would effectively mitigate many hazards traditionally experienced with ISV, the technology has not been sufficiently demonstrated on the variety and type of waste found in the SDA. Extensive analysis, design, and testing would be required before implementing ISV at the SDA.

4.5.2.9.2 Administrative Feasibility—Though most actions under this alternative would be implemented under CERCLA and would not require permits, substantive provisions of permits that would otherwise be required are considered ARARs. Any selected remedial alternative would be required to demonstrate ARAR compliance. The IDEQ and EPA would determine whether the selected remedy adequately addresses ARARs and would achieve ARAR compliance. Requirements for off-gas treatment would be stringent and may pose an implementation difficulty. Because the waste is not fully characterized, it may be difficult to design and permit an off-gas system to ensure air quality standards are not violated.

Safety disciplines, including radiation safety, industrial hygiene, and construction safety, are readily available at the INEEL. Regulatory compliance supports, including permitting required for construction activities, are also available. Though any changes to the storm water or Big Lost River systems may require assessing wetlands and associated environmental receptors or habitats, this issue is not anticipated to adversely affect the administrative implementability of this alternative.

Activities associated with the ISV treatment pose numerous nuclear hazards. According to DOE policy, all hazards need to be clearly identified and mitigated before the start of any nuclear operation. The approval process for any nuclear treatment or processing facility is inherently difficult and the uncertainties associated with ISV would further complicate the administrative approval.

4.5.2.9.3 Availability of Services and Materials—Currently, one commercial vendor is available to provide subsurface planar ISV services. Some equipment and services used in previous ISV remediation would be available, but given the potential consequence of an inadvertent radiological release, the equipment and systems, including the hood and off-gas treatment system, would be identified as safety-significant systems in accordance with DOE orders. That requires engineers to conservatively estimate the consequences to workers and the public that could result from normal operations and certain accident scenarios. In the case of ISV processing at the SDA, the preliminary conclusions are that the risks to workers would be significant enough to require specialized equipment. Determining safety risk would require designing and fabricating new equipment not readily available from the commercial ISV provider. The difficult design, manufacturing, and testing requirements associated with safety-significant systems structures and components substantially lower the implementability of this alternative.

One power line at the OU 7-10 substation can provide 15 MW of power. This alternative incorporates construction of an additional substation to meet project-specific power demands.

4.5.2.10 Cost (Balancing Criterion). The net present value of the ISV alternative is estimated at $1,197 million, as shown in Table 4-12. The net present value for capital is estimated at $1,193 million, and O&M costs are estimated at $4 million. The primary capital costs are associated with the vitrification application.

Table 4-12. Total estimated costs for the in situ vitrification alternative with contingency.

Cost Element	Total Costs ($M)	Net Present Value ($M)
Capital costs		
In situ vitrification and ISTD treatment	991.8	—
Surface barrier	70.9	—
In situ grouting and foundation grouting	191.7	—
Pad A retrieval and treatment	163.0	—
Testing	109.2	—
Management, design, and reporting	258.5	—
Total capital costs	1,785.1	1,193.3
Operating and maintenance		
Monitoring and surveillance	16.7	—
Cover maintenance	9.0	—
Fencing and signage	0.3	—
Management	4.2	—
Total operating and maintenance costs	30.2	4.1
Total	**1,815.3**	**1,197.3**

ISTD = in situ thermal desorption

A cost evaluation has been performed to show the sensitivity of the total costs for the ISV alternative when melt production rates are varied. Figure 4-15 shows the projected cost increase if the power-on time for each melt were increased from 8 days.

As illustrated, if ISV melt production rates slow from a power-on time per melt of 8 days to 16 days and the schedule for completing the alternative established for the 8-day power-on cycle is retained for the 16-day power-on cycle, total costs would be estimated to increase from $1.8 to $2.6 billion. While the costs increase in a nearly linear fashion, costs do not double when the power-on melt time is doubled. This demonstrates that, while production rates are a significant cost factor for the ISV alternative, other substantial costs could be incurred independent of the production rate.

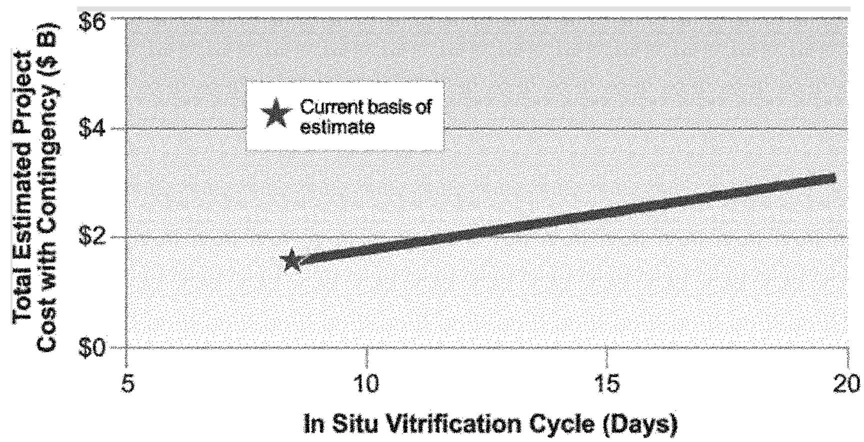

Figure 4-15. Sensitivity analysis comparing in situ vitrification production rates and total cost.

4.6 Alternative 5—Retrieval, Treatment, and Disposal

4.6.1 Alternative Description

The RTD alternative involves retrieval, ex situ treatment, and disposal of onsite buried waste within the SDA. Scope of this alternative is similar to that of in situ treatment alternatives, in that the primary RTD technologies focus on remediating the RFP waste in Pits 1 through 6 and Pits 9 through 12, Trenches 1 through 10, and Pad A. The basic premise of this alternative is that TRU waste and soil would be retrieved from these disposal units, characterized, treated as required to meet WAC, packaged, and then transported to WIPP for final disposal. All other retrieved materials, including LLW and MLLW, would be treated onsite to meet regulatory and risk-based requirements, then placed in an onsite, engineered disposal facility.

A summary of the detailed process required to implement the RTD alternative from signing of the ROD through site closure is presented in Figure 4-16. Bulleted items identify technical components of the process.

Retrieval, Treatment, and Disposal Alternative Remediation Strategy

Retrieval and ex situ treatment of buried waste materials. Retrieved TRU waste would be transported off-Site to the Waste Isolation Pilot Plant (WIPP) for disposal. All other retrieved waste would be treated on-Site to meet risk-based and regulatory standards and then disposed of at the Idaho National Engineering and Environmental laboratory (INEEL) in an engineered long-term facility.

Key Elements:
(1) Waste retrieval
(2) Ex situ treatment
(3) Transuranic waste disposal at WIPP
(4) Low-level waste and mixed low-level waste disposal at INEEL landfill
(5) Selective in situ grouting at designated waste sites
(6) In situ thermal desorption in areas of high volatile organic compounds
(7) Installation of cap
(8) Institutional controls
(9) Long-term monitoring and maintenance

As shown in Figure 4-16, the RTD alternative also includes the in situ remediation of the activation and fission product waste within the SVRs and the LLW trenches using the ISG technology. Applying ISG technologies in these areas is also a common remediation component of the Surface Barrier, ISG, and ISV alternatives. A second common supplemental technology is using the ISTD technology in the high VOC waste streams to minimize material-handling requirements during retrieval. Following remediation, excavated waste sites would be backfilled and systematically capped with a low-permeability, modified RCRA Subtitle C cap. Ancillary facilities and programs would be established to maintain the cover and to facilitate long-term monitoring of the area.

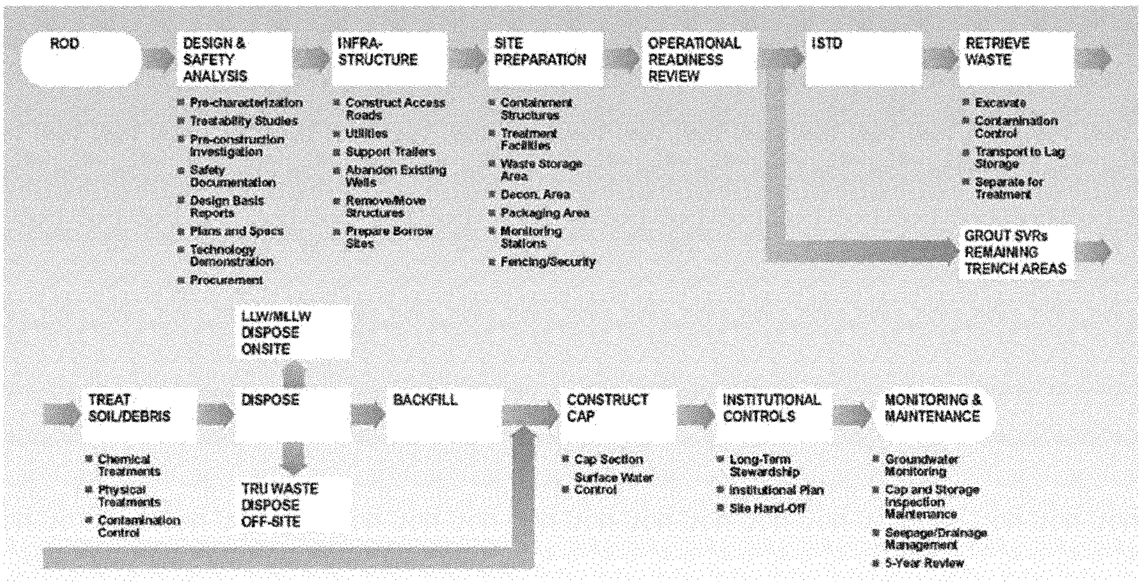

Figure 4-16. Process summary of the Retrieval, Treatment, and Disposal alternative.

Implementing the elements of the RTD alternative is relatively complex. The basic elements are outlined in Figure 4-17 and individually discussed in the following subsections.

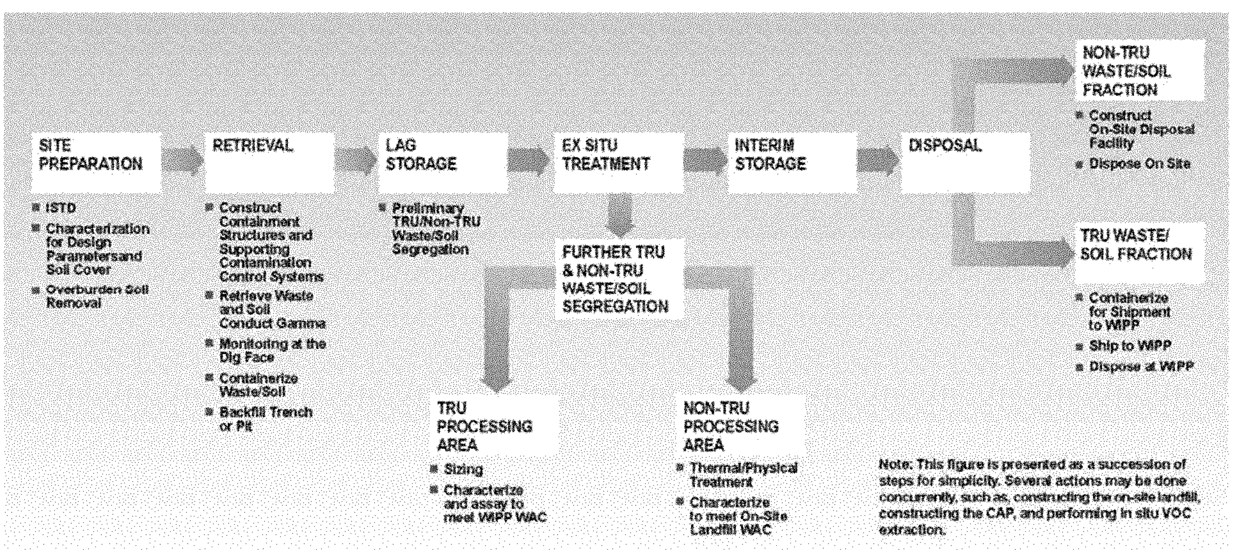

Figure 4-17. Retrieval, ex situ treatment, and disposal actions.