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Engineering Evaluation/Cost Analysis for the OU 7-13/14 Early Actions Beryllium Project

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U.S. Department of Energy
Idaho Operations Office

EXECUTIVE SUMMARY

This engineering evaluation and cost analysis document is being prepared for public comment. This document evaluates two options and recommends using in situ grouting to isolate beryllium reflector blocks buried at the Subsurface Disposal Area within the Idaho National Engineering and Environmental Laboratory. This action is being evaluated to mitigate C-14 release while being consistent with the final remedy.

Field-monitoring data and modeling of contaminant fate and transport from the *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area* suggest that release and migration of mobile, long-lived fission and activation products (including C-14) pose risk from the Subsurface Disposal Area to the groundwater in the near term (less than 100 years) and to the Snake River Plain Aquifer in the long term (peak risk in approximately 300 years). Beryllium-block corrosion and the effects of water infiltrating through areas where the beryllium reflector blocks are buried in the Subsurface Disposal Area have caused C-14 to migrate.

In situ grouting uses conventional technology to stabilize the beryllium reflector blocks buried in soil vaults and trenches, thereby mitigating the release of C-14. Grout will be injected to encapsulate the beryllium reflector blocks and to minimize infiltration of water to reduce corrosion of the blocks, release of contaminants from the blocks, and transport of those contaminants to the groundwater. The risk to human health can be greatly reduced through early action to stabilize this waste and to reduce infiltration.

This action is being proposed under a non-time-critical removal action. Under a non-time-critical removal action, a removal action can be taken to abate, prevent, minimize, stabilize, mitigate, or reduce the release or threat of release of contaminants. An engineering evaluation and cost analysis is required under the *Code of Federal Regulations* Section 300.415(b)(4)(i) of the National Oil and Hazardous Substances Pollution Contingency Plan for all non-time-critical removal actions.

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ACRONYMS

ABRA	*Ancillary Basis for Risk Analysis*
ARAR	applicable or relevant and appropriate requirement
ATR	Advanced Test Reactor
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ETR	Engineering Test Reactor
FFA/CO	Federal Facility Agreement and Consent Order
INEEL	Idaho National Engineering and Environmental Laboratory
ISG	in situ grouting
MTR	Materials Test Reactor
NTCRA	non-time-critical removal actions
OU	operable unit
PERA	*Preliminary Evaluation of Remedial Alternatives*
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation and feasibility study
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SVR	soil vault row
TRU	transuranic
WAG	waste area group

Engineering Evaluation/Cost Analysis for the OU 7-13/14 Early Actions Beryllium Project

1. INTRODUCTION

This engineering evaluation and cost analysis is intended to aid the U.S. Department of Energy Idaho Operations Office in identifying a preferred response action alternative to reduce the release of fission and activation products, specifically C-14, from beryllium reflector blocks buried in the Subsurface Disposal Area (SDA). The SDA is a radioactive waste landfill at the Radioactive Waste Management Complex (RWMC), which is part of the Idaho National Engineering and Environmental Laboratory (INEEL).

Beryllium is of particular interest because it is the primary source of C-14 being released and contains approximately 19% of the total C-14 inventory in the SDA. Although this action addresses only 19% of the total C-14 activity in the SDA, the majority of the mobile C-14 activity would be stabilized by this action. Data in the *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area* (Holdren et al. 2002) show that a small set of long-lived, mobile radionuclides in relatively unstable waste forms in the SDA pose an unacceptable risk to the Snake River Plain Aquifer during the next 300 years (peak risk). This action is being implemented to mitigate the threat of C-14 to human health from the beryllium reflector blocks. This action is being evaluated to mitigate C-14 release from the beryllium blocks, and is consistent with the final remedy for the entire SDA.

1.1 Purpose

Under the "National Oil and Hazardous Substances Pollution Contingency Plan" (40 CFR 300) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980), an engineering evaluation and cost analysis must be prepared for all non-time-critical removal actions (NTCRA). This report fulfills that requirement for a NTCRA.

1.2 Scope

This document provides the information necessary to show that a potential threat of C-14 exists and the origin of this contamination. Two alternatives are also presented so that a decision can be made as to the appropriate action necessary to mitigate the release of C-14.The U.S. Department of Energy (DOE), as the lead agency, has determined that a removal action is appropriate, and the planning for the action must begin. Both the Idaho Department of Environmental Quality and the U.S. Environmental Protection Agency (EPA) agree that a NTCRA action is warranted to protect human health and the environment. Through the NTCRA process, the risks presented in this document will be mitigated in a much more timely manner.

1.3 Site History

This section provides a brief history of the site, its operations, and the regulatory background. Figure 1 provides a map of the INEEL showing the location of RWMC and other major facilities.

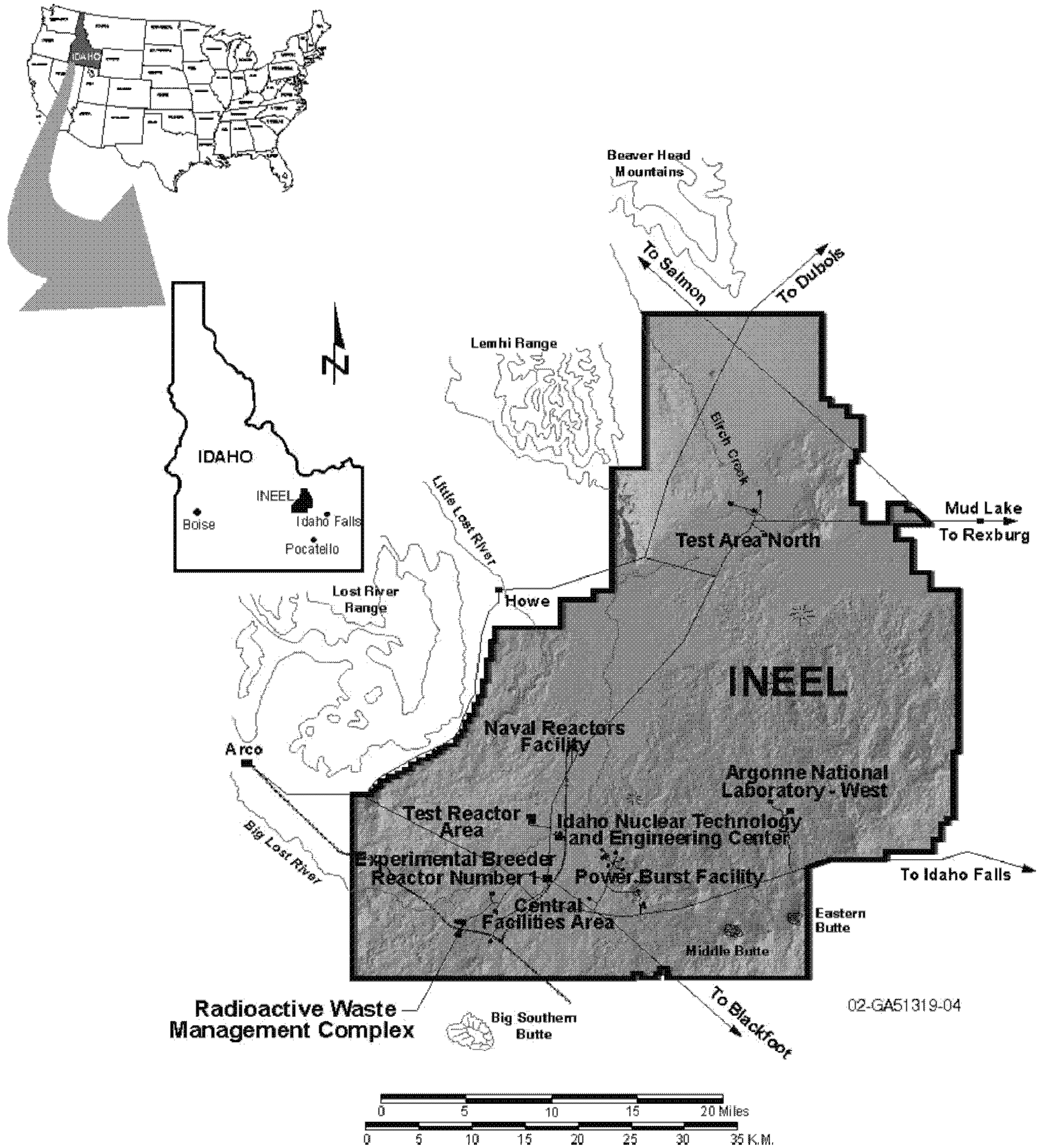


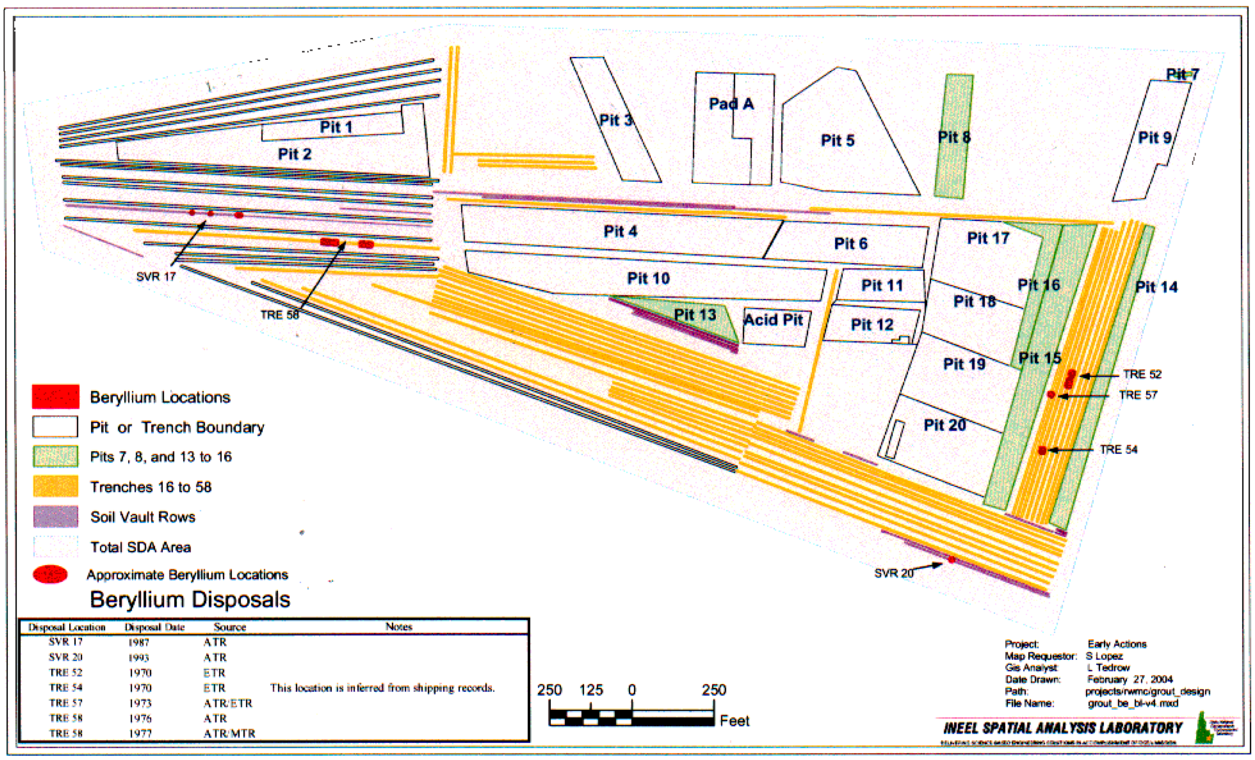
Figure 1. Map of the Idaho National Engineering and Environmental Laboratory showing locations of the Radioactive Waste Management Complex and other major facilities.

1.3.1 Background of the Idaho National Engineering and Environmental Laboratory

The INEEL is located in southeastern Idaho and occupies 2,305 km^2 (890 mi^2) in the northeastern region of the Snake River Plain. Regionally, the INEEL is nearest to the cities of Idaho Falls and Pocatello and to U.S. Interstate Highways I-15 and I-86. The INEEL extends nearly 63 km (39 mi) from north to south, is about 58 km (36 mi) wide in its broadest southern portion, and occupies parts of five southeast Idaho counties. Public highways (i.e., U.S. 20 and 26 and Idaho 22, 28, and 33) within the INEEL boundary are accessible without restriction. Otherwise, access to the INEEL is controlled. Neighboring lands are used primarily for farming or grazing, or are in the public domain (e.g., lands managed by the U.S. Bureau of and Management).

1.3.2 Background and Operations of the Radioactive Waste Management Complex

Currently, the RWMC covers 71.6 ha (177 acres) in the southwestern quadrant of the INEEL. This includes the administration area of approximately 8.9 ha (22 acres), the SDA, and the Transuranic Storage Area (established in 1970 at 23.3 ha [57.56 acres]). Figure 2 provides a map of the RWMC showing the location of pits, trenches, and soil vaults in the SDA. In 1952, the SDA was established at 5.26 ha (13 acres) for disposal of solid radioactive waste. Burial of defense waste with transuranic (TRU) elements from the Rocky Flats Plant began in 1954; by 1957 the original SDA was nearly full. In 1958, the SDA was expanded to 35.6 ha (88 acres), which remained the same until 1988 when the security fence was relocated outside the dike surrounding the SDA and the current size of 39.3 ha (97.14 acres) was established.



Disposal Location	Disposal Date	Source	Notes
SVR 17	1987	ATR	
SVR 20	1993	ATR	
TRE 52	1970	ETR	
TRE 54	1970	ETR	This location is inferred from shipping records.
TRE 57	1973	ATR/ETR	
TRE 58	1976	ATR	
TRE 58	1977	ATR/MTR	

Figure 2. Layout of the Radioactive Waste Management Complex showing pits, trenches, and soil vaults in the Subsurface Disposal Area.

From 1952 to 1970, radioactive waste was buried in pits, trenches, and soil vault rows excavated into a veneer of surficial sediment. This sediment is underlain by a thick series of basaltic lavas intercalated with sedimentary deposits. In 1970, the shallow burial of TRU waste ended, burial of low-level radioactive waste has continued and TRU waste has been stored on above-ground asphalt pads in retrievable containers. Between 1952 and 1997, approximately 215,000 m^3 of radioactive waste containing about 12.6 million Ci of radioactivity were buried at the SDA (French and Taylor 1998). A 1998 inventory of annual amounts of 38 radioactive buried contaminants (Becker et al. 1998) was updated in 2002 for 25 radionuclides in the *Ancillary Basis for Risk Analysis* (ABRA) (Holdren et al. 2002).

Between 1960 and 1963, the RWMC accepted radioactive waste from private sources such as universities, hospitals, and research institutes. This service stopped in September 1963 when commercial burial sites became available for contaminated waste from private industry. When the Transuranic Storage Area became operational, asphalt pads were constructed on which TRU waste was stacked and then covered with plywood, plastic sheeting, and 1 m (3 ft) of soil. From 1975 to 1996, air-support buildings were used to protect recently received waste containers during stacking operations. These support structures were emptied in 1996 and decommissioned in 1998.

Since 1985, waste disposals in the SDA have been limited to low-level radioactive waste from INEEL waste generators, and in the fall of 1988 the governor of Idaho banned all further shipments of TRU waste to the RWMC from out-of-state sources.

Contaminants in the SDA radioactive waste landfill thus include elements resulting from weapons manufactured at the Rocky Flats Plant, fission and activation products resulting from on- and off-INEEL reactor operations, and hazardous chemicals associated with all waste sources.

1.3.3 Regulatory Drivers for Remediation of the Subsurface Disposal Area

The INEEL is a federal facility, and DOE, as the responsible federal entity, is ultimately responsible for the INEEL. As such, DOE has the authority to identify and implement NTCRAs when they are deemed necessary. Federal statutes, agreements, and enforceable deadlines drive evaluation of the SDA for potential remediation actions. The INEEL was added to the EPA National Priorities List of Superfund sites (54 FR 48184, 1989) under CERCLA. In 1991, the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (DOE-ID 1991) established the procedural framework for identifying and implementing appropriate actions that must be implemented to protect human health and the environment at the INEEL in accordance with the following:

- National Contingency Plan (40 CFR 300)
- Comprehensive Environmental Response, Compensation and Liability Act
- Resource Conservation and Recovery Act (RCRA) (42 USC § 6901 et seq., 1976)
- Idaho Hazardous Waste Management Act (Idaho Code § 39-4401 et seq., 1983).

The action plan attached to the Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991) includes the original schedule for developing, prioritizing, implementing, and monitoring response actions. The action plan provides for remediation of RWMC under the designation of Waste Area Group (WAG) 7.[a] The SDA is currently being evaluated through a comprehensive CERCLA remedial investigation and feasibility study (RI/FS) under Operable Unit (OU) 7-13/14. Ultimately the RI/FS will lead to risk management decisions and selection of a final comprehensive remedial approach through development of a CERCLA record of decision. This action is not inconsistent with the envisioned final remedy.

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a. The FFA/CO lists 10 WAGs for the INEEL. Each WAG is subdivided into OUs. The RWMC is identified as WAG 7 and originally contained 14 OUs. Operable Unit 7-13 (transuranic pits and trenches RI/FS) and OU 7-14 (WAG 7 comprehensive RI/FS) were ultimately combined into the OU 7-13/14 comprehensive RI/FS for WAG 7.

2. CONTAINANT INFORMATION

2.1 Previous Investigations

Two previous studies have performed the following:

1. Analyzed the estimated cumulative human health and ecological risks of the SDA (Holdren et al. 2002)

2. Evaluated alternatives to identify and screen potential technologies and process options for remediating the SDA (Zitnik et al. 2002).

The ABRA (Holdren et al. 2002) presents an estimate of cumulative human health and ecological risks associated with the SDA. The ABRA assesses potential risk associated with OU 7-13/14 at the RWMC. Though the ABRA has no formal standing under the FFA/CO, it was prepared in accordance with EPA RI/FS guidance (EPA 1988). Primary elements of the ABRA include the following:

- Description of the nature and extent of contamination associated with WAG 7

- Evaluation of current and future cumulative and comprehensive risks to human health posed by waste buried in the SDA

- Performance of a limited, screening-level ecological risk assessment to validate the assumption that the SDA poses unacceptable risk to ecological receptors (DOE-ID 1998)

- Identification of contaminants of concern within WAG 7. Contaminants of concern are defined as those contaminants likely to require a risk management decision to address potential threats to human health and the environment.

The *Preliminary Evaluation of Remedial Alternatives for the Subsurface Disposal Area* (Zitnik et al. 2002) identifies a range of potential remedial alternatives for effective treatment for contaminated conditions at the SDA. More recent studies provide updated supporting information to identify radionuclides and waste forms that are candidates for early action. Carbon-14 in activated beryllium was identified as an important cause of near-term risk in the postoperational period.

Like the ABRA, the *Preliminary Evaluation of Remedial Alternatives* (PERA) (Zitnik et al. 2002) has no formal standing under the FFA/CO, but was prepared in accordance with EPA RI/FS guidance (EPA 1988). The PERA analysis evaluates remediation options for their ability to (1) protect human health and the environment and (2) meet specific regulatory requirements at WAG 7. The evaluation is based on preliminary evaluations of applicable or relevant and appropriate requirements (ARARs), remedial action objectives, and preliminary remediation goals. During the initial stage of the analysis, existing, demonstrated remedial technologies and process options were compiled, listed, and evaluated for technical applicability. The primary purpose of the initial evaluation or screening was to eliminate alternatives that could not be implemented or would not effectively mitigate risk.

Any technology or process option not applicable to the SDA was removed from further consideration. The remaining remedial technologies and process options form the pool from which assembled alternatives can be developed. The PERA also presents a preliminary set of assembled remedial alternatives.

2.2 Sources, Nature, and Extent of Contamination

The following sections provide historical data describing the beryllium reflector blocks as the source of contamination, which this action is designed to reduce.

2.2.1 Brief Description of Beryllium Reflector Block Disposal and Characterization in the Subsurface Disposal Area

Modeling of release and migration of C-14 for OU 7-13/14 has been limited to dissolved-phase approaches. However, C-14 can be released and migrate as a vapor, particularly in CO_2. Recent modeling to estimate the quantities and concentrations of radioactivity in beryllium blocks has focused on monitoring at a beryllium disposal in Soil Vault Row (SVR)-20 and an activated metal disposal in SVR-12. It should be noted that the C-14 has a half-life of 5,715 years.

2.2.1.1 Estimated Activity in Beryllium Blocks Buried in the Subsurface Disposal Area. Research reactors at the INEEL Test Reactor Area, including the Materials Test Reactor (MTR), the Engineering Test Reactor (ETR), and the Advanced Test Reactor (ATR), used beryllium reflectors. Beryllium was used as a neutron reflector to intensify the neutron flux in the reactor core. The amount of beryllium used as a reflector varied in each reactor (Mullen et al. 2003). The ATR reflector assembly consisted of a set of eight beryllium blocks and 16 beryllium outer shim control cylinders (see Figure 3). Each block was 129.5 cm (51 in.) long, approximately 40.6 cm (16 in.) square, and weighed 81,420 g (179.5 lb). When all eight blocks were assembled, their cross section was approximately 127 cm (50 in.) in diameter. For the ETR, the reflector assembly was essentially four slabs that surrounded the core; the MTR reflector assembly was much more complex. This document discusses the beryllium blocks as including the outer shim control cylinders.

Historically, reflector assemblies from the test reactors were replaced every 8 to 10 years because of swelling. The majority of irradiated beryllium reflector waste was disposed of in the SDA in three major events: 1976, 1977, and 1993. A total of 5,309 kg (11,703 lb) of beryllium was disposed of from the ATR, ETR, and MTR (Mullen et al. 2003). Early characterization efforts of the beryllium reflector blocks relied on modeling alone to develop the isotope inventories, and there was a concern that certain key nuclides were overestimated. To increase understanding of the inventory estimates, samples were taken from irradiated beryllium reflector blocks stored at the Test Reactor Area. The analysis was necessary to estimate C-14 content. Limitations on C-14 content for low-level waste destined for disposal in the SDA are defined in the waste acceptance criteria (DOE-ID 2001) based on the low-level waste operation performance assessment (Maheras et al. 1994; Case et al. 2000). Similar analysis had not been required for previous beryllium disposals because earlier versions of the waste acceptance criteria did not limit C-14. Current and future management of beryllium from reactor operations is and will be handled so that they will not be disposed of on the INEEL.

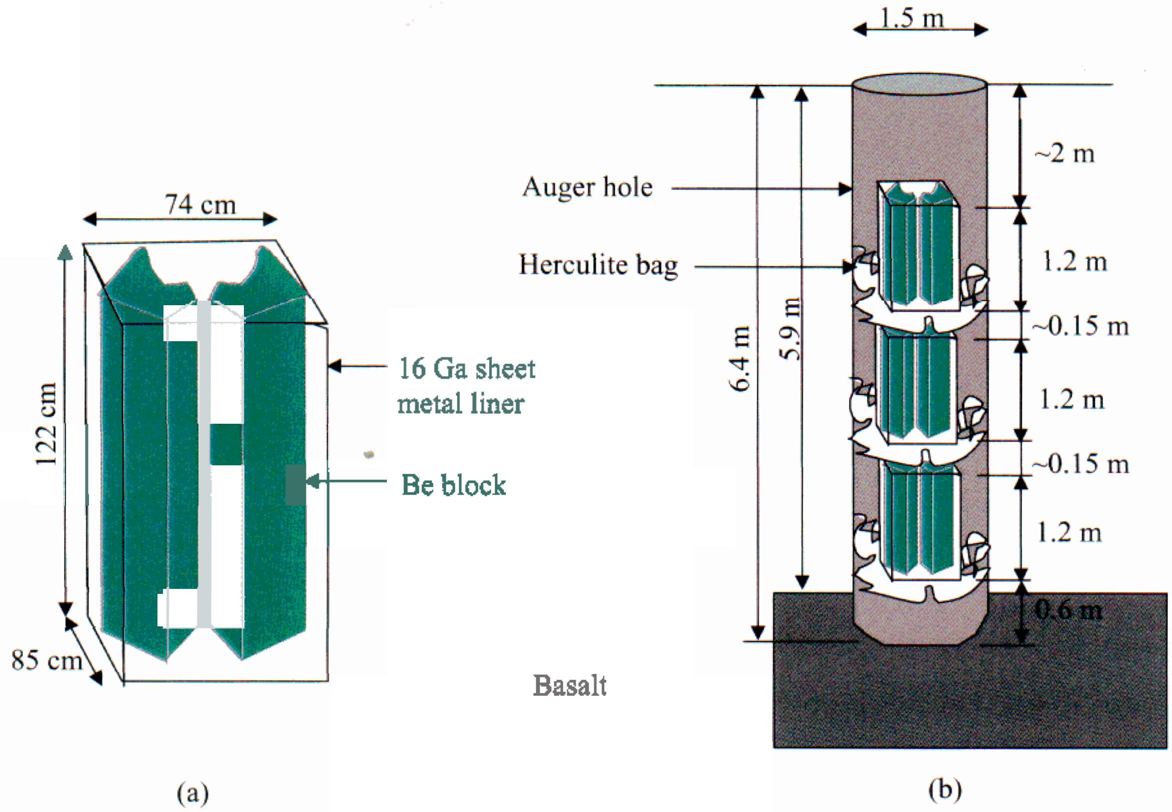

Figure 3. Conceptual view of the Advanced Test Reactor beryllium reflector blocks in Soil Vault Row 20.

Activated metals, including beryllium reflector blocks, were disposed of in SVRs 1–16, 18, 19, and 21. Rows of holes were drilled with an auger, with each vault separated by approximately 0.6 m. Soil vaults are unlined holes ranging from 5.2 to 7.6 m deep and with diameters from 0.4 to 2 m. If the vault penetrated the basalt, then 0.6 m of soil were added before waste emplacement. Remote-handled waste was transferred to soil vaults from a bottom-discharge shipping cask. Full vaults were covered with at least 0.9 m of soil. Additional soil was added when necessary to reduce exposure rates above the covered vault to less than 1 mR/hour at the soil surface. Table 1 presents a tabulation of the information specific to beryllium reflector blocks for which this action is recommended. Figure 3 shows a conceptual view of a beryllium reflector block's container in the auger hole. Figure 3(a) illustrates beryllium reflector blocks inside the open-topped transport liner, and Figure 3(b) shows a conceptual view of ATR beryllium reflector blocks in a soil vault. At this time, the beryllium identified in Table 1 is all of the beryllium that records identify as being disposed of at the SDA. All known locations and numbers of beryllium disposals will be verified and validated before initiation of any action proposed in this document.

Table 1. Summary of the Advanced Test Reactor, Engineering Test Reactor, and Materials Test Reactor irradiated beryllium reflector waste disposed of in the Subsurface Disposal Area.

Reactor and Beryllium Waste Disposed of by Serial Number or Core Position	Beryllium Metal Mass (g)	Metal Volume (m^3)	Disposal Location	Total C-14 (Ci)	C-14 Concentration (Ci/m^3)
Materials Test Reactor	~2,000,000	~1.08	Trench 58 3+10-20 to 3+40-50	29.2	27.00
Engineering Test Reactor	~624,000	~0.337	Trench 52, 4+175, 4+70, 4+85, 4+50	21.7	64.40
Advanced Test Reactor					
Block NW-L	81,420	0.044	Trench 58 200+05-15	0.9997	22.72
NW-R	81,420	0.044	Trench 58 200+05-15	0.9997	22.72
NE-L	81,420	0.044	Trench 58 200+25-35	0.9679	22.00
NE-R	81,420	0.044	Trench 58 200+25-35	0.9679	22.00
SW-L	81,420	0.044	Trench 58 200+25-35	0.9683	22.01
SW-R	81,420	0.044	Trench 58 200+25-35	0.9683	22.01
SE-L	81,420	0.044	Trench 58 200+25-35	0.9696	22.04
SE-R	81,420	0.044	Trench 58 200+25-35	0.9696	22.04
Block NE-L	81,420	0.044	Trench 58 3+10-20	0.8189	18.61
NE-R	81,420	0.044	Trench 58 3+10-20	0.8189	18.61
SW-L	81,420	0.044	Trench 58 3+10-20	1.2540	28.50
SW-R	81,420	0.044	Trench 58 3+10-20	1.2540	28.50
SE-L	81,420	0.044	Trench 58 3+10-20	0.8441	19.18
SE-R	81,420	0.044	Trench 58 3+40-50	0.8441	19.18
Block 018L	81,420	0.044	SVR 20 0+315	1.8530	42.11
013R	81,420	0.044	SVR 20 0+315	1.8530	42.11
015L	81,420	0.044	SVR 20 0+315	1.6270	36.98
019L	81,420	0.044	SVR 20 0+315	2.0660	46.95
014R	81,420	0.044	SVR 20 0+315	2.0660	46.95
011R	81,420	0.044	SVR 20 0+315	2.4970	56.75
Nine outer shim control cylinders	489,881	0.2648	SVR 17 0+10, 0+18, 1+00, 1+56	15.9100	60.08
Total	4,742,281	2.562		92.4170	

2.2.1.1.1 Beryllium Reflector Block Monitoring—Six beryllium reflector blocks from ATR were buried in SVR-20 (Ritter and McElroy 1999). The blocks contained a total of 293,000 Ci of tritiated hydrogen gas and approximately 20 Ci of C-14. Both radionuclides form mobile compounds. About one-fifth of the total C-14 inventory in the SDA is associated with the beryllium. Carbon-14 was identified as a contaminant of concern in the *Second Revision to the Scope of Work for the Operable Unit 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study* (Holdren and Broomfield 2003) and the *Radioactive Waste Management Complex Low-Level Waste Radiological Composite Analysis* (McCarthy et al. 2000). Tritium, though not a risk driver, was identified as a contaminant of interest because of its potential as a model calibration target for vapor phase transport. Dedicated monitoring at SVR-20 began in 1994 to characterize the migration of tritium and C-14 from buried beryllium reflector blocks.

Carbon-14 samples are collected quarterly from the functioning Type B vapor probes at SVRs 12 and 20. The C-14 samples are analyzed for C-14 specific activity (i.e., C-14 activity per unit mass of total carbon). Carbon-14 results for the functioning probes at SVRs 12 and 20 indicate that the C-14 specific activity in SVR 12 samples is approximately two orders of magnitude above the typical background concentration of C-14, which is 6.5 pCi/g. The C-14 specific activity in SVR 20 samples is approximately four to five orders of magnitude above the typical background concentration of C-14.

2.3 Summarized Risk Evaluation

Risks posed by waste buried in the SDA were evaluated in the ABRA (Holdren et al. 2002). The ABRA shows that a small set of long-lived, mobile radionuclides in relatively unstable waste forms in the SDA pose an unacceptable risk to the Snake River Plain Aquifer during the next 300 years. The model used to determine estimated risk has identified 300 years as the peak risk point.

Based on data developed in the ABRA, C-14 released from the beryllium reflector blocks is a primary contributor to predicted groundwater pathway risk now and for several hundred years. Carbon-14 has a peak risk of 6E-04 in the Year 2278. Groundwater ingestion is the primary exposure pathway. A peak risk estimate of this magnitude indicates that six people in 10,000 could develop cancer attributable to ingestion of groundwater contaminated with C-14. This exposure scenario is a hypothetical future residential model that assumes human ingestion of contaminated groundwater at its highest simulated concentration in approximately 100 years. The highest simulated concentration is at the SDA. Moving away from the SDA, the simulated concentrations at the INEEL boundary are much lower. Moving even farther away from the SDA and the INEEL, the simulated concentrations decrease significantly. Approximately 19% of the C-14 inventory in the SDA is associated with the beryllium reflector blocks. The remaining C-14 inventory is in other activated metals. The inventory associated with the beryllium reflector blocks is of particular concern due to the higher corrosion rate of beryllium in the SDA environment (approximately two orders of magnitude higher corrosion rates than the other activated metals). The estimated rate of dissolution is 5E-03 to 8E-03 mm/year (Adler-Flitton et al. 2001).

3. REMOVAL ACTION OBJECTIVES

The DOE is implementing in situ grouting (ISG) at the SDA to reduce the threat to public health and welfare and the environment. This action is being taken to stabilize the beryllium reflector blocks buried at the SDA, thus mitigating the threat to human health and the environment. Goals of the action are to achieve the following:

- Minimize release of C-14 resulting from corrosion of the beryllium reflector blocks
- Implement an action that is consistent with the final remedy
- Implement an action that provides an effective, long-term remedy to mitigate water infiltration to the beryllium reflector blocks
- Reduce a large percentage of the immediate risk to human health from the SDA
- Complete the removal action activity at the SDA within Fiscal Year 2004.

4. IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

Guidance from the EPA (1993) states that appropriate objectives for actions include site stabilization, prevention of further degradation, and significant risk reduction. For C-14 release, the site-specific remedial objective is to mitigate the release of C-14 from the beryllium reflector blocks.

The PERA presents an analysis of possible technologies. ISG is the technology identified to address waste forms containing fission and activation products (e.g., beryllium reflector blocks).

4.1 Development of Alternatives

Because of the nature of the contamination, the location of the beryllium reflector blocks, and the focused nature of this NTCRA, the two alternatives evaluated are ISG and No Action. These alternatives are discussed in the following subsections.

In developing the alternatives, retrieving the beryllium blocks was considered, but dismissed due to several factors: the unacceptable risk to workers, no current path to disposal for the beryllium, and retrieval would place the activity several years into the future instead of accomplishing the risk reduction in FY 2004. However, ISG under this NTCRA does not preclude retrieval.

4.1.1 No Action

The No Action alternative provides a baseline against which impacts of the proposed action can be compared. Under the No Action alternative, no remedial action would be taken at the SDA to mitigate C-14 release. The No Action alternative would continue the existing situation in regards to contamination and leaching of C-14 from the beryllium reflector blocks.

The No Action alternative consists of (1) continuing with the present course of action with no changes, (2) maintaining existing site conditions with no changes, and (3) taking no action to reduce contaminant toxicity, mobility, and volume. The key element of the No Action alternative is implementation of a monitoring system from Year 2004 to 2020. This monitoring system would be an interim measure until the long-term monitoring program is implemented after Year 2020. The Year 2020 was identified as the approximate time a long-term monitoring action would be implemented and in order to have a basis for calculating a total cost for the No Action alternative. The No Action alternative includes only monitoring and requires no direct action to treat, stabilize, or remove contaminants. Costs for this alternative include monitoring of air, vadose zone soil moisture, and the aquifer for 15 years. The existing monitoring system for the SDA will proceed regardless of either action.

This comparatively inexpensive alternative is easily implemented, incurring only costs associated with monitoring. However, the No Action alternative offers no reduction in toxicity, mobility, or volume of contaminants within the SDA. Because aspects of the site present unacceptable risks to human health and the environment, the No Action alternative does not satisfy the remedial action objectives.

4.1.2 In Situ Grouting

In situ grouting is a technique developed in the construction industry and recently adapted for environmental use. The process entails injecting a slurry-like mixture of cements, chemical polymers, or petroleum-based waxes into contaminated soil or a waste landfill. Grouts are specially formulated to isolate the waste, which isolates contaminants from the surrounding environment. As used in the environmental industry, the process employs nondisplacement jet grouting whereby soil and waste debris are mixed with grout-forming materials in the subsurface (DOE-ID 1999; Loomis, Zdinak, and Bishop

1997). Grouting is accomplished without displacing contaminants or debris or causing the ground to heave. Overall volume of the waste site remains constant, but density of the site is substantially increased as grout fills void spaces between discrete waste components.

In situ grouting has been approved by regulating agencies and implemented on small-scale sites at the Oak Ridge National Laboratory, the Savannah River Site, the Brookhaven National Laboratory, and the Acid Pit within the SDA (Armstrong, Arrenholz, and Weidner 2002). Though ISG has not been applied to sites as large or with as many radiological and chemical hazards as the SDA, research has been conducted at the INEEL to evaluate the usefulness of ISG. Results of past applications at other sites and the INEEL research are promising. An evaluation of the technology and application to the SDA conditions, including a summary of ISG case histories, is provided in the *Evaluation of In Situ Grouting for Operable Unit 7-13/14* (Armstrong, Arrenholz, and Weidner 2002).

Single-phase grouting in the dense surficial soil of the INEEL results in emplacement of grout columns approximately 2 ft in diameter. Single-phase grouting uses a high-velocity jet of neat grout to break up and physically mix waste and soil and does not inject free water or high-pressure air. The objective of using ISG is to encapsulate buried waste in contiguous grout columns to stabilize C-14 resulting from corrosion of the beryllium reflector blocks buried in soil vaults and trenches. This ISG technology will minimize infiltration of water (i.e., reducing corrosion of the blocks) and reduce release of contaminants from the blocks.

The main objective of ISG is to encapsulate waste in a hydrophobic material that would achieve the following:

- Limit metallic corrosion and nonmetallic dissolution by minimizing the amount of water that can reach the waste and by insulating dissimilar metals to mitigate galvanic corrosion
- Limit diffusion of released radionuclides into surrounding soil
- Limit the chemical environment that promotes leaching of contaminants.

The objective of using ISG is to totally surround (encapsulate) buried waste in grout monoliths. Under this action, the beryllium blocks will be encapsulated using commercially available, high-pressure (nondisplacement) ISG methods. The grouting will reduce infiltration into the beryllium blocks and stop the migration of contaminants resulting from corrosion of these blocks. The in situ encapsulation will be accomplished by using a high-pressure (300–500 bars [4,500–7,500 psi]) nondisplacement jet grouting method. The injection of a specially formulated grout (e.g., Waxfix) will be completed with a drill rig, which inserts and pushes a removable drill stem stinger to the bottom of the waste zone (i.e., bedrock), injecting the specially formulated grout while the stinger is removed. During the injection process, grout returns to the surface along the outside of the drill stem will confirm filling the void space. The tentative schedule for grouting shows mobilization in May 2004, with grouting starting in June, and completion of the grouting action by October 2004.

4.2 Identification of Applicable or Relevant and Appropriate Requirements

Table 2 summarizes the evaluation of regulatory compliance and ARARs. Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations.

Table 2. Regulatory compliance evaluation summary for the In Situ Grouting alternative.

Applicable or Relevant and Appropriate Requirements or to Be Considered	Type	Relevancy[a]	Citation
Radiation protection of the public and the environment	Chemical Action	TBC	DOE Order 5400.5
Idaho toxic air pollutants	Chemical	A	IDAPA 58.01.01.585 and .586
Idaho ambient air quality standards for specific air pollutants	Chemical	A	IDAPA 58.01.01.577
National emission standards for emissions of radionuclides other than radon from DOE facilities	Chemical	A	40 CFR 61 Subpart H
National ambient air quality standards	Action	A	40 CFR 50
Idaho control of fugitive dust emissions	Action	A	IDAPA 58.01.01.650 and .651
Hazardous waste determination	Action	A	IDAPA 58.01.05.006 (40 CFR 262.11)
Standards for owners and operators of treatment, storage, and disposal facilities—use and management of containers.	Action	A	IDAPA 58.01.05 (40 CFR 264 Subpart I)
Radioactive waste management	Action	TBC	DOE Order 435.1
Radiation protection of the environment	Action	TBC	DOE Order 5400.5

a. A = applicable requirement, TBC = to-be-considered requirement

CFR = *Code of Federal Regulations*
DOE = U.S. Department of Energy
IDAPA = Idaho Administrative Procedures Act

4.2.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

Because of the limited scope of this NTCRA, there are no chemical-specific ARARs. Groundwater quality rules and associated maximum contaminant levels (IDAPA 58.01.11) will probably be ARARs for the comprehensive remedy.

4.2.2 Location-specific Applicable or Relevant and Appropriate Requirements

Because the SDA is a previously disturbed area, and because of the limited scope of this NTCRA, no location-specific requirements are identified.

4.2.3 Action-specific Applicable or Relevant and Appropriate Requirements

Substantive RCRA generator requirements for hazardous waste identification and management (40 CFR 261 and 262) would be applicable to ISG if hazardous types of waste were generated during these activities. Requirements for storage (40 CFR 264 Subpart I) are identified as ARARs to address this possibility. The need to implement RCRA ARARs will be based on the hazardous waste determination that will be completed before implementation of the action alternative.

Construction and remediation would meet state and federal requirements for air quality standards. Requirements for the State of Idaho 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), and limitations on emissions from process equipment (IDAPA 58.01.01.710). Federal requirements include "National Emission Standards for Hazardous Air Pollutants" (e.g., radionuclides) (40 CFR 61) and national ambient air quality standards (e.g., particulate matter) (40 CFR 50). These requirements would be met by using appropriate engineering controls.

Relevant substantive requirements of DOE Order 5400.5, "Radiation Protection of the Public and the Environment"; and DOE Order 435.1, "Radioactive Waste Management"; which specify DOE radiation protection and management requirements, would be met as to-be-considered (TBC) requirements.

5. ANALYSIS OF ALTERNATIVES

Section 300.415(b)(4)(i) of the National Contingency Plan requires an engineering evaluation and cost analysis for all NTCRAs. Guidance from EPA (1993) identifies three criteria to be used in the analysis of NTCRA alternatives. This section presents the analysis of two alternatives: No Action and ISG. Information used for analysis of the alternatives was based on the PERA, which identified a range of potential remedial options that offer effective treatment for contaminated conditions at the RWMC. But again, it should be noted that this document is being prepared as a NTCRA. Three criteria by which the two alternatives were compared are

1. Effectiveness

2. Implementability

3. Cost.

5.1 Criterion 1. Effectiveness

The effectiveness criterion assessed whether the alternatives leave an unacceptable risk after the conclusion of the actions, and it evaluates whether the alternative achieves adequate overall elimination, reduction, or control of risks to human health and the environment posed by the probable exposure pathways. Another criterion to be addressed in this section is to determine whether the alternative provides protection to human health and the environment during the action, and how long it will take to achieve the established objectives.

Under the No Action alternative, C-14 will continue to migrate, creating and increasing a threat to human health and the environment. The No Action alternative provides no additional protection of human health and the environment, except by attenuation of the contaminants over an extended period of time. Under this alternative C-14 will continue to migrate and contaminate groundwater at concentrations that will pose unacceptable risk (Holdren et al. 2002).

The In Situ Grouting (ISG) alternative would not, by itself, achieve long-term effectiveness and permanence for the C-14 contamination. However, grouting contamination within and adjacent to the beryllium reflector blocks will reduce the risk resulting from release of mobile contaminants associated with corrosion. This alternative provides overall protection of human health and the environment by minimizing the potential for further release of contaminants and further corrosion of the beryllium reflector blocks, thus reducing the potential risks associated with the contaminants. Encapsulation of this area by the grout would stabilize C-14, thus mitigating release of the contaminant. Isolation of this area, also by the grout, would serve as a barrier for infiltration of water. And this barrier would prevent the further corrosion of the block, which is the root cause of the contaminant release from the blocks.

The greatest hazard associated with operation of a grouting system is to workers. Potential exposure includes vapor-phase contaminants displaced from soil during grout emplacement. Using personal protective equipment, engineered barriers, procedures for radiation work, and specific safety plans for the project will mitigate the risk to workers.

5.2 Criterion 2. Implementability

The implementability criterion assesses whether the alternatives are technically and administratively feasible. Additionally, the question and concerns about public and Agency (i.e., Idaho

Department of Environmental Quality and the EPA) acceptance criteria, and whether the alternatives will address those concerns, must be determined. The main purpose and scope of the Agencies is protection of citizens and the environment. Public acceptance of an alternative will be determined by examining the alternatives and determining which one best mitigates damage to the public health or welfare or to the environment.

The No Action alternative is implementable because it requires no immediate expenditure of time or resources and, technically, no engineering or development is necessary. However, in the interim, maintenance and implementation of a temporary monitoring system will require an expenditure of resources. The No Action alternative will not address the Agency concerns. If no action is taken, a potential threat to human health and welfare will exist. This will also be contrary to concerns expressed by the public.

In situ grouting is technically achievable as it has been demonstrated at the INEEL before this action. Previous studies and demonstrations carried out over 9 years at the INEEL show that ISG has the potential to be an effective and implementable technology for in situ stabilization of the beryllium reflector blocks (Loomis and Thompson 1995; Loomis, Thompson, and Heiser 1995; Loomis, Zdinak, and Bishop 1997). To minimize the risk of mobilizing contaminants within the waste zone, the INEEL recommends a single-phase, nondisplacement, jet-grouting approach that does not require injection of high-pressure air or free water. This approach drives a drill stem to the bottom of the waste zone, then injects grout at high pressure as the drill stem is removed. During this process, excess grout may be returned to the surface along the outside of the drill stem.

Administratively, a grouting operation of the type discussed in this document is achievable from a management, cost, schedule, and programmatic point of view. By grouting the beryllium reflector blocks in conjunction with the final remedy, the spread of C-14, which could threaten human health or welfare, is mitigated and thus satisfies Agency concerns about C-14 contamination.

5.3 Criterion 3. Cost

This section provides an analysis of costs for the two alternatives. Activities for the No Action alternative (e.g., engineering implementation) would incur no cost. The part of the No Action alternative that is costed in this analysis is monitoring; therefore, monitoring costs need to be taken into account. Management and oversight are required for monitoring, which is an additional cost. Although monitoring is a continual activity at the INEEL, a long-term monitoring program (greater than 100 years) will not be in place until after implementation of the recommended actions in the OU 7-13/14 record of decision. The No Action alternative would monitor the specific beryllium source term from 2005 until implementation of the final remedy, around 2020. For these reasons, a 15-year monitoring duration is used.

Costs for grouting are presented as entire project costs, from start to finish. Development of the grouting alternative for beryllium reflector blocks has a proposed duration of 1 year. Although monitoring for grouting is also necessary, the level and degree of monitoring between ISG and No Action is very different. The grout monitoring will be localized at the source of the contamination and in the area of the grouting operation, and will be incremental over time.

Table 3 summarizes the initial cost estimate for the No Action and ISG alternatives.

Table 3. Total estimated costs for the No Action and In Situ Grouting alternatives.

Cost Element	No Action Alternative ($)	In Situ Grouting Alternative ($)
Management and oversight	—	1,000K
Engineering	—	100K
Procurement	—	50K
Construction	—	3,000K
Operation and maintenance support	—	250K
Surveillance and monitoring installation	3,000K	100K
Total	3,000K	4,500K

6. COMPARATIVE ANALYSIS OF ALTERNATIVES

Using three criteria—effectiveness, implementability, and cost—the two alternatives can be compared with each other. It is also necessary to compare the two alternatives in terms of the scope and purpose of the action.

Criterion 1 addresses overall protection and effectiveness of the alternatives to reduce risk. The No Action alternative does not mitigate the risk posed to human health near-term and during the hundred-year timeframe.

Criterion 2 addresses implementability. The No Action alternative requires no implementation, but would require complex effort over 15 years to monitor the spread of contamination. In comparison, the ISG alternative is time and labor intensive over the life of the operation (1 year).

Criterion 3 addresses cost. The cost for the No Action alternative includes interim monitoring and management of the monitoring system. The cost of the monitoring system includes monitoring the spread of contamination from the entire SDA, and the ISG cost is associated only with implementing the isolation activity. Therefore, while not directly comparable, the costs to implement each alternative are comparable on that basis.

Table 4 shows the results of comparing ISG and No Action alternatives using the three criteria.

Table 4. Summary of the comparative analysis of alternatives.

Criteria	No Action Alternative	In Situ Grouting Alternative
1. Effectiveness	Does not address remedial action objectives Does not provide for overall protection of human health and the environment Does not provide effective risk reduction.	Addresses remedial action objectives Reduces the release of C-14 from the beryllium block disposals Provides for standard industry precautions to be taken to protect workers.
2. Implementability	Easily implemented through continuing routine programs.	Researched specifically for implementation at the SDA and is both technically and administratively feasible Appropriate measures can be easily implemented to protect workers.
3. Cost	Total cost: \$3.3M over 15 years for monitoring. Note: These costs will be incurred regardless of whether this NTCRA is deployed.	Total cost: \$4.5M for completion of the action (i.e., 1 year), and includes monitoring of the beryllium blocks.

NTCRA = non-time-critical removal action
SDA = Subsurface Disposal Area

7. RECOMMENDED EARLY ACTION ALTERNATIVE

A NTCRA is conducted at a Superfund site when the lead agency, in this case DOE, determines that a removal action is appropriate. An action that implements ISG at the SDA could significantly reduce source release and contaminant mobility and minimize the time it will take to prepare and implement final remedial action. The ABRA estimates groundwater ingestion risk greater than 1E-04 from C-14 from all sources. Nineteen percent of the C-14 risk is attributable to the beryllium source. Though detected aquifer concentrations do not corroborate ABRA simulations yet, vadose zone monitoring data indicate contaminants are being released and are moving toward the aquifer.

The grouting alternative will meet the objectives of this action, which is to reduce the release and mobility of C-14 from beryllium reflector blocks in the SDA. This recommendation to grout the beryllium reflector blocks is consistent with the PERA and the Second Revision to the OU 7-13/14 Scope of Work. With proper grout selection, ISG offers a remedial solution to encapsulate and stabilize C-14 and Tc-99, as well as an engineering solution to structurally stabilize SDA waste. Early action should be taken to design and construct an appropriate ISG delivery system.

By implementing grouting now, the risk to human health will be substantially reduced. No Action at this time will allow corrosion of the beryllium blocks to continue, causing a release of C-14, which will ultimately contaminate the groundwater.

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