PERFORMANCE OF A RADIOACTIVE WASTE INTERNMENT SITE

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ABSTRACT

Aerojet disposed of 30,000 cubic meters of uranium and thorium wastes in an engineered 12,000 square meter (3 acre) internment site in Tennessee. The operation, performed under a State of Tennessee source material license, is based on termination of the license with the material remaining in place, and the option of future commercial use of the site.

The closure plan included a long-term monitoring program. Yearly monitoring of the site has verified performance within the design criteria. Full-time construction monitored by a licensed engineer and extensive testing of materials ensured construction of the site according to or better than the specifications. Surface subsidence of the site has averaged about 2.2 cm with a range of 0 to 4.3 cm at 11 settlement markers after 4 years. The anticipated settlement, based on design parameters, was between 15 and 25 cm. The present anticipated settlement is 8 to 15 cm, based on the as-built parameters, and the long-term monitoring results. Slope stability analysis indicates the stability has improved with time due to consolidation of materials and reduced groundwater activity as a result of site construction. There has been no need for corrective action maintenance due to erosion, sluffing of slopes, or subsidence. Groundwater monitoring indicates the materials have been isolated, and there have also been no indications of springs or leakage from the site.

INTRODUCTION

Aerojet disposed of 30,000 cubic meters of uranium and thorium wastes in an engineered 12,000 square meter (3 acre) internment site in eastern Tennessee, about 100 km east of Knoxville, near Jonesborough. The closure was completed in September 1985. The project was performed by Aerojet Heavy Metals Company, now Aerojet Ordnance Tennessee (Aerojet), subsidiary of GenCorp, Inc. of Ohio. The closure included excavating the wastes and subsurface contamination from the inactive process waste pond which had been used for uranium and thorium processing activities, decontaminating the surrounding area, and placing the contaminated materials in an on-site engineered internment cell. Prior to the final closure, sludge and the more mobile radioactive waste materials were removed and disposed of at a licensed radioactive low-level waste disposal site (1).

Rogers and Associates Engineering Company (RAE) was responsible for developing criteria for the final closure, preparing the design and construction specifications, construction monitoring, and certifying the closure. Dames and Moore provided assistance in developing the design and construction specifications, and performing construction monitoring. Geotek Engineering performed much of the initial site characterization work, geotechnical consultation for the design, materials testing during the construction activities, and long-term geotechnical monitoring. Environmental sampling of the groundwater and stream has been performed by EMPE of Knoxville, Tennessee. The closure program has been described by Bernhardt et al. (1,2,3,4). The closure program included preparing a long-term monitoring program to assess the performance of the site (5).

Objective

This paper discusses the performance of the site five years after closure. During this period there has been continuous monitoring of the stability of the site, groundwater, and surface water effects in an adjoining stream. The focus of the paper is on the subsidence and stability of the site. The measured subsidence is compared to assessments based on the as- built parameters. The assessments include determining the factor of safety for stability and maximum anticipated ground-surface settlement, based on the design specifications, as-built parameters, and the results of four years of monitoring.

CONSTRUCTION OF INTERNMENT CELL

The decontamination of the area and closure of the pond were performed according to the site design and detailed construction specifications. Full-time construction monitoring by an independent third part during all construction activities ensured that the construction was performed according to the specifications. The monitoring was performed by a licensed engineer with certification in Tennessee. Figure 1 shows the general layout of the site and the internment cell. The site, built into the side of a hill, is supported on the down-hill side by a rock buttress wall. The buttress wall was constructed prior to excavation or placement of the waste, and was placed on bedrock. The locations of 7 groundwater monitoring wells along the southeastern edge of the site are shown. There are 11 subsidence markers on the site. The area south of Station 6 + 00 is denoted as Zone 1 (3 markers) and the area north of Station 6 + 00 is Zone 2 (8 markers).

Figure 2 shows a cross section indicating the internment cell, bedrock, and the buttress wall. The cross section is for Station 7 + 00 which represents the area of the site containing the greatest depth of waste material. The nominal depth of waste in this area is about 7 m, with about 2.7 m of base and cover material (total of about 10 m).

The basic construction specifications and criteria were (1,2,3):

- Rock buttress wall, of shot rock, constructed in a trench excavated to bedrock. Geofabric (Polyfelt TS 500 geotextile fabric) was used between the clay liner and the rock wall to prevent migration of the clay into the void space of the buttress wall.
- Excavation of all waste material. The basic criteria were 1.1 Bq/g (30 pCi/g) of U-238 and 0.19 Bq/g (5 pCi/g) of Th-232 (6).

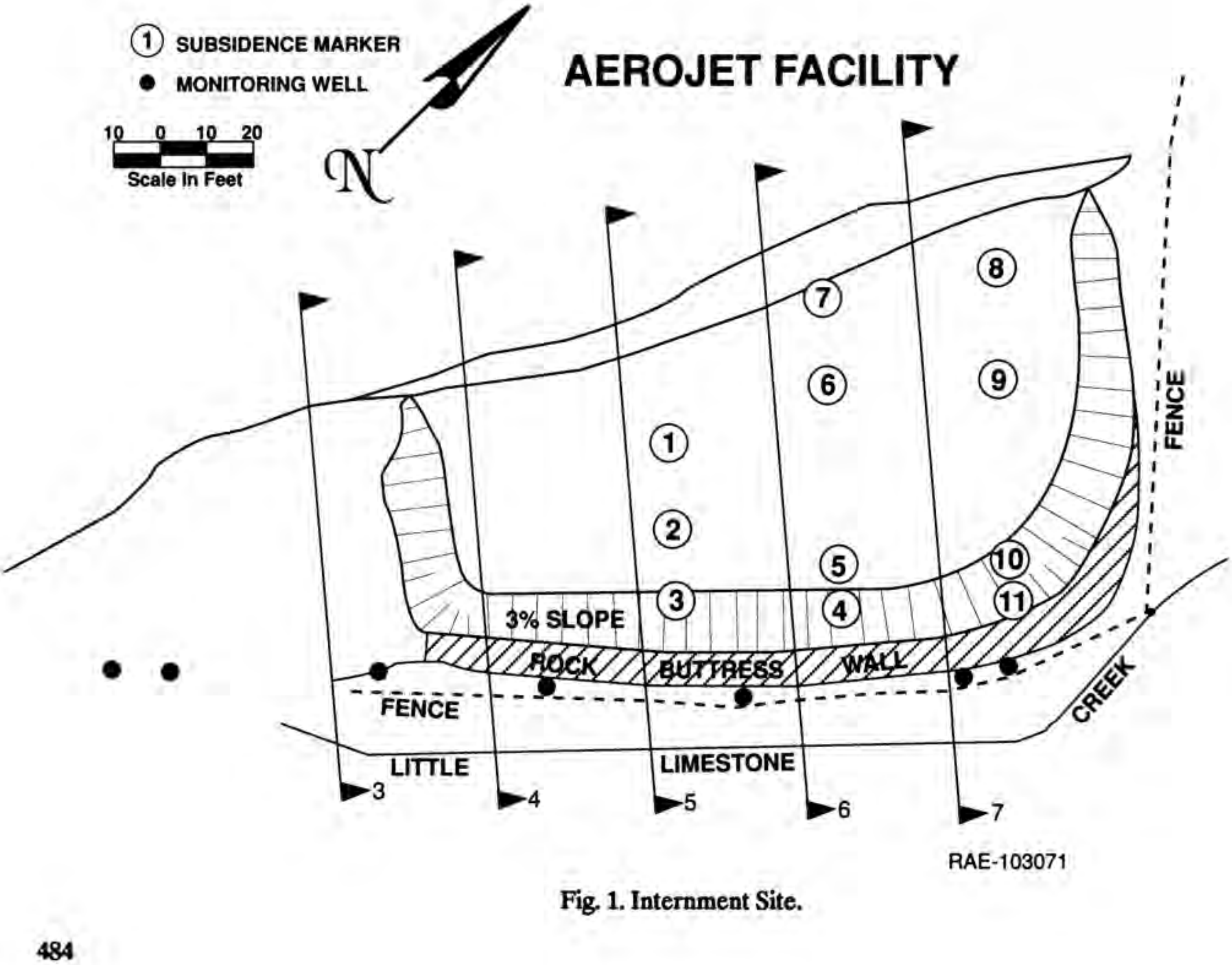

Fig. 1. Internment Site.

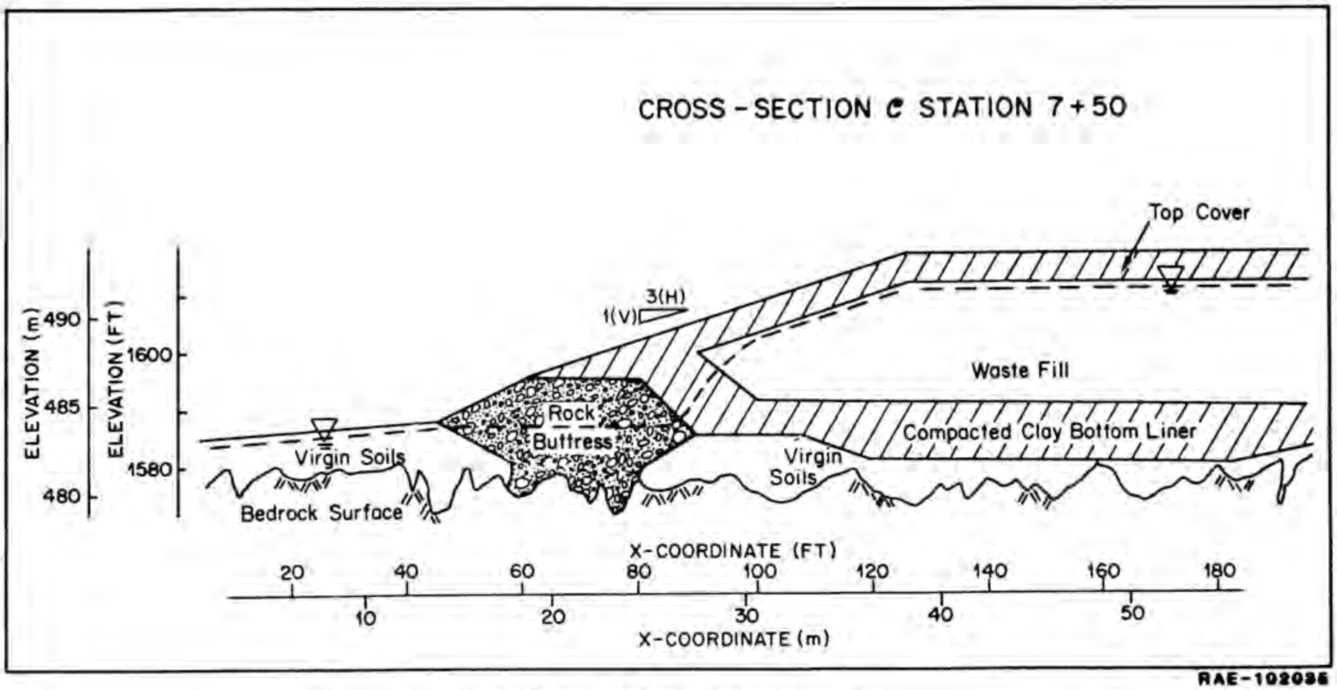

Fig. 2. Cross Section of Internment Site.

- Placement of all waste material above the projected 100 to 50-yr reoccurrence flood base; 485.4 m (1592 ft) MSL.
- Placement of a 1.2-m (4-ft) compacted clay liner for the base and sides of the internment cell. The liner was compacted to greater than 95 percent of the maximum dry density as defined by ASTM D-698 (referred to as 95 percent compaction), and had a hydralic conductivity of less than 10^{-6} cm/sec. The average compaction was greater than 96 percent. Measurements of the hydralic conductivity indicated two values of 1 and 0.5 x 10^{-7} cm/sec.
- Waste material was placed at an average compaction of greater than 87 percent, compared to the specification of 85 percent compaction, or that accepted by the field engineer. When necessary, the waste was mixed and allowed to dry prior to placement. Small areas of the waste were placed with a compaction of 80 to 85 percent, if the placed material had the desired properties of strength, based on the judgement of the site engineer.
- A cap of 1.2 m of compacted clay was placed over the waste and tied to the sides of the clay cell. The average compaction of the cap was about 98 percent, compared to the design criteria of greater than 95 percent. Hydralic conductivity tests were not performed on samples from the compacted cover. However, based on the relative compaction results for the clay base and for the cover, and the hydralic conductivity measurements for samples from the base, it is estimated that the hydralic conductivity of the cover is about 10^{-7} cm/sec, or less.
- The compacted clay cap was covered with 30 cm of soil and native grass was planted. The cover was sloped to expedite runoff and prevent ponding. The slope of the cover was limited to less than 3 percent.

The clay for the lining and cap were obtained from an on-site borrow area. The clay was placed and compacted in 20-cm lifts. The waste material was compacted in 30-cm lifts. The excavation of the waste material often resulted in excavation to bedrock. These areas were backfilled with gravel prior to placing the base clay liner.

Compaction Measurements

Over 350 compaction tests were made during the construction of the cell and placement of waste material. The proper placement of the clay base was verified by 128 measurements, 169 measurements were made for the waste, and 57 measurements were made for the clay cap (7). The compaction results are summarized in Table I. Zone 1 is the area south of Station 6+00, Zone 2 is to the north. The average compaction for the base was over 96 percent and the cap was compacted to an average of about 98 percent. The overall average compaction was over 92 percent.

TABLE I
Average Compactions by Zone (Percent)

	Zone 1				Zone 2			
	Overall	Base	Waste	Cap	Overall	Base	Waste	Cap
Mean	94.6	97.9	89.7	97.8	92.1	96.5	87.7	97.8
St.Dev.	5.23	1.87	4.73	1.44	6.07	3.28	4.61	1.92
n	143	67	58	18	211	61	111	39

PERFORMANCE OF SITE

The long-term monitoring program has included the following (5):

- Measurements of subsidence or settling.
- Visual inspection of stability, erosion, or other degradation of the site.
- Groundwater monitoring.
- Monitoring of surface water and stream biota.

This assessment focuses on the results of the subsidence measurements and slope stability. The measurements of subsidence are compared to geotechnical assessments based on the as-built construction parameters. A previous assessment of the groundwater and surface water impacts indicated that the internment site is performing as designed and that it has not had adverse impacts on surface water or groundwater (6). There do not appear to be any overall trends towards changes in the groundwater levels for the monitoring wells to the east of the site (Fig. 1) (8).

Factors of Safety and Subsidence

The stability and surface settlement assessments were performed using a computer code and conventional soil mechanics theory. Stability assessments were performed using the STABLE 2 computer code developed by Purdue University in 1975. The assessment of the Factor of Safety for slope stability was performed for Station 7+50, the north area of the site where the largest relative amount of waste was placed and where the stability is most critical. The analysis for settlement was performed using conventional soil mechanics theory and the Terzaghi theory of consolidation (9).

The measured subsidences for the 11 subsidence markers (see Fig. 1) are given in Table II (8). The subsidence has been generally uniform over the site, preventing depressions with ponding. The measured subsidence as of August 1989 varied from 0 to 4.3 cm. The average settlement after about 4 yr has been 2.2 cm, with a standard deviation of 1.3 cm. The anticipated subsidence based on the design parameters, as-built parameters, and based on the actual settlement are given in Table III. The anticipated average subsidence for the as-built compactions is about 88 percent of the average based on the design parameters. The maximum subsidence as of August 1989 was about 60 percent of the average anticipated subsidence, based on the as-built compactions. In addition to the as-built parameters resulting in a more stable site than the design parameters, the measurements of actual subsidence indicate the future subsidence will be less than anticipated from the as-built parameters.

The Factors of Safety for design, as-built, and projected conditions are given in Table III. The assessments indicate the Factor of Safety was 1.8 for the as-built conditions, versus 1.6 based on the design. The performance of the site indicates the Factor of Safety is now 2.1.

SUMMARY AND CONCLUSIONS

Aerojet placed 30,000 cubic meters of contaminated soil in an engineered disposal site, which was completed in September 1985. Results from the long-term monitoring program, which includes ground and surface water sampling, measurement of surface subsidence, assessment of slope stability, and periodic visual inspection indicate the site will provide long-term isolation of the materials, with minimal maintenance. Anticipated surface subsidence is 8 to 15 cm, one-half of the initial estimate based on the design parameters. The average subsidence after 4 years has been about 2.2 cm. The range of settlement has been between 0 to 4.3 cm, resulting in continual good drainage of the site, with minimal tendency for ponding of precipitation. The performance of the site indicates long-term stability and isolation of the materials. Implementation of the design using full-time construction monitoring and extensive materials testing to ensure construction according to specifica-

TABLE II
Surface Subsidence Measurements

Settlement PIN Number	Initial Elev. (cm) 03/25/86	Elevation change (cm) 07/25/86	10/13/86	06/17/87	08/24/88	08/24/89
1	49182.2	-0.6	-1.2	-1.5	-2.7	-1.8
2	49160.3	-0.9	-1.2	-1.8	-3.0	-2.7
3	48988.4	-0.6	-0.3	-0.3	-1.2	-0.9
4	48989.9	-0.6	-0.6	0.3	-0.9	0.0
5	49228.9	-0.9	-1.2	-1.2	-1.8	-1.2
6	49267.9	-1.5	-1.8	-2.4	-3.4	-3.4
7	49317.2	-1.8	-1.8	-2.4	-3.7	-3.4
8	49380.6	-0.9	-0.9	-0.6	-1.8	-1.5
9	49307.2	-1.5	-1.2	-1.8	-4.0	-4.3
10	49272.1	-1.2	-1.5	-2.1	-2.7	-3.0
11	49021.0	-1.2	-0.9	-0.9	-2.4	-1.5

TABLE III
Subsidence and Factors of Safety

Basis of Estimate	Design Estimate	Estimates of Subsidence: Measured Estimate	As-Built Estimate	Based on 4-Yr Observation
Factor of Safety	1.6	N/A	1.8	2.1
Surface Settlement				
Range	15-25 cm	0-4.3 cm	13-23 cm	8-15 cm
Average	20 cm	2.2 cm	18 cm	11 cm

tions resulted in construction of an internment site with performance that is exceeding the original design.

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