HANDLING 78,000 DRUMS OF MIXED-WASTE SLUDGE

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ABSTRACT

The Oak Ridge Gaseous Diffusion Plant (now known as the Oak Ridge K-25 Site) prepared two mixed-waste surface impoundments for closure by removing the sludge and contaminated pond-bottom clay and attempting to process it into durable, nonleachable, concrete monoliths. Interim, controlled, above-ground storage of the stabilized waste was planned until final disposition. The strategy for disposal included delisting the stabilized pond sludge from hazardous to nonhazardous and disposing of the delisted monoliths as radioactive waste.

Because of schedule constraints and process design and control deficiencies, ~46,000 drums of material in various stages of solidification and ~32,000 drums of unprocessed sludge are presently being stored. In addition, the abandoned treatment facility still contains ~16,000 gal of raw sludge. Such conditions do not comply with the requirements set forth by the Resource Conservation and Recovery Act (RCRA) for the storage of listed waste.

Various steps are being taken to bring the storage of ~78,000 drums of mixed waste into compliance with RCRA. This paper (1) reviews the current situation, (2) discusses the plan for remediation of regulatory noncompliances, including decanting liquid from stabilized waste and dewatering untreated waste, and (3) provides an assessment of alternative raw-waste treatment processes.

PURPOSE

Approximately 78,000 drums of low-level radioactive mixed waste, generated from an environmental restoration project, are currently being stored at the Oak Ridge K-25 Site under conditions that are not in compliance with RCRA requirements. A plan of action has been initiated to (1) treat the raw sludge by dewatering and repackaging it into new containers, (2) decant the water from the stabilized-sludge drums and repair the drums or overpack them as necessary, and (3) move all the drums into existing buildings and/or new storage facilities. This strategy would protect human health and the environment, comply with applicable or relevant and appropriate requirements, and address RCRA regulatory requirements.

The schedule associated with the plan calls for completion of the improved storage phase in February 1993. Because a disposal site for treated waste is currently not available, final disposition of the treated raw sludge and decanted stabilized drums of pond waste material will be postponed until a later date. The objective of this paper is to describe: (1) the background for the situation, (2) a plan for remediating the waste, and (3) an analysis of alternative raw-waste treatment processes.

BACKGROUND

CURRENT SITUATION

Sludge from two settling ponds has been placed in ~ 78,000 mild-steel drums at the K-25 Site. The waste involved generally falls into two categories: raw sludge and processed solids. The raw sludge is a mixture of liquids, clay, and sludge materials. The "processed solid" is waste that is in various stages of grout stabilization. Approximately 32,000 drums contain raw sludge and 46,000 drums contain processed solid.

The drums (55-, 89-, and 96-gal capacities) are stored on an asphalt storage pad and in K-25 building storage vaults in a manner that is not compliant with RCRA requirements because of violations listed in detail below. This situation has resulted in an immediate need to remediate all 78,000 drums of grout and raw sludge.

In addition to drummed raw sludge, ~ 16,000 gal of raw pond sludge is being stored in holding tanks at the Sludge Treatment Facility (STF) and solidified waste is stored in two, 6-ft culverts and four B-25 boxes (4 x 4 x 6 ft) on the asphalt storage pad.

The pond waste is classified as a mixed waste because it is listed as F006 and contains low levels of radionuclides, such as technetium and uranium (Table 1).

HISTORICAL BACKGROUND

From 1955 to 1985, the Oak Ridge Gaseous Diffusion Plant (now known as the Oak Ridge K-25 Site) utilized two ponds (B and C) as settling/holding basins for neutralized waste streams from the steam plant, metals cleaning facility, plating shop, and sludge generated from the cascade scrubber blowdown treatment system. The primary difference between the sludges in the two ponds is that cascade scrubber blowdown sludge, ion-exchange resin, chlorides, and fluorides, were added to the "C Pond" only. Large quantities of sludge from coal pile runoff treatment, sludge for other steam-plant activities, and fly ash were added to the "B Pond" only.

In an attempt to meet a RCRA-directed closure of the ponds by November 1988, the pond sludges were excavated, and a portion was immobilized in a cement-based grout. Process control and quality assurance for the grout operations were inadequate, resulting in the production of an as-yet undetermined number of drums of "solidified" waste that were not properly stabilized. The grout-to-waste ratio and the solids content of the feed were inadequately controlled. All of the sludge was not grouted because of time constraints; raw sludge was drummed in order to close out the ponds prior to the deadline. As a result of this activity, ~ 78,000 drums containing either grouted sludge or raw sludge are now stored at the Oak Ridge K-25 Site.

During solidification operations, grab samples of grout slurry were removed from various batches to cast into cubes for the unconfined compressive strength and for EP-Toxicity testing, Multiple Extraction Procedure (MEP), total-constituents analyses, organics, and oil and grease. Radionuclide data are reported for 18 samples in the Appendix. The unconfined compressive strengths were found to range between 1000 and 1500 psi (ASTM C-109), and the leachates from 40 cubes of grout easily passed the EP-Toxicity test as well as the primary and secondary drinking water standards when applied directly. Because of a loss of process control during grouting operations; however, these data are not considered to be representative of the entire process — only of the 40 batches sampled.

Table 1. Summary of pond waste characterization data[a]

	Pond B Mean Concentration	Pond C Mean Concentration	Units[b, c]
Density	1.1	1.4	
pH	7.0	10	
Technetium	3640	1570	pCi/g
Plutonium	3.2	27.9	pCi/g
Cesium	53.6	6.8	pCi/g
Neptunium	3.2	20.3	pCi/g
Uranium	444	550	pCi/g
U-235 enrichment	1.2	1.6	wt %

[a]Due to electroplating solutions, waste is RCRA listed as F006.

[b]DOT defines radiological material as that which has an activity greater than 2000 pCi/g.

[c]NRC criteria for lowest-classification material (Class A) is that which has an activity greater than 3×10^6 pCi/g.

A cement-based grout formula was developed for use with both pond sludges. The target formulation used the proportions determined to be optimal as shown in Table 2.[1] In this formulation, the optimum solids content of the influent slurry was 25 wt % during all batching operations, which normally produced between 12 and 20 drums per batch. Following the stabilization of sludge from each pond, a bleed water problem was encountered with the grouted product due to poor process control during treatment. The full extent of this problem is unknown.

Table 2. Target grout formula

Component	Weight percent
Portland cement (Type I)	25
Fly ash (Class F)	25
Sludge (15-30 wt % solids)	50
Admixture (MB-AE 10)	0.125

The raw waste is heterogeneous; that is, the drummed sludge was removed from Ponds B and C by five different removal and drum-filling methods, which can be described as follows:

1. Sludge, rocks, and debris were removed directly from the ponds by backhoe or dragline and placed directly into drums.

2. Sludge, rocks, and debris were removed directly from the ponds by backhoe or dragline, put into a concrete truck, mixed and transported and then placed in drums from the concrete truck.

3. Sludge in the ponds was mixed into pockets or pools by use of graders and/or dragline. Pond waste and bottom clay were also mixed into the pools on occasion. These blended pools were placed into drums by direct pumping, direct backhoe or dragline filling, or pumping to concrete trucks prior to drum filling.

4. Sludge was removed by floating dredge pump, transferred to a 15000-gal blend tank (located at the STF), blended, and pumped into drums after rocks and debris had been screened.

5. Sludge was removed by dragline, put into concrete trucks, transferred to a 2700-gal, twin-screw, mix tank, blended, and pumped into drums after the rocks and trash had been screened out.

The resulting composition of the drummed raw waste is, therefore, heterogeneous with regard to chemical and physical properties. For example, the volume of liquid contained in individual drums is quite variable, ranging from 0 to 75 vol % free liquid. Furthermore, the weight percent solids in the sludge is expected to range between 20 and 60 wt %. The liquid associated with this sludge has been shown to have an extremely low dissolved solids content due to solubles leaching from the material contained in the holding ponds over a number of years. Despite this fact, enough chloride and fluoride are present in the liquid to promote corrosion and cause holes to form in the drums, especially at the grout/air interface.

Analytical data on the sludge from the ponds are limited to pond sampling that occurred in May 1985. These data were obtained from core samples of the ponds and the underlying clay bed[1]. Twelve samples of sludge were removed from B Pond and fifteen samples from C Pond. The data which are summarized in the Appendix, are based on the statistical sampling process employed at that time. As can be seen from Table 1, the radionuclides of concern are uranium ($^{235,238}U$), cesium, neptunium, plutonium, and technetium.

RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) COMPLIANCE CONCERNS

The following is a list of the RCRA non-compliances associated with the current waste storage operations:

- *Waste Stored in Nonpermitted Facility* - Approximately 16,000 gal of raw pond sludge (listed as F006 waste) has been stored in holding tanks at the K-1419 STF since cessation of closure operations in 1989. The STF is permitted as a treatment facility but not as a storage facility. A revised Part A with a request to modify interim status has been submitted to the Tennessee Department of Environment and Conservation (TDEC) to correct this deficiency, but approval of that modification request has not been received.

- *Noncompliant Storage Facilities* - Because of the presence of free liquids in the ungrouted sludge and some populations of the solidified sludges, the stored wastes are being handled as liquid wastes. Unfortunately, the current secondary-waste-containment capability at K-1417 and in several of the K-25 building vaults will not meet the design requirements of TN Rule 1200-1-11-.06(9)(f) for the storage of liquid wastes. Some processed sludge drums may be dry and could qualify as wastes containing no free liquids; however, until an appropriate analysis program is performed, they will be managed in the same manner as liquid waste.

- *Noncompliant Container Storage Configuration* - The present drum storage configuration at K-1417 and the K-25 building vaults does not provide sufficient aisle space for the unobstructed movement of personnel, emergency response, or drum retrieval equipment in accordance with TN Rule 1200-1-11-.06(3)(f). In addition, the stacking array does not allow for inspection of the drums in accordance with TN Rule 1200-1-11-06(9)(e).

- *Incompatible Storage Containers* - Requirements of TN Rule 1200-1-11-06(9)(c) state,that waste storage containers must be compatible with the stored waste materials. Because of the presence of free liquids containing corrosive constituents, and/or a moist environment in both the raw and solidified sludge drums, the mild-steel drums (some with suspect liners) have not proved to be compatible with the stored waste. Internal corrosion of the drums has been evident, and holes have been observed in drums of both raw and solidified wastes.

ENVIRONMENTAL, SAFETY, AND HEALTH CONCERNS

The presence of the K-1417 radioactive mixed waste in uncontrolled storage conditions represents a manageable environmental, safety, and health (ES&H) concern. The radioactivity levels in the stored waste do not result in an external radiation hazard to inspection or waste-handling personnel. The hazardous constituents in the waste are principally heavy-metal and radioactive substances in extremely low concentrations and some free liquid in excess of pH 12.5. None of these factors would pose a significant ES&H threat in a controlled, monitored storage environment. Therefore, short of a catastrophic failure or destructive natural event affecting a large number of drums simultaneously, the risk to public health and safety is low in the current storage configuration. Also, past analysis of samples collected from surface water runoff, soil, and sediment in the areas adjacent to the K-1417 drum storage pad and Mitchell Branch (outfall for runoff from K-1417) has indicated that contaminant levels are well below the National Pollutant Discharge Elimination System (NPDES) limits. The ES&H consideration of greatest concern, then, is the stability of the existing drum storage array. This situation is both an Occupational Safety and Health Act (OSHA) issue and a potential RCRA release concern.

With this perspective of relative risk, the following remediation strategy has been developed. In this strategy, the primary near-term focus is to dewater and improve containment of the most vulnerable waste forms (drummed raw sludge) and provide compliant storage for all of the waste material in the most cost-effective and expeditious manner. The rates at which these near-term improvements and the longer-term treatment and disposal activities are conducted should be governed by the relative risks that such wastes represent in comparison with the risks of other Oak Ridge Reservation Remedial Action Sites.

REMEDIATION PLAN

OBJECTIVE

The Pond Waste Management Project has been established to implement the remediation plan. The objective of implementing this plan is to provide full compliance with the RCRA requirements for management of the stored wastes. Toward that end, RCRA-permitted storage and treatment facilities must be developed and operated in accordance with those permits. The ultimate objective of the plan is final disposition of the waste.

Under this plan, a phased program is proposed to correct the current compliance deficiencies and provide remediation and compliant long-term storage of the waste. Steps in the plan include implementation of improved container storage; development, testing, and implementation of a dewatering process for the stored raw-waste; and long-term storage and/or disposal of the stabilized waste form. Each phase of the proposed plan is intended to improve the containment of the stored waste and result in a corresponding reduction in the potential ES&H risk of the waste inventory. Finally, a treated waste form will be produced that can meet hazardous waste delisting criteria and/or RCRA's Land Disposal Restrictions (LDR) treatment standards to allow ultimate disposal as a nonhazardous radioactive waste or as a stabilized mixed waste.

A six-phase program for correction of the current noncompliance issues is outlined as follows:

Phase 1 - Immediate Actions. Continue activities providing maintenance and surveillance of the stored waste and monitoring of the K-1417-A and -B Drum Storage Yard runoff.

Phase 2 - Characterization. Statistically sample and characterize drums containing raw and stabilized sludge from K-1407-B and -C Ponds.

Phase 3 - Temporary Storage. Modify existing facilities and construct new RCRA-compliant temporary storage to allow contained space for all dewatered raw sludge, as well as space for the decanted, stabilized-drum inventory that can be inspected during the period (to be determined) prior to completing final waste treatment activities.

Phase 4 - Stabilized Drums. Subcontract operations to decant, repair, or overpack deteriorated drums and transfer those stabilized drums to existing or new storage facilities.

Phase 5 - Raw Sludge Drums. Subcontract the dewatering of raw sludge, place the dewatered material in compatible bulk containers, and transfer the containers to new storage facilities.

Phase 6 - Final Treatment. At a time to be determined, prepare waste materials as required for long-term storage or disposal.

Final closure of the processing and storage facilities will be performed in compliance with RCRA requirements at the conclusion of these activities.

STORAGE FACILITIES

Existing gaseous diffusion process buildings on the K-25 Site that are no longer in operation (i.e., K-31 and K-33 facilities) are being considered for the storage of solidified waste drums. As presently configured, it is estimated that ~ 24,000 drums can be stored in these two facilities.

It is assumed that storage areas will be used as they are. No secondary containment is planned, and no sealant will be applied on the floors; however, stabilized drums will be stored in arrays that will facilitate inspection and retrieval. The storage containers are mild-steel drums (89- and 96-gal capacities) that contain mixed-waste material classified as solid. These drums will be stored without overpacks but with surface- and tier-level-installed pallets. Most of the drums will be stacked in a two- or three-high array; however, the floor-to-ceiling height limitation may make this arrangement impossible in some areas.

K-25 Storage Site No. 1, known as K-1065, has been identified for five new RCRA-compliant buildings that are planned for construction to store low-level and hazardous wastes. The K-1065 buildings will consist of pre-engineered metal bays that are 80 ft wide and 200 ft long. There will be four three-bay storage buildings (240 by 200 ft) and one two-bay storage building (160 by 200 ft). Proposed drum and solidified waste storage in these buildings is illustrated in Figures 1 and 2 (plan view of a typical three-bay building).

Additional storage has been slated for Site No. 2, known as K-861. Depending on site investigation activities, which will include a characterization of the soil and an engineering topographical survey, development of this site for warehousing any remaining waste drums will be determined on the basis of cost-effectiveness and need, using the same building configuration as that described for K-1065.

DRUM CONTAINMENT SYSTEM

Waste storage containers will be procured to provide either long- or short-term containment of the K-1407-B and -C Pond sludge materials during the various phases of the project. These phases may include, but will not be limited to, dewatering, storing, restacking, and treating the waste. The containers may serve as overpacks for the existing storage drums or as primary containers for the waste. The container design will allow filled containers to be stacked in a three-high array under either indoor or outdoor storage conditions.

Pallets will be procured to aid in the materials-handling aspects of transporting and storing the drums during the various phases of the project. The pallet design will be compatible with existing drums and new containers. Each pallet will support filled containers or drums stacked in a three-high array. When used during transport, each pallet will support containers or drums stacked individually.

DRUM PROCESSING OF STABILIZED WASTE

The drum processing element of the Pond Waste Management Project will include, but will not be limited to, decanting the free liquid, drum repair and lid replacement, bar-coding, storing, and restacking the waste and transporting it to designated storage locations. This element will concentrate its effort on preparing ~ 46,000 drums of stabilized waste that was previously processed through the STF to be placed indoors in RCRA-compliant storage for waste containing no free liquid. The lids of these drums will be removed, and the free liquid will be decanted and sent to the Central Neutralization Facility (CNF) for treatment (Figure 3). Pallets will be used to allow the stabilized sludge drums to be safely stacked in a two- or three-high array in the proposed indoor storage buildings.

TREATMENT OF RAW WASTE

Approximately 32,000 (3,000,000 gal) will be dewatered to prepare the waste for future solidification by removing rubble and to reduce the volume of waste requiring storage. An assessment of alternative treatment processes was conducted prior to the selection of the dewatering treatment scenario as discussed below. The treated waste will be stored in compliance with RCRA requirements until its disposal. (Currently, no disposal site has been identified for radioactive mixed waste.) Untreated waste will be remediated, including the raw liquid sludge and the fraction of "solidified" waste that was not properly stabilized.

Vendors will be required to submit a written quality assurance (QA) program and supporting procedures and must provide evidence that they have participated in a similar project within the past 3 years. A vendor will be selected to provide project planning, personnel, and process equipment for treating the waste to the required

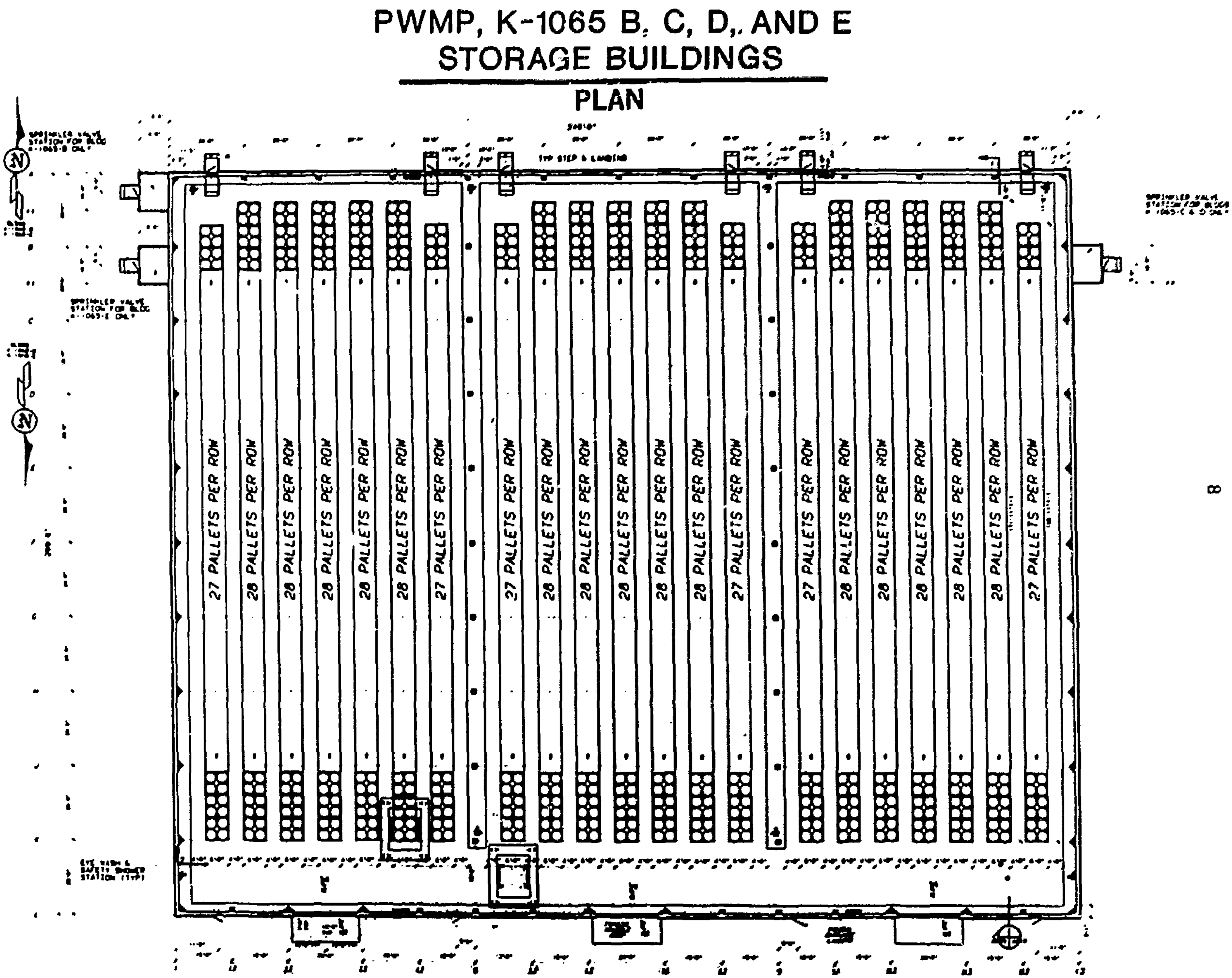

Figure 1. Drum storage configuration.

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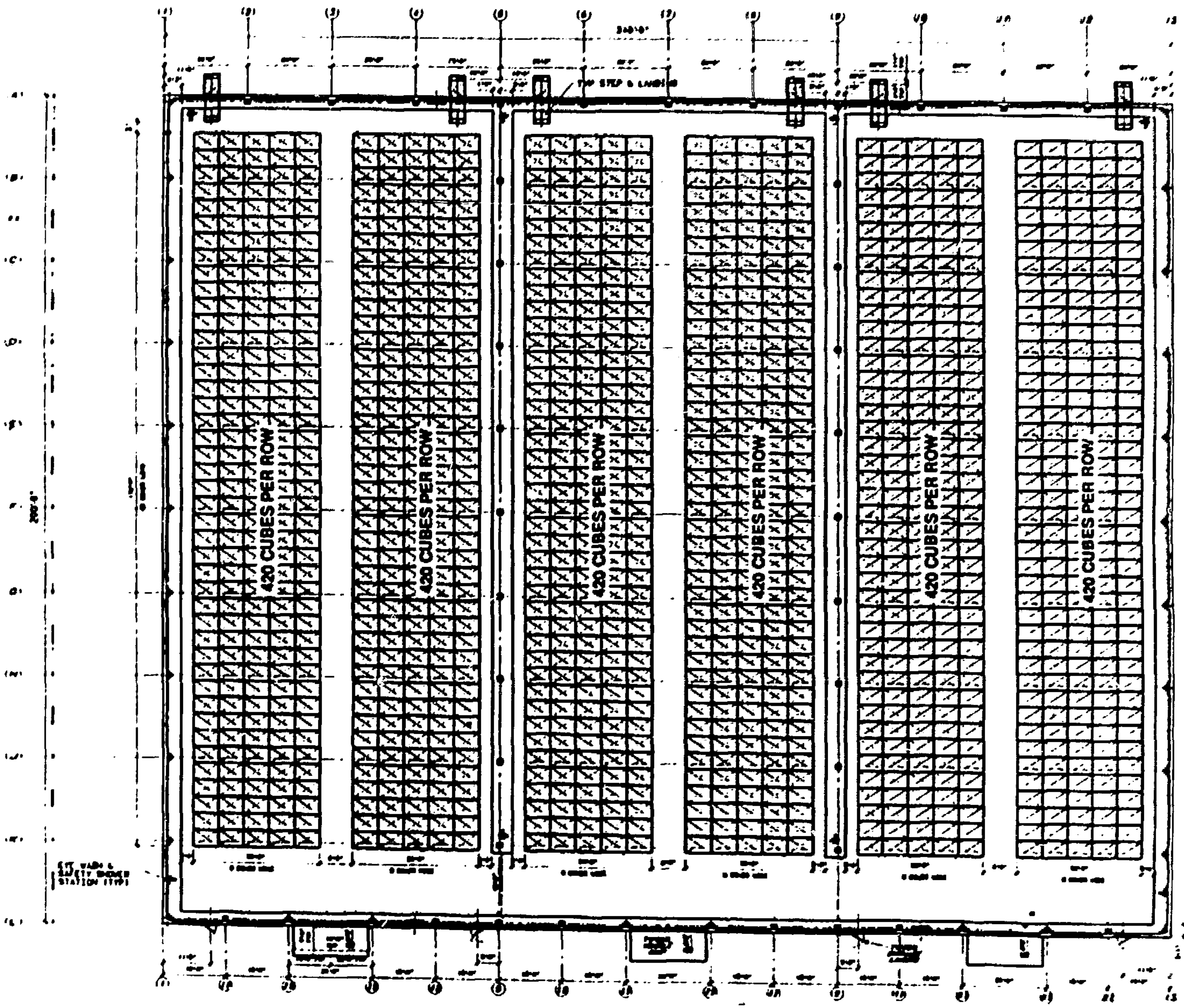

Figure 2. Solid waste storage configuration.

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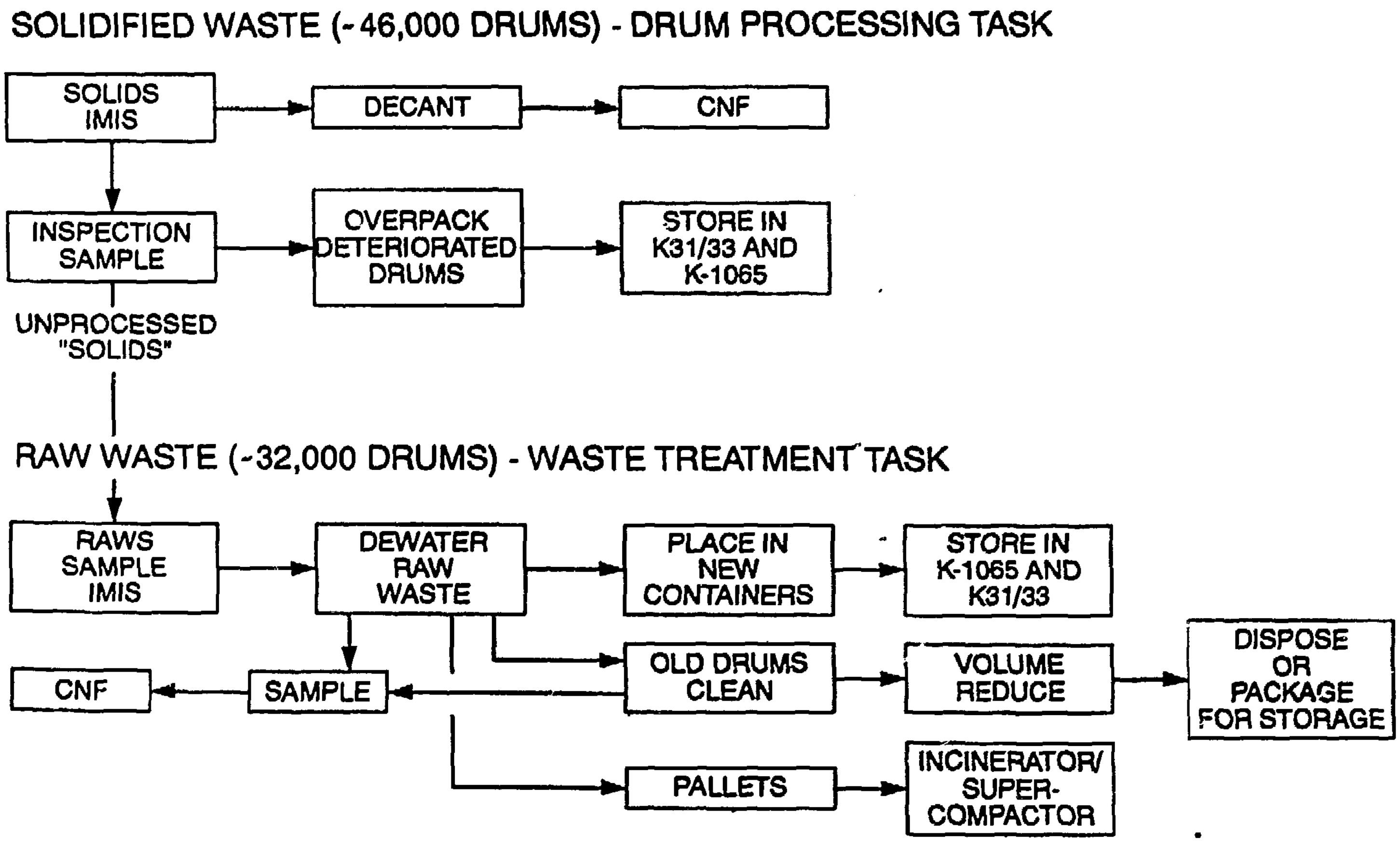

Figure 3. Flowsheet for the Pond Waste Management Project.

performance criteria. Technical, QA, system inspection and testing, documentation, and on-site work requirements will be met as outlined by Martin Marietta Energy Systems, Inc. (Energy Systems).

A method for handling the used mild-steel drums containing raw, unprocessed waste must be devised. The method could include removal of the raw waste from the drums, followed by treatment to meet waste acceptance criteria for decontaminated used drums. Such criteria would fall into four categories: (1) RCRA-defined empty container, (2) radioactively contaminated scrap, (3) clean scrap metal, and (4) Department of Transportation (DOT)-defined radiological material.

During the treatment process, the insult to human health and the environment shall be minimized in accordance with the principle of As Low As Reasonably Achievable (ALARA) in all phases of processing. In addition, it shall be an objective of any treatment scheme that the volume increase of the resulting waste form or the production of new products classified as new waste be minimized. The treated waste will then be stored in new storage facilities discussed above. A flowsheet that defines the basic steps in the raw waste treatment process is shown in Figure 3.

ASSESSMENT OF RAW-WASTE TREATMENT ALTERNATIVES

ASSESSMENT OF ALTERNATIVES

Process flowsheets have been developed and costs have been estimated for three waste treatment processes: (1) dewatering, (2) drying, and (3) solidification/stabilization. The treatment of raw waste could be conducted to achieve two different project objectives: (1) reduce the volume of waste requiring storage, or (2) ensure that LDR treatability standards are met. Treatment alternatives were analyzed with regard to these objectives as well as to the cost and risk of each. For the purpose of the alternative assessment, neither the treatment options nor the forms of the final product were limited.

As described below, the mass of waste to be treated and the material handling aspects of each process are similar. Primary differential cost drivers are the equipment, solidification agents, operation, and volume of treated waste requiring storage. Major assumptions include the operating schedule, the mass of the raw waste to be treated, the bulk density and solids content of the treated waste, and the assumed solids content of the packaged material. Any changes in these assumptions will have a significant effect on the size of the system and the volume reduction achieved by the system. Capital costs to install each treatment system and construct the required storage facilities were estimated along with container costs to establish the basis for an assessment of treatment alternatives. Energy Systems will subcontract an industrial firm to treat the waste; however, the actual subcontract price has not been negotiated. Charges incurred because of processing will be determined through negotiation of technically detailed contracts. The rough-order-of-magnitude cost for the entire project, including the cost of supporting organizations (e.g., project management, treatability studies, environmental compliance, health and safety, and industrial hygiene) were estimated for each treatment option (Table 3).

BENCH-SCALE STUDIES

Bench-scale studies will be conducted using composite samples and will provide data necessary to improve assumptions regarding waste processing performance, to support the specification of procurement requirements for the dewatering process, and to evaluate potential treatment subcontractors. Experimental plans for assessment of the drying and dewatering alternative treatment processes are discussed in the following paragraphs.

Table 3. Rough order-of-magnitude cost estimates and implementation times for Pond Waste Management Project

Element	Stabilization	Dewatering	Drying
Total project cost (in $\$10^6$)	80	69	69
Implementation time (months)	26	20	20

The sludge dewatering potential will be estimated. Using laboratory-scale equipment, waste samples will be dewatered using the following methodologies: (1) oven drying, (2) vacuum filtration, and (3) centrifugation. In each case, water content and density data will be collected using the resulting dewatered material. The collected data will then be used to estimate the waste volume reduction potential resulting from these three methods, a critical parameter in project cost.

Data collected to date have established that the dewatered or dried waste will not meet LDR treatability standards for F006 nonwastewaters.

A comparison of liquid characterization data will be made with CNF waste acceptance criteria. This comparison will provide the data necessary to determine whether pretreatment is required (and, if so, what type) prior to acceptance of this material at the CNF.

The water release potential of dewatered sludge will be determined. It is recognized that complete drying of the sludge samples will eliminate the potential for long-term water release during storage; however, dewatering by use of either a filter or a centrifuge will leave residual water in the final products. An evaluation of the water-release potential of these materials will be performed. Specifically, sludge samples will be dewatered to varying degrees (ranging from the raw sludge, as received, to zero water content), and the resulting dewatered material will be subjected to the following three tests: (1) EPA paint filter liquids test (SW-846 Method 9095), (2) EPA liquid release test (SW-846 Method 9096), and (3) a modified ASTM B553 thermal cycle test. The paint filter test is an EPA-approved method used to determine that no free liquids are present in waste destined for a RCRA landfill. The liquid release test, presently under development, is expected to eventually be used in conjunction with, or as a replacement for, the paint filter test. The liquid release test, which evaluates liquid release potential under an overburden pressure of 50 psi, coupled with a modified ASTM B553 test (which will evaluate liquid release potential under potential temperature variations during storage) appears to reasonably approximate the potential environmentally-induced liquid release mechanisms during actual storage of the waste. This evaluation will provide the data necessary to evaluate the potential for liquid release during storage.

MASS OF RAW WASTE TO BE PROCESSED

Average densities and solids contents for both K-1407-B Pond and K-1407-C Pond sludge were estimated, based on process knowledge, and were assumed to be as follows:

	K-1407-B pond	K-1407-C pond
Density, g/cm^3	1.30	1.40
Solids content, wt %	30	45

The distribution of the 32,000 drums of raw waste was assumed to be 50% 89-gal drums and 50% 96-gal drums, and each was assumed to be 90% full. The operating schedule was assumed to be 7 days per week and 16 h per day, with each operating day including 1 h for startup and 1 h for shutdown, resulting in 14 actual operating hours per day. All subsequent calculations were based on these assumptions.

DEWATERING

The basis for investigation of the dewatering system was that 32,000 drums would be processed in 30 weeks. The availability factor was assumed to be 80%, and the average processing rate was calculated to be 14 drums per hour, or ~ 22 gal/min. A preliminary flow diagram is shown in Figure 4.

A filter press was considered to be the most likely dewatering device, based on literature that indicates it is capable of achieving the highest level of dryness of the various types of dewatering devices employed in the municipal wastewater industry. The filter press was assumed to be able to dewater the raw waste to 50% solids. It was assumed to have a 2-h cycle time (from the start of filtration to discharge of the dewatered cake).

In calculating the final volume of filter cake that would require packaging for storage, the bulk volume of the broken-up cake was assumed to be 25% less than the cake density calculated based on the basic sludge solids content. It was assumed that the dewatered filter cake would be packaged in 120-gal containers that would be filled to 90% capacity. Free liquid is expected to form gradually in the dewatered product; therefore, the storage containers must be corrosion resistant. Structural integrity must be sufficient to stack the containers in a three-high array to meet requirements for inspectability and for the designed storage configuration (Figure 1). Because these criteria are identical to those established for the overpack container, the overpack containers (specified above) were selected for this purpose.

The process will produce more homogeneous waste form, place the waste in containers that are constructed of material that is compatible with the waste, reduce the amount of liquid requiring storage, and prepare used mild-steel drums and pallets for disposal. The dewatered waste will not meet LDR requirements and will require further treatment during phase 6 of the remediation plan.

DRYING

The basis for investigation of the drying system was that 32,000 drums of raw sludge would be processed in 30 weeks at an average processing rate of 14 drums per hour, or ~ 22 gal/min. A preliminary flow diagram is shown in Figure 5.

A process consisting of mechanical dewatering followed by thermal drying was considered. based on the premise that it would be less expensive to remove as much water as possible by mechanical means prior to achieving final dryness with the application of heat.

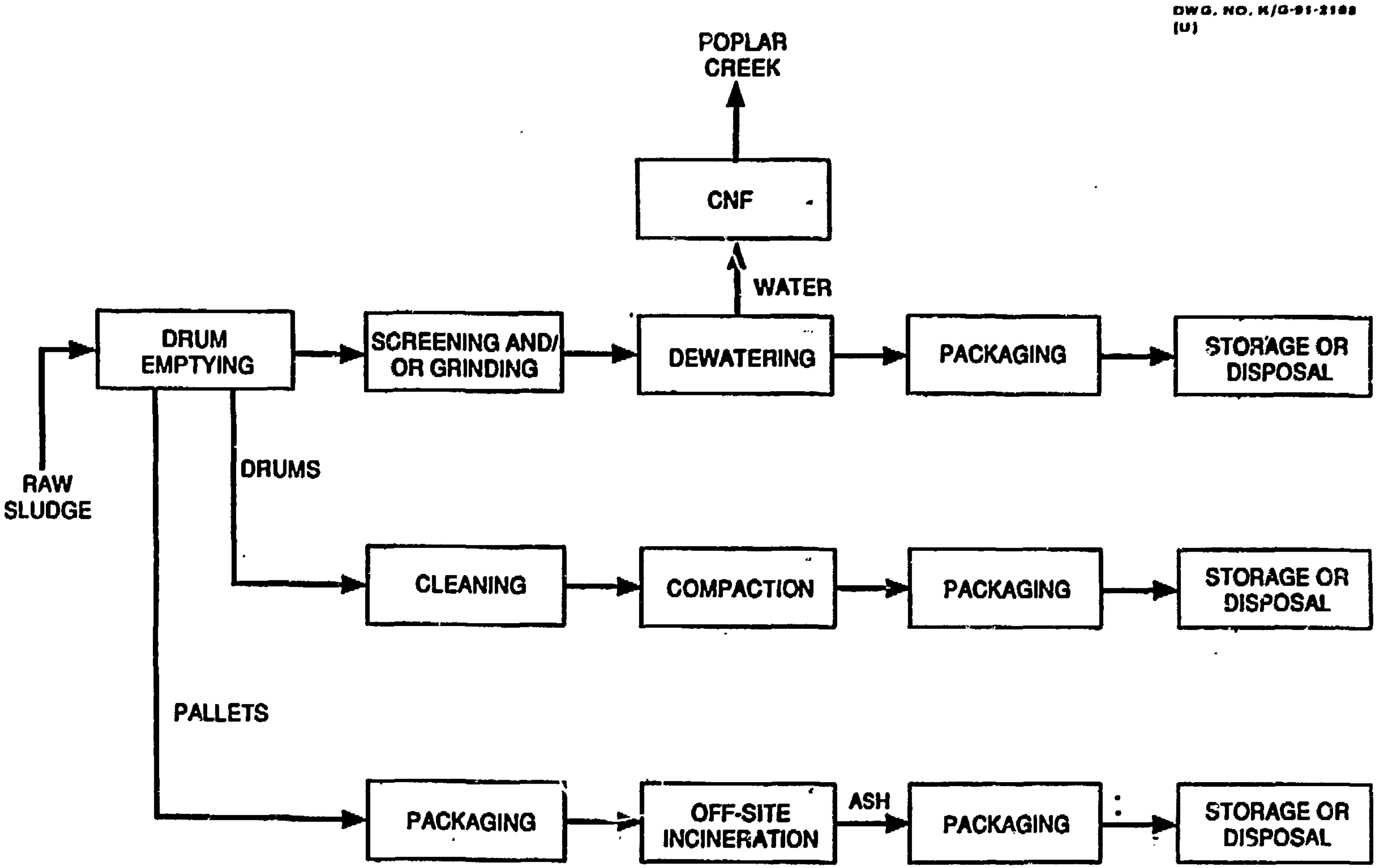

Figure 4. Block flow diagram — dewatering.

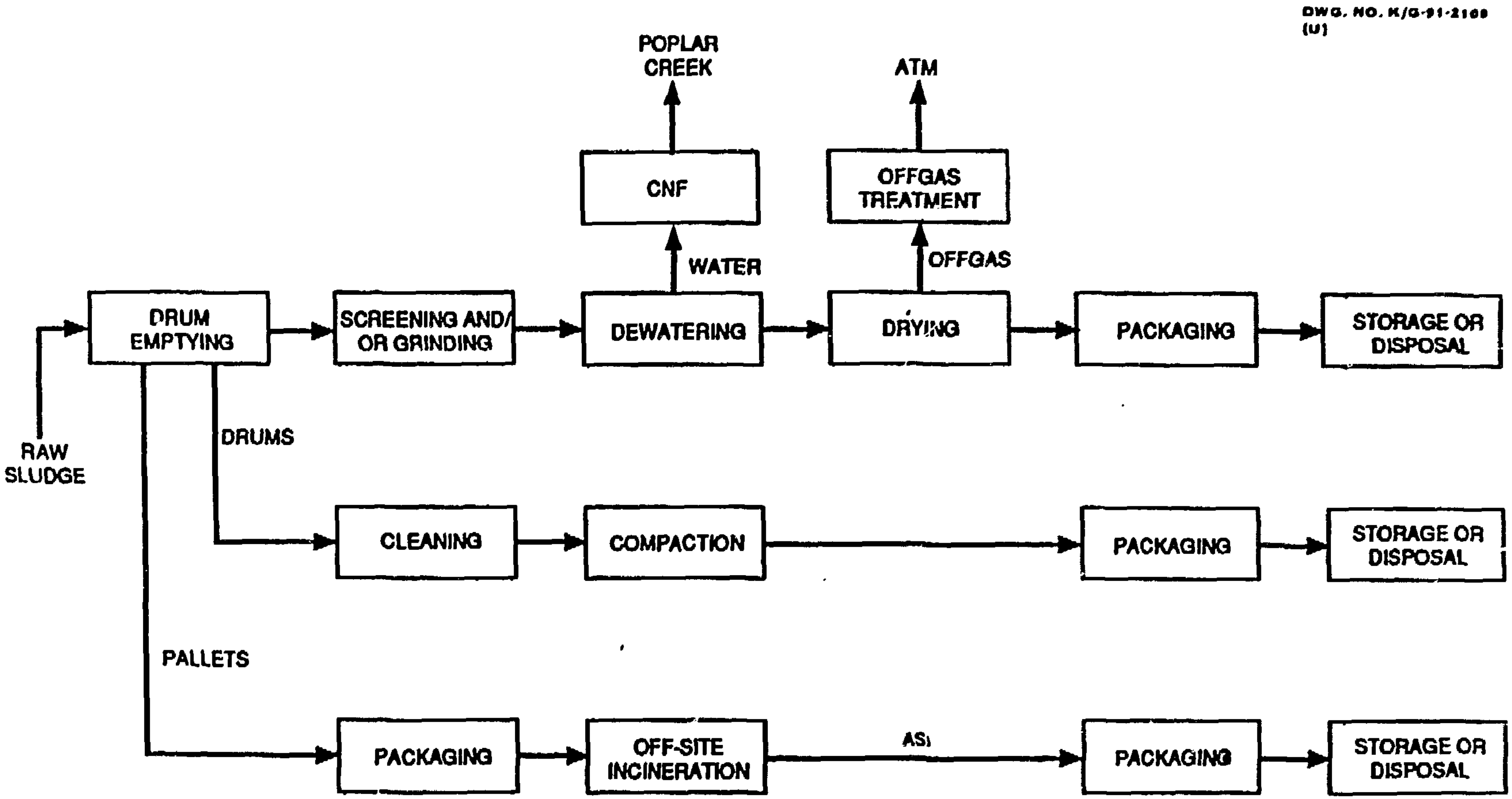

Figure 5. Block flow diagram — drying.

A filter press was considered to be the most likely dewatering device, based on literature that indicated it is capable of achieving the highest level of dryness of the various types of dewatering devices employed in the municipal wastewater industry. The filter press was assumed to use a 2-h cycle time (from the start of filtration to discharge of the dewatered cake) and to be capable of dewatering the sludge to 50% solids.

An indirect, steam-heated rotary disk dryer was considered as the thermal drying device, based on descriptions of such equipment in various textbooks and periodicals. The dryer was assumed to be capable of drying the dewatered cake to 95% solids. Textbook values for the evaporation rate and the steam requirement of 1.8 lb per ft^2 per hour and 1.3 lb steam/lb water evaporated, respectively, were assumed. The air flow rate through the dryer was based on the vessel volume and the normal working level of the material in the dryer, which is 60 to 90% (according to the manufacturer's literature). It was assumed that one air change per minute would be required to remove water vapor at the necessary rate. Based on data that indicate the radionuclides will not volatilize at the estimated drying temperature, water vapor and particulates (from entrainment) were assumed to be the only contaminants in the off-gas. Therefore, the off-gas treatment system was comprised of a mist eliminator, reheat coil, roughing filter, and HEPA filter.

In calculating the final volume of filter cake that would require packaging for storage, the bulk volume of the broken-up cake was assumed to be 50% less than the cake density calculated based on the basic sludge solids content. It was assumed that the dewatered filter cake would be packaged in 120-gal containers that would be filled to 90% capacity.

The uncertainty regarding the corrosive nature of the dried sludge mandates that the storage containers would be corrosion resistant. The proposed storage configuration and the requirement for inspectability dictates that the containers would have a structural integrity sufficient to stack in a three-high array (Figure 1). Therefore, the overpack containers, specified above, were selected for this purpose.

The treatment process would result in a dried material with unknown characteristics (e.g., particle size, packing, density) that would not meet LDR requirements. Drying of heterogeneous waste is not commonly practiced to produce an end product, and industrial processes are not readily available; therefore, this option was eliminated from consideration because of technical risk.

SOLIDIFICATION/STABILIZATION

The basis for the investigation of the solidification system was that 32,000 drums of raw sludge would be processed in 49 weeks at an average processing rate of 9 drums per hour, or ~ 14 gal/min. Because the QA procedures for solidification operations would be more rigorous than those for dewatering or drying options, the process throughput was assumed to be slower. A preliminary flow diagram is shown in Figure 6.

It was assumed that the sludge would be formulated into grout using the proportions determined to be optimal prior to the previous solidification campaign, as shown in Table 2. The drums would be processed in batches that are adjusted to 25 wt % solids before being mixed with cement and fly ash. It is assumed that the batch size (~ 27 drums) would be large enough that it would not be necessary to decant supernate to adjust the solids concentration to 25 wt %, although it would be necessary to add water to some batches for concentration adjustment. Since the sludge consistency in the drums would range from a slurry to solids similar to clay, it would be necessary to use heavy-duty blending equipment to homogenize the batches of sludge. The 2600-gal conical twin-screw auger tank used in the

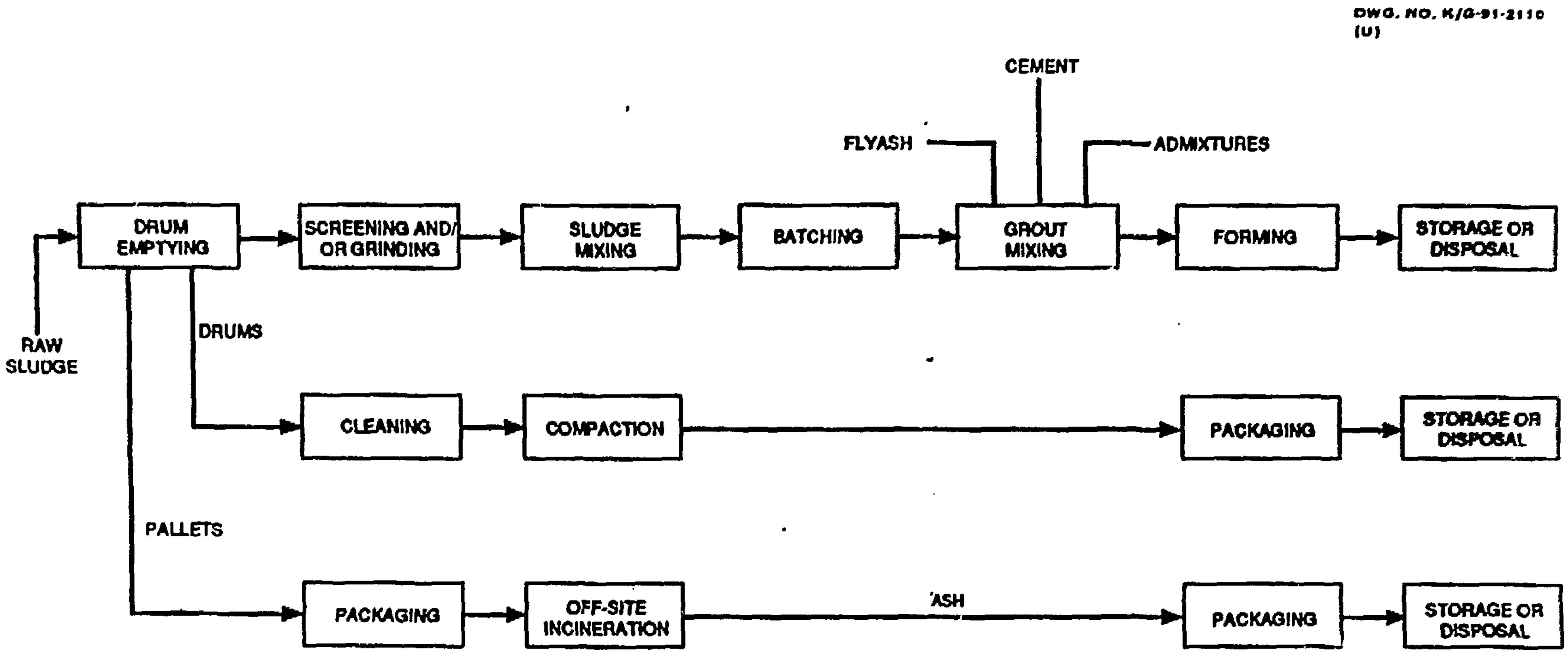

Figure 6. Block flow diagram — solidification/stabilization.

previous operation with pond sludge operated very satisfactorily in pulverizing, delumping, and blending the sludge. Based on this information, the same type of blend tanks was selected for the sludge solidification flowsheet.

Two 2600-gal conical auger tanks would be operated in parallel. Sludge from the dumping station would be transported into one tank while the other is being processed. The tanks would operate on a 3-h-fill, 3-h-discharge cycle. The sludge would be blended, sampled, and water added (if required) to adjust the concentration. It would be necessary to transfer the sludge rapidly from the blend tank to meet the production schedule. A 50-gal/min slurry pump would be installed at the discharge of each blend tank.

A batch mixing operation was selected over a continuous process since it was considered to provide more effective process control. A weigh tank (for weighing each batch of sludge that goes into the grout mixer) would be located downstream of each blend tank.

The equipment items most likely to be used for grout mixing are high-energy mixers, pug mills, and in-line mixers. The high-energy mixer appears to be more suitable for the batch operation flowsheet. The Littleford mixer gave good performance in the previous sludge processing operation. Two 5-yd^3, high-energy mixers operated in parallel were selected for grout mixing. At the processing rate of 9 drums per hour and 14 h of operation per day, each mixer would process ~ 11 batches of sludge. This is a conservative design since each mixer should be capable of processing 2 or more batches per hour.

A standard cement plant with 100-yd^3, silos (which provide approximately a 3-d supply of materials) would be used for storage of the cement and fly ash. The cement plant would include the conveyor and separate weigh tanks for the cement and fly ash. A 2000-gal additive storage tank and metering system would be provided. The system would also require a tank or basin for the holdup of water used to wash the grouting equipment at the end of each operating period. Grout from the mixers would be pumped directly into the grout containers.

The waste loading of solids was based on the grout formulation shown in Table 2 and was calculated to be 12.5% solidified material A trough-like configuration was assumed for receipt of the solidification process effluent. One trough would support 24 boxes (4 x 4 x 6 ft) that would be filled sequentially. The grout would be maintained in the trough/box configuration to cure for 4 d so that it would develop enough strength to be self-supporting. Bleed water would be managed before the boxes were moved into storage buildings.

It was assumed that the treated waste would be classified as a "waste pile" as defined under 40 CRF 264.250(c). The exterior of the storage building would be inspected periodically and after storm events; however, no inspection of individual containers would be required. This assumption allows a stacking array that is more dense than the array required for dewatered or dried waste. A cubical configuration was also assumed, further increasing the stacking density of the solidified material (Figure 2). Because of the bearing strength of the storage building floor, cubes of solidified material could be stacked in a array no more than two high.

Prior to the assessment of the dewatering and drying alternatives, vendors were contacted and proposed treatment processes that would meet treatment and waste form criteria. In this way, a wide range of processes could be evaluated. Solidification/stabilization vendors would have been required to warrant that the waste will meet LDR treatability standards after treatment. Compliance with performance criteria originating from the governing regulatory agencies (i.e., the DOE, TDEC, and the EPA) would be established for the chosen process and any final resulting waste form. The prevailing criterion would be the treatability standard established for F006 nonwastewaters by the LDR. The treated waste form would be subjected to a total-constituent analysis and the toxicity characteristic leaching procedure (TCLP) to ensure compliance with LDR treatability standards. The data obtained would be used to support a delisting petition and to quantify radionuclide concentrations so that disposal alternatives could be assessed when they became available. Vendors would have been required to conduct tests specified by the U. S. Nuclear Regulatory Commission (NRC) to quantify waste form performance with regard to the leachability of radionuclides.

Bench-scale treatability tests would have been required to support waste solidification/stabilization procurement to demonstrate that the proposed process would provide a waste form that meets LDR treatability standards. Confirmatory tests would have been performed by Energy Systems staff members, and the vendor would provide data necessary to evaluate proposals. Prior to bench-scale tests being conducted at a vendor's facility, that vendor would have been required to provide written documentation of NRC and state licenses to handle the specific types and quantities of radionuclides likely to be present in the mixed-waste sludge, namely, enriched uranium. In addition, all expenses related to bench-scale testing would have been incurred by the vendor.

The process would yield a solid monolith that would meet LDR requirements, and solidification is considered the best demonstrated available technology (BDAT) for F006 wastes. However, it was not selected as the treatment option because the volume of waste requiring storage would be increased and the waste form requirements for radioactive waste disposal have not been established.

HANDLING OF USED DRUMS AND PALLETS

The empty drums were assumed to be cleaned to RCRA standards — but not decontaminated to radiological standards, because it is doubtful that decontamination could be accomplished and verified with old, rusty drums. They were then assumed to be compacted to a height of 3 in. and packaged in strong, tight containers (ST-5 boxes) at 64 crushed drums per box.

It was assumed that the pallets would be low-level waste, not mixed waste, and that they could be incinerated. The amount of ash was calculated assuming that the pallets were about 5 ft^2 6 in. high and that incineration would result in a 100:1 volume reduction factor. It was assumed that this ash would be placed in ST-5 boxes and returned to the K-25 Site.

SUMMARY

Approximately 78,000 drums of low-level radioactive mixed waste, generated from an environmental restoration project, are currently stored at the Oak Ridge K-25 Site under conditions that are not in compliance with RCRA requirements. A plan of action has been initiated to (1) treat the raw sludge by dewatering and repackaging it into new containers, (2) decant the water from the stabilized-sludge drums and repair the drums or overpack them as necessary, and (3) move all the drums into existing buildings and/or new storage facilities. This plan includes six phases to correct the noncompliance issues expeditiously and to protect human health, environment, and technology implementation.

Three alternative treatment processes were assessed to establish a base line for comparison. Dewatering the raw waste was selected as the preferred approach because both the process and the resulting waste form present the lowest risk with regard to human health, environment, and technology implementation.

LDR requirements would not be met by dewatering or drying the waste; however, volume reduction, removal of debris, and placement of the waste in compatible containers would be achieved. Drying the waste was not selected because the uncertainty associated with the final waste form is high and industrial processes are not readily available for this approach. Implementing the solidification alternative would have resulted in a waste form that would meet

LDR requirements, but the volume would be significantly increased. Further, criteria for radioactive waste disposal have not been established because disposal sites are not currently available. The uncertainty associated with solidifying the waste to unknown standards contributed to the decision to dewater the raw waste rather than to solidify it.

The schedule for the plan of action calls for completion of the improved storage phase in February 1993. Because a disposal site for treated waste is currently not available, final treatment and disposition of the raw sludge and decanted stabilized drums of pond waste material will be postponed until a later date. The objective of this paper is to describe: (1) the background for the situation; (2) a plan for remediating the waste; and (3) an analysis of alternative treatment processes for raw waste.

ACKNOWLEDGMENTS

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REFERENCE

1. *Support for Characterization, Grout Formulations, and Stabilization of K-1407-B and -C Pond Sludges*, Report No. K/QT-199, September 1988.

APPENDIX.
SLUDGE CONSTITUENT ANALYSIS

7/17/90
Update

Table A.1. Preliminary radionuclide analysis of solidified drums

Samples: solidified cement cubes

Date completed: April 2, 1990

Number of samples: 18

Batches represented: 35-2641 ("C" Pond only)

Sample results:

Radionuclide	Range of Results	Simple Average	Draft waste classification limits* (pCi/g) Limit A	Limit B
^{99}Tc	36-580 pCi/g	160 pCi/g	490	8
^{137}Cs	0.36-10 pCi/g	2.7 pCi/g	190	720
^{137}Np	0.3-11 pCi/g	2.3 pCi/g	8.8	0.01
Total U	28.5-436 μg/g 18.5-399 pCi/g	120 μg/g (101 pCi/g) 1.0 wt % ^{235}U	50	30
^{238}Pu	0.04-0.31 pCi/g	0.13 pCi/g	1160	800
^{239}Pu	0.25-13 pCi/g	2.7 pCi/g	690	800

*Waste classification:

Limit A is based on exceeding the limits for any single radionuclide established by the low-level waste disposal development and demonstration program.

Limit B is based on exceeding the limits for any single radionuclide established by the site Environmental Impact Statement.

Table A.2. Summary data for K-1407-B pond sampling[a]

Parameter	Mean	Maximum	Minimum	Units
Aluminum	36200.	49000.	19000.	µg/g
Arsenic	162.	250.	5.0	µg/g
Barium	221.	290.	120.	µg/g
Beryllium	2.0	3.1	1.4	µg/g
Boron	110.	190.	77.	µg/g
Cadmium	2.0	5.6	0.30	µg/g
Calcium	58000.	200000.	29000.	µg/g
Chromium	815.	2400.	290.	µg/g
Cobalt	42.	61.	22.	µg/g
Copper	1030.	1600.	420.	µg/g
Iron	75500.	20000.	35000.	µg/g
Lead	121.	180.	66.	µg/g
Lithium	23.	37.	16.	µg/g
Magnesium	6790.	16000.	4700.	µg/g
Manganese	642.	830.	460.	µg/g
Molybdenum	17.	49.	1.0	µg/g
Nickel	4133.	7100.	34.	µg/g
Niobium	≤0.70	≤0.70	≤0.70	µg/g
Phosphorus	12790.	21000.	6200.	µg/g
Potassium	4100.	7300.	2000.	µg/g
PCBs[b]	≤0.0010	≤0.0010	≤0.0010	µg/g
Selenium	88.	140.	5.0	µg/g
Sodium	1151.	3100.	390.	µg/g
Strontium	136.	190.	81.	µg/g
Thorium	21.	30.	20.	µg/g
Titanium	363.	460.	220.	µg/g
Vanadium	44.	61.	17.	µg/g
Zinc	607.	810.	480.	µg/g
Cesium	15.	16.	15.	dpm/g
Neptunium	7.2	17.	1.3	dpm/g
Plutonium	7.1	19.	1.9	dpm/g
Technetium	8088.	15000.	2500.	dpm/g
Density	1.1	1.2	1.1	g/mL
pH	7.0	7.4	6.7	
Uranium	516.	1044.	69.	µg/g
Uranium-235	1.2	1.3	1.1	wt %
Acetone	≤0.0010	≤0.0010	≤0.0010	µg/g
Fluorocarbons	≤0.0010	≤0.0010	≤0.0010	µg/g
Trans-1,2-dichloroethylene	≤0.0030	≤0.0030	≤0.0030	µg/g
Phosphate (total)	38370.	63000.	18600.	µg/g

[a]Taken from K/QT-199, *Support of Characterization, Grout Formulations, and Stabilization of K-1407-B and -C Pond Sludges*. See full report for detailed characterization data.
[b]Polychlorinated biphenyls.

Table A.3. Summary data for K-1407-C pond sampling[a]

Parameter	Mean	Maximum	Minimum	Units
pH	10.	11.	8.1	
Aluminum	25392.	42000.	8500.	μg/g
Arsenic	20.	97.	5.0	μg/g
Barium	89.	150.	13.	μg/g
Beryllium	≤0.030	≤0.030	≤0.030	μg/g
Boron	4252.	11000.	85.	μg/g
Cadmium	0.65	1.8	0.30	μg/g
Calcium	35000.	90000.	30000.	μg/g
Chromium	601.	2400.	30.	μg/g
Cobalt	51.	210.	2.0	μg/g
Copper	583.	2000.	120.	μg/g
Iron	25185.	73000.	2500.	μg/g
Lead	42.	140.	6.0	μg/g
Lithium	16.	31.	2.9	μg/g
Magnesium	7885.	11000.	5500.	μg/g
Manganese	383.	1000.	73.	μg/g
Molybdenum	≤1.0	≤1.0	≤1.0	μg/g
Nickel	5667.	21000.	240.	μg/g
Niobium	2.7	5.3	0.70	μg/g
Phosphorus	5016.	18000.	320.	μg/g
Potassium	9507.	15000.	2600.	μg/g
PCBs[b]	≤0.0010	≤0.0010	≤0.0010	μg/g
Selenium	6.0	13.	5.0	μg/g
Sodium	7388.	15000.	740.	μg/g
Strontium	111.	150.	95.	μg/g
Thorium	37.	52.	20.	μg/g
Titanium	361.	770.	110.	μg/g
Vanadium	23.	45.	11.	μg/g
Zinc	221.	660.	68.	μg/g
Cesium	119.	511.	15.	dpm/g
Neptunium	45.	183.	1.5	dpm/g
Plutonium	62.	241.	1.0	dpm/g
Technetium	3476.	13600.	293.	dpm/g
Density at 25°C	1.4	1.7	1.1	g/mL
Acetone	0.32	1.0	0.10	μg/g
Benzene	≤0.040	≤0.040	≤0.040	μg/g
Bromodichloromethane	≤0.020	≤0.020	≤0.020	μg/g
Bromoform	≤0.050	≤0.050	≤0.050	μg/g
Carbon tetrachloride	≤0.030	≤0.030	≤0.030	μg/g
Chlorobenzene	≤0.060	≤0.060	≤0.060	μg/g
Chloroform	≤0.020	≤0.020	≤0.020	μg/g
Cis-1,3-dichloropropane	≤0.050	≤0.050	≤0.050	μg/g
Dibromochloromethane	≤0.030	≤0.030	≤0.030	μg/g
Ethyl benzene	≤0.070	≤0.070	≤0.070	μg/g
Freon-113	0.11	0.27	0.10	μg/g
Freon-114	≤0.10	≤0.10	≤0.10	μg/g
Freon-123	≤0.10	≤0.10	≤0.10	μg/g
Methyl ethyl ketone	≤0.10	≤0.10	≤0.10	μg/g
Methylene chloride	0.030	0.040	0.030	μg/g
Other halomethanes	≤0.10	≤0.10	≤0.10	μg/g
Permethylated cyclosiloxane	≤2.4	≤2.4	≤2.4	μg/g
Tetrachloroethylene	≤0.040	≤0.040	≤0.040	μg/g
Toluene	0.062	0.090	0.060	μg/g
Trans-1,2-dichloroethylene	≤0.020	≤0.020	≤0.020	μg/g
Trans-1,3-dichloropropene	≤0.050	≤0.050	≤0.050	μg/g
Trichloroethylene	≤0.020	≤0.020	≤0.020	μg/g
Trichlorofluoromethane	≤0.10	≤0.10	≤0.10	μg/g
Uranium	515.	1841.	58.	μg/g
1,1-Dichloroethane	≤0.050	≤0.050	≤0.050	μg/g
1,1-Dichloroethylene	≤0.030	≤0.030	≤0.030	μg/g
1,1,2-Trichloroethane	≤0.050	≤0.050	≤0.050	μg/g
1,1,2,2-Tetrachloroethane	≤0.070	≤0.070	≤0.070	μg/g
1,2-Dichloroethane	≤0.030	≤0.030	≤0.030	μg/g
1,2-Dichloropropane	≤0.060	≤0.060	≤0.060	μg/g
Uranium-235	1.6	2.6	1.3	wt %

[a]Taken from K/QT-199, *Support of Characterization, Grout Formulations, and Stabilization of K-1407-B and -C Pond Sludges*. See full report for detailed characterization data.

[b]Polychlorinated biphenyls.