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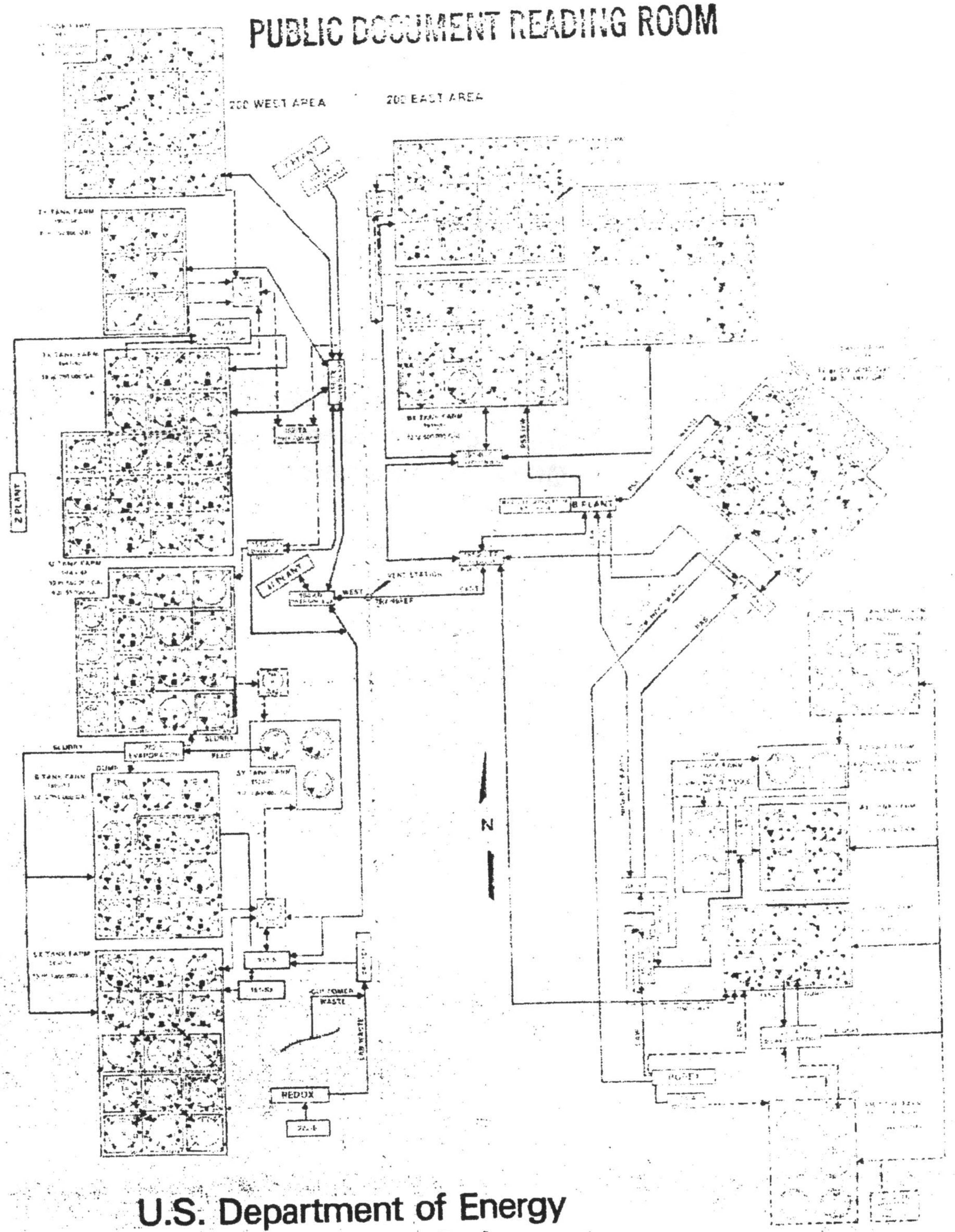
REP-032780

Assessment of the Surveillance Program of the High-Level Waste Storage Tanks at Hanford



U.S. Department of Energy

Assistant Secretary for Environment

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Assessment of the Surveillance Program of the High-Level Waste Storage Tanks at Hanford

D. E. WOOD

Robert J. Catlin, Deputy Director
Office of Environmental Compliance and Overview
Office of Environment

MARCH 1980

Report to the

U.S. Department of Energy
Assistant Secretary for Environment
Washington, DC

R00775

March 27, 1980

Fact Sheet

Assessment of the Surveillance Program of the High Level Radioactive Waste Storage Tanks at the Hanford Reservation

The DOE Assistant Secretary for Environment, Ruth C. Clusen, initiated an independent assessment of the surveillance program of the high level radioactive waste storage tanks at the Hanford Reservation, Richland, Washington in the fall of 1979. Major findings and conclusions of this assessment are:

- The Panel on Hanford Wastes of the National Academy of Science/ National Research Council in 1978 concluded that there had not been in the past, and is not at present, any significant radiation hazard to public health and safety from waste management operations at Hanford. The same conclusion is reached in this independent assessment.

- Hanford has two types of high level waste storage tanks: 149 single shell tanks built between 1943 and 1964 that were not heat treated for stress relief, and 7 double shell tanks built after 1968 (plus 13 tanks under construction) that are heat treated. Leakage in storage tanks are associated only with tanks that were not heat treated.

- To date, 24 single shell tanks have been classified as confirmed leakers, 34 single shell tanks have been classified to be of questionable integrity. Leakage or suspected leakage has generally been determined by loss of liquid in the tanks or by evidence of ground contamination outside the tank as measured in dry wells. No leakage has been found in double shell tanks.

- Since the first tank leak in 1958, over 120 million gallons of drainable liquids have been processed from the tanks. About 11 1/2 million gallons of drainable liquids are presently stored in the tanks; this volume will be reduced to about 1 million gallons in the mid 1980's from waste solidification efforts. Removal of tank liquids from the single shell tanks progressively affects the capability to detect tank leakage and to take appropriate corrective action.

- It was determined that DOE Headquarters should promptly issue formal health and safety and quality control and assurance orders, to assure uniform waste management practices at DOE facilities. More meaningful requirements are needed in operations directives regarding detection of tank leakage and appropriate corrective actions of such leakage. Formal, flexible criteria should be established for classification of tank soundness, determination of leakage, and graded remedial action in event of leakage or suspected leakage.

- The surveillance program for leak detection in single shell tanks is adequate, except as leak monitoring systems are made non-functional due to liquid removal during waste solidification. Development of newer in-tank monitoring methods now under study may help remedy this situation. Further evaluation of such methods is needed. The surveillance program for leak detection in double shell tanks is adequate.

- Formal criteria are needed to establish proper dry well surveillance frequencies: These should be determined on a tank-by-tank basis, taking into account pertinent technical factors such as available monitoring systems, tank contents and the relative mobility of such contents. Until formal criteria are developed, some tanks should be monitored more frequently than every two weeks and some less frequently. Tanks with redundant monitoring systems can remain on a bi-weekly frequency. But active tanks in a dynamic state and inactive tanks monitored only by dry wells and containing substantial quantities of drainable liquids should be monitored more frequently than every two weeks.

- Programs for surveillance of tank concrete integrity, including measurements of heat generation rates, are adequate. The related tank dome survey program under development should be made operational.

- The intrusion monitoring program for determining leakage into the waste storage tanks is adequate for all tanks. Intrusion monitoring should be maintained until the tanks are fully isolated.

- Recorded data used in day-to-day waste management and surveillance operations is adequate and up-to-date. Other documents, reports and procedures lack consistency and contain erroneous data. Quality control is needed to update and simplify this latter documentation.

- Except as noted, quality control organization and procedures, and material balance methods applied to waste management operations are adequate, taking into account the physical limitations of the measurement systems in the latter case.

- Decisions on the final disposition of the storage tanks should be accelerated before more tank failures occur so that the ease of fixation of tank content inplace or their transfer may be improved, and the amount of further environmental contamination may be lessened.

- Additional research is recommended in the determinations of mobility of interstitial liquids contained in salt cake in the storage tanks, and of improved techniques for stabilization of salt cake and sludge residues in the tanks.

Assessment of the Surveillance Program of the High-Level Waste Storage Tanks at Hanford

Robert J. Catlin, Deputy Director
Office of Environmental Compliance and Overview
Office of Environment

MARCH 1980

Report to the

U.S. Department of Energy
Assistant Secretary for Environment
Washington, DC

Preface

This report presents an assessment of the technical adequacy of the surveillance program of the high-level radioactive waste storage tanks on the Hanford Reservation of the U.S. Department of Energy (DOE) located in southeastern Washington. The assessment was made in response to an assignment from Ruth C. Clusen, Assistant Secretary for Environment (ASEV), to Robert J. Catlin, Deputy Director, Office of Environmental Compliance and Overview.

ASSESSMENT BACKGROUND

In June 1978, the Department of Energy (DOE) Richland Operations Office (RL) requested that the operating contractor, Rockwell Hanford Operations, review the overall monitoring program for the high-level waste storage tanks on the Hanford Reservation and recommend appropriate cost effective changes/redirection while continuing to protect man and the environment. The RL request was based on the success of the waste solidification program, which at that time had resulted in 109 of the 149 single-shell tanks being pumped to a minimum heel and put in an inactive status; the plan was to have all 149 tanks removed from service by the end of 1980. As a result of the Rockwell review of the overall monitoring program, only the dry well monitoring schedule was changed from weekly to biweekly. Stephen Stalos, Manager of Rockwell's Tank Farm Surveillance Analysis, expressed concern to Rockwell management about the adequacy of biweekly dry well monitoring. Rockwell management reviewed Stalos's concerns and concluded that the overall tank monitoring program did provide adequate surveillance coverage, and the biweekly frequency was maintained.

Stalos resigned on Dec. 6, 1978, and in a subsequent press conference alleged irregularities in waste management operations and deficiencies in the tank surveillance program. Stalos subsequently expressed his concern to DOE officials at Richland Operations and Headquarters. At the request of ASEV, the Office of Inspector General (IG) obtained a sworn statement from Stalos dated Feb. 2, 1979, to clearly define his concerns. Essentially, the major concerns stated are: (1) "coverup" of leaking waste tanks, specifically Tanks 107-TX, 110-TX, and 104-AX, and (2) reduction in dry well monitoring frequency from weekly to biweekly, which reduced capability for prompt detection of leaks, as required by the EIS ERDA-1538 and DOE policy. The IG initiated a review of alleged mismanagement and coverup, and the ASEV initiated this review of the technical adequacy of the waste tank surveillance program.

Concurrently, many public inquiries were received on the Hanford waste management and surveillance program; letters were exchanged between Stalos and DOE officials; and an inquiry was sent to DOE by Senator Jackson in January 1979. On Aug. 3, 1979, Senator Udall sent a detailed inquiry to Secretary Duncan about the Stalos concerns. In response, the Department promised Senator Udall the results of the IG and ASEV reviews.

OBJECTIVE AND SCOPE OF ASSESSMENT

On Aug. 29, 1979, Ruth C. Clusen, Assistant Secretary for Environment, assigned Robert J. Catlin the task of developing an "independent assessment of the surveillance program of the high level radioactive waste storage tanks at Hanford." A copy of the assignment memorandum, dated Aug. 29, 1979, which is appended to this preface, details the objective and scope of the review. Consultants were retained to provide special expertise, and analytical and other support to Catlin. Unfortunately, one consultant, Betty N. MacDonald, had to withdraw for medical reasons shortly after the assessment began; she was not replaced. Part of the scope included a charge to interview Stalos to clearly define his concerns about the surveillance program. The scope required a technical review of the surveillance program to determine:

1. "The adequacy of the surveillance program and procedures judged against DOE policy and the referenced reports."

2. "The degree of actual implementation of the surveillance program and procedures."

3. "The adequacy of the basis and justification for changing the frequency of dry well monitoring."

4. "The effect on the margin of safety and protection from environmental damage caused by changing the frequency of dry well monitoring from weekly to biweekly, considering the total tank farm surveillance program and the condition and content of the tanks."

The full group met in Washington, D.C., Sept. 27 and 28, 1979, for an organizational and briefing meeting. The plan of work involved meetings with Stalos, briefings by appropriate DOE Headquarters program divisions and staff of the Inspector General, field trips to the Hanford Reservation and the Savannah River Plant for the purpose of gaining information through briefings and interviews, and the acquisition of pertinent data, reports, and procedures for use during the review. The assessment was to be developed in detail by Catlin, with technical and administrative support from the Division of Operational and Environmental Safety, DOE. The consultants would review and make inputs to this assessment and would provide expertise in their specialized areas of competence, inputs to the completed assessment, and, if they desired, final statements to be appended to the report without change. In this manner, the consultants were to be afforded the opportunity to express views independent of those reached by Catlin. Statements by three of the consultants appear as Appendices A, B, and C.

During the initial meeting, the full group was briefed by Headquarters representatives of the Office of Nuclear Waste Management and the Office of Inspector General. Also, Stephen Stalos was interviewed by the full group. In the ensuing period Catlin met with Stalos several times to review his concerns about the surveillance program. Stalos formally restated his concerns on surveillance in a Feb. 5, 1980, letter to Catlin, which is included as Appendix G.

The group met in Richland, Washington, on Oct. 11 and 12, 1979, for a briefing by the DOE Richland Operations Office and Rockwell Hanford Operations on the surveillance program and a field review of waste management and surveillance activities. Later, meetings were held in San Diego and Berkeley, Calif., and in Washington, D.C. Catlin and Schneider also reviewed the waste surveillance practices at the Savannah River Plant to compare techniques and practices at the two sites. Catlin spent the week of Jan. 7, 1980, at Richland.

DOE Headquarters and RL and the operating contractor, Rockwell Hanford Operations, responded to many requests for specific information from individuals, as well as from the full group. The group had available many formal documents and technical reports. Much use was made of the "Final Environmental Impact Statement on Waste Management Operations at the Hanford Reservation," ERDA-1538; the "Draft Environmental Impact Statement, Supplement to ERDA-1538," DOE/EIS-0063-D, January 1980; the report, "Radioactive Wastes at the Hanford Reservation," 1978, by the National Research Council of the National Academy of Sciences; and the "Alternatives for Long-Term Management of Defense High Level Radioactive Waste, Hanford Reservation," ERDA-77-44, September 1977.

The charge was to "....prepare an independent assessment of the surveillance program of the high level radioactive waste storage tanks at Hanford." This assessment has been an independent one, but it has been based, by necessity, on a large amount of data, reports, procedures, and presentations by the contractor operating the waste management facilities, Rockwell Hanford Operations, and on information supplied by the staff of the DOE Richland Operations Office and the waste management program group at DOE Headquarters. Insofar as possible, independent checks and re-evaluations of the data and information were made, particularly where similar data were drawn from different sources.

Second, this assessment is not a general treatise on surveillance of radioactive wastes of all kinds. It is limited strictly to a technical evaluation of the current practices for surveillance of the high-level radioactive wastes now accumulated in storage tank farms at the Hanford Reservation.

In developing this assessment, it was not feasible to separate the surveillance program from the need for a detailed understanding of the operations involving high-level radioactive wastes, the historical operations, and the monitoring experience in the tank farm areas. In this regard, it is recognized that waste management practices at Hanford have been criticized and mistakes may have been made in the past when judged by present-day practices. Furthermore, most of the high-level waste was produced at a time when production of plutonium was urgent, and the wastes were a separate problem that could be postponed. This assessment has considered past practices only in the context of the surveillance program and does not pass judgement on questions of Hanford history.

REVIEW OF THE INSPECTOR GENERAL

The inquiry by the Office of Inspector General (IG) focused on Stalos's allegations of coverup of leaking waste tanks at Hanford, which he charged were being perpetrated by the operating contractor, Rockwell Hanford Operations, and the DOE Richland Operations Office. In part, Stalos charged that the organizations concerned were following a policy of not announcing tank leaks although a Hanford policy promulgated in 1973 required that all leaking waste tanks at the site be promptly and publicly announced to local and regional news media.

The IG's report, released on Jan. 22, 1980, criticized certain aspects of the Hanford waste management program but could not conclude there was deliberate "coverup" of leaking tanks. Copies of this report are available from the IG.

DOE Form AD 10A
(10-77)

U.S. DEPARTMENT OF ENERGY

memorandum

DATE: AUG 29 1979

REPLY TO
ATTN OF:

SUBJECT: Assessment of the Surveillance Program of the Waste Storage Tanks at Hanford

TO:

R. J. Catlin, Deputy Director
Office of Environmental Compliance
and Overview, EV-10

In accordance with our recent conversation, you are to prepare for me an independent assessment of the surveillance program of the high level radioactive waste storage tanks at Hanford. The objective and scope of the assessment is set forth in the attachment. The following consultants have been retained to provide analytical and other support to you in this task:

Dr. Patricia W. Durbin
University of California
Lawrence Berkeley Laboratory
Berkeley, California 94720

Dr. Allyn H. Seymour
Professor of College of Fisheries
University of Washington
Seattle, Washington 98195

Mrs. Betty N. MacDonald
Former Energy Chairman
League of Women Voters of the U.S.
1155 Edgewood Avenue
Madison, Wisconsin 53711

Dr. Keros Cartwright
Head, Hydrogeology & Geophysics Section
Illinois Geological Survey
Urbana, Illinois 61801

Dr. Alfred Schneider
Professor of Nuclear Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Additional technical assistance will be made available if needed. Arrangements have been made with the Richland Operations Office to have Mr. F. R. Standerfer, Assistant Manager for Technical Operations, assist you with advisory and administrative support at Richland.

Please provide this assessment by November 15, 1979.

Lynda L. Brothers /for
Ruth C. Clusen
Assistant Secretary for Environment

Attachment

cc w/attachment:
J. M. Deutch, US
J. K. Mansfield, IG-1
C. E. Williams, ET-1
A. G. Fremling, Mgr., RL
Consultants
T. G. Frangos, EV-10
G. P. Dix, EV-12

ATTACHMENT

OBJECTIVE AND SCOPE OF ASSESSMENT OF THE SURVEILLANCE PROGRAM OF THE HIGH-LEVEL WASTE TANKS AT HANFORD

The objective is to develop an independent assessment of the surveillance program of the high-level radioactive waste storage tanks at Hanford. The surveillance program should be evaluated within the context of DOE policy and the Environmental Impact Statement (ERDA-1538), "Waste Management Operations - Hanford Reservation." The scope should include an assessment of Mr. Stephen Stalos' complaint that the reduced surveillance of dry-well radiation monitoring readings from a weekly to a biweekly schedule has reduced the ability to take prompt corrective action in the event of leaks and to promptly detect leaks of radioactive waste as required by DOE policy and the EIS, ERDA-1538. Mr. Stalos should be interviewed to clearly define his concerns about the surveillance program. The Group should review the tank farm surveillance program and make independent assessment of its adequacy. The EIS, ERDA-1538, and the National Research Council report, "Radioactive Wastes at the Hanford Reservation," should be used as baseline references. The findings should cover, as a minimum, the following points:

1. The adequacy of the surveillance program and procedures judged against DOE policy and the referenced reports.

2. The degree of actual implementation of the surveillance program and procedures.

3. The adequacy of the basis and justification for changing the frequency of dry-well monitoring.

4. The effect on the margin of safety and protection from environmental damage caused by changing the frequency of dry-well monitoring from weekly to biweekly, considering the total tank farm surveillance program and the condition and content of the tanks.

Acknowledgments

The Author wishes to acknowledge with thanks the continued and effective cooperation of the following consultants who brought their expertise and analytical skills to bear on this effort: Keros Cartwright, Head, Hydrogeology and Geophysics Section, Illinois Geological Survey, Urbana, Illinois; Patricia W. Durbin, University of California Lawrence Berkeley Laboratory, Berkeley, California; Betty N. MacDonald, former Energy Chairman, League of Women Voters of the United States, who resides in Madison, Wisconsin; Alfred Schneider, Professor of Nuclear Engineering, Georgia Institute of Technology, Atlanta, Georgia; and Allyn H. Seymour, Professor of the College of Fisheries, University of Washington, Seattle, Washington. Betty MacDonald was very helpful in the initial organizational and background reviews and her withdrawal from the assessment for medical reasons was deeply regretted by her colleagues.

Blake P. Brown, Senior Process Safety Engineer, Safety Analysis Branch, Division of Operational and Environmental Safety, who is located at the Headquarters of the U.S. Department of Energy (DOE) in Germantown, Maryland, provided day-by-day technical support and his contributions were essential to the success of the assessment. Mary E. Meadows, Staff Assistant to the Director, Office of Environmental Compliance and Overview, of the DOE Office of Environment in Germantown, Maryland, was especially helpful in handling the administrative details for many meetings of the assessment team.

Stephen Stalos, former Manager of Tank Farm Surveillance Analysis, Rockwell International, Rockwell Hanford Operations, and now of Laurel, Maryland, participated in the initial briefing and subsequent meetings with the Author, and provided much valuable reference material and insights.

Alex G. Fremling, Manager of the DOE Richland Operations Office in Richland, Washington, and members of his staff—in particular, Ron E. Gerton and Albert R. Schwankoff—were instrumental in providing briefings at the Hanford Reservation on waste management operations and related high level radioactive waste storage tank surveillance programs. They freely provided voluminous information and documentation on those programs, and made arrangements for the team to visit the site to inspect the facilities, receive field briefings on the operations, and have the opportunity to talk individually with various members of the contractor's operating and technical staff.

John L. Deichman, Program Director for Waste Management, and other staff of Rockwell International, Rockwell Hanford Operations at the Hanford Reservation in Richland, Washington, provided invaluable assistance and information regarding the actual operational and technical workings of the surveillance program and its integration into waste management operations, both of which Rockwell Hanford Operations performs for DOE under contract with the Richland Operations Office.

Members of the assessment team also reviewed the waste storage tank operations and surveillance program at the DOE Savannah River Plant located in Aiken, South Carolina, which is operated for DOE by E. I. DuPont de Nemours and Company, Inc. The Author acknowledges the excellent cooperation received from the DOE and DuPont staff at Savannah River in providing comparative information on waste tank surveillance.

Stephen P. Cowan, of the Office of Nuclear Waste Management, DOE Headquarters in Germantown, Maryland, provided detailed waste management policy, program and budget information on the operations and surveillance programs at Hanford at at other DOE major sites, and acted as liaison in obtaining needed data and other information from DOE Headquarters and the field.

This report went through a number of preliminary drafts and required a great deal of specialized editorial work due to the large number of graphics involved. The Author is particularly appreciative of the superb and unstinting technical assistance given him by Marian C. Fox and D. M. (Meg) Jared, Technology Transfer Branch, DOE Technical Information Center, located at Oak Ridge, Tennessee. Credit for graphics and layout assistance belongs to Samuel D. Baughman, Chief, Design and Graphics Section, Office of Administrative Services, and his staff at DOE Headquarters, located in Germantown, Maryland.

George P. Dix, Director of the Division of Operational and Environmental Safety, Office of Environment, DOE Headquarters located at Germantown, Maryland, deserves special commendation for providing extensive, technical, administrative and clerical support in the development and production of this report; in particular, George E. Kley who coordinated the final production, and Nancy A. Cashour who guided the clerical effort and prepared most of the final text for printing.

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Abstract of Principal Conclusions and Recommendations

PREAMBLE

On Aug. 29, 1979, Ruth C. Clusen, Assistant Secretary for Environment, assigned Robert J. Catlin, Deputy Director of the Office of Environmental Compliance and Overview, the task of developing an "independent assessment of the surveillance program of the high level radioactive waste storage tanks at Hanford." Catlin was assisted in this task by several consultants. This assessment came as the result of concerns expressed by Stephen Stalos, a former Hanford employee, and others on the adequacy of the surveillance program. A separate report by the Office of Inspector General on allegations by Stalos of coverup of leaking waste tanks at Hanford was released on Jan. 22, 1980.

Review of the technical adequacy of the surveillance program of the waste storage tanks cannot be treated independently of the related portions of waste management operations at Hanford from the initial startup in 1943 through the present. Early design philosophy, which relied on the advantageous characteristics of soil and site hydrology for secondary containment, led to construction of single-shell tanks. Leaks to date from these tanks have proven the worth of such characteristics; no significant radiation hazard to public health and safety has arisen from waste management operations at Hanford. Present design philosophy, which considers the contact of radioactive waste with the soil as undesirable, has led to the construction of double-shell tanks and eventual elimination of the use of single-shell tanks for storage of high level radioactive liquid waste.

After the first tank leak in 1958, a program was undertaken to transfer the contents of leaking tanks to sound tanks and to concentrate waste in tanks by evaporation. This led, in turn, to the waste solidification program in which solids would be stored in single-shell tanks and terminal liquids (nonsolidifiable) would be transferred to double-shell tanks. The success of this program is indicated by the removal of over 120 million gallons of radioactive liquids that might otherwise have been a source of leakage and that would have required additional storage capacity. As currently conceived, the waste solidification program will not leave dry solids in the tanks; of the estimated 15 million gallons of drainable liquids now present, about 1 million gallons will be left in the single-shell tanks at the end of the program in the mid-1980s.

As a result of the waste solidification program, the single-shell tanks are in a transitional state, fully recognized by waste management at Hanford, in which the tanks are being moved from an active to storage state, one by one, and their contents are being progressively modified by evaporation and pumping to leave amounts of liquids and solids that vary as processing proceeds. This transitional state is directly affecting the adequacy of policies and procedures, surveillance methodology and practices, and operating objectives to the extent that certain of these elements of the waste management program are becoming progressively obsolete and require modification.

The major conclusions about the technical adequacy of the waste tank surveillance program and major recommendations for the future are summarized below. Following this list of principal findings are additional suggestions for research which it is felt should be augmented.

CONCLUSIONS AND RECOMMENDATIONS

1. It is concluded, following an update of information relative to risks associated with radioactive wastes in the waste storage tanks, that such risks do not modify the conclusion reached in the National Academy of Sciences 1978 Technical Review that "....there has not been in the past, and is not at present, any significant radiation hazard to public health and safety from waste-management operations at Hanford."

2. DOE Headquarters has not yet issued a formal health and safety order or a quality control and assurance order. It is recommended that such directives be issued promptly. The Richland Operations Office deserves credit for issuing such rules as mandatory requirements at the field level.

3. Relevant portions of the DOE Operations Directive to the contractor must be revised to relate requirements to the diversity in tank types and status more completely. For example, leak detection and corrective action requirements should not be imposed that progressively become ineffective or unfeasible as a result of the waste solidification program.

4. On the basis of failure experience of the single-shell tanks, a limited extrapolation indicates that an additional 10-15 tanks will become unsound in the next several years. Caution must be exercised to maintain an adequate degree of waste tank surveillance while drainable liquids are being removed during the waste solidification program. Due to reductions in liquid levels in the tanks, leak indications may be delayed; small leaks could go undetected. Some tanks may not have sufficient liquid left to leak.

5. It is strongly recommended that formal, flexible criteria be established for classification of tank soundness, for determination of whether or not a tank is leaking and for remedial actions. Criteria should be separate for single-shell and double-shell tanks, and distinct from criteria used to define operational status.

6. The surveillance program for leak detection in the single-shell tanks is generally considered adequate at the present time, as the majority of drainable liquids are monitored by one or more monitoring systems. This situation could change markedly as the present in-tank monitoring system becomes non-functional due to supernatant liquid withdrawal during the waste stabilization program. Careful planning is recommended to ensure that pumping and monitoring tank contents are optimized so that the possibility of release to the soil is minimal.

7. Development of an in-tank monitoring capability for measuring levels of interstitial liquids has not kept pace with the waste solidification program. In the absence of such monitors and as present liquid level monitors become non-functional, tank leakage can only be inferred by external systems, for example, dry wells. Interstitial liquid monitors may serve only a transient need; their development and use must be balanced by consideration of utility, risk avoided, cost, and possible alternative measures such as acceleration of pumping and final desiccation of tank contents. Further evaluation of the need for such monitors should be made.

8. Because of the transitional nature of the single-shell tanks, dry well and horizontal lateral well monitoring frequency should be determined on a tank by tank basis. Formal criteria are needed to redetermine the surveillance frequency for each tank and the development of such criteria is recommended, taking into account pertinent technical factors such as available monitoring systems, tank contents and their relative mobility. Until formal tank by tank criteria are developed, which may result in some tanks being read more frequently than biweekly for certain periods of time and some less frequently, tanks with redundant monitoring systems can remain on a biweekly frequency; but active tanks in a dynamic state and inactive tanks monitored only by dry wells and containing substantial quantities of drainable liquids should be monitored more frequently than every two weeks.

9. Programs for surveillance of the integrity of the reinforced concrete shell of single-shell tanks, including monitoring of heat generation levels, appear to be adequate. The related dome survey program under development should be brought to an operational state.

10. Liquid intrusion monitoring in single-shell tanks is adequate. The liquid intrusion experience requires that the liquid-level monitoring systems be maintained in a fully operable state until tanks are fully isolated.

Chapter 1 Background

1.1 INTRODUCTION

The Hanford Reservation, the tank farm facilities, sources of the waste, waste management programs, organizations, and budgets are briefly summarized in this chapter to provide background on the assessment of the surveillance program. Detailed descriptions of the Hanford Reservation, the tank farm facilities, and the waste management program have been published, particularly in the Environmental Impact Statement, ERDA-1538, and the Alternatives Document, ERDA 77-44.

Since 1944, facilities on the Hanford Reservation, located near Richland, Washington, in the Columbia Basin region of southeastern Washington State, has been producing special nuclear materials (primarily plutonium) for defense and research. High-level radioactive liquid waste has been and will continue to be accumulated as part of the process of producing plutonium.

1.2 TANK FARM FACILITIES

The radioactive waste processing and storage activities are located in the 200 East (200-E) and 200 West (200-W) areas of the Hanford Reservation. These areas are approximately 2.5 miles apart and are located in the middle of the reservation on a plateau about 7 miles from the Columbia River. Their location was chosen not only to provide the most isolation from the Hanford boundaries but also to be the most removed from both surface and subsurface water. The groundwater table under these areas is 150 to 300 feet below the surface. A diagram of the 200 Areas, the facilities, and the tank farms is shown in Fig. 1.

A total of 156 large underground storage tanks exist at Hanford for the storage of high-level radioactive waste, and an additional 13 tanks are now under construction. The tanks are grouped in 17 farms of 2 to 18 tanks per farm as shown on Fig. 1. During 1943-44 48 tanks of 500,000-gallon capacity each and 16 of 55,000-gallon capacity were constructed to provide storage for the waste streams from fuel processing plants using the original bismuth phosphate process. Additional underground storage tanks were built over the years to contain the waste generated by continued processing and, later, by newer and improved separation processes. Twelve more 500,000-gallon tanks were built in 1946-47. During the period from 1947 to 1952, a total of 48 750,000-gallon tanks were constructed and, from 1953-64, 25 1,000,000-gallon tanks were constructed. All of these tanks were of single-shell variety, with waste containment being provided by a single-shell (SS) carbon-steel tank cup liner surrounded by a reinforced concrete, domed structure. The concrete dome of the tank vault is exposed to the tank interior above the level of the cup liner. The 149 SS tanks are listed in Table 1. The SS tanks were designed for both nonboiling and boiling wastes; details of the tanks are shown in Figs. 2 and 3.

The other seven existing tanks, which were built in the period 1968-77, and the additional 13 tanks under construction, as listed in Table 2, are of a reinforced concrete vault, carbon-steel double-shell (DS) design. Each of these tanks consists of three concentric structures. The outer tank is a reinforced concrete vault; inside that is a carbon-steel secondary shell that extends beyond the haunch (junction of dome and sidewall) to the concrete vault dome. Within the secondary steel shell is the inner, freestanding, completely enclosed carbon-steel tank referred to as the primary tank. An 8-inch slab of insulating concrete (a castable refractory made with an aluminate cement and a slate aggregate) is sandwiched between the primary and secondary tank bottoms. This slab protects the reinforced concrete foundation from excessive temperatures during the stress relief of the primary tank. The primary and secondary steel tanks are separated at the vertical sidewalls by an annular space of about 2.5 feet to allow for monitoring and inspection, ventilation, containment of liquids should the primary tank leak, and installation of equipment for pumping liquid out of the annular space to another tank. During operation of the tanks, the annulus ventilation system routes air through slots in the insulating concrete slab to the annulus for monitoring leakage. At the top, the steel dome of the primary tank lies contiguous with the interior surface of the concrete vault dome. The upper, unsealed edge of the secondary steel liner terminates at the juncture of the primary tank and the concrete vault domes.

Extensive piping interties exist within and between tank farms in the 200-E and 200-W Areas so that wastes can be transferred to or from any tank in the system. Within tank farms, certain tanks require pump-out jumpers or short lengths of overground piping to be installed before pumping can be initiated. Some of these lines have secondary containment (pipe or concrete); others do not. A detailed description of these lines can be found in Appendix II.1-C, Parts 3 and 4, ERDA-1538, Volume 2. In addition to several older transfer lines, a relatively new doubly-encased (pipe-in-pipe) line exists for transfer of wastes between the 200-E and 200-W Areas. Concrete diversion boxes and vaults each play an active role in waste processing and transfer operations. These functions are detailed in the reference previously cited. In brief, diversion boxes provide a shielded enclosure for jumper connections between various transfer lines and for collection of any waste leakage from such connections. Vaults, on the other hand, are shielded enclosures, used to collect, clarify, and allow physical and chemical modification of content before such contents are transferred elsewhere.

Associated with the various tank farms are the evaporators used to convert liquid waste to salt cake. Two units are presently in operation. A third unit, the 242-T evaporator in the 200-W Area, has been shut down but a portion of its facilities are used for salt waste neutralization. The 242-A evaporator and 242-S evaporator are separate facilities located in the 200-E and 200-W Areas, respectively.

The tanks built at Hanford in the period 1943-64 had single-shell carbon-steel liners that were not stress relieved after fabrication. The hot alkaline radioactive waste mixture of liquid plus sludge induced stress-corrosion cracking of the steel, and over the years leakage was confirmed or suspected in a number of these SS tanks, as shown in Table 3. Tank failure is discussed in more detail later in this report and in the appendices. The DS tanks have been stress-relieved, and stress-corrosion failure is unlikely. A more complete description of the double-shell tanks may be found in DOE/EIS-0063-D, Jan. 1980.

1.3 DESCRIPTION OF WASTE TYPES

Four basic chemical processing operations were the sources of radioactive waste solutions transferred to the underground storage tanks since startup of the Hanford site in 1944. The bismuth phosphate ($BiPO_4$), Redox, and Purex processes were specifically designed for the recovery of plutonium from spent fuel elements. The tributyl phosphate (TBP) process was designed for the recovery of relatively large amounts of uranium which remained in the $BiPO_4$ process waste. The more advanced Redox and Purex processes recovered both the uranium and plutonium. Relatively small amounts of other waste added to tank storage include: research and development program wastes, facility and equipment decontamination wastes, plutonium purification facility wastes, and B Plant wastes (waste fractionization process). Significant quantities of high-level waste have not been added to storage since the Purex plant was placed in standby status in September 1972. The acidic wastes have been neutralized with sodium hydroxide and/or sodium carbonate for storage in the carbon-steel tanks.

1.4 CHEMICAL COMPOSITION OF HIGH-LEVEL WASTES

High-level wastes from the various separation processes have been mixed, but the composition is not uniform from tank to tank. In general the high-level wastes consist chiefly of sodium salts such as the nitrate, nitrite, carbonate, aluminate, and phosphate with free sodium hydroxide and small amounts of the hydrous oxides of iron and manganese. These salts are distributed between an aqueous supernatant and a solid, complex precipitate or "sludge." In addition, the waste contains fission-product radionuclides and actinide elements (U, Th, Pu, and Np). Section 3.3 of the Alternatives Document, ERDA 77-44, presents an estimate of the average chemical composition and estimates of the major fission products and actinides in the Hanford high-level wastes.

1.5 WASTE SOLIDIFICATION PROGRAM

A program to help ensure continued waste containment and to limit the number of new tanks required was undertaken in 1957 when atmospheric pressure evaporations were used to extract water and thereby reduce the volume of stored wastes. Beginning in 1958, problems were experienced with liquid leaking from some of the tanks. As a result, the primary thrust of waste management since the 1960s has been reduction of the volume of liquid waste by evaporation of water to form "salt cake" and residual liquor.

Additional waste concentration was achieved in the mid-1960s by the use of an in-tank solidification scheme. A more recent process involves the use of two vacuum evaporator-crystallizer units to produce salt cake. These systems have been in operation since early 1974 with excellent results. The product of such evaporation, as previously noted, is salt cake, which still has about 50 volume percent of interstitial liquid. Approximately 60% of this liquid can eventually be extracted from the salt cake by screened jet pumps; this liquor may be further concentrated by recycle to the evaporator-crystallizer units. The concentration of free sodium hydroxide must be kept below 6 molal, however, to prevent the resulting salt cake from becoming deliquescent. The remaining highly caustic liquid ("terminal liquor"), which cannot be further concentrated by evaporation without forming an unacceptably deliquescent product, may be partially neutralized with successive additions of nitric acid and recycled to the evaporator-crystallizer units. This neutralization and production of salt cake can be continued until aluminum hydroxide starts to precipitate, after which the residual liquor is placed in high-integrity double-wall tanks to await future development of a solidification process.

Sludge, as previously noted, is a complex precipitate resulting from neutralization of incoming acid waste solutions;

the tank sediments other than salt cake can be considered sludge. Approximately 12.5% of the sludge volume is drainable liquid, as contrasted with 30 to 50% of salt cake volume. Other characteristics of the salt cake and sludge are presented in Table 4, which is adapted from the 1978 National Research Council/National Academy of Sciences Technical Review.

The objectivesof the waste management program are:

- Store the water-insoluble low-heat sludge precipitated from the original liquid waste in the existing single-shell tanks.
- Process the high-heat sludges and overlying solutions to remove, solidify, and store, in double-walled metal capsules, most of the ^{90}Sr and ^{137}Cs. The removal of these isotopes (fractionization) allows solidification of the remaining waste to be completed without concern for possible overheating of the tanks.
- Concentrate existing dilute liquid wastes via evaporation to produce damp salt crystals (salt cake) for storage in existing single-shell tanks.
- Pump as much of the interstitial liquid as possible from the damp salt cake contained in single-shell tanks (stabilization) for further evaporation.
- Store the remaining nonevaporable liquid (residual liquor) in double-shell tanks.
- Continue storage of stabilized solidified wastes in single-shell tanks, which are modified by sealing the tanks against liquid intrusion from any credible source and by confining the atmosphere in the tank, except for filtered airways for normal tank breathing and (where necessary) ventilation for temperature control.

By 1977, the backlog of dilute radioactive liquid wastes had been concentrated to a working inventory such that radioactive liquids could be concentrated as they were generated; presently that is at a rate of about 1 million gallons annually. Substantial quantities of the cesium and strontium have been removed from the stored wastes. Not all the strontium was recovered from certain tank farms because of the age of the tanks and possibility that liquid leakage might occur during sluicing of the sludge.

The waste management solidification program is scheduled to be completed in the mid 1980s. The progress of the waste solidification program is shown in Table 5 and Fig. 4. As the liquid is evaporated, the single-shell (SS) tanks are in a transitional state in which individual tank operational status is moving from active through inactive to a quasi-solid storage state. Of the 149 SS tanks, 25 are in active use, 66 are inactive, other than 24 confirmed leakers and 34 questionable integrity. The distribution of total drainable liquids in the SS and double-shell tanks is shown in Table 6.

Resumption of Purex plant operation, presently scheduled for the early 1980s will result in the generation of comparatively small volumes of high-level waste. This impact is discussed in Section 3.4 of the Alternatives Document, ERDA 77-44.

1.6 ORGANIZATIONS FOR WASTE MANAGEMENT

Various government agencies and contractors have been responsible for the waste management operations at Hanford (Manhattan Engineer District to 1947, U.S. Atomic Energy Commission from 1947 until 1974, U.S. Energy Research and Development Administration from 1974 to 1977, and at present the U.S. Department of Energy). The contractor presently operating at Hanford high-level waste facilities is Rockwell Hanford Operations (RHO), Rockwell International.

The line organization for the Hanford waste management program is shown on Fig. 5. Key components are DOE Headquarters, DOE Richland Operations Office (RL), and RHO. Figure 6 shows the RL line organization for the waste management program.

Rockwell Hanford Operations is responsible for the actual operation of the high-level waste facilities, including surveillance. The RHO organizational charts are shown in Figs. 7 through 12. The line responsibilities for surveillance have been emphasized on the charts. RHO utilizes a matrix management approach; Figure 13 shows schematically the interactions between the program offices and the functional organizations.

1.7 BUDGET

Funding for the interim waste operations program at Richland is given in Table 7 for fiscal years 1979 and 1980 together with projected figures for fiscal 1981. As shown in the table, Hanford (Richland) is receiving a substantial portion of the waste management funds in comparison with the other major DOE sites, slightly greater than the funding for the Savannah River Plant. A finer breakdown of the $59.4 million for Hanford waste operations for fiscal 1980, presented in Table 8, shows that 11% of the funds are allotted to surveillance and maintenance, 30% to waste concentration and solidification, 25% to radioactive cesium and strontium removal and encapsulation, and the remainder to other site waste operations. Surveillance and maintenance funding for fiscal year 1980 is 4% ($300 thousand) lower than for the previous year; this is offset by a 25% ($1.6 million) increase projected for fiscal year 1981, intended to expand efforts in a number of critical areas, such as tank monitoring and related research and development. The detailed breakdown of surveillance and maintenance funding presented in Table 9 shows the various activities encompassed within this budget category.

TABLE 1.

HANFORD SS TANK FARM FACILITIES

STATUS AS OF 1-25-80

TANK FARM	YEARS OF CONSTRUCTION	NO. OF TANKS	INDIV. TANK CAPACITY (GAL)
(200-E)			
A	1954-55	6	1,000,000
AX	1963-64	4	1,000,000
B	1943-44	12	500,000
		4	55,000
BX	1946-47	12	500,000
BY	1948-49	12	750,000
C	1943-44	12	500,000
		4	55,000
(200-W)			
T	1943-44	12	500,000
		4	55,000
TX	1947-48	18	750,000
TY	1951-52	6	750,000
U	1943-44	12	500,000
		4	55,000
S	1950-51	12	750,000
SX	1953-54	15	1,000,000
	TOTAL:	149	

TABLE 2.

HANFORD DS TANK FARM FACILITIES

STATUS AS OF 1-25-80

TANK FARM	YEARS OF CONSTRUCTION	NO. OF TANKS	INDIV. TANK CAPACITY (GAL.)
(200-E)			
AY	1968-70	2	1,000,000
AZ	1971-77	2	1,000,000
AW	1976 FUNDING	6	1,000,000 (UNDER CONSTRUCTION)
AN	1977-78 FUNDING	7	1,000,000 (UNDER CONSTRUCTION)
(200-W)			
SY	1974-77	3	1,000,000
	TOTAL:	20 (13 UNDER CONSTRUCTION)	

TABLE 3.

HANFORD SS TANK FARM FACILITIES
TANK FAILURE EXPERIENCE

STATUS AS OF 1-25-80

YEAR CLASSIFIED	CONFIRMED LEAKER (NO. OF TANKS)		QUESTIONABLE INTEGRITY (NO. OF TANKS)	
	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
1958	1	1	0	0
1959	1	2	0	0
1960	2	4	0	0
1961	1	5	0	0
1962	1	6	0	0
1963	0	6	0	0
1964	1	7	0	0
1965	2	9	0	0
1966	0	9	0	0
1967	0	9	0	0
1968	1	10	1	1
1969	1	11	3	4
1970	0	11	2	6
1971	1	12	4	10
1972	1	13	3	13
1973	3	16	1	14
1974	2	18	8	22
1975	2	20	0	22
1976	0	20	5	27
1977	0	20	10	37
1978	0	20	1	38
1979	0	20	0	38
1980	4	24	(–4)	34 (4 TANKS RECLASSIFIED AS LEAKERS)

TABLE 4.

VOLUMES AND RADIOACTIVITY CONCENTRATIONS IN THE VARIOUS FRACTIONS OF HANFORD WASTES AS OF 1980, WHEN EVAPORATION OF RESIDUAL WATER IS COMPLETE

Waste Form	Volume ($ft^3 \times 10^6$)	Fission Products*			Plutonium and Actinides**†		
		MCi	Ci/ft^3	$\mu Ci/cm^3$	kg	$\mu Ci/ft^3$	$\mu Ci/cm^3$
Sludge	1.0	50	50	1.8×10^3	350	5.9×10^4	2.2
Salt cake	4.0	25	6.2	2×10^2	75	3.2×10^3	0.11
Terminal liquor	1.6	20	12.2	4.4×10^2	1.0	1.0×10^2	0.003
Capsules of ^{137}Cs and ^{90}Sr		165 (corrected)					

* Chiefly residual ^{90}Sr and ^{137}Cs; about 7 percent is contributed by ^{99}Tc and rare earths.

** Most of the ^{237}Np and U isotopes have been recovered from wastes. These calculations assume that the trivalent actinides are distributed among the waste forms in the same proportions as the Pu isotopes. The total alpha radioactivity is about 2.7 times that of the Pu isotopes alone.

† Assuming the following densities (grams per cubic centimeter) for the waste forms: terminal liquor, 1.5; salt cake, 1.75; sludge, 3.0; the concentrations of alpha emitters by weight are 0.002, 0.063, and 0.73 microcuries per gram, respectively.

Source: National Research Council (1978) Radioactive Wastes at the Hanford Reservation - A Technical Review, Table F:6, p. 219.

TABLE 5.

HANFORD HIGH LEVEL RADIOACTIVE WASTES
WASTE SOLIDIFICATION PROGRAM

YEAR	SUPERNATANT LIQUIDS IN STORAGE (MILLION GALLONS)	SOLIDS IN STORAGE (MILLION GALLONS)
1973	42.6	22.4
1977	12.4*	35.6
1979	11.5**	37.7
1981 (PROJECTED)	12.0	40.3

* "CURRENCY" WAS ATTAINED. THE BACKLOG OF DILUTE RADIOACTIVE LIQUID WASTES HAD BEEN CONCENTRATED TO A WORKING INVENTORY AND RADIOACTIVE LIQUIDS CAN NOW BE CONCENTRATED AS THEY ARE GENERATED.

** BETWEEN 1973 AND 1979 AN ADDITIONAL 13 MILLION GALLONS OF RADIOACTIVE LIQUID WASTE WERE GENERATED.

TABLE 6.

HANFORD 200 AREAS TANK FARM FACILITIES INVENTORY—TOTAL DRAINABLE LIQUID

STATUS AS OF 12-31-79

TANK STATUS*	NO. OF TANKS	SUPERNATANT (KGAL)	INTERSTITIAL LIQUID DRAINABLE (KGAL)	TOTAL DRAINABLE (KGAL)
SINGLE-SHELL TANKS (SS)				
L	24	3	429	432
QI	34	104	2,067	2,171
I	66	724	3,160	3,884
A	25	6,718	2,063	8,781
SUBTOTALS	149	7,549	7,719	15,268
DOUBLE-SHELL TANKS (DS)				
A	7	3,978	84	4,062
TOTALS	156	11,527	7,803	19,330

KEY: L = LEAKER; QI = QUESTIONABLE INTEGRITY; I = INACTIVE (OTHER THAN L AND QI); A = ACTIVE

*STATUS OF TANKS 107-B, 201-B, 101-C AND 112-U CHANGED TO L ON 1-25-80

TABLE 7.

INTERIM WASTE OPERATIONS PROGRAM FUNDING
(Dollars in Millions)

SITE	FY 79	FY 80	FY 81
RICHLAND	$ 59.6	$ 59.4	$ 68.0
IDAHO	41.2	27.9	42.2
SAVANNAH RIVER	39.3	56.8	60.9
OTHER SITES	6.8	18.9	48.1
TOTAL	$146.9	$163.0	$219.2

TABLE 8.

HANFORD WASTE OPERATIONS FUNDING
(Dollars in Millions)

	FY 79	FY 80	FY 81
SURVEILLANCE & MAINTENANCE[1]	$ 6.7	$ 6.4	$ 8.0
WASTE CONCENTRATION & SOLIDIFICATION[2]	14.0	18.0	15.2
Cs & Sr REMOVAL & ENCAPSULATION	15.2	15.0	16.0
OTHER SITE WASTE OPERATIONS	23.7	20.0	28.8
TOTAL	$59.6	$59.4	$68.0

[1] Includes surveillance data acquisition, analysis, and reporting; maintenance of monitoring equipment; and technology development.

[2] Includes operations to solidify waste (evaporators) and to remove liquids from old tanks (stabilization).

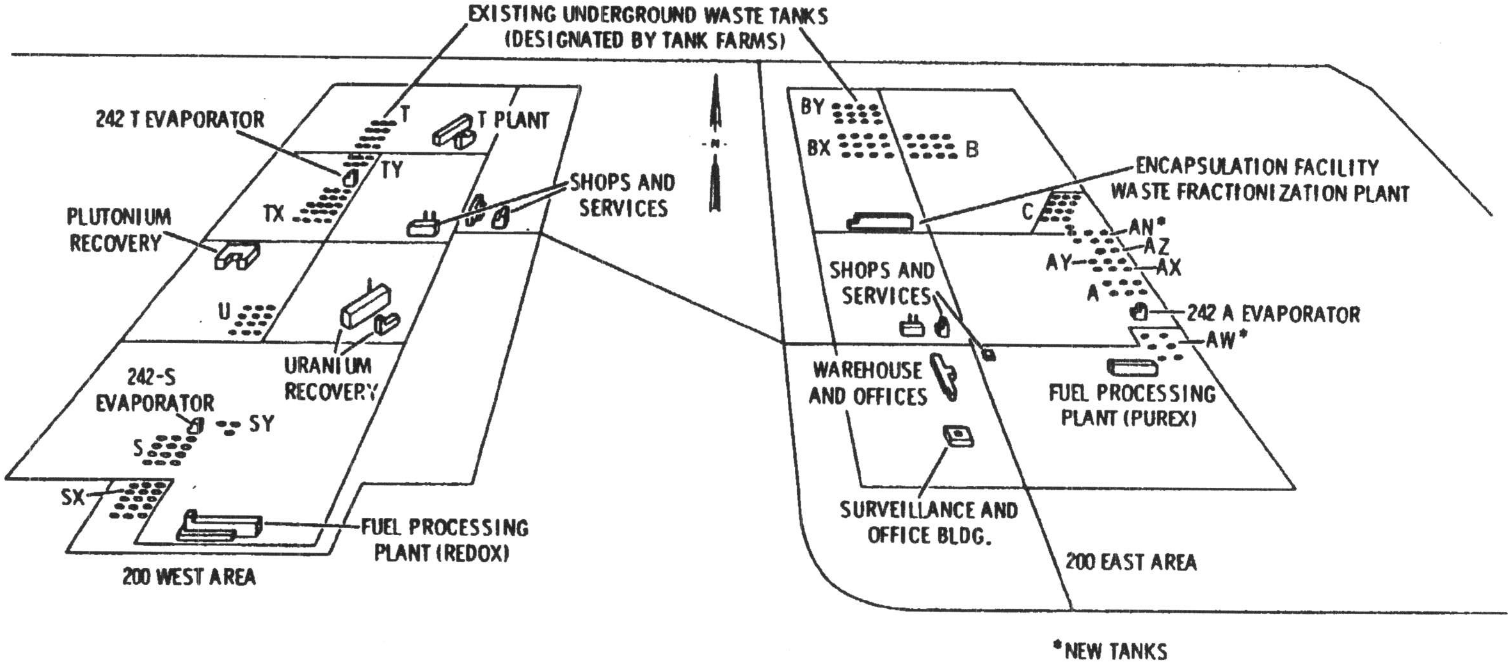

FIGURE 1.
200 AREAS TANK FARM LOCATION AND LOCATION OF NEW TANKS.

SOURCE: DOE/EIS-0063-D: 3.1.2, FIGURE 3.3, 3-5.

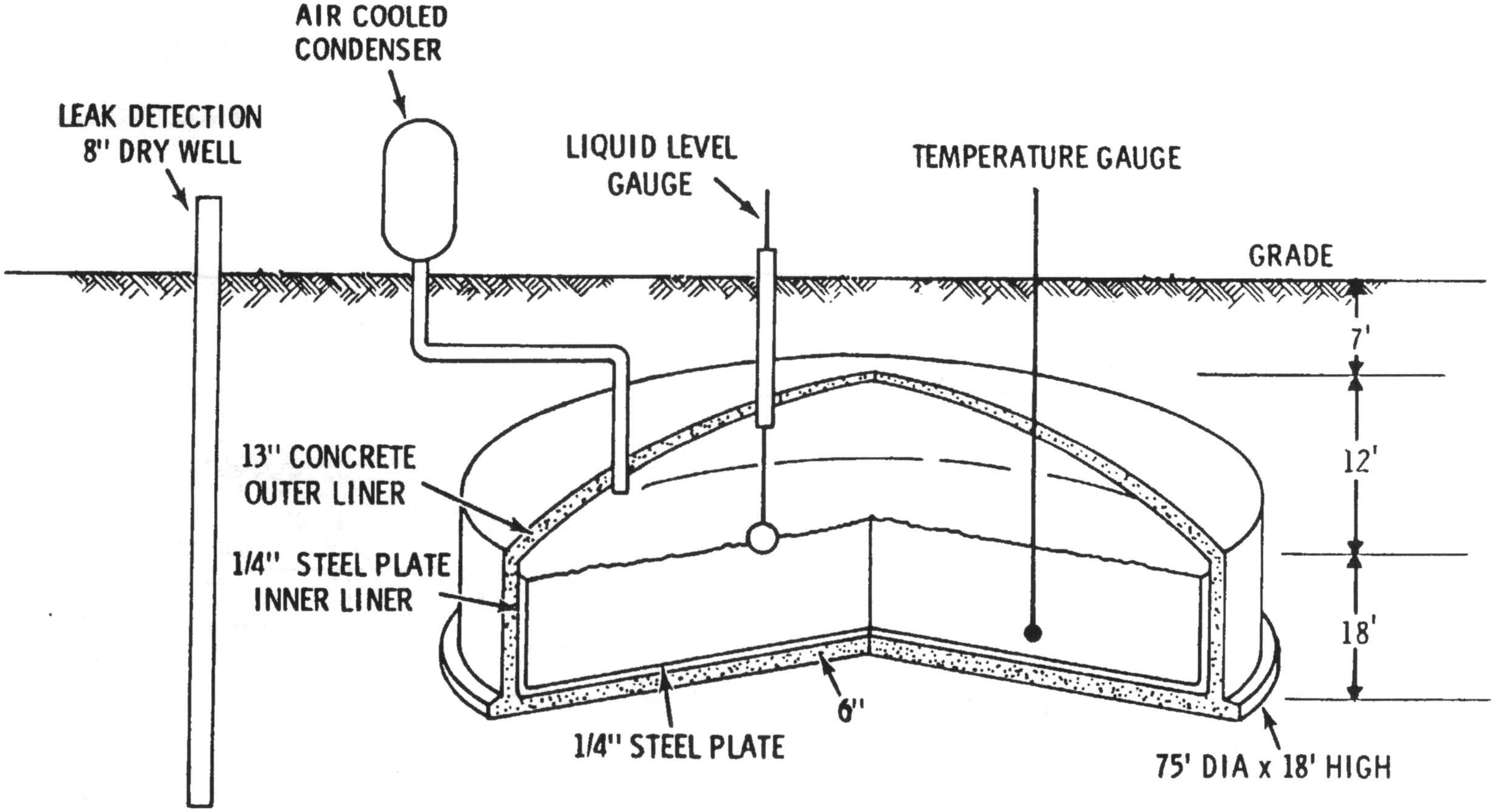

FIGURE 2.
TYPICAL STORAGE TANK FOR LOW-HEAT (NONBOILING) HIGH-LEVEL RADIOACTIVE WASTES.

SOURCE: ERDA-1538:II.1-37, FIGURE II.1-39.

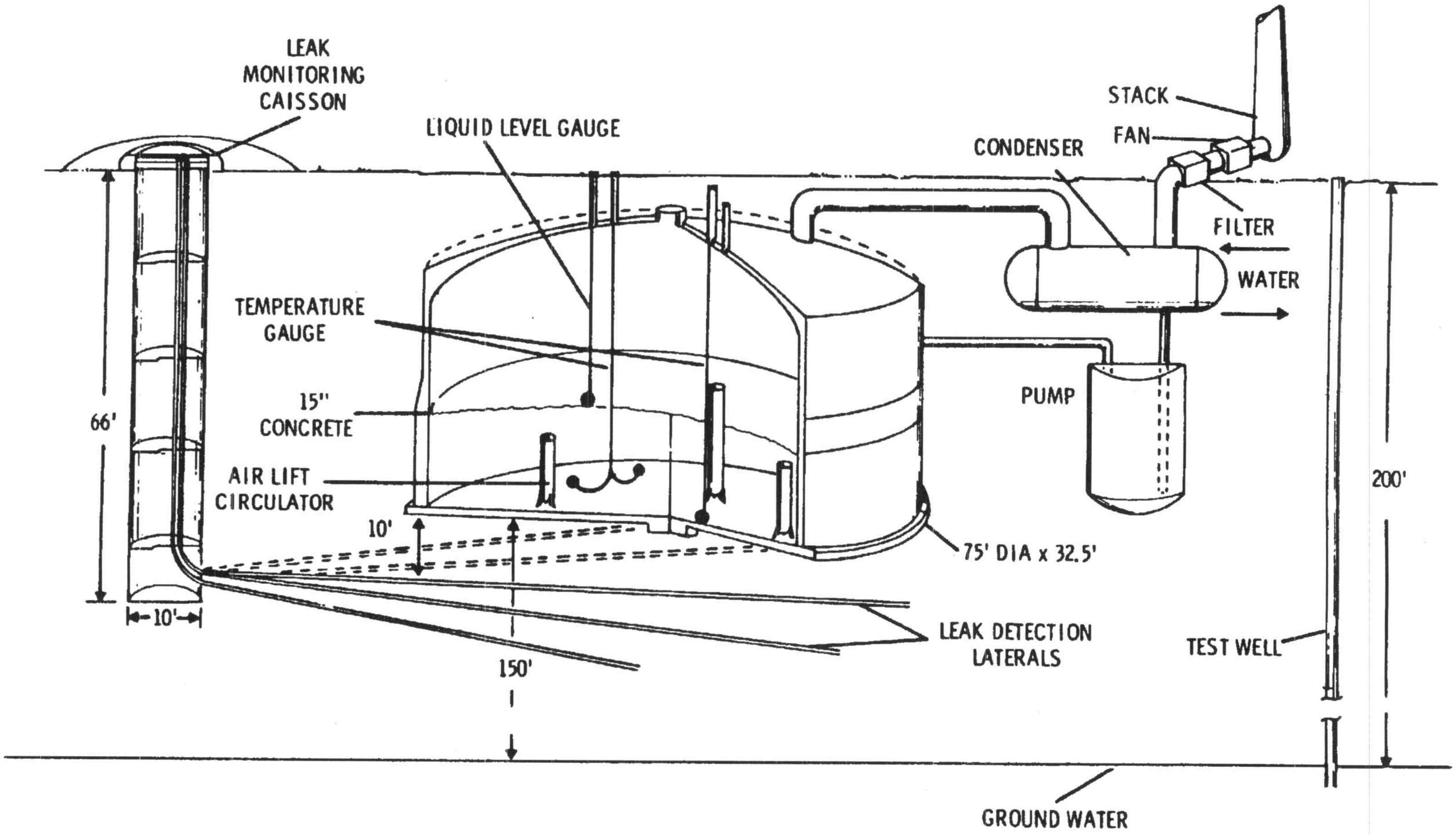

FIGURE 3.
TYPICAL CONTROL AND SAFETY FEATURES FOR HIGH-HEAT (BOILING) HIGH LEVEL WASTES.

SOURCE: ERDA-1538:II.1-39, FIGURE II.1-43.

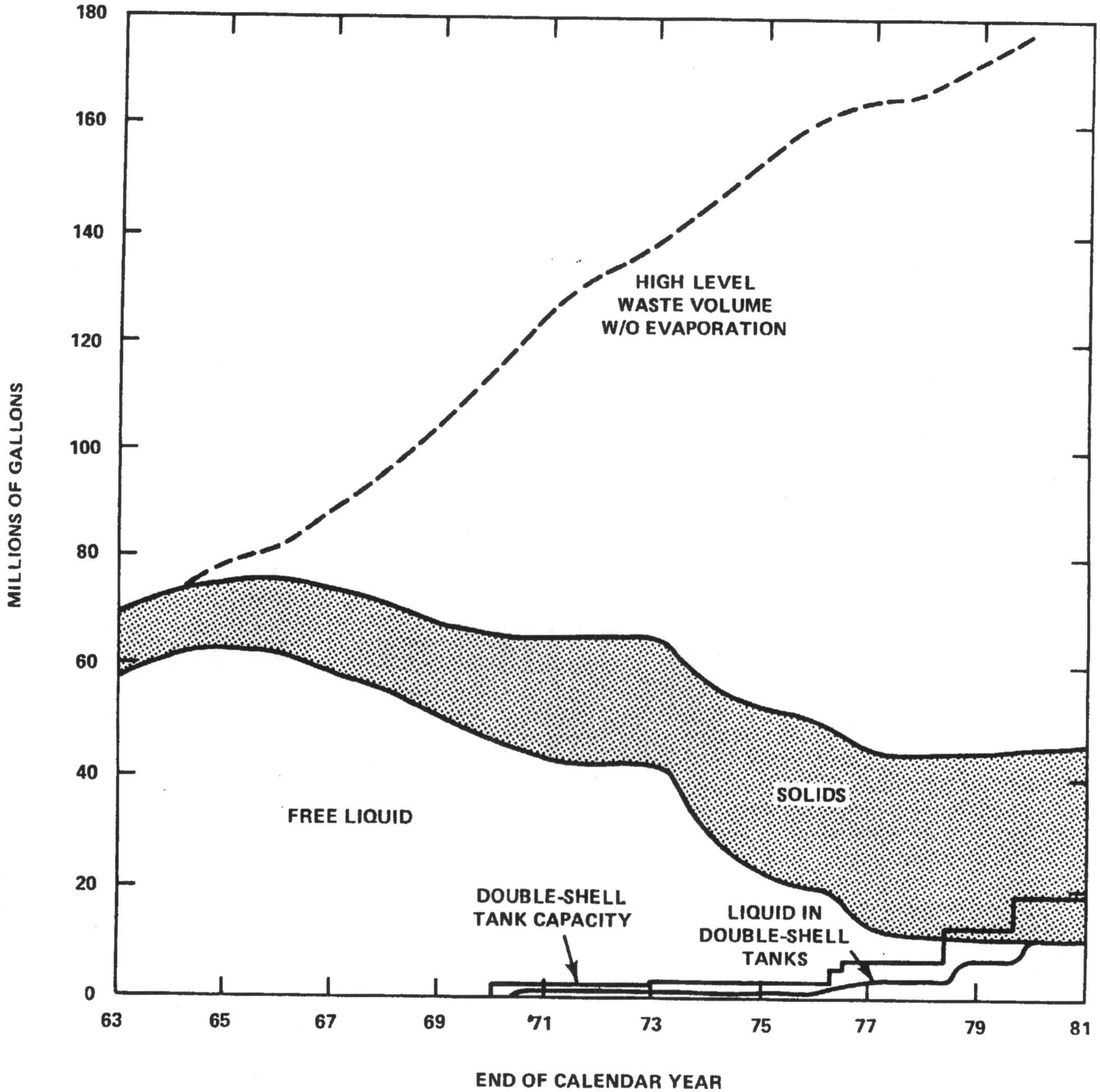

FIGURE 4.
RICHLAND 200 AREA TANK FARM FACILITIES HIGH LEVEL WASTE INVENTORY.

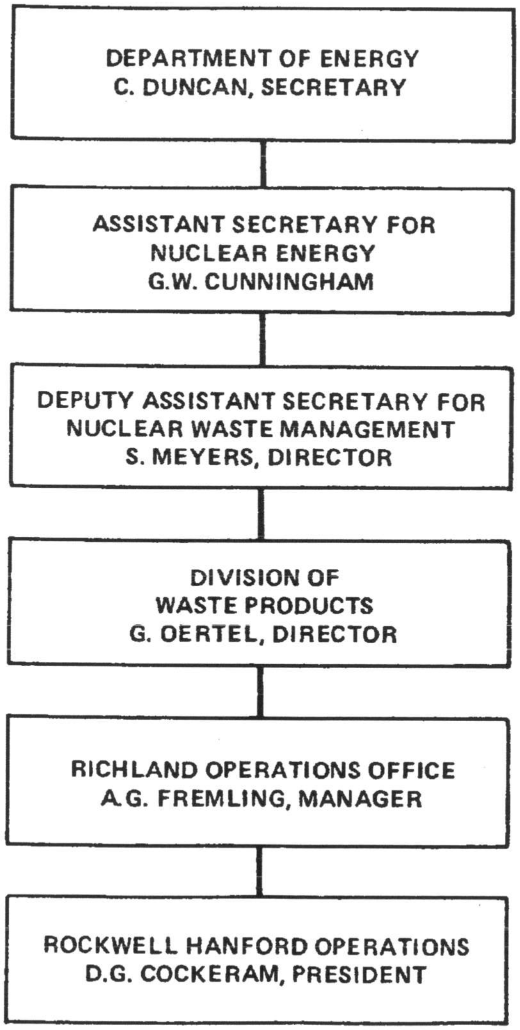

FIGURE 5.
DOE ORGANIZATION FOR HANFORD WASTE MANAGEMENT.

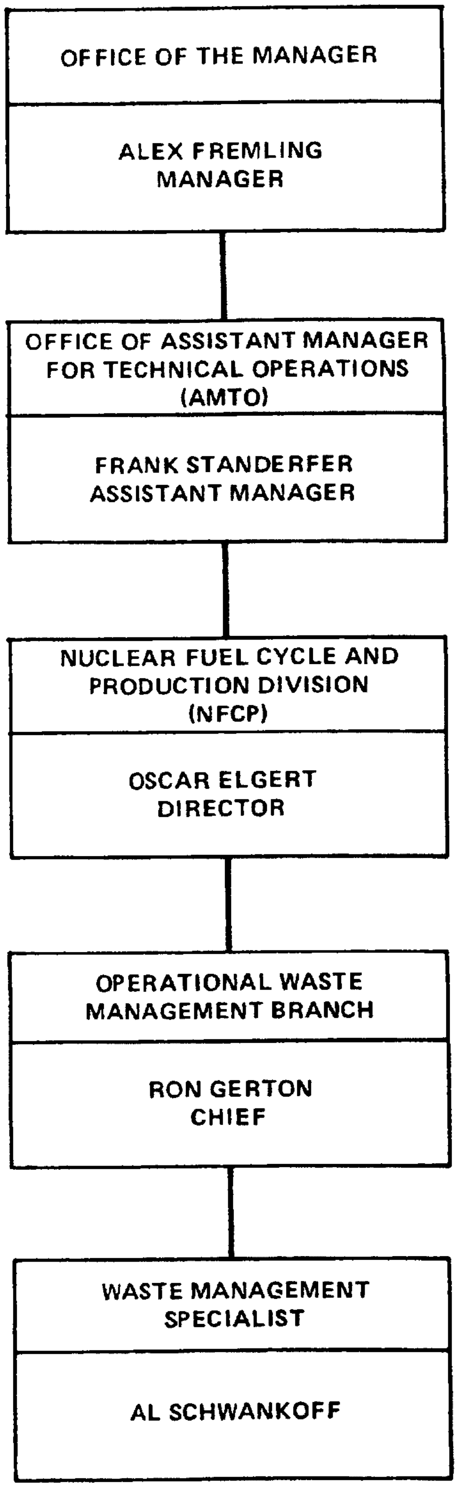

FIGURE 6.
DEPARTMENT OF ENERGY, RICHLAND OPERATIONS OFFICE
LINE ORGANIZATION FOR THE WASTE MANAGEMENT PROGRAM.

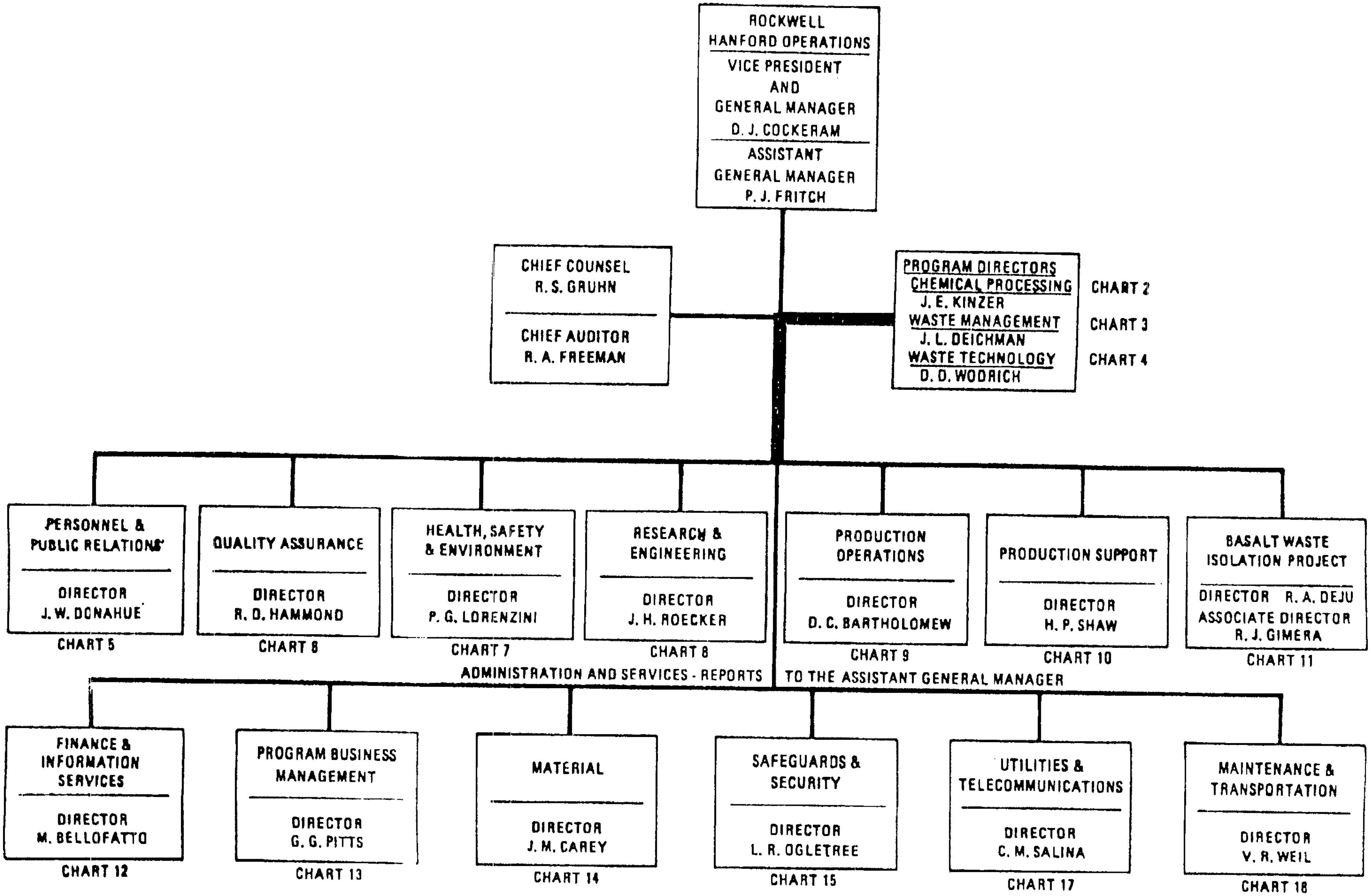

FIGURE 7.
ROCKWELL HANFORD OPERATIONS.

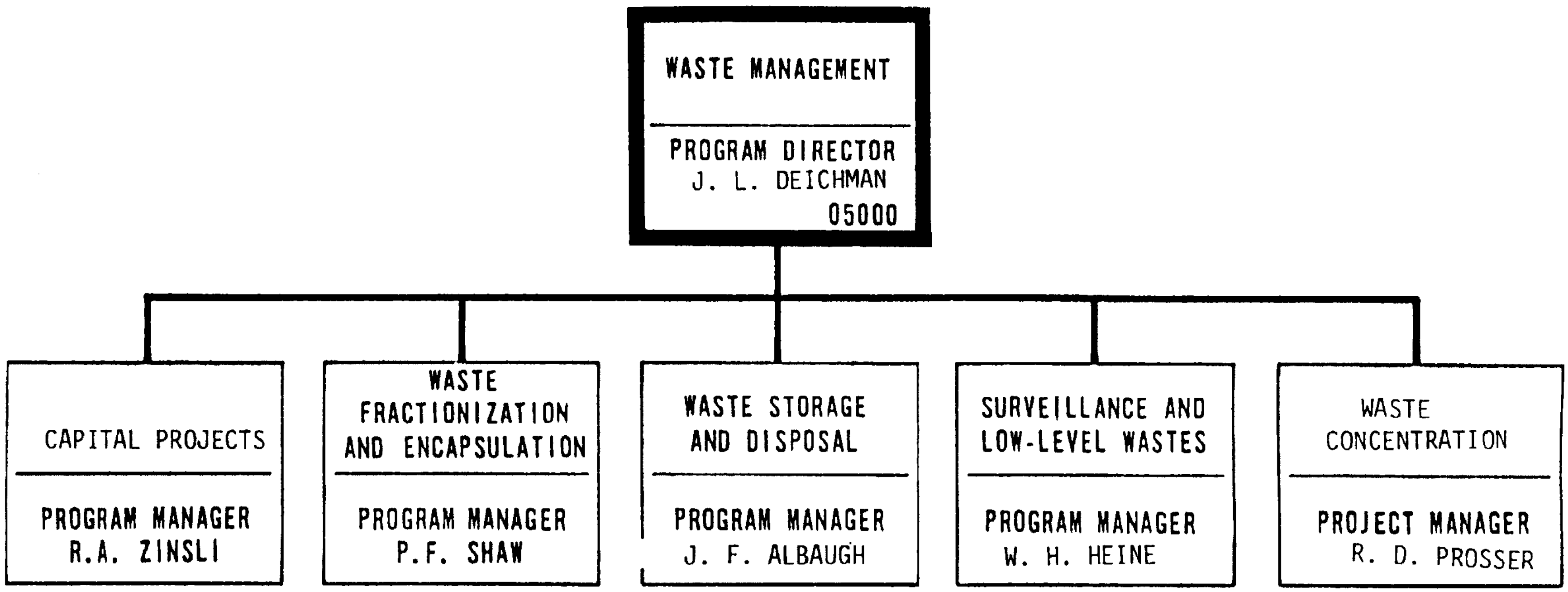

FIGURE 8.
WASTE MANAGEMENT.

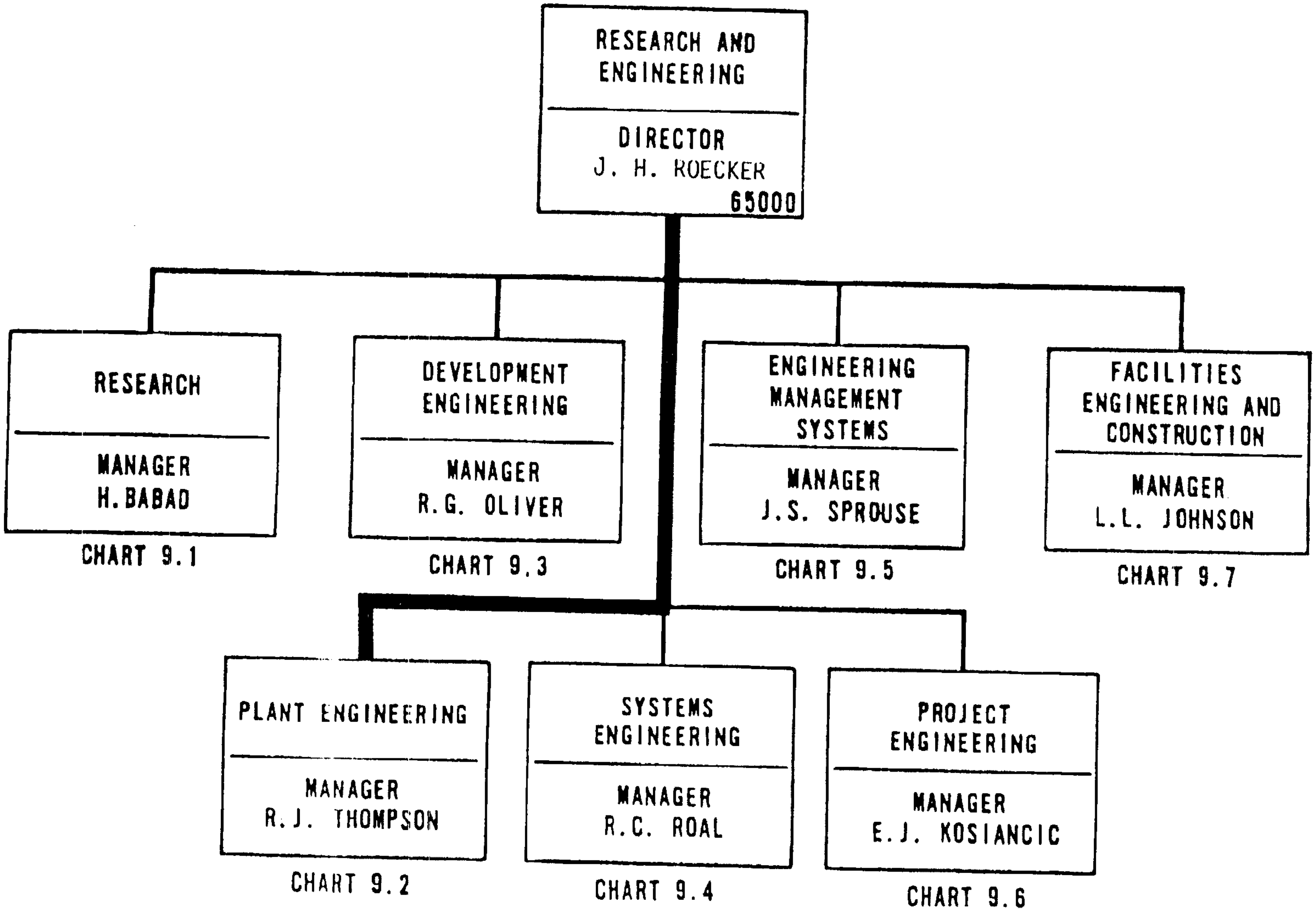

FIGURE 9.
RESEARCH AND ENGINEERING.

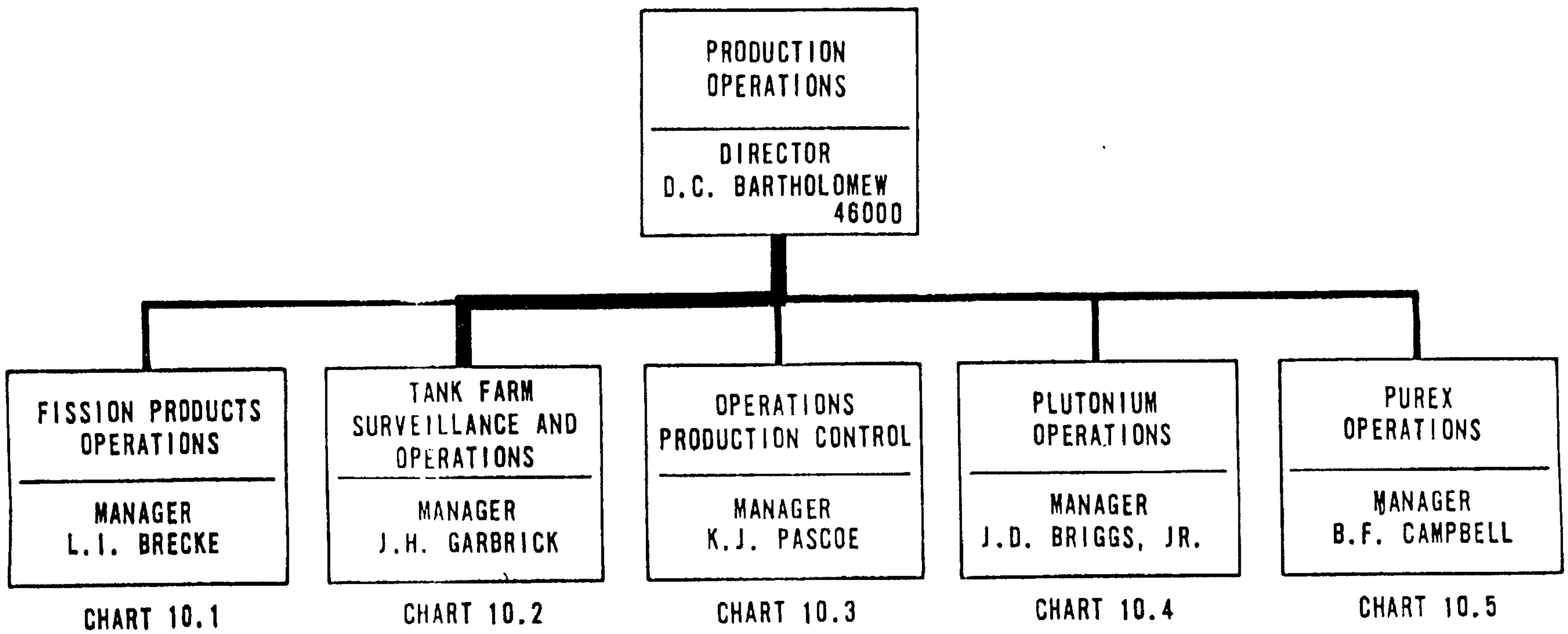

FIGURE 10.
PRODUCTION OPERATIONS.

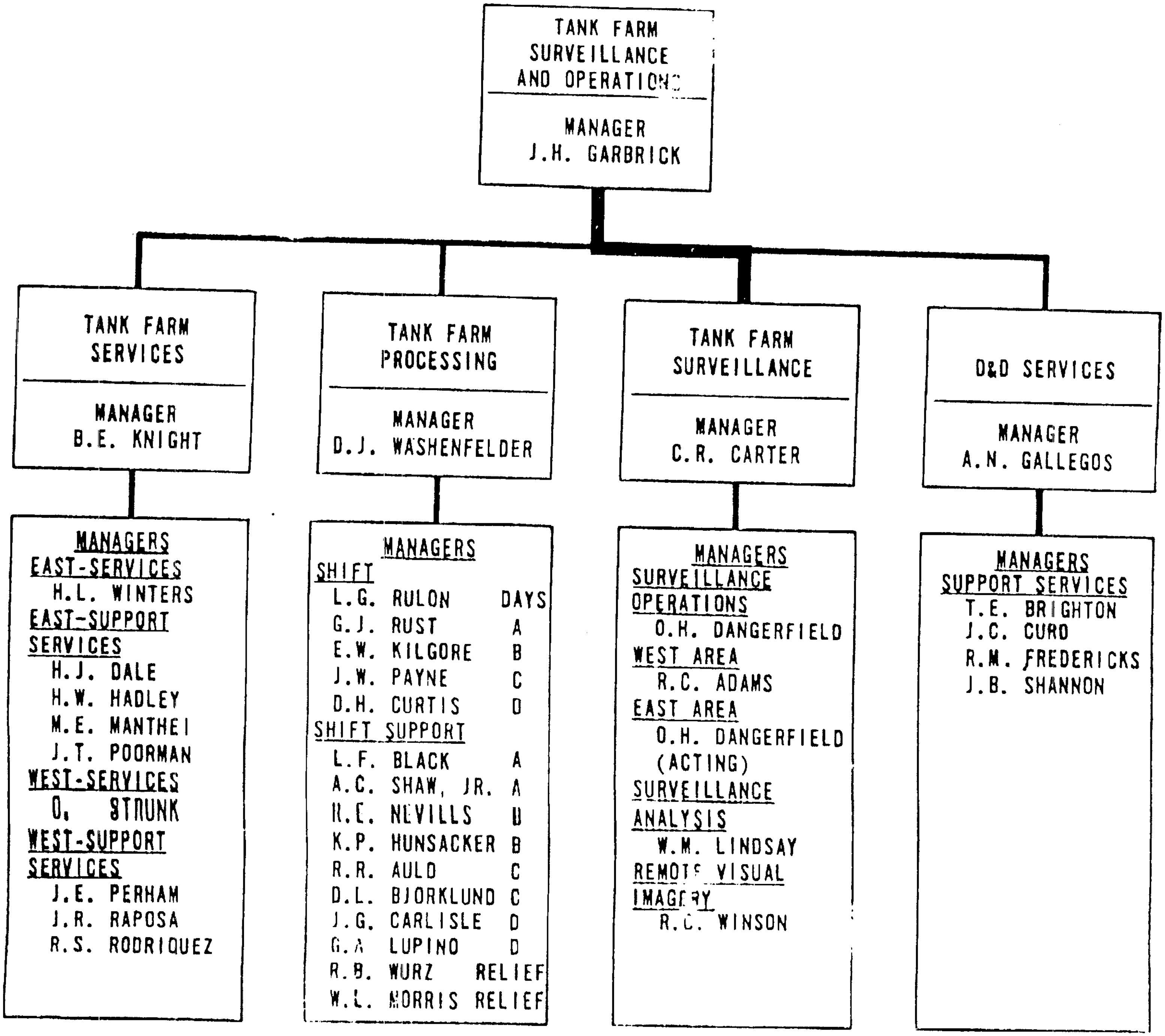

FIGURE 11.
TANK FARM SURVEILLANCE AND OPERATIONS.

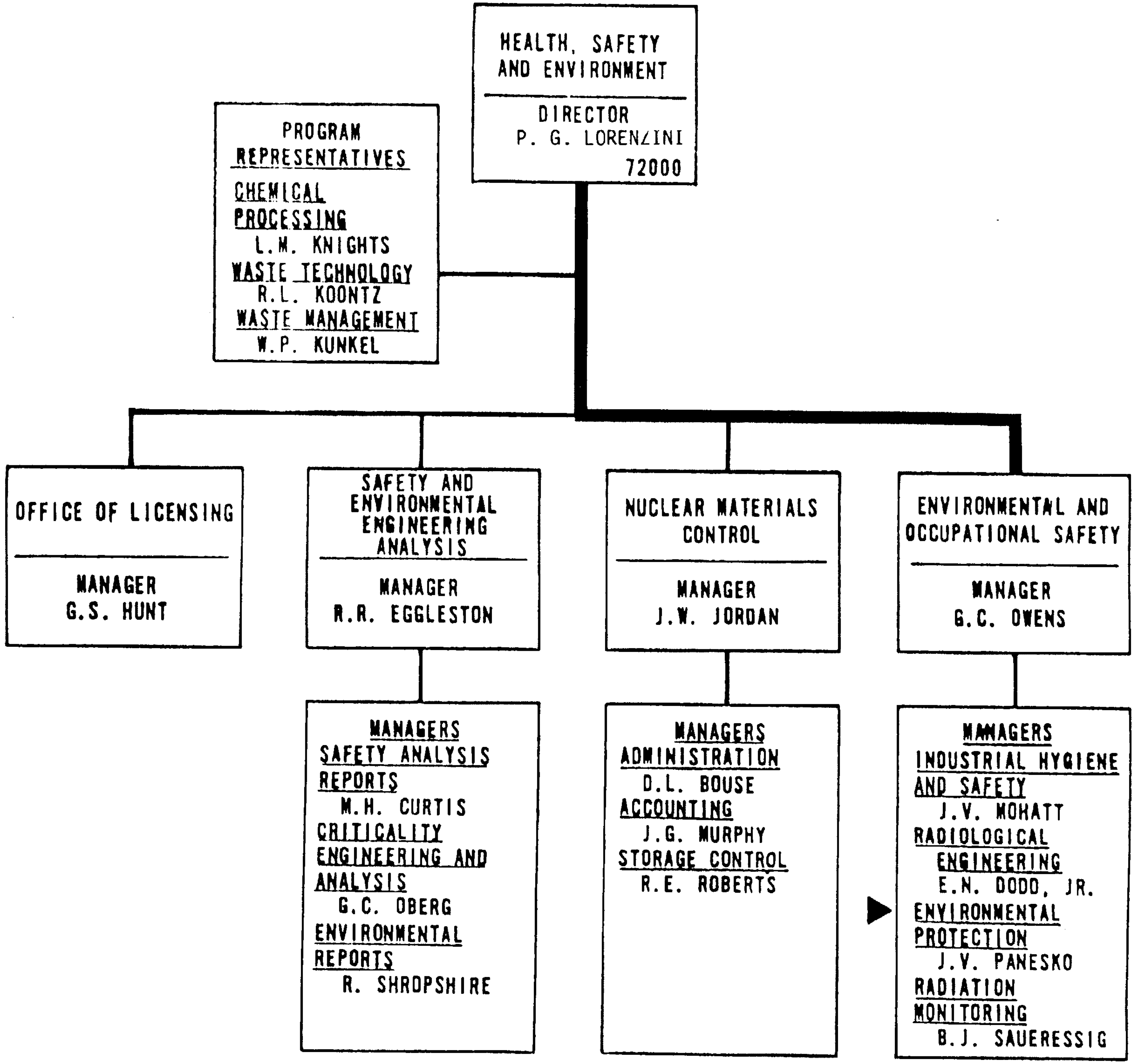

FIGURE 12.
HEALTH, SAFETY, AND ENVIRONMENT.

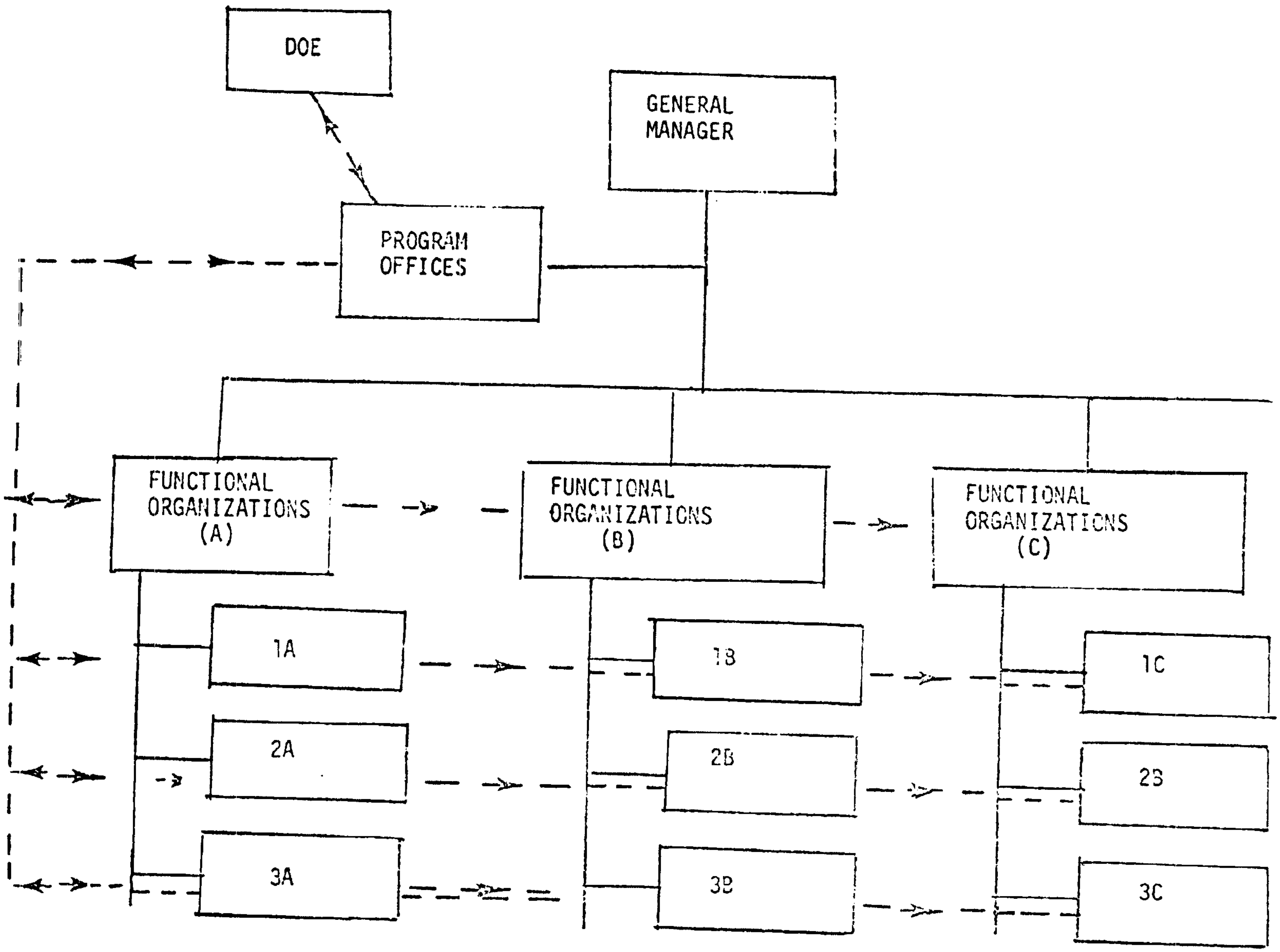

FIGURE 13.
MATRIX MANAGEMENT CHART.

Chapter 2 Waste Tank Surveillance Program

2.1 POLICIES AND REQUIREMENTS

General guidance to the Department of Energy (DOE) for discharging the safety, health, property, and environmental protection responsibilities in DOE and DOE-controller operations is set forth in Interim Management Directive (IMD) 5001, "Safety, Health and Environmental Protection," dated Sept. 29, 1977 (Appendix D). Among other considerations, IMD 5001 provides that:

> "It is the policy of the DOE to assure that DOE-controlled operations are conducted in a manner that will minimize undue risks to the safety and health of the public and employees and will provide adequate protection of property and the environment,"

> "Operational safety, health, property, and environmental protection is assigned as a basic line management responsibility within DOE and extended to DOE-controlled activities as appropriate through the respective environmental, safety, and health (ES&H) contract clauses,"

> "Authority for ES&H policy development, standards, safety and environmental reviews, and audits relating to DOE operations is delegated to the Assistant Secretary for Environment,"

"Pending the development and promulgation of DOE management directives pertaining to environmental, safety, and health matters ...." certain referenced Energy Research and Development Administration (ERDA) Manual Chapters (abbreviated ERDAM or MC's) ".... may be used as guideline procedures and standards in the discharge of the Department's safety, health, and environmental protection responsibilities...." under various statutes and Executive Orders as required.

Under the provisions of IMD 5001, certain key guidance is issued to Managers of Field Offices, such as Richland, and to DOE contractors, such as Rockwell Hanford Operations. This key guidance includes the following DOE Headquarters Manual Chapter provisions:

- MC 0513 - "Effluent and Environmental Monitoring and Reporting," issued Mar. 28, 1972, states:

  "DOE contractors shall monitor and evaluate the environment in the vicinity of DOE sites to determine compliance with DOE MC 0524, 'Standards for Radiation Protection,' and DOE MC 0510, 'Prevention, Control and Abatement of Air and Water Pollution.'"

- MC 0511 - "Radioactive Waste Management," issued Sept. 19, 1973 (Appendix E), states:

  "High-Level Radioactive Waste

  (1) High-level liquid wastes shall be converted to suitable physical and chemical forms and confined in a manner which shall provide high assurance of isolation from man's environment with minimal reliance on perpetual maintenance and surveillance by man under conditions of credible geologic, seismic, and other naturally occurring events.

  (2) High-level liquid radioactive wastes may be initially stored in carefully engineered systems equipped with adequate provision for leak detection and control. Tanks and transfer systems shall be designed to resist credible internal and external forces. Technology shall be developed and employed as soon as practical to reduce the volume and mobility of the high-level liquid wastes placed in initial storage facilities.

  (3) High-level liquid wastes in initial storage and high-level wastes in long-term storage, or in pilot plant facilities shall, in each case, be contained and emplaced so as to be retrievable for removal and transfer elsewhere. The method of storage and the physical and chemical forms of the stored waste shall be predicated on safety and not on possible retrieval for recovery of fission products for beneficial uses."

Manual Chapters are commonly issued by DOE Operations Offices to implement directives, requirements, and guidance issued by DOE Headquarters. In regard to the storage of radioactive liquid waste at Hanford, the Richland Operations Office (DOE-RL) Manual Chapter includes the following requirements:

- MC 0511 RL Appendix states:

  "All non-dischargeable radioactive liquid waste shall be solidified to the extent technically and economically practicable and stored or further processed in the 200 East or West Areas....

The use of existing 200 Area single-shell underground tanks for storage of non-dischargeable liquid waste shall be eliminated as soon as technically and economically practicable."

DOE Manual Chapter requirements are contractually binding on the contractors.

Each fiscal year DOE-RL prepares and provides to the contractors guidance amplifying program requirements. Prior to fiscal year 1978 these were in the form of "Goals and Objectives." The following are examples of goals and objectives established in prior fiscal years.

In FY-74:

"Develop and implement auditable procedures for all operations involving radioactive wastes with the view of minimizing unplanned releases to the environment.

Maintain established schedule for solidification of liquid wastes and minimize, to the extent practicable, the number of tanks used for liquid storage, utilizing preferentially the newest tanks."

In FY-75:

"Issue a revised 'Waste Storage Tank Status and Leak Detection Criteria,' and initiate a continuous updating of the surveillance data obtained for each waste tank by Aug. 29, 1975.

Investigate and report a tank's status within 24 hr whenever surveillance data exceeds the criteria.

Tank Farm Geology. Characterize sediments and complete geologic cross-sections and maps for tank farms by February 1976."

Starting in FY-78, "Goals and Objectives" were replaced with an "Operations Directive." The following excerpt is from the FY-78 DOE Operations Directive to Rockwell:

"Establish an approved program to centralize and improve tank farm computer surveillance and trend analysis that places minimum reliance on manual surveillance and analysis. Establish effective procedures that will provide prompt detection, redundant evaluation, and notification of any liquid radioactive waste leakage."

In FY-79, this requirement was expanded somewhat, as follows:

> "Develop and submit to DOE for approval a program plan to centralize tank farm surveillance and trend analysis that is appropriate to the tank status and places minimum reliance on manual surveillance and analysis. Implement the approved program plan. Establish effective procedures that will provide prompt detection, redundant evaluation, notification and appropriate corrective action of tank leakage."

The FY-80 Operations Directive to Rockwell provided for implementation of the program plan:

> "Implement the program plan for surveillance and maintenance that will centralize tank farm surveillance and trend analysis that is appropriate to the tank status and places minimum reliance on manual surveillance and analysis. Establish effective procedures that will provide prompt detection, redundant evaluation, notification and appropriate corrective action of tank leakage."

Also, on an annual frequency, "Assumptions" for out-year program requirements (usually for the next 5 years) are developed by DOE-RL and provided to the contractors. The contractors use these assumptions in developing their long-range planning documents.

The following is from the Jan. 1, 1975, through Sept. 30, 1980, assumptions document:

> "Tank farm surveillance will strive for improved and automated leak detection with minimum reliance on manual readings. Terminal liquor will be expeditiously pumped from salt cakes."

This has been expanded upon through the years and in the Oct. 1, 1978, through Sept. 30, 1985, assumptions document, is as follows:

> "Tank farm surveillance will strive for centralization of improved and automated leak detection including trend analysis with minimum reliance on manual readings of active tanks. Effective

procedures will be in place to provide prompt detection, evaluation, appropriate corrective action, and notification of any liquid radioactive waste leakage. As single-shell tanks are removed from active service, surveillance is to be optimized with the need for environmental monitoring."

2.2 DOE CONTRACT PROVISIONS

In FY 1978 an incentive-type contract, award fee, was awarded to Rockwell. This required that part of their fee be dependent upon actual performance. The general provisions of the DOE/Rockwell contract include the following requirements and considerations:

Article XVIII - Safety and Health

"The Contractor shall take all reasonable precautions in the performance of the work under this Contract to protect the Safety and Health of employees and all members of the public and shall comply with all applicable safety and health regulations and requirements (including reporting requirements) of ERDA. In the event that the Contractor fails to comply with said regulations or requirements of ERDA, the Contracting Officer may, without prejudice to any other legal or contractual rights of ERDA, issue an order stopping all or any part of the work; thereafter a start order for resumption of the work may be issued at the discretion of the Contracting Officer. The Contractor shall make no claim for an extension of time or for compensation or damages by reason of or in connection with such work stoppage."

Appendix B

"The criteria against which the Contractors performance is evaluated for fee purposes are:
(a) Safety of Operations and Environmental Control;
(b) Cost effectiveness;
(c) Quality of Operations;
(d) Timely planning and adherence to schedules."

Every 6 months, DOE-RL establishes the award fee goals for the next 6-month period and evaluates the contractor's performance for the past 6-month period. If the contractor does a good job under the criteria established by DOE-RL, he can earn extra fees beyond what he could have received under the previous fixed-fee type of contract. On the other hand, if the contractor does a poor job, he will not earn as much fee.

The general mandate to the contractor in all the award-fee criteria issued to date states that the contractor shall:

> "Operate, manage, and maintain in a safe, environmentally sound, cost-effective manner those facilities and programs associated with the treatment, storage, and/or disposal of radioactive and nonradioactive solid, liquid, and gaseous waste from production and research and development programs."

To this general requirement specific criteria are added on a semiannual fiscal-year basis. For example, a criterion for the second half of fiscal year 1978 specified that the contractor submit to DOE for approval a program plan, in sequential order, for the certain specific activities: waste concentrations, waste fractionization, and encapsulation; storage and disposal; and surveillance and maintenance. In the same instruction, the separate criterion required the contractor to achieve a 6-million-gallon reduction in waste by operating the evaporators in sequential operation. Performance instructions of this kind appear in the criteria issued for previous and succeeding semiannual periods.

On June 13, 1978, R. P. Fasulo, acting on behalf of the DOE-RL Manager, sent a letter to D. J. Cockeram, General Manager, Rockwell Hanford Operations, stating:

> "Since 1973-74 when the present intensified subject program was implemented, many changes have occurred. Namely, millions of gallons of high level radioactive liquid waste have been evaporated, resulting in 109 of the 149 single-shell tanks being pumped to a minimum heel and put in inactive status with plans to have all 149 tanks removed from service by the end of 1980. Consequently, Rockwell is requested to review the overall tank monitoring program and recommend appropriate cost effective changes/redirection while continuing to protect man and the environment. The Nuclear Fuel Cycle and Production Division will be meeting with you to discuss development of this updated program."

Presumably this letter was based on a May 11, 1978, analysis by RL staff that proposed changing projected yearly increases in both cost and manpower for monitoring and surveillance activities in FY-79 and FY-80 to yearly decreases. This analysis was later included in a RL draft letter dated June 15, 1978, of which the contractor was knowledgeable.

Before the start of fiscal year 1979, DOE-RL sent to Rockwell a specific criterion on which the award fee for the first half of FY-79 would be based, which read:

> "Revise tank farm surveillance activities, as appropriate, consistent with the status of each tank or tank farm (i.e., inactive, stabilized, isolated) and begin implementation by December 1, 1978. Provide an analysis by February 15, 1979, of the potential surveillance cost reductions as the proposed line items for isolation and stabilization of tank farms are completed."

Rockwell modified its dry well monitoring schedule from a weekly to a biweekly schedule in November 1978.

On balance, it seems odd that the specific criterion presented above would appear at all as an award fee consideration. Management in a safe, environmentally sound, cost-effective manner has always been in the general mandate for all award fee periods. This additional requirement had the effect of imposing a direct conflict between performance criteria for cost-effectiveness (related to reduction of surveillance costs, i.e., labor) and criteria for safety of operations and environmental control. In the preparation of subsequent award fee criteria, such a criterion has not reappeared.

2.3 SURVEILLANCE PLAN

The stated objectives of Rockwell's Surveillance Data Acquisition Activity are to operate a monitoring system that acquires and records data about the status of high-level wastes in underground tanks and associated pipeline systems, monitor the integrity of the tanks, track radionuclides introduced in past years into subterranean strata, and sample and analyze the groundwater beneath the 200 Areas control zone.

The scope of this assessment is limited to consideration of the technical adequacy of surveillance for the waste storage tanks. Consequently, environmental movement of radionuclides in the soil and groundwater monitoring beneath the 200 Areas have not been intensively reviewed and are considered only in terms of materials directly involved with the storage tanks and associated piping.

The status of 204 underground waste storage tanks is generally monitored at levels of surveillance specified in the "Waste Storage Tank Status and Leak Detection Criteria" RHO-CD-213 which is updated periodically. These 204 tanks include: 149 single-shell and 7 double-shell waste storage tanks, 22 catch tanks, 14 receiving vessels, 10 sumps, and 2 tanks containing contaminated hexone. A generalized surveillance schedule is given in Table 10. A more detailed discussion of revisions to this schedule is presented in Chapter 3. Pipe encasements are checked before and after all waste transfers by swabbing through risers and checking the swabs for radioactivity. The following description of the surveillance activity is drawn from the Rockwell "Surveillance and Maintenance Program Plan" RHO-CD-430.

Rockwell Tank Farm Processing Operations and Tank Farm Surveillance acquire and record all surveillance data, and perform initial data review before transmittal to the analysis groups. Intank photography is also performed by these functions. Approximately 3200 data entries per day are made at present surveillance frequency schedule levels. This number will reduce as tanks are stabilized and isolated as shown in Fig. 14. The effect of the 13 new double-shell tanks which will go operational in FY 1980 and FY 1981 is also shown.

Surveillance activity may be described as follows:

- Liquid-level measurements are taken manually or automatically by CASS on all tanks with conductivity tapes.
- External dry wells (756) around 128 tanks in all tank farms are monitored with specially designed scintillation and Geiger-Muller probes pulled through the dry wells at a constant speed to detect radiation.
- Tank dome surveys are being initiated in tanks being jet pumped and tanks having a history of high radioactive contents. Ultimately, all tank domes will be routinely monitored.
- Forty-five lateral wells, approximately 10 feet below 15 tanks in the A and SX farms, are monitored in a manner similar to the dry wells.
- Leak detection pits, in which radiation and liquid-level data are taken, are provided on tanks in the AX Tank Farm and in the double-shell tank farms.
- Tank temperature measurements are taken for process control purposes, some manually and some through CASS.
- Prototype dry wells are being installed in selected waste storage tanks and are now undergoing testing in conjunction with instruments systems designed to detect the level of drainable liquid within a solids matrix. If successful, wells will be installed in approximately 30 tanks.

- Tank exhaust is continuously sampled through filter paper sample collectors.

- Double-shell tanks have alarmed conductivity probes in the annular space between the primary and secondary shell.

The objectives of the Analysis and Reporting Activity are to perform trend analysis and limit checking on all surveillance data for the early detection of possible leaks in underground storage tanks and all associated facilities, maintain a permanent record of all data, track radioactive material which has spilled or leaked into the ground, document evaluation conclusions, and indicate and expedite initiation of corrective options to contain radioactive materials should analysis indicate breach of containment.

2.4 CASS OPERATION

The CASS computer automatically monitors surface levels in 77 underground waste storage tanks. Liquid-level data for 127 other tanks are entered manually into the computer, giving a complete listing of liquid levels on CASS. The computer checks each liquid level to determine whether the assigned decrease or increase and maximum or minimum tank operating limits have been violated. The computer automatically acquires in-tank thermocouple data and monitors certain operational alarms from the 242-S and 242-A evaporator buildings. In addition, the computer is used to analyze dry well data.

Production Operations stations one operator around the clock in the central terminal in the Waste Management Surveillance and Operations Facility (2750-E Building) to operate the computer, observe signals, and make appropriate notifications upon an alarm. The assigned operators and Tank Farm Surveillance technicians provide security and access control to the computer room, record the computer memory on tape daily, and monitor liquid transfers between active tanks. Technical Systems updates, adds to, or refines existing programs and develops new ones as required by the user.

A second Data General Eclipse computer has been installed to provide operational backup and computer trend analysis of incoming data. Software is being developed to provide automatic switching of the second computer in case of failure of the monitoring computer.

Concurrent with the CASS software development and implementation of the automatic backup, the dry well system software will be improved to provide for entry of dry well data over the CASS microprocessors and for new probe types. Also, a number of additional changes will be made to improve data precision, system flexibility, and ease of use.

TABLE 10.

SURVEILLANCE FREQUENCY SCHEDULE

TANK SURVEILLANCE MONITORING PERIMETERS	TANK CLASSIFICATION PER WASTE CONCENTRATION PROGRAM				
	ACTIVE	INACTIVE WAITING	PRIMARY STABILIZED	INTERIM STABILIZED	INTERIM ISOLATED
EXTERNAL TO THE TANK					
(VERTICAL DRY WELLS; HORIZONTAL LATERALS)	2 WEEKS	2 WEEKS	2 WEEKS	3 MONTHS	12 MONTHS
WITHIN THE TANK					
LIQUID LEVEL	SHIFT	DAILY	DAILY	DAILY	NONE
TEMPERATURE	← MANUAL AND AUTOMATIC →				
PHOTOGRAPHY	12 MONTHS (AFTER TANK PUMP DOWN)	AS NEEDED	AS NEEDED	AS NEEDED	1-5 YEARS
OTHER (SEE FIG. 14)	← BY PROCEDURE →				
DRY WELL (FUTURE)	NONE	NONE	MONTHLY	MONTHLY	6 MONTHS
GAS SAMPLING (FUTURE)	AS NEEDED	AS NEEDED	AS NEEDED	AS NEEDED	VARIABLE
TANK PRESSURE (FUTURE)	NONE	NONE	NONE	NONE	CONTINUOUS
TANK INTEGRITY					
DOME SURVEY (FUTURE)	ANNUALLY FOR TANKS THAT HAVE NO DOME SUSPENDED EQUIPMENT. MONTHLY FOR TANKS WITH DOME SUSPENDED EQUIPMENT AND ARE BEING SALT WELL PUMPED. EVERY SIX MONTHS FOR TANKS HAVING DOME SUSPENDED EQUIPMENT FOLLOWING SALT WELL PUMPING.				
ELECTRONIC (FUTURE)	CONTINUOUS	CONTINUOUS	CONTINUOUS	CONTINUOUS	CONTINUOUS
PHOTOGRAPHY (FUTURE)	36 MONTHS	36 MONTHS	36 MONTHS	36 MONTHS	36 MONTHS

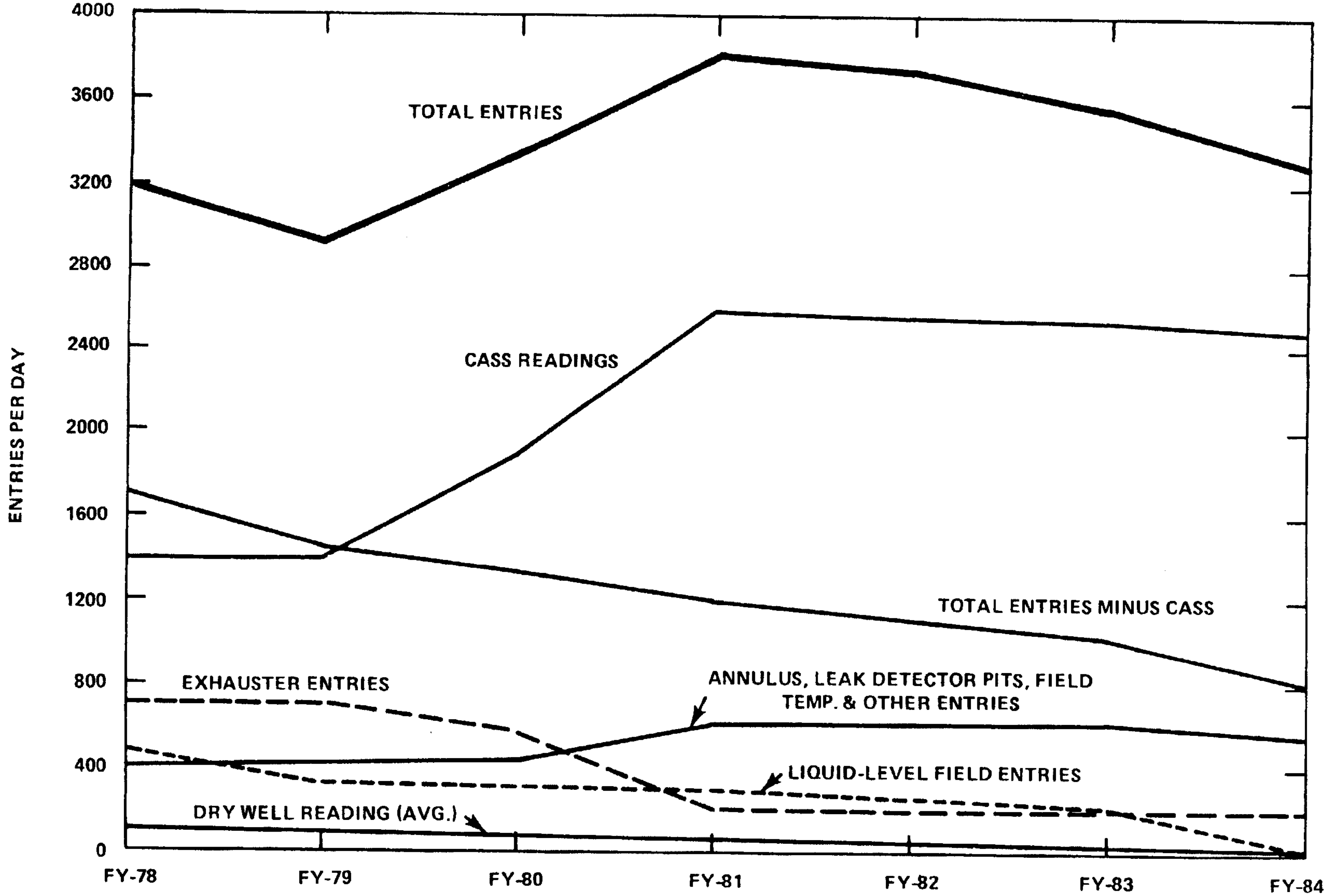

FIGURE 14.
PROJECTED TOTAL DAILY ENTRIES ON SURVEILLANCE SCHEDULE.

Chapter 3 Review of Surveillance Program

3.1 CLASSIFICATION OF TANKS

Various systems of classification have been applied to the waste storage tanks over the years. One such system relates to the operational usability (e.g., active, active-restricted, inactive, inactive-contingency, and removed from service); another system relates to the generalized condition of the contents (e.g., static storage, static bottoms, operating bottoms, and boiling waste storage). A third system classifies tanks on the bases of content immobilization and tank isolation (e.g., inactive waiting, primary stabilized, interim stabilized, and interim isolated). At least nine categories for classification of tank operational status and soundness have been used at Hanford, of which four or five are presently used, as shown in Table 11. The purpose and utility of such categories should be reexamined as they pertain to operations accounting, management of tank use and surveillance requirements. As can be seen in the table, the terms "sound" and "active" have been used interchangeably despite the separate category combining active with restricted; further, "active-restricted" tanks appear to lose their restricted status when they are moved to inactive status. In this regard, a discrepancy is noted between the latest Rockwell document (RHO-CD-896) that indicates that the active-restricted category is dropped after 1973, and other documents cited in Table 11 that continue to carry the category through the present. A clear distinction must be made between categories relating to the operational status of tanks and those relating to tank soundness. Furthermore, as stated in the 1973 letter from L. M. Richards to A. G. Fremling (see Appendix F), separate categories were established for classifying the soundness of double-shell tanks as opposed to single-shell tanks because they differ in degree of access of the contents to the environment, in ease of surveillance, and in the nature and ease of remedial actions that may be required in the event of tank unsoundness.

No formal criteria exist for assigning waste storage tanks to soundness categories. Some working guidelines have been in common use for many years, of which the most recent derive from criteria set forth in the above-mentioned letter in Appendix F. A synopsis of the criteria used as working guidelines appears in Table 12. None of these criteria or working guidelines have been applied uniformly or consistently, as can be seen in Figures 15 and 16, which show the types of criteria that were used to classify tanks as questionable integrity or as confirmed leakers. For example, Figure 15 shows that single monitoring system criterion was used to classify present questionable integrity tanks despite evidence that corraborative information from other monitoring systems was also taken into account. It is interesting to note, as shown in Figure 17,that a dry well criterion has been used more often in recent years, presumably due to removal of liquids during waste solidification that made the liquid level monitoring systems non-functional.

Figure 16 shows that dual monitoring system criteria were applied to only about 50 percent of the confirmed leaker determinations despite information received during this assessment that dual criteria were necessary for this classification. The differences in application of the working guidelines lie, of course, in the degree and validity of monitoring system indications. The need for flexible criteria at Hanford is recognized but such criteria must be formally documented to ensure uniform and consistent tank classification.

The working guidelines also have been used for determining whether or not a tank is leaking, although there is no compelling rationale as to why the guidelines for these two purposes should be identical. For example, as shown above, there is an active-restricted category that indicates tank unsoundness above a given level, yet the tank is not considered to leak below that level and, therefore, is kept active, with operational restrictions. Direct, prompt evidence of tank leakage has occurred in only a few cases, as shown in Table 13, which provides illustrative periods of leakage ranging from days to years. The majority of tank leaks have had to be inferred indirectly from monitoring evidence over a period of time. During this time, other liquid removal processes, such as vaporization into off-gas, may be significant. The lack of a formal, objective system for making a determination that a tank is leaking has led to inconsistent and nonuniform evaluations, compounded to some degree by the limitations of the inferential process.

Criteria for determining leakage in double-shell tanks should include scheduled visual inspection in the tank annulus during the year. Experience at the Savannah River Plant has shown that the primary tank may develop one or more minute flaws (technically rendering that inner shell unsound) which may seep, but immediately become self-sealing. Continued inspection in most instances indicates that leakage has stopped and, therefore, the tank may continue in use. Even if the seepage continues, the outer shell remains sound.

Furthermore, the working guidelines also have been used to set points for remedial action for leakage, although, again, there is no compelling reason why these guidelines should be the same as those for tank classification or determination of leakage.

Evidence shows that other informal criteria, such as rates of change (in liquid level or dry well radiation level) below the levels of the working guidelines, have also been used as action points; this contributes to the inconsistency of levels at which action is taken. In other words, such precautionary actions as pumping out tank contents and removing a tank from service (hence, moving the tank to inactive status) have been taken at levels below the action points where the tank otherwise might have been classified as a confirmed leaker or to be of questionable integrity. This prudence in protecting the environment is laudable, and it is unfortunate that such action can be misinterpreted as a desire to avoid a finding that the tank is unsound.

3.2 TANK FAILURE RATE

A series of evaluations were made to determine whether some relationship could be established between the failures observed in single-shell waste storage tanks, as indicated by tanks presently classified as confirmed leakers or of questionable integrity, and some parameter that would permit an estimate of future short-term failure experience. Such an estimate would be useful in determining the need for both additional surveillance and acceleration of waste stabilization efforts for the single-shell tanks.

Evaluations of this type are fraught with varying degrees of uncertainty that suggest caution in claiming ability to understand the present or to predict the future. The total population of single-shell tanks is statistically small (149 in number). The fact that these tanks were built at different times by different contractors and of differing materials, and sizes, and in at least one tank farm, of a different design, is significant. Furthermore, tanks were exposed to varying chemical and thermal stresses during service. The only features common to all tanks are their general design, including use of carbon steel liners, and the fact that none of these liners were stress relieved.

Another problem is related to the characterization of the degree of failure needed to classify a tank as unsound. Massive failures, such as the 106-T tank leak, have been obvious. It is highly likely that tank liners could undergo small failures or even miniscule corrosion penetrations so small as to be undetectable with present surveillance technology, perhaps even self-sealing by waste crystallization at the point of penetration. The only common denominator seemed to be the judgment of the experts who classified tanks as leakers or as of questionable integrity, and the various categories in Table 11 were used to express degrees of failure or unsoundness (actual or suspected) in the analyses.

The first evaluation, shown in Figure 18, involved a review to determine whether there was any relationship between failure experience and tank size. The smallest single-shell tanks (55,000 gallons) were fewer in number (16) than the larger tanks, which ranged from 25 to 60 tanks per size group. Chi-square tests of the differences in failure rates between the tank sizes showed that significance was not established for tanks of questionable integrity, nor for confirmed leaking tanks grouped together with tanks of questionable integrity; that the difference for confirmed leaking tanks was at the 5 percent probability level; and that more data would be needed to confirm a significance.

As a result of this analysis, it was decided to group confirmed leaker and questionable-integrity tanks together; this grouping is justified because these classifications are not uniquely different but merely represent varying certainties of tank unsoundness. A second evaluation was carried out on this basis to see if there was any relationship between failure experience and years of construction, as shown in Figure 19. A chi-square test of this relationship indicates that the significance of difference in failure rates between tanks grouped by years of construction is not established; i.e., that the rates observed might occur with a 20 to 30 percent probability.

Upon reflection, the years of construction for given tanks were considered to be an inadequate measure of tank usage, since some tanks were put into service one or more years after construction was completed, and leaking and questionable integrity tanks were taken out of service at times not related to years of construction. Accordingly, a determination was made of the service life of each leaking and questionable integrity tank, defined as the period of time from the date the tank was put into service to the date of removal from service because of unsoundness. These dates were difficult to determine from the records available to the investigator, particularly for the early years of Hanford operation; when the year was known but not the month, credit was given for a full year of service for the tank in question. These determinations are given in Tables 14 and 15.

With service life as a parameter, several evaluations were made to see what relationship might be determined between service life and failure experience, from the standpoint of possible linear, logarithmic, and exponential relationships. The unexpected result was that the relationship appeared to be normally distributed insofar as data was available. For convenience in plotting, the data was grouped as shown in Table 16. The results, plotted on a linear probability graph, are shown in Figure 20. The straight-line relationship confirms that the distribution is normal up to the 39 percent failure point. Limited extrapolation was considered justified so that the 50 percent failure experience could be projected. This shows that the estimated mean service life (for 50 percent failure) is 425 months, with a standard deviation of 174 months. Extrapolation beyond that point is not justified because the future direction of the curve cannot be accurately predicted. The extrapolation to 50 percent failure projects that an additional 10 to 15 tanks will become unsound in the next several years. At the present time, each of about 40 sound active and inactive tanks have 400 months of service use. This projected failure of additional tanks may occur without prompt detection by leak monitoring systems; leak indications may be delayed, depending on the degree of failure of the tank and the nature of its contents, or the leaks may be too small to be detected.

A group of seven more tanks that have limitations on fill level, listed in Table 17, were not included in the tank failure analysis. Three other tanks that were included in the analysis are also listed in the table. These seven tanks are considered to be unsound above the fill limits that have been set but sound below. Inclusion of these tanks in the failure analysis would result in a large number of single-shell tanks considered unsound and a possible reduction in the mean estimated service life. These seven tanks may possibly be part of the additional failure projections given in the previous paragraph. It may be worthwhile to investigate why 9 of the 10 tanks listed in the table are located in a single tank farm. The seven inactive and active tanks were not included in the failure analysis because they were not fully removed from service due to unsoundness. The relationship between tar rings and tank failure is obscure, although, as shown in Figure 15, one tank has been classified to be of questionable integrity due to tar rings.

3.3 MONITORING SYSTEMS FOR SINGLE-SHELL TANKS

The primary elements affecting the adequacy of the surveillance program for waste storage tanks are:

1. The contents of each tank and the nature of those contents, i.e., how such contents are expected to change over time,

2. The functional capability* of the monitoring systems at each tank to monitor leaks, unwanted intrusions, and the movement of radionuclides in the soil,

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* Functional capability, as used in this report, is defined as the ability of a monitoring system to achieve its design purpose. Lack of functional capability may be caused by system malfunction or to factors causing an operable system to become unresponsive (e.g., insufficient source or too much source).

3. The frequency of monitoring and its appropriateness to the status of the tank and its contents.

An analysis of the contents of the single-shell tanks and how such contents are expected to be modified over time has been presented previously in the discussion on the waste solidification program in Chapter 1. A summary of this data is set forth in Table 18 of this Chapter and in Appendix H.

The volumes for the supernatant and drainable interstitial liquid in the tanks are taken from the Waste Status Summary report (RHO-CD-14) of December 31, 1979. It is assumed that active tanks will have a fluctuating volume, depending on the operations in the waste solidification program, but that the volumes of all other tanks will steadily decline (first the supernatant and then the interstitial liquid) as the pumping program is augmented over the next four years. As shown in Table 18, column 7, an estimated 15.3 million gallons of drainable liquid are stored in single-shell tanks: 57 percent in active tanks, 25 percent in inactive tanks, 14 percent in questionable-integrity tanks, and 3 percent in confirmed leaking tanks at the present time. Column 8 of the Table indicates that the total nonpumpable drainable liquid to be left in the tanks in the future, is on the order of 1 million gallons. The quantity of drainable liquid stored in double-shell tanks is estimated to be 19.3 million gallons at present.

Column 2 of Appendix H gives the status (e.g., active, or inactive) for each single-shell tank as of December 31, 1979, and Column 3 gives the criteria applied to classify leaker and questionable integrity status. Liquid-level inventories are summarized for each tank in terms of supernatant, drainable interstitial liquid, and total drainable liquid (Columns 4, 5, and 6, respectively). All the 149 tanks have installed conductivity probes for liquid-level measurement; 136 tanks have manually operated probes; 79 tanks have automatic probes that are directly connected to the Computer Automated Surveillance System (CASS); 67 of these 79 tanks also have manual probes.

Monitoring leak detection criteria for each tank are tabulated for both decreases (leaks) and increases (intrusions) in Appendix H, columns 7 and 8. A zero (or "no") criterion for liquid-level decrease indicates nonfunctioning of the conductivity probes because of lack of supernatant or presence of excessive solids at the air-liquid interface of the contents; this occurs in 63 single-shell tanks. An additional 25 single-shell tanks are adjudged to have nonfunctional conductivity probes, although these tanks are assigned finite (or "yes") criterion for liquid-level decrease, they reportedly have no supernatant liquid present [except for one tank (201-B) classified as a confirmed leaker with a content of about one thousand gallons of supernatant]. This means that liquid-level monitoring by conductivity probe is nonfunctional for 88 out of 149 single-shell tanks (59 percent), as shown in Appendix H, column 14. On the other hand, all 149 tanks have functional capability (conductivity probe) for detecting intrusions.

As shown in Table 18, column 3, most of the single-shell tanks have between two and eight dry wells located in close proximity for monitoring changes in radioactivity level as indicators of possible leakage, as well as buildup, migration, and decay of radioactivity already in the soil. Dry wells were drilled in the tank farms as they were constructed and were added in increasing numbers around each tank to improve detectability of leakage and to monitor leak migrations, as shown in Figure 21. Since the 106-T leak in 1973, the number of dry wells has increased by about 50 percent. There are presently over 760 of these wells, including investigation wells. The wells are open bottom mild steel casings of either six or eight inch diameter and their depths range from 75 to 250 feet. Although a number of the wells are randomly situated within tank farms as happens, for example, when wells are drilled to monitor movement of leaked material through the soil, most wells are located adjacent to specific tanks at a distance of six to ten feet from the outer walls. A dry well is monitored by lowering a radiation detector into the well and recording the radiation profile (radiation level in counts per second versus distance from the bottom of the well on the ascent of the detector. The rate of ascent is kept constant to preclude variance as a function of time that the detector is exposed to radioactivity in the soil around the dry well. The radiation profiles are recorded on strip charts and the data is entered into CASS. Leakage from a tank is determined from the depth of a radiation peak and continued changes of the peak and profile.

Each tank has been categorized in Table 18, column 4, and in Appendix H, column 13, for the volume of the maximum leak undetectable by its individual dry well pattern, in accordance with the estimates set forth in Appendix F. In determining the category for each tank, credit was given to dry wells that service more than one tank, but wells in close proximity to each other (i.e., near duplicates) or those on the far side of adjacent tanks were disallowed. The dry well system for any tank was adjudged to be nonfunctional for the detection of leaks if the content of total drainable liquid did not exceed the volume of the maximum undetectable leak. No distinction was made for the relative mobility of supernatant and drainable interstitial liquid, although studies indicate that the mobility of interstitial liquid from salt cake is at least one order of magnitude less than that of supernatant liquid (see Appendix B). For tanks classified as confirmed leakers or of questionable integrity, the dry well system was considered functional to a limited degree in those instances where the tank status has been classified on the basis of one or more contaminated dry wells. Supernatant liquid generally has been removed from such tanks.

On the basis of insufficient liquid content, the dry well systems are considered nonfunctional for 36 tanks (8 sound inactive tanks and 28 questionable-integrity or confirmed leaker tanks). Seven of these tanks contain volumes of drainable liquid ranging from 11 to 37 thousand gallons each. An additional 16 small (55,000 gallon) tanks have essentially no dry well monitoring systems installed. Although these 52 of the 149 single shell tanks (35 percent) have nonfunctional dry well systems, most of these tanks have been pumped down to near-zero supernatant, including the small tanks.

The dry well monitoring systems are functional for leak detection for 74 of the single shell tanks (50 percent), as shown in Appendix H, column 14. The remaining 23 tanks, which are classified as confirmed leakers or of questionable integrity, have contents sufficient in volume to be detected by dry wells but have one or more contaminated dry wells. The dry well monitoring systems for these tanks are considered functional to a limited extent for monitoring further indications of leakage or migration of radionucludes in the soil. Most of these 23 tanks have negligible supernatant liquid, but over half contain substantial quantities of drainable interstitial liquid.

Horizontal lateral (dry well) leak monitoring systems are installed at only 16 of the 149 single-shell tanks, but the system for one empty tank is not used. The laterals are four inch (inner diameter) tubes located ten feet beneath the tank's concrete base that are brought to ground level in vertical caissons adjacent to the tank where they are installed. There are three to five laterals per tank and the horizontal portions extend in a fan-like manner underneath the tank. A radiation probe is driven pneumatically to the end of the lateral, after which it is withdrawn by cable and drive mechanism in a uniform manner as in dry well monitoring. Readouts of radiation level versus distance along the lateral are recorded and the data processed in a manner similar to dry wells. The maximum leak undetectable by these systems has been estimated at five thousand gallons per tank. These lateral systems are nonfunctional for 4 of the 16 tanks where the total drainable liquid content per tank is less than this detection limit, as shown in Appendix H, column 16. In 6 of the 16 tanks (38 percent), the lateral systems are considered fully functional. This group includes five tanks in active status and one questionable-integrity tank, classified on the basis of drop in liquid level. The remaining six tanks (one questionable integrity and five confirmed leakers) have been classified in whole or in part on the basis of the contamination around the tanks, and these horizontal lateral systems are considered functional to a limited degree for monitoring further indications of leakage or migration of radionuclide in the soil.

Leak detection pit monitoring systems are located at only four of the 149 single-shell tanks. They have pressure differential probes to indicate flooding of a collection grid and are considered to have a leak detection capability of about 100 gallons. These systems are functional for the four (three active and one questionable integrity) tanks where they are installed, as shown in Appendix H, column 18. The value of each system in determining leaks other than from the bottoms of the tanks has not been demonstrated, however; for example, tank 104-AX was classified of questionable integrity on the basis of dry well, not leak detection pit monitoring.

The preceding analysis present the functional capability separately for each of the major leak monitoring systems for single-shell waste storage tanks. Further analysis of the Appendix H data provides an understanding of the interrelationships of these systems. Figure 22 shows that most of the drainable liquids (8.8 million gallons) is contained in active tanks and that the next highest fraction (3.9 million gallons) is in inactive tanks (other than questionable-integrity or confirmed leaker tanks). Leak monitoring of active tanks is provided by two, and in some cases, three detection systems per tank and is considered adequate.

For inactive tanks, two leak monitoring systems are functional for 21 tanks. Only one system is functional for 33 other tanks. Most (98 percent) of the drainable waste liquid in inactive tanks is about evenly divided between these two groups of tanks. The 12 remaining inactive tanks have no functional leak monitoring system at all but contain only 80 thousand gallons of drainable liquid. Nevertheless, this 80 thousand gallons, which is mostly in salt cake, could leak out slowly.

Monitoring of the 33 inactive tanks with one functional leak detection system is marginally adequate but clearly is not adequate if dual criteria must be met to determine whether a tank is a confirmed leaker. Further review of these 33 tanks shows that for 11 tanks, the liquid-level probe systems are functional; for the other 22 inactive tanks, the dry well monitoring systems are functional. The first group of 11 tanks are almost empty of drainable liquids, containing 56 thousand gallons. The second group of 22 tanks contains 1.87 million gallons of drainable liquids. The liquid-level leak monitoring systems for this latter group have been rendered non-functional by the pumping out of supernatant as part of the waste solidification program. Interestingly, if the jet pumping schedule of the waste solidification program continues on the schedule, set forth in the Waste Concentration Program Plan (FHO-CD-330, rev. 11-9-79), one of the two functional leak monitoring systems—that based on liquid-level measurement—will become non-functional for an estimated 15 more inactive tanks by the end of fiscal 1981 due to removal of about 500 thousand gallons of supernatant. The offsetting end result of pumping these tanks is the removal of about 1.5 million gallons of pumpable liquids as a source of potential leakage.

Turning to unsound and suspected unsound single shell tanks, i.e., those classified as of questionable integrity and as confirmed leakers (a philosphical distinction can be made between tanks demonstrated to leak and those merely suspected), the practice at Hanford has been to regard both categories as unsound, to remove supernatant liquids to sound tanks as rapidly as possible, and to schedule the removal of drainable interstitial liquid, subject to the limitations of available pumping equipment and the state of technology for liquid removal from salt cake and sludge. Nevertheless, approximately 2.6 million gallons (17 percent of the total drainable liquids in single-shell tanks) remains in these 58 tanks, as shown in Figure 22.

As shown on the left in Figure 22, 12 of the 34 questionable integrity tanks have at least one functional leak monitoring system but only one of these 12 tanks is monitored by two separate leak detection systems. Three of the 12 tanks, the second group from the left identified by an asterisk in Figure 22, also have dry well monitoring systems but, because of dry well radioactivity in the wells, these systems are adjudged functional only to a limited degree for monitoring further indications of leakage or movement of radionuclides in the soil.

Of the remaining 22 questionable-integrity tanks, 14 have contaminated dry well systems that may be functional to a limited degree for monitoring movement of radionuclides through the soil. It is a matter of concern that these 14 tanks with marginal monitoring capability contain approximately 1.6 million gallons of drainable radioactive waste liquid. As for the other inactive tanks previously discussed, the liquid-level leak monitoring systems for these tanks have become unresponsive because of removal of supernatant. Removal of the remaining substantial quantities of interstitial liquid must await the procurement and installation of more sophisticated pumping equipment, which is scheduled over the next several years. The outer eight tanks have no functional leak monitoring system but contain practically no drainable liquid.

As shown on the right in Figure 22, 8 of the 24 confirmed leaker tanks have contaminated dry well or lateral systems that are functional to a limited degree for monitoring further indications of leakage or movement of radionuclides in the soil, whereas 16 such tanks have no functional monitoring system. All the supernatant has been removed from these tanks. Half of the drainable interstitial liquid remaining is tightly held in sludge in 22 tanks. The other half is held in large volumes of salt cake in two tanks, which are scheduled for jet pump installation starting in fiscal 1981. The lack of leak monitoring for these tanks is not of concern unless the interstitial liquid becomes less bound to the solids in the tanks or substantial intrusions occur. It should be noted, as stated at the beginning of this chapter, that all tanks are adequately monitored for intrusion and that such monitoring would detect the appearance of supernatant from whatever source.

Frequency of monitoring is an important parameter of the tank surveillance program. Liquid-level monitoring systems for each tank are either automated and connected to the Computer Automated Surveillance System (CASS) for readout or are read manually and the data is entered into the CASS information bank. The CASS operation is fairly continuous in monitoring; that is, the sensors are read routinely every hour, with automatic alarm if set points are exceeded. The frequency can be altered on command; e.g., a 5-minute frequency is used to track the start of transfer operations. Manual probes are normally operated and read by an operator daily. If a tank has no supernatant or has excessive salt cake at the surface, these readings measure only intrusions; otherwise the measurements detect liquid level changes from both leakage from and intrusions into the tanks. An overall picture of the liquid-level monitoring frequency for single-shell tanks is given in Figure 23, which summarizes the following details.

All the 25 active single-shell tanks are connected to CASS; 24 tanks are monitored hourly for leakage and intrusions; one tank is monitored hourly for intrusions but not for leakage owing to a momentary lack of supernatant. Because of changing tank liquid levels and disturbance of tank contents, materials balance procedures must replace liquid-level measurements during liquid transfer operations.

The liquid-level monitoring systems of 35 of the 66 inactive single-shell tanks are tied into CASS, and hourly intrusion information is provided. Daily intrusion determinations are made manually for the other 31 tanks. For leak detection, however, 34 of the inactive tanks have insufficient supernatant to be monitored, 15 tanks are monitored hourly on CASS, and 17 tanks are monitored manually on a daily basis.

Liquid-level monitors for 12 of the 34 questionable integrity tanks are tied into CASS for hourly intrusion determinations; such determinations are made manually for the other 22 questionable integrity tanks on a daily basis. Most (29) of the questionable integrity tanks cannot be monitored for loss of liquid because they lack supernatant liquid. As a result, only five such tanks are monitored for leakage—four tanks hourly on CASS and one tank manually on a daily basis.

All 24 confirmed leaking tanks are monitored manually for liquid intrusions on a daily basis, but none of these tanks are monitored for loss of liquid since the lack of supernatant liquid renders the conductivity probes nonfunctional.

The appropriate frequency for monitoring by dry wells is dependent on many factors and therefore difficult to determine. The relative mobility of drainable liquids during waste solidification processes has already been indicated as a principal factor of consideration, as discussed in Appendix B. The present surveillance schedule as set forth in Table 19 provides for monitoring every two weeks, except for interim stabilized tanks which are monitored every three months. Ninety percent of the dry wells are presently monitored biweekly and ten percent, associated with 13 interim stabilized tanks, are scheduled quarterly.

The frequency is more varied in the case of the horizontal lateral monitoring systems, as shown in Table 19. Of the 50 horizontal laterals under 16 single-shell tanks, five under one empty tank are not used, nor are the six laterals under two other tanks, of which one tank is active and the other tank interim stabilized. The three laterals under a fourth tank, also interim stabilized, are monitored weekly. Five tanks with three laterals each are monitored every two weeks; all these tanks are active and contain appreciable quantities of drainable liquids. The three laterals under each of the remaining seven tanks which are interim stabilized are on a quarterly monitoring schedule. All of the interim stabilized tanks except one have been emptied or pumped to minimum heel. From the above frequencies, it appears that only the five active tanks on a biweekly schedule and the single interim stabilized tank monitored weekly are serviced by horizontal lateral monitoring with any degree of urgency, out of a total of 16 tanks with such systems installed.

Eleven of the single-shell tanks, as listed in Table 20, contain high-heat solids and must be monitored for temperature level. Without auxiliary cooling, these tanks would likely exceed the maximum allowable temperature (350°F) set to protect the tank concrete from degradation and subsequent failure. Another 19 tanks listed in Table 21 with heat-generating solids may present similar problems without cooling. Temperature monitoring is also important for maintaining adequate process control during the waste evaporation process. Initially thermocouple temperature-monitoring systems were installed in all single-shell tanks, but because of failure these are presently nonfunctional in 11 tanks. As thermocouples fail, they are replaced on an as-needed basis related to the heat-generation status of the tank involved. Temperatures are monitored routinely each day in 40 of the single-shell tanks by the CASS operations. The other 98 tanks are monitored manually—those with high heat content (11 tanks), on a monthly basis and the others, quarterly. Temperature monitoring is adequate for the single-shell tanks because the heat-up rates for their contents have been well established.

Single-shell tanks are inspected by in-tank photography to observe contents, measurement anomalies, and anomalies or defects at the tank walls. The 25 active tanks that are scheduled for yearly photography are full of liquids and will not be photographed until pumped down. Minimal information is gathered from photographs of full tanks unless there is a surveillance or process control problem in which photographs may be useful. The 72 tanks classified as primary stabilized are photographed every 2 years. Photography for the 26 inactive tanks, including 22 questionable integrity and confirmed leaker tanks, which have been interim stabilized is scheduled every 3 years. The remaining 26 tanks are photographed on a yearly basis.

Under development is a dome survey program to evaluate the physical and structural integrity of the steel-reinforced concrete tank domes; to monitor internal dome loadings, anomalies, and defects on a selective schedule; and to survey structural movement or deflections as indicators of stress. An initial pilot program is under way which uses visual survey techniques to examine certain tanks, such as listed in Table 22, with dome suspended equipment, with a history of heavy salt loadings, or with dome anomalies or defects. This program is augmented by periodic sampling and analysis of dome concrete.

3.4 MONITORING PROGRAMS FOR DOUBLE-SHELL TANKS

All seven active double-shell tanks are monitored at three locations for the detection of leaks: inside the primary tank (shell), within the annulus between the primary tank and the secondary tank (shell), and at the leak detection pit located adjacent to each tank which collects any leakage through the secondary tank through a system of slots in the base slab. Liquid level in the primary tank is measured by a conductivity probe system that detects both leaks from and intrusions into the tank. The liquid-level probes in primary tanks are automated on CASS for three double-shell tanks and are read hourly; for the other four double-shell tanks, the primary-tank liquid level monitors are manually operated and are read daily. Ultimately, all double-shell primary-tank liquid-level monitors will be tied into CASS, including the 13 new double-shell tanks in the final stages of construction.

Leaks from the primary tanks and other intrusions into the annulus are monitored in two ways: (1) by liquid-level conductivity probles at various levels within the annulus which are activated by the presence of liquid in the annulus and which sound an alarm in the instrument building, and (2) by radiation monitors used to detect airborne radioactivity in annulus ventilation air. Conductivity probes and radiation monitors located in the leak detection pits for each double-shell tank monitor the underside of the secondary shell in a manner identical to that of the annulus monitors.

Temperature-monitoring systems (thermocouples) are installed on all seven double-shell tanks; systems for four of the tanks are on CASS and are monitored daily, and the other three, now monitored manually on a monthly basis, will be added to the CASS operation, as will the 13 new double-shell tanks now entering their final construction period.

There are no dry wells around the seven double-shell tanks presently in use and the 13 additional double-shell tanks under construction to monitor the soil for spills, possible transfer line failures, and migration of radioactive materials from adjacent areas. The complex of multiple tank containment and monitoring systems has been assumed to justify this lack. A similar lack of dry wells exists at the evaporator-crystallizer facilities, where an older, singly encased transfer line failed just recently and a loss of about 500 gallons was detected only by its presence at the surface. Experience at the Savannah River Plant has demonstrated the value of dry wells near double-shell tanks and evaporators. Indeed, one of two major leaks there, which resulted from a failure in a doubly encased transfer line next to a double-shell tank, was detected by dry well measurements.

3.5 MATERIAL BALANCES

Transfers of liquids are carried out for a variety of reasons. Generally these transfers are planned operations and individual procedures are written and approved for each transfer. Occasionally, emergency transfers may be necessary in case of tank or pipe failure. Material balances provide a method of accountability during transfer operations and immediately thereafter. Material balances are also discussed in Appendix C.

In conducting a transfer, proper routing is determined and liquid levels are established and monitored during material flow. Lines are periodically tested for leaks. Fluid additions to the particular system, such as flush water, are monitored. The allowable discrepancy in transfer material balance between pumping and receiving tanks and between transfers to and from processing plants and the tank farms is about 1,500 gallons due to measurement accuracy limitations. In salt well pumping, the volume of liquid transferred and the rate are dependent on the functioning of the well, and standard material balance techniques are not always applicable. This situation results from the ever-decreasing rate of flow as liquid is progressively removed from the tank. Estimates are that discrepancies of 800 to 1,500 gallons would probably go undetected by material balance. Daily overall material balances are maintained on the 242-A and 242-S evaporator-crystallizer bottoms tanks; allowable discrepancies are negative 5,000 to plus 9,000 gallons. An additional 10 day average is maintained for the 242-S system with an allowable discrepancy of less than negative 2,000 gallons. The material balances are performed either manually or by the CASS system. The balances are reviewed and discrepancies in excess of established limits are investigated.

3.6 QUALITY ASSURANCE

The function of an independent quality assurance (QA) program in connection with the tank farm surveillance program is recognized in requirements established by the DOE Richland Operations Office and is outlined in Rockwell Hanford Operations (RHO) procedures. The quality assurance program is also discussed in Appendix C. Organizationally, the RHO Director of QA reports to the Vice-President and General Manager thus providing the necessary level of authority for the independent conduct of this function. The formalized requirements cover a wide range of activities including specific responsibilities aimed at assuring the adequacy of the monitoring systems. Verification of actual implementation of the QA program was not extensive during this review due to the priority of reviewing other surveillance matters. Organizationally and procedurally, the program appears adequate, except as noted in the following section on procedures, records, and reports.

3.7 PROCEDURES, RECORDS, AND REPORTS

As noted previously, a lack of consistency has been observed in documentation of the status and history of the waste storage tanks and associated systems. One chief exception to this statement is the Monthly Waste Status Summary report. This lack of consistency, due in large measure to out-of-date data, procedures and criteria, extends more broadly across the surveillance program; however, when inquiries were made to field personnel concerning confusing or erroneous information obtained during this review, the record data used in direct day-to-day waste management operations was found to be fully correct and up-to-date. Examples of inconsistencies include: status of criteria and categories for classifying soundness of single-shell tanks; the elements of such criteria; pumping policies for inactive tanks, including selection of tanks to be pumped; errors in quarterly status sheets, surveillance schedules and status of dry wells and horizontal laterals; and heat generation rates. Full cooperation was given by DOE and contractor staffs in supplying correct data and deficiencies in information; any documentation desired during the course of the review was made available without hesitation. Nevertheless, the discrepancies between documents and out-of-date data, and absence of formal criteria for decision making in certain critical areas like classification of unsound tanks, has led to misunderstandings and misinterpretations in the past and will continue to do so until some system of quality control over these operational aids is established.

3.8 LIQUID INTRUSIONS

Intrusions (unwanted additions) of liquids into the waste tanks and catch tanks associated with the waste management operations at Hanford are occurring with increasing numbers and volume. The significance of intrusions to the surveillance program is two-fold; first, intrusion monitoring, which is excellent, must be continued despite the degree of stabilization or degree of isolation of any tank or related system as long as there is a finite possibility for further intrusions to occur, and, second, considering the fact that some 54 single-shell tanks are unsound and that the remaining single-shell tanks will ultimately become unsound, every intrusion represents a potential leaching agent to remove tank contents to the soil outside. The causes of intrusion are varied--leaks at valves and jumpers, misroutings, leakage during transfers, snowmelt runoff, etc. The number of tanks involved doubled from 1978 to 1979, as shown in Figure 24. The total volume of intrusions also doubled during the same period, as may be seen in Figure 25. The trend for intrusions has steadily increased from 1977 through 1979. During January of 1980, 10 thousand gallons of snowmelt runoff apparently entered two tanks classified as leakers and one tank of questionable integrity. The net impact of this worsening situation raises the question of whether the proposed elimination of liquid-level monitoring for interim isolated tanks can be effected in the near future.

TABLE 11.

TANK CLASSIFICATION CATEGORIES

DOCUMENTATION	CATEGORIES: SOUND	BORDERLINE	DORMANT	SUSPECT	RESTRICTED USE	QUESTIONABLE	QUESTIONABLE INTEGRITY	CONFIRMED (DECLARED) LEAKER	OTHER
LETTER–RICHARDS TO FREMLING 8–31–73,ATT. REV. 10–18–73[1]	(X)			X	X			X	
RHO–CD–213 REV.1–1–77[2]	(X) ACTIVE				X ACTIVE		X INACTIVE	X	INACTIVE
RHO–CD–213 DEC. 1977[3]	(X) ACTIVE						X (REV.1–10–79)	X	
RHO–CD–430 REV.4–13–79[4]	(X) ACTIVE				X ACTIVE				INACTIVE
RHO–MA–151 6–20–79[5]	X						X	X	
RHO BRIEFING 10–11–79[6]	(X) ACTIVE				X ACTIVE		X INACTIVE	X	INACTIVE
RHO–CD–14 12–31–79[7]	(X) ACTIVE				X ACTIVE		X INACTIVE	X	INACTIVE
RHO–CD–896 JAN. 1980[8]:									
1971–72	X	X	X	X				X	
1972–73	X	X – or –	X	X				X	
1972–73	X			X	X			X	
1973–74	X					X		X	
1974	X			X				X	
1974–PRESENT	X ACTIVE						X	X	INACTIVE

TABLE 11 (Continued).

FOOTNOTES:

[1] LETTER-RICHARDS (ARHCO) TO FREMLING (DOE-RL) DATED 8-31-73, 'WASTE STORAGE TANK LEAK DETECTION METHODS AND CRITERIA"; ATTACHMENT DATED 10-18-73, "LEAK CATEGORIZATION SUMMARY–REVISION 1"

[2] RHO-CD-213 "TANK FARM SURVEILLANCE PLAN", REV. 1-1-77, p. 00-00-08

[3] RHO-CD-213 "WASTE STORAGE TANK STATUS AND LEAK DETECTION CRITERIA", DEC. 1977, VOL I-IV; GLOSSARY pp. 00-02-01 THROUGH 00-02-05; pp. 00-02-02 THROUGH 00-02-05 REV. 1-10-79

[4] RHO-CD-430 "SURVEILLANCE AND MAINTENANCE PROGRAM PLAN" 10-30-78; pp. A-2 THROUGH A-10 REV. 4-13-79

[5] RHO-MA-151 "SPECIFICATIONS AND STANDARDS FOR THE OPERATION OF RADIOACTIVE WASTE TANK FARMS AND ASSOCIATED FACILITIES" 3-27-79, SECTION B, p. 3-1 DATED 6-20-79 (AND OTHER SECTIONS)

[6] ROCKWELL HANFORD OPERATIONS BRIEFING TO DOE-EV ASSESSMENT GROUP 10-11-79

[7] RHO-CD-14 'WASTE STATUS SUMMARY–DECEMBER 1979", DATED 1-11-79 (sic), pp. 45-48

[8] RHO-CD-896 "REVIEW OF CLASSIFICATION OF NINE HANFORD SINGLE-SHELL 'QUESTIONABLE INTEGRITY' TANKS" JANUARY 1980, APPENDICES A AND D

TABLE 12.

HANFORD 200 AREAS TANK FARM FACILITIES
CRITERIA FOR CLASSIFICATION OF TANKS

DOCUMENTATION	CONFIRMED LEAKER CLASSIFICATION	QUESTIONABLE INTEGRITY CLASSIFICATION
SINGLE-SHELL (SS) TANKS:		
LETTER-RICHARDS TO FREMLING 8-31-73, ATTACHMENT REV. 10-18-73[1]	LIQUID-LEVEL DECREASE *AND* DRY WELL READINGS INCREASE BEYOND SET CRITERIA, *OR* LIQUID LEAK BEYOND DOUBT.	LIQUID-LEVEL DECREASE *OR* DRY WELL READINGS INCREASE BEYOND SET CRITERIA.
RHO BRIEFING TO DOE-EV ASSESSMENT GROUP 10-11-79	LIQUID-LEVEL DECREASE *AND* DRY WELL READINGS INCREASE BEYOND SET CRITERIA.	LIQUID-LEVEL DECREASE *OR* DRY WELL READINGS INCREASE BEYOND SET CRITERIA.
RHO-CD-896 (JAN. 1980)[2]	NO HARD CRITERIA, BUT WORKING GUIDELINES STATE: LIQUID-LEVEL DECREASE *AND* DRY WELL READINGS INCREASE BEYOND SET CRITERIA, *OR* SINGLE SOURCE (LIQUID LEVEL DECREASE OR DRY WELL READINGS) DATA IF SUFFICIENT AND NO OTHER REASONABLE EXPLANATIONS.	LIQUID-LEVEL DECREASE *OR* DRY WELL READINGS INCREASE BEYOND SET CRITERIA.
DOUBLE-SHELL (DS) TANKS:		
LETTER-RICHARDS TO FREMLING 8-31-73, ATTACHMENT REV. 10-18-73[1]	LIQUID IN LEAK DETECTION PIT AND/OR RADIATION IN THE ANNULAR SPACE.	(NONE)

FOOTNOTES:

[1] LETTER-RICHARDS (ARHCO) TO FREMLING (DOE-RL) DATED 8-31-73, "WASTE STORAGE TANK LEAK DETECTION METHODS AND CRITERIA"; ATTACHMENT DATED 10-18-73, "LEAK CATEGORIZATION SUMMARY–REVIEW 1"

[2] RHO-CD-896 "REVIEW OF CLASSIFICATION OF NINE HANFORD SINGLE-SHELL 'QUESTIONABLE INTEGRITY' TANKS", JANUARY 1980

TABLE 13.

HANFORD SINGLE-SHELL TANKS AVERAGE LEAK RATE (ILLUSTRATIVE)

TANK	STATUS*	CRITERIA FOR CLASSIFICATION	ESTIMATED LOSS (GAL)	DURATION OF LOSS (DAYS)	AVG LEAK RATE (GAL/DAY)	DRY WELLS INFORMATION	YEARS OF LEAKAGE
107-B	L	LIQUID LOSS (QI)	~8,000	457	~17	CONTAMINATED WHEN DRILLED (1973)	1968-1969
201-B	L	LIQUID LOSS (QI)	~1,180	1,156	~1	ONLY 1 DRY WELL-120' AWAY PEAK (1971)	1968-1971
101-C	L	LIQUID LOSS (QI)	17,000 TO 24,000	699	24 TO 34	CONTAMINATED WHEN DRILLED (1970)	1968-1969
106-T	L	LIQUID LOSS & DRY WELL	~115,000		~2,450	DRY WELL INCREASE (1973)	1973
110-U	L	LIQUID LOSS** & DRY WELL	~8,150	425	~19	DRY WELL INCREASE (1975)	1975
112-U	L	LIQUID LOSS (QI)	7,000 TO 10,000	393	18 TO 25	CONTAMINATED WHEN DRILLED (1974)	1969-1970
110-B	QI	LIQUID LOSS	~8,300	699	~12	CONTAMINATED WHEN DRILLED (1973)	1969-1971
110-SX	QI	LIQUID LOSS+ (3RD OCCURRENCE)	~2,000	7	~285	DRY WELL ACTIVITY (1974)? (NO LATERAL ACTIVITY)	1976
108-T	QI	LIQUID LOSS	~800	243	~3	DRY WELL ACTIVITY (1978)	1973-1974
111-T	QI	LIQUID LOSS	~800	261	~3	NO DRY WELL ACTIVITY	1973-1974
101-TY	QI	LIQUID LOSS & DRY WELL INCREASE	~930	54	~17	INCREASED DRY WELL ACTIVITY (1973)?	1973

*L, confirmed leakers; QI, questionable integrity.
**Three-inch liquid loss masked by transfers — action due to dry well increase.
+Possible liner failure — between 304 and 360 inches.

TABLE 14.

HANFORD SINGLE-SHELL TANK FARM FACILITIES
SERVICE LIFE – QUESTIONABLE INTEGRITY TANKS

TANK	DATE BUILT	DATE IN SERVICE	DATE OUT OF SERVICE	SERVICE LIFE (MONTHS)
104-AX*	1963-64	-66	-78	156
101-B	1943-44	5- -45	2- -73	334
103-B	1943-44	12- -45	-78	397
105-B	1943-44	1- -47	-72	312
110-B*	1943-44	5- -45	8- -70	304
111-B	1943-44	11- -45	-78	398
112-B	1943-44	4- -46	-78	393
101-BX	1946-47	1-17-48	-72	299
110-BX	1946-47	-49	-77	348
111-BX	1946-47	-50	6- -77	325
105-BY	1948-49	6- -51	-74	283
106-BY	1948-49	-50	-77	252
107-BY	1948-49	12- -50	-74	289
110-C	1943-44	5- -46	-76	368
111-C	1943-44	8- -46	-76	365
104-S	1950-51	2-09-53	-70	215
110-SX	1953-54	11- -60	-76	194
114-SX	1953-54	11- -56	-72	194
103-T	1943-44	11- -45	2- -74	340
107-T	1943-44	12- -44	-76	385
108-T	1943-44	9- -45	-74	352
109-T	1943-44	12- -45	-74	349
111-T	1943-44	10- -45	-74	351
105-TX	1947-48	3-02-51	-77	322
107-TX	1947-48	-50	6- -77	330
110-TX	1947-48	9- -49	-77	340
113-TX	1947-48	12- -50	-71	253
114-TX	1947-48	4- -51	-71	249
115-TX	1947-48	-51	-72	264
116-TX	1947-48	-51	-69	228
117-TX	1947-48	4- -51	-69	225
101-TY	1951-52	-53	-73	252
104-TY	1951-52	8-10-53	3- -74	248
106-U	1943-44	5-02-48	-77	356

NOTE: *date out of service unclear

TABLE 15.

HANFORD SINGLE-SHELL TANK FARM FACILITIES
SERVICE LIFE – CONFIRMED LEAKING TANKS

TANK	DATE BUILT	DATE IN SERVICE	DATE OUT OF SERVICE	SERVICE LIFE (MONTHS)
104-A	1954-55	6-30-59	4- -75	190
105-A*	1954-55	1-31-63	11- -63	10
107-B	1943-44	5- -45	8- -69	292
201-B	1943-44	-45	-71	324
102-BX*	1946-47	6-10-48	5- -70	264
108-BX	1946-47	-49	3- -74	303
103-BY	1948-49	11- -50	5- -73	271
108-BY*	1948-49	4-19-51	-71	248
101-C	1943-44	3- -46	-69	286
107-SX	1953-54	4- -56	-64	105
108-SX	1953-54	11- -55	-62	86
109-SX*	1953-54	9- -55	-65	124
111-SX	1953-54	6- -56	5- -74	216
112-SX	1953-54	2- -56	-69	167
113-SX	1953-54	2- -58	-58	11
115-SX	1953-54	9- -58	-65	88
106-T	1943-44	6- -47	6- -73	313
103-TY	1951-52	7-16-53	10- -73	243
105-TY	1951-52	1-29-53	9- -60	92
106-TY	1951-52	6-27-53	-59	78
101-U*	1943-44	2-25-46	11- -59	165
104-U*	1943-44	7-21-47	-61	173
110-U	1943-44	7-22-46	7- -75	348
112-U	1943-44	10- -47	-70	279

NOTE: *date out of service unclear. Tanks 107-B, 201-B, 101-C and 112-U reclassified from questionable integrity to confirmed leakers 1-25-80; out-of-service date taken from questionable integrity classification.

TABLE 16.

HANFORD SINGLE-SHELL TANK FARM FACILITIES CUMULATIVE FAILURE RATE BY SERVICE LIFE

UNSOUND TANKS (QUESTIONABLE INTEGRITY PLUS CONFIRMED LEAKERS)

GROUPED SERVICE LIFE (MONTHS)	GROUPED CUMULATIVE NO. OF TANKS	GROUPED CUMULATIVE FAILURE RATE (%)
10	1	0.67
11	2	1.3
78	3	2.0
86, 88 } 87	5	3.4
92	6	4.0
105	7	4.7
124	8	5.4
156	9	6.0
165, 167 } 166	11	7.4
173	12	8.1
190	13	8.7
194, 194 } 194	15	9.4
215, 216 } 215.5	17	11.4
225, 228 } 226.5	19	12.8
243	20	13.4
248, 248, 249 } 248.3	23	15.4
252, 252, 253 } 252	26	17.4
264, 264 } 264	28	18.8
271	29	19.5
279	30	20.1
283, 286 } 284.5	32	21.5
289, 292 } 290.5	34	22.8
299	35	23.5
303, 304 } 303.5	37	24.8
312, 313 } 312.5	39	26.2
322, 324, 325 } 323.7	42	28.2
330, 334 } 332	44	29.5
340, 340 } 340	46	30.9
348, 348, 349 } 348.3	49	32.9
351, 352 } 351.5	51	34.2
356	52	34.9
365, 368 } 366.5	54	36.2
385	55	36.9
393	56	37.6
397, 398 } 397.5	58	38.9

TABLE 17.

HANFORD SS TANK FARM FACILITIES

OPERATIONAL LIMITATION TANKS – POSSIBLE LEAKERS

STATUS AS OF 1-25-80

TANK	STATUS*	LIMITATION
102-BY	I	AIR LIFT CIRCULATOR FLOATS AT 65" LEVEL (PREVIOUSLY RESTRICTED – TAR RINGS ABOVE 240" LEVEL) – ADMINISTRATIVE LEVEL 165"
104-BY	I	MAXIMUM OPERATING LEVEL 270" – ADMINISTRATIVE LEVEL 177"
109-BY	I	MAXIMUM OPERATING LEVEL 226" (TAR RINGS ABOVE 235")
110-BY	I	MAXIMUM OPERATING LEVEL 257" (TAR RINGS ABOVE 266")
111-BY	I	MAXIMUM OPERATING LEVEL 257" (TAR RINGS ABOVE 260")
112-BY	I	MAXIMUM OPERATING LEVEL 270" (TAR RINGS ABOVE 276")
102-S	A	CONSIDERED SOUND BELOW 233" (SURFACE ANOMALIES AT 240")
		FORMER OPERATIONAL LIMITATIONS – L & QI TANKS
103-BY	L	MAXIMUM OPERATING LEVEL 177" (TAR RINGS ABOVE 186")
106-BY	QI	MAXIMUM OPERATING LEVEL 245" (TAR RINGS ABOVE 270")
107-BY	QI	MAXIMUM OPERATING LEVEL 250" (TAR RINGS ABOVE 256")

*L = leaker; QI = questionable integrity; I = inactive (other than L and QI); A = active.

TABLE 18.

HANFORD SS TANK FARM FACILITIES DRAINABLE LIQUID INVENTORY AND DRY WELL DETECTION CAPABILITY

STATUS AS OF 12-31-79

TANK	STATUS*	ESTIMATED NO. OF SYMMETRICAL DRY WELLS	DRY WELL MAXIMUM UNDETECTED LEAK (KGAL)	SUPERNATANT (KGAL)	INTERSTITIAL LIQ. DRAINABLE REMAINING (KGAL)	TOTAL PRESENTLY DRAINABLE (KGAL)	INTERSTITIAL ESTIMATED NON-PUMPABLE DRAINABLE LIQ. (KGAL)
101-A	A	8	10	11	146	157	19
102-A	A	7	17.5	85	4	89	4
103-A	A	7	17.5	324	90	414	19
104-A	L	7	17.5	0	4	4	4
105-A	L	7	17.5	0	4	4	2
106-A	A	8	10	607	6	613	6
101-AX	A	7	17.5	0	188	188	20
102-AX	A	8	10	500	11	511	11
103-AX	A	6	17.5	882	1	883	1
104-AX	QI	5	17.5	3	0	3	0
101-B	QI	6	17.5	0	10	10	6
102-B	I	5	17.5	14	9	23	6
103-B	QI	5	17.5	24	20	44	5
104-B	I	4	30	14	66	80	6
105-B	QI	4	30	0	81	81	6
106-B	I	4	30	14	16	30	6
107-B	L	4	30	0	7	7	5
108-B	I	5	17.5	33	21	54	6
109-B	I	4	30	14	36	50	6
110-B	QI	6	17.5	0	0	0	0
111-B	QI	4	30	3	31	34	6
112-B	QI	5	17.5	6	5	11	5
201-B	L	(1)	55	1	0	1	0
202-B	I	0	55	0	3	3	0
203-B	I	(1)	55	3	6	9	0
204-B	I	(1)	55	3	6	9	0

*Status of tanks 107-B, 201-B, 101-C and 112-U changed to L, 1-25-80

TABLE 18 (Continued).

TANK	STATUS*	ESTIMATED NO. OF SYMMETRICAL DRY WELLS	DRY WELL MAXIMUM UNDETECTED LEAK (KGAL)	SUPERNATANT (KGAL)	INTERSTITIAL LIQ. DRAINABLE REMAINING (KGAL)	TOTAL PRESENTLY DRAINABLE (KGAL)	INTERSTITIAL ESTIMATED NON-PUMPABLE DRAINABLE LIQ. (KGAL)
101-BX	QI	4	30	0	1	1	1
102-BX	L	8	17.5	0	5	5	5
103-BX	I	6	17.5	0	10	10	6
104-BX	A	6	17.5	80	17	97	5
105-BX	A	6	17.5	39	11	50	6
106-BX	I	4	30	14	4	18	4
107-BX	I	4	30	0	47	47	6
108-BX	L	7	17.5	0	1	1	1
109-BX	I	5	17.5	0	26	26	6
110-BX	QI	5	17.5	0	42	42	6
111-BX	QI	6	17.5	22	51	73	5
112-BX	I	6	17.5	0	22	22	5
101-BY	I	5	17.5	8	70	78	6
102-BY	I	5	17.5	0	103	103	14
103-BY	L	6	17.5	0	133	133	14
104-BY	I	5	17.5	11	179	190	6
105-BY	QI	4	30	0	171	171	6
106-BY	QI	5	17.5	0	157	157	6
107-BY	QI	6	17.5	0	18	18	6
108-BY	L	7	17.5	0	74	74	6
109-BY	I	6	17.5	33	116	149	6
110-BY	I	5	17.5	61	119	180	6
111-BY	I	5	17.5	0	172	172	9
112-BY	I	7	17.5	0	89	89	11

*Status of tanks 107-B, 201-B, 101-C and 112-U changed to L, 1-25-80

TABLE 18 (Continued).

TANK	STATUS*	ESTIMATED NO. OF SYMMETRICAL DRY WELLS	DRY WELL MAXIMUM UNDETECTED LEAK (KGAL)	SUPERNATANT (KGAL)	INTERSTITIAL LIQ. DRAINABLE REMAINING (KGAL)	TOTAL PRESENTLY DRAINABLE (KGAL)	INTERSTITIAL ESTIMATED NON-PUMPABLE DRAINABLE LIQ. (KGAL)
101-C	L	4	30	0	9	9	6
102-C	I	3	64	0	37	37	6
103-C	I	6	17.5	25	22	47	6
104-C	A	6	17.5	146	38	184	6
105-C	I	8	10	22	21	43	6
106-C	I	6	17.5	22	25	47	6
107-C	I	7	17.5	0	21	21	6
108-C	I	6	17.5	0	4	4	4
109-C	I	5	17.5	6	3	9	3
110-C	QI	6	17.5	2	20	22	5
111-C	QI	5	17.5	0	2	2	2
112-C	I	5	17.5	0	12	12	6
201-C	I	(1)	55	4	0	4	0
202-C	I	0	55	2	0	2	0
203-C	I	(1)	55	4	1	5	1
204-C	I	(2)	55	3	0	3	0
101-S	A	5	11.5	253	57	310	6
102-S	A	8	10	108	152	260	13
103-S	A	7	11.5	555	48	603	12
104-S	QI	5	11.5	0	14	14	5
105-S	I	5	11.5	53	26	79	14
106-S	I	6	11.5	0	78	78	8
107-S	A	6	11.5	349	52	401	6
108-S	I	5	11.5	58	48	106	13
109-S	I	6	11.5	0	57	57	11
110-S	I	6	11.5	0	0	0	0
111-S	I	6	11.5	0	160	160	6
112-S	I	6	11.5	0	76	76	13

*Status of tanks 107-B, 201-B, 101-C and 112-U changed to L, 1-25-80

TABLE 18 (Continued).

TANK	STATUS*	ESTIMATED NO. OF SYMMETRICAL DRY WELLS	DRY WELL MAXIMUM UNDETECTED LEAK (KGAL)	SUPERNATANT (KGAL)	INTERSTITIAL LIQ. DRAINABLE REMAINING (KGAL)	TOTAL PRESENTLY DRAINABLE (KGAL)	INTERSTITIAL ESTIMATED NON-PUMPABLE DRAINABLE LIQ. (KGAL)
101-SX	A	6	11.5	143	99	242	7
102-SX	A	5	11.5	371	129	500	7
103-SX	A	6	11.5	71	208	279	7
104-SX	A	8	10	110	213	323	7
105-SX	A	5	11.5	64	210	274	7
106-SX	A	5	11.5	745	43	788	13
107-SX	L	6	11.5	0	14	14	7
108-SX	L	7	11.5	0	11	11	6
109-SX	L	8	10	0	32	32	6
110-SX	QI	9	10	0	8	8	7
111-SX	L	8	10	0	10	10	7
112-SX	L	8	10	0	13	13	6
113-SX	L	3	43	0	1	1	1
114-SX	QI	7	11.5	0	25	25	6
115-SX	L	7	11.5	0	1	1	1
101-T	I	5	11.5	143	13	156	6
102-T	I	6	11.5	0	1	1	1
103-T	QI	7	11.5	0	4	4	4
104-T	I	6	11.5	0	14	14	5
105-T	I	5	11.5	0	14	14	5
106-T	L	7	11.5	0	3	3	3
107-T	QI	3	43	28	19	47	6
108-T	QI	6	11.5	0	6	6	6
109-T	QI	7	11.5	0	14	14	5
110-T	I	4	20	0	43	43	5
111-T	QI	6	11.5	0	56	56	6
112-T	I	7	11.5	6	8	14	6
201-T	I	(1)	55	0	0	0	0
202-T	I	(1)	55	0	0	0	0
203-T	I	(1)	55	0	0	0	0
204-T	I	0	55	0	4	4	0

*Status of tanks 107-B, 201-B, 101-C and 112-U changed to L, 1-25-80

TABLE 18 (Continued).

TANK	STATUS*	ESTIMATED NO. OF SYMMETRICAL DRY WELLS	DRY WELL MAXIMUM UNDETECTED LEAK (KGAL)	SUPERNATANT (KGAL)	INTERSTITIAL LIQ. DRAINABLE REMAINING (KGAL)	TOTAL PRESENTLY DRAINABLE (KGAL)	INTERSTITIAL ESTIMATED NON-PUMPABLE DRAINABLE LIQ. (KGAL)
101-TX	A	6	11.5	96	9	105	6
102-TX	I	5	11.5	0	137	137	14
103-TX	A	5	11.5	467	18	485	6
104-TX	I	5	11.5	8	12	20	12
105-TX	QI	6	11.5	0	121	121	14
106-TX	I	7	11.5	0	136	136	14
107-TX	QI	6	11.5	0	12	12	12
108-TX	I	4	20	0	39	39	14
109-TX	I	5	11.5	0	135	135	14
110-TX	QI	5	11.5	0	132	132	13
111-TX	I	5	11.5	33	111	144	14
112-TX	I	6	11.5	9	155	164	14
113-TX	QI	3	43	0	204	204	13
114-TX	QI	4	20	0	194	194	14
115-TX	QI	4	20	0	192	192	14
116-TX	QI	4	20	0	189	189	13
117-TX	QI	3	43	0	188	188	14
118-TX	A	7	11.5	261	128	389	14
101-TY	QI	4	20	0	15	15	6
102-TY	I	5	11.5	5	9	14	6
103-TY	L	3	43	0	21	21	5
104-TY	QI	4	20	0	6	6	6
105-TY	L	2	110	0	36	36	6
106-TY	L	4	20	0	3	3	3

*Status of tanks 107-B, 201-B, 101-C and 112-U changed to L, 1–25–80

TABLE 18 (Continued).

TANK	STATUS*	ESTIMATED NO. OF SYMMETRICAL DRY WELLS	DRY WELL MAXIMUM UNDETECTED LEAK (KGAL)	SUPERNATANT (KGAL)	INTERSTITIAL LIQ. DRAINABLE REMAINING (KGAL)	TOTAL PRESENTLY DRAINABLE (KGAL)	INTERSTITIAL ESTIMATED NON-PUMPABLE DRAINABLE LIQ. (KGAL)
101-U	L	4	20	0	5	5	5
102-U	I	6	11.5	0	121	121	6
103-U	I	6	11.5	42	118	160	9
104-U	L	4	20	0	16	16	6
105-U	I	5	11.5	25	124	149	8
106-U	QI	5	11.5	16	59	75	9
107-U	A	6	11.5	335	58	393	11
108-U	I	4	20	17	128	145	9
109-U	I	5	11.5	11	125	136	6
110-U	L	6	11.5	0	20	20	6
111-U	A	6	11.5	116	127	243	10
112-U	L	5	11.5	2	6	8	6
201-U	I	(1)	55	1	1	2	1
202-U	I	0	55	1	1	2	1
203-U	I	(1)	55	1	0	1	0
204-U	I	0	55	1	0	1	0
			TOTAL:	7,549	7,719	15,268	978

*Status of tanks 107-B, 201-B, 101-C and 112-U changed to L, 1-25-80

TABLE 19.

HANFORD SINGLE-SHELL TANK FARMS WELL MONITORING FREQUENCIES

DRY WELLS

NO. OF WELLS	% OF WELLS	MONITORING FREQUENCY	COMMENTS
1	–	–	CAPPED OFF
702	90	BIWEEKLY	
76	10	QUARTERLY	13 INTERIM STABILIZED TANKS

HORIZONTAL LATERALS (HL)

NO. OF HL'S	% OF HL'S	MONITORING FREQUENCY	COMMENTS
5	11	NOT USED	EMPTY INTERIM STABILIZED TANK
6	11	NOT MONITORED	1 ACTIVE TANK AND 1 INTERIM STABILIZED TANK
3	6	WEEKLY	1 INTERIM STABILIZED TANK
15	30	BIWEEKLY	5 ACTIVE TANKS
21	42	QUARTERLY	7 INTERIM STABILIZED TANKS

TABLE 20.

TANKS WITH HIGH HEAT GENERATION CONTENTS*

TANK	SOLIDS	ESTIMATED HEAT GENERATION RATE (BTU/HR)		ESTIMATED COOLING TIME REQUIRED (350°F LIMIT)	ESTIMATED COOLING TIME REQUIRED (300°F LIMIT)
104-A	28 KGAL	60,000	± 40 K	4 YR	14 YR
105-A	33 KGAL	60,000	± 30 K	4 YR	14 YR
106-A	50 KGAL	64,000	± 40 K	7 YR	16 YR
106-C	197 KGAL	170,000	± 40 K	50 YR	60 YR
107-SX	109 KGAL	60,000	± 20 K	7 YR	15 YR
108-SX	87 KGAL	65,000	± 20 K	10 YR	18 YR
109-SX	257 KGAL	60,000	± 20 K	10 YR	20 YR
110-SX	32 KGAL	55,000	± 20 K	1 YR	9 YR
111-SX	125 KGAL	65,000	± 20 K	8 YR	18 YR
112-SX	106 KGAL	70,000	± 20 K	12 YR	22 YR
114-SX	200 KGAL	70,000	± 20 K	15 YR	24 YR

*Definition: Tanks in which the heat generation could raise the concrete temperature above 350°F when no auxiliary cooling system is used. Above about 350°F the structural integrity of the concrete fails.

TABLE 21.

TANKS WITH BORDERLINE HEAT GENERATION CONTENTS*

103-AX	105-C	103-S	102-SX	102-TX
104-AX	107-C	107-S	103-SX	110-TX
104-BY	101-S	110-S	104-SX	111-U
110-BY	102-S	101-SX	105-SX	

*Definition: Tanks in which the heat generation could raise the concrete temperature between 250°F and 350°F when no auxiliary cooling system is used.

TABLE 22.

HANFORD SS TANK FARM FACILITIES DOME CONCERNS

STATUS AS OF 1-25-80

TANK	STATUS	CONCERN
101-BY	I	DUE TO DOME SUSPENDED AND SALT-ENCRUSTED EQUIPMENT ITEMS, TRANSFERS REQUIRE STRINGENT CONTROLS TO PREVENT EXCESSIVE DOME LOADING.
102-BY	I	SALT WELL PUMPING IN STEPWISE PROCEDURE TO AVOID EXCESSIVE DOME LOADS DUE TO SALT BUILDUP ON DOME SUPPORTED STRUCTURES.
105-TX	QI	LARGE DOME LOADS IN PAST DUE TO DOME SUSPENDED EQUIPMENT. TANK WILL BE INCLUDED IN DOME ELEVATION/INTEGRITY MONITORING PLAN.
112-TX	I	LARGE DOME LOADS IN PAST DUE TO DOME SUSPENDED EQUIPMENT. TANK WILL BE INCLUDED IN DOME ELEVATION/INTEGRITY MONITORING PLAN.
117-TX	QI	RADIAL CRACK IN TANK'S CONCRETE DOME.

KEY: I = inactive (other than leaking or questionable integrity tanks); QI = questionable integrity

STATUS AS OF 1-25-80

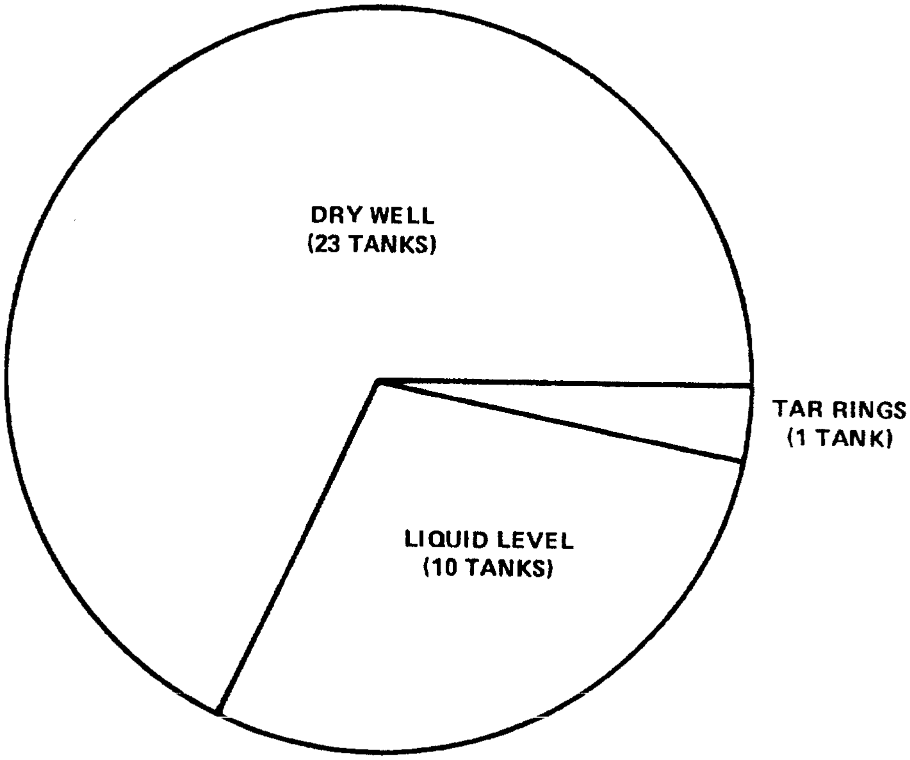

FIGURE 15.
HANFORD SS TANK FARM FACILITIES
CRITERIA USED TO CLASSIFY QUESTIONABLE INTEGRITY TANKS.

STATUS AS OF 1-25-80

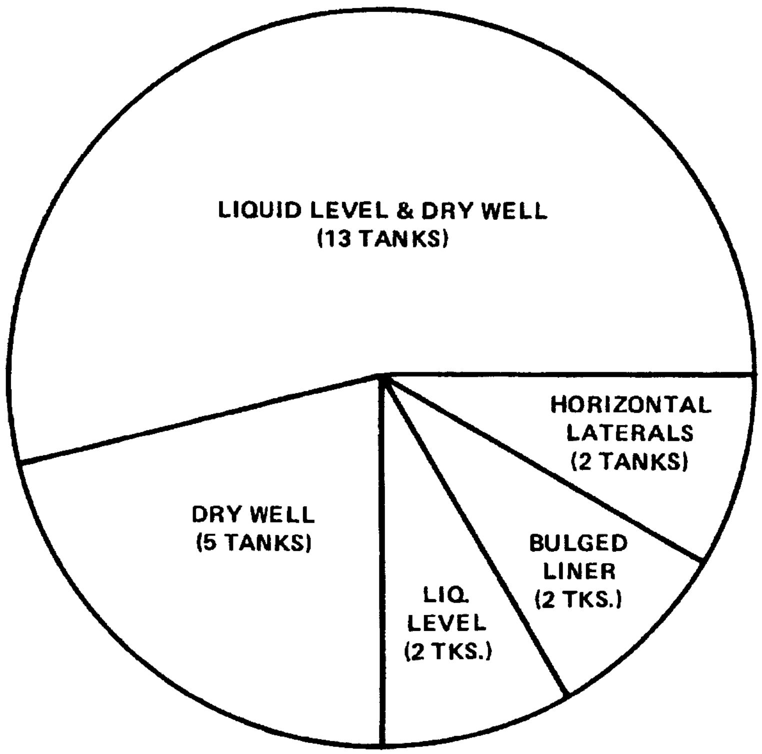

FIGURE 16.
HANFORD SS TANK FARM FACILITIES
CRITERIA USED TO CLASSIFY CONFIRMED LEAKING TANKS.

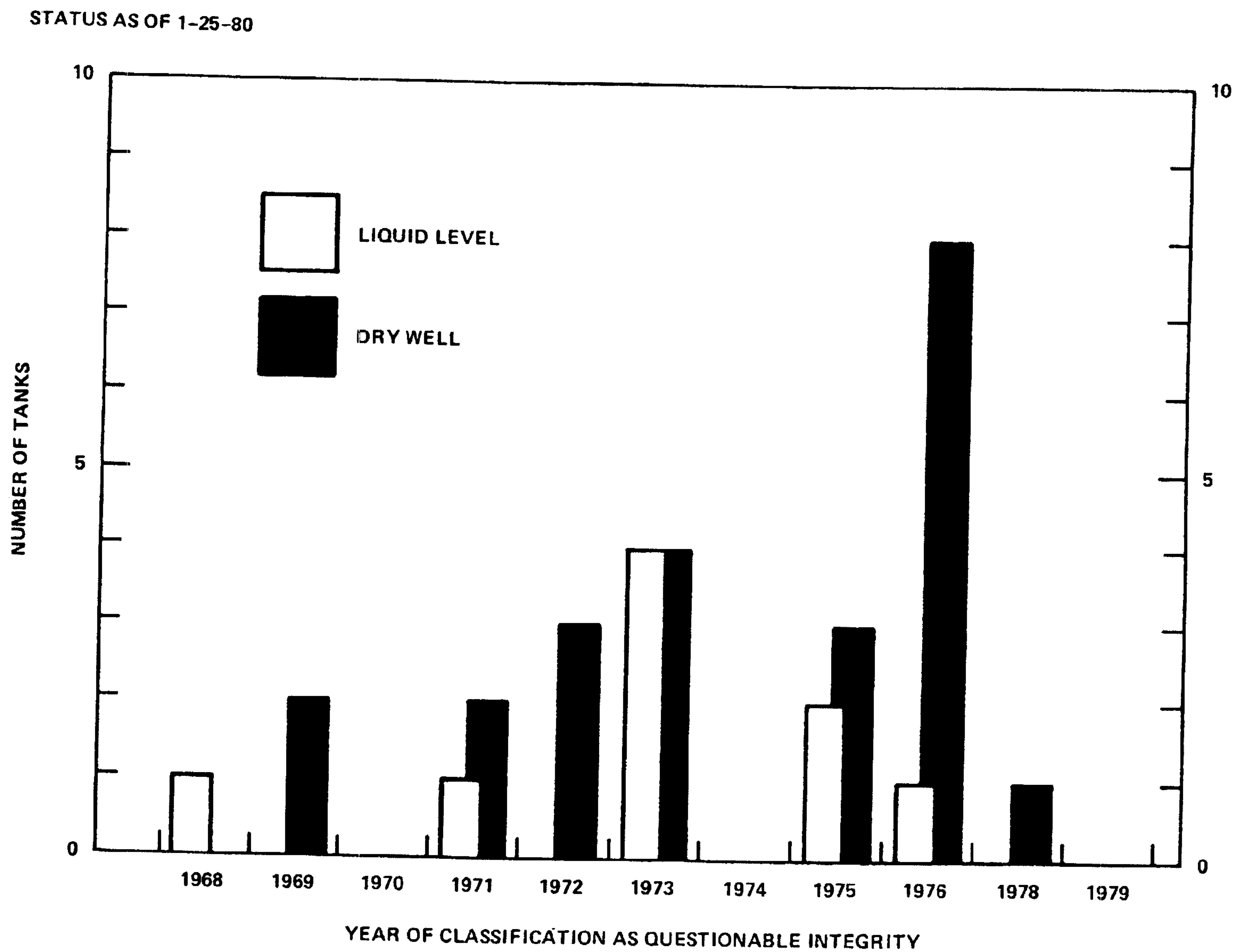

FIGURE 17.
HANFORD SS TANK FARM FACILITIES
CRITERION USED TO CLASSIFY QI TANKS, BY YEAR.

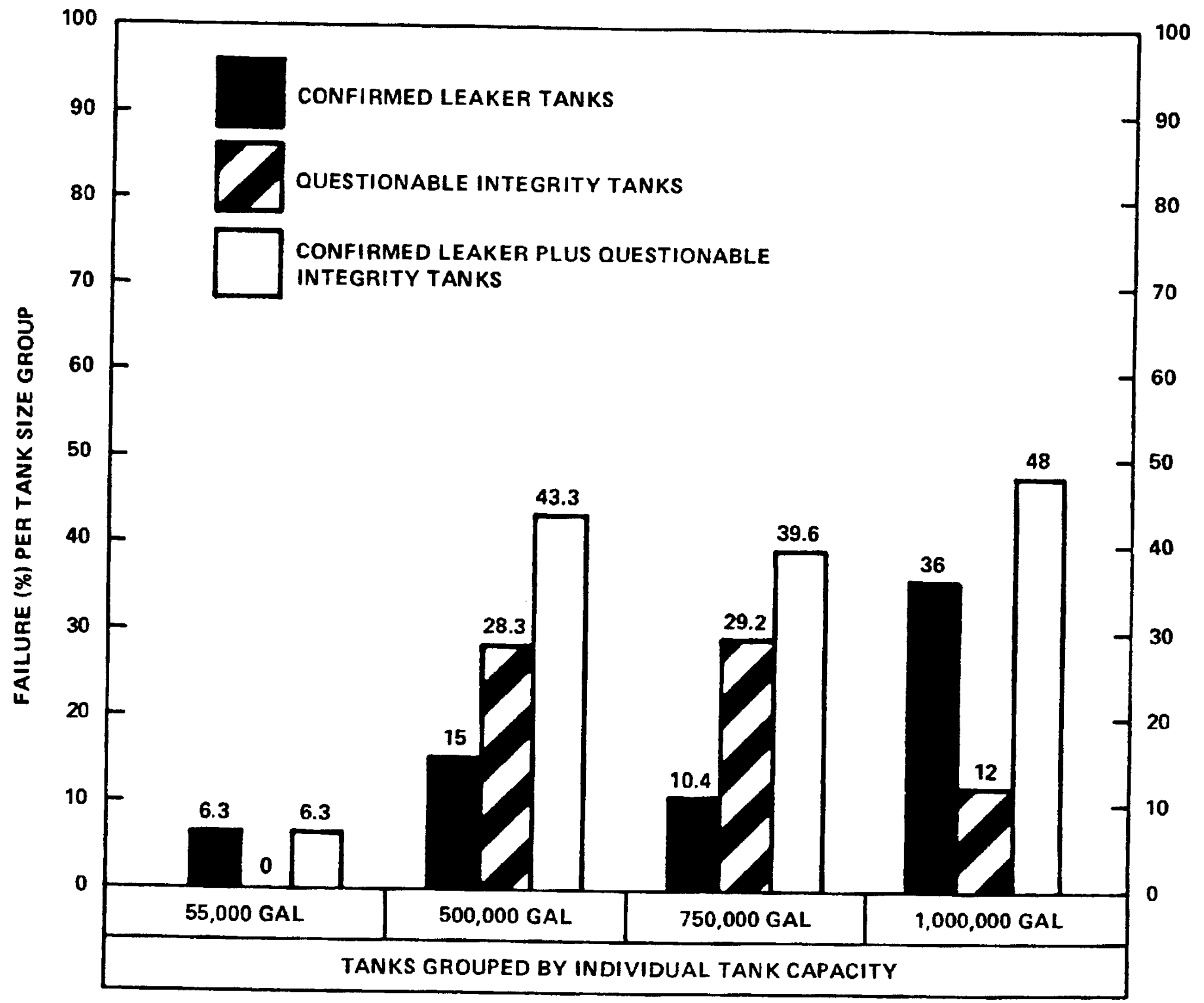

FIGURE 18.
SINGLE-SHELL TANK FAILURE RELATIONSHIP TO TANK CAPACITY.

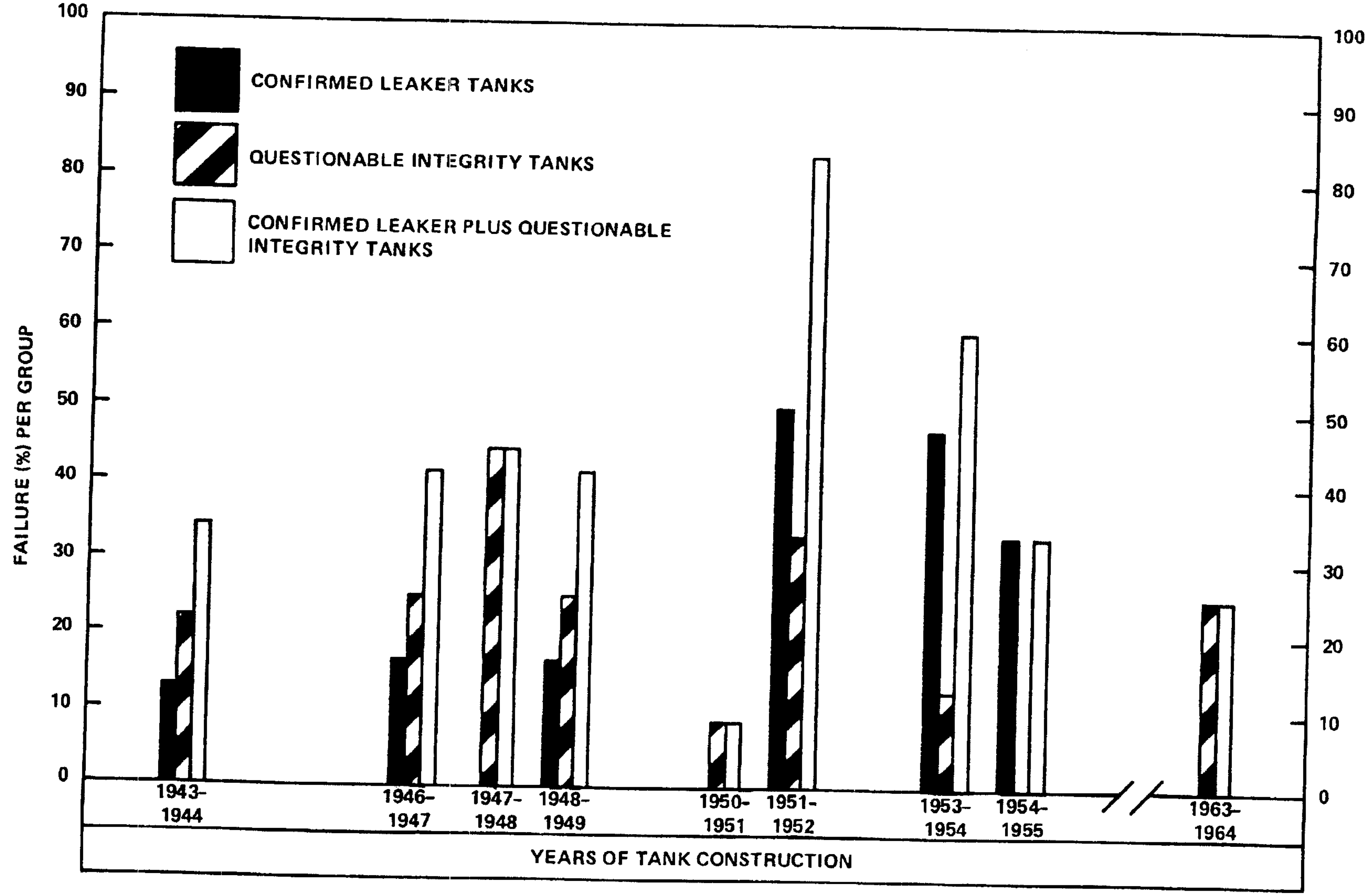

FIGURE 19.
SINGLE-SHELL TANK FAILURE RELATIONSHIP TO YEARS OF CONSTRUCTION.

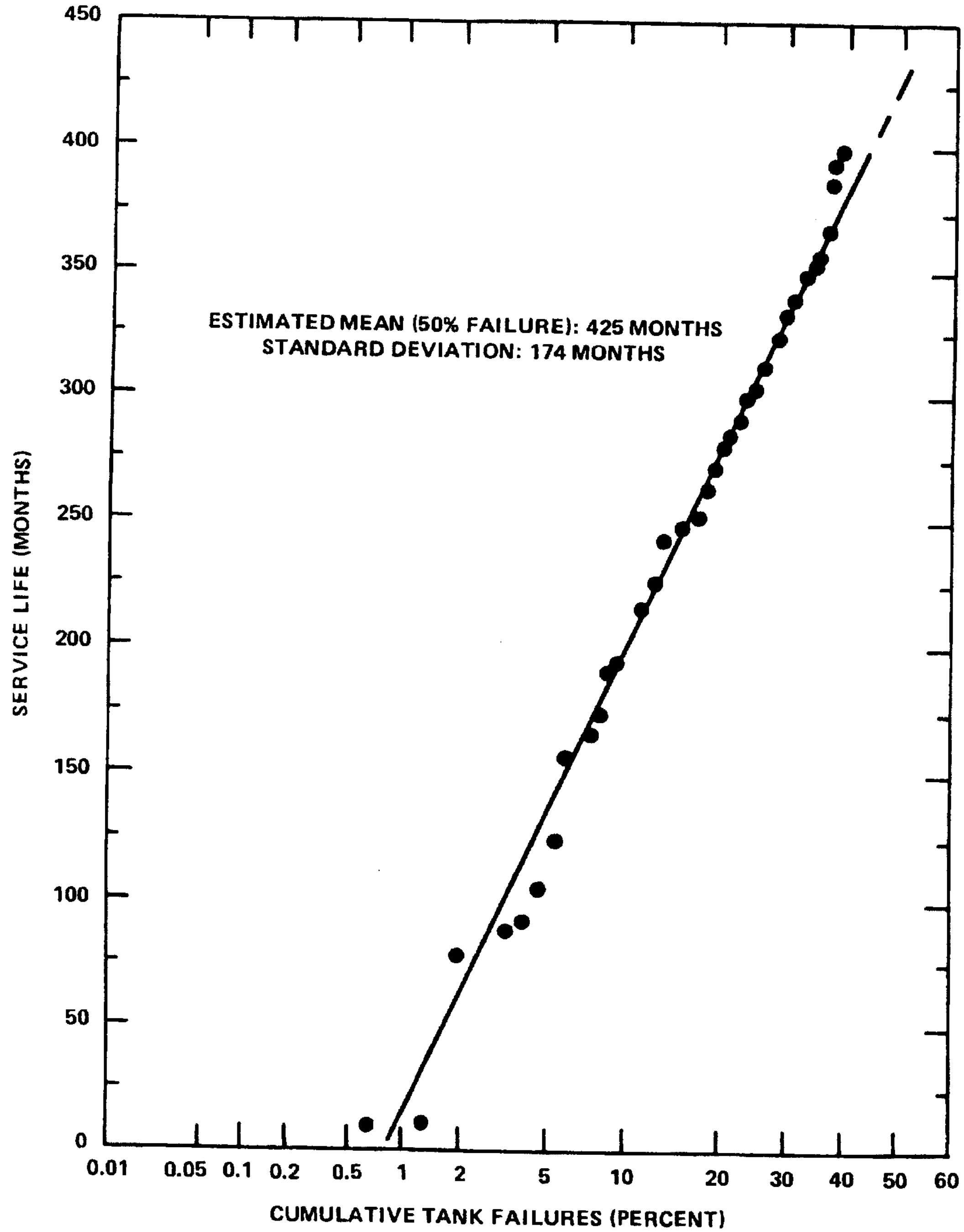

FIGURE 20.
SINGLE-SHELL TANK FAILURE EXPERIENCE
(QUESTIONABLE INTEGRITY AND CONFIRMED LEAKER TANKS).

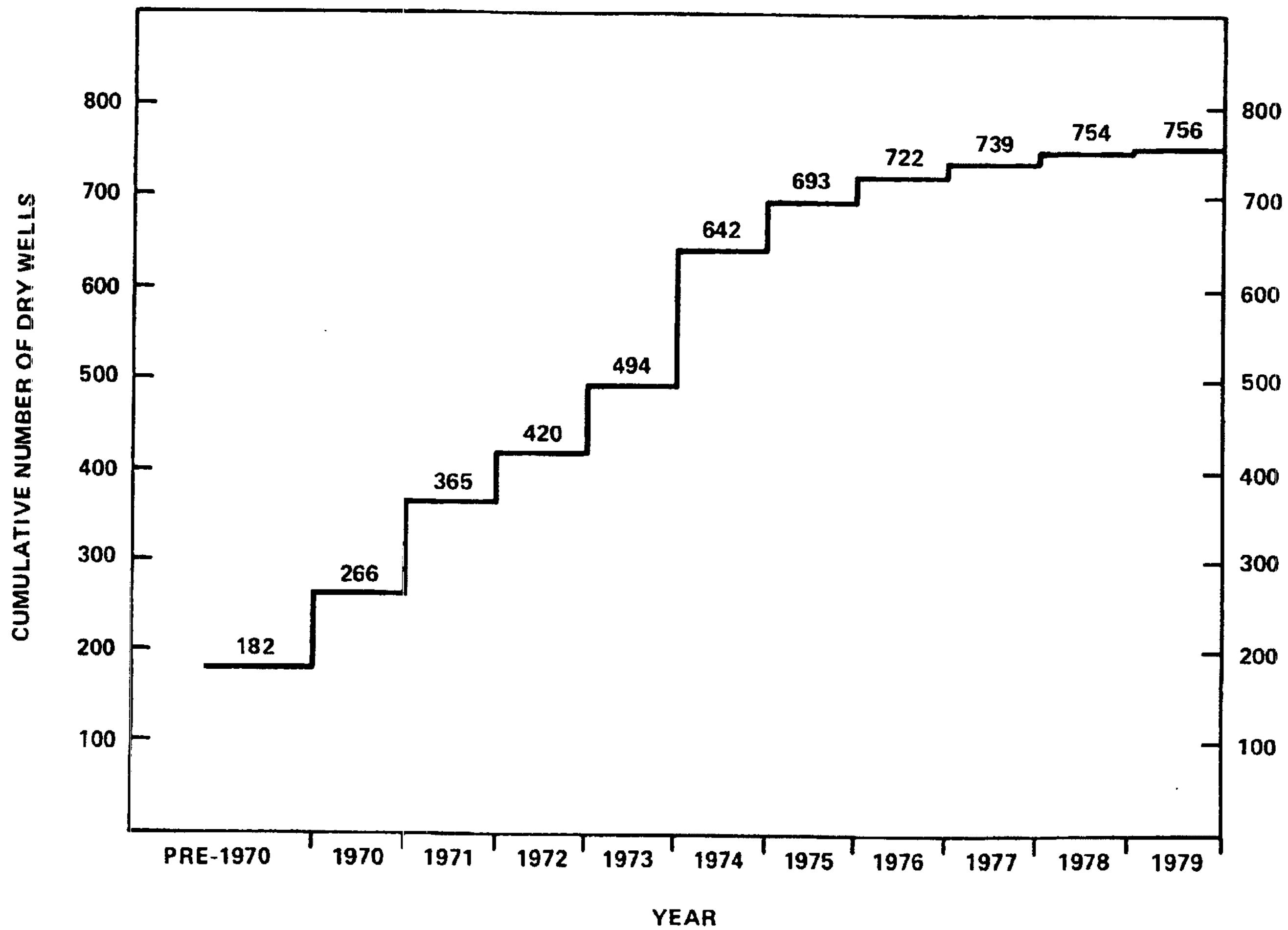

FIGURE 21.
HANFORD SS TANK FARM FACILITIES
CUMULATIVE NUMBER OF DRY WELLS BY YEAR.

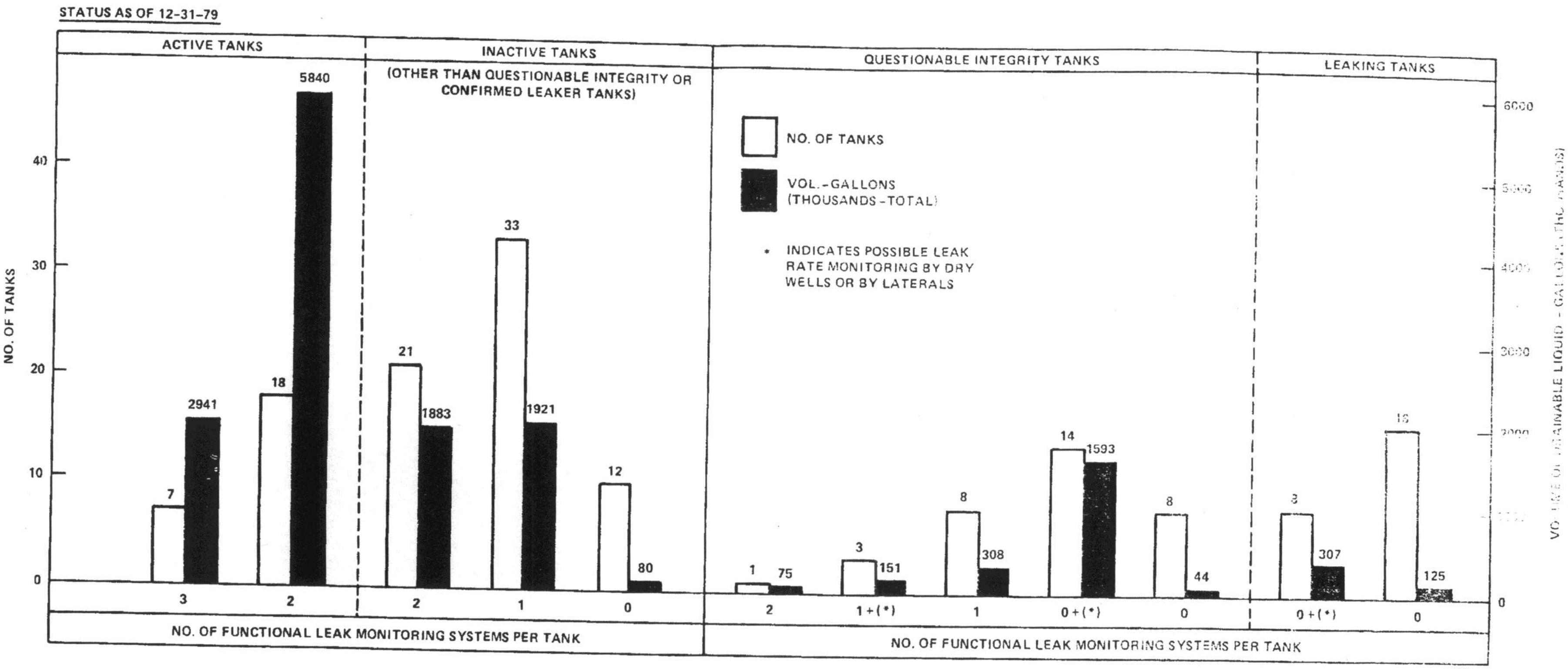

FIGURE 22.
LEAK MONITORING STATUS – HANFORD SINGLE-SHELL TANKS.

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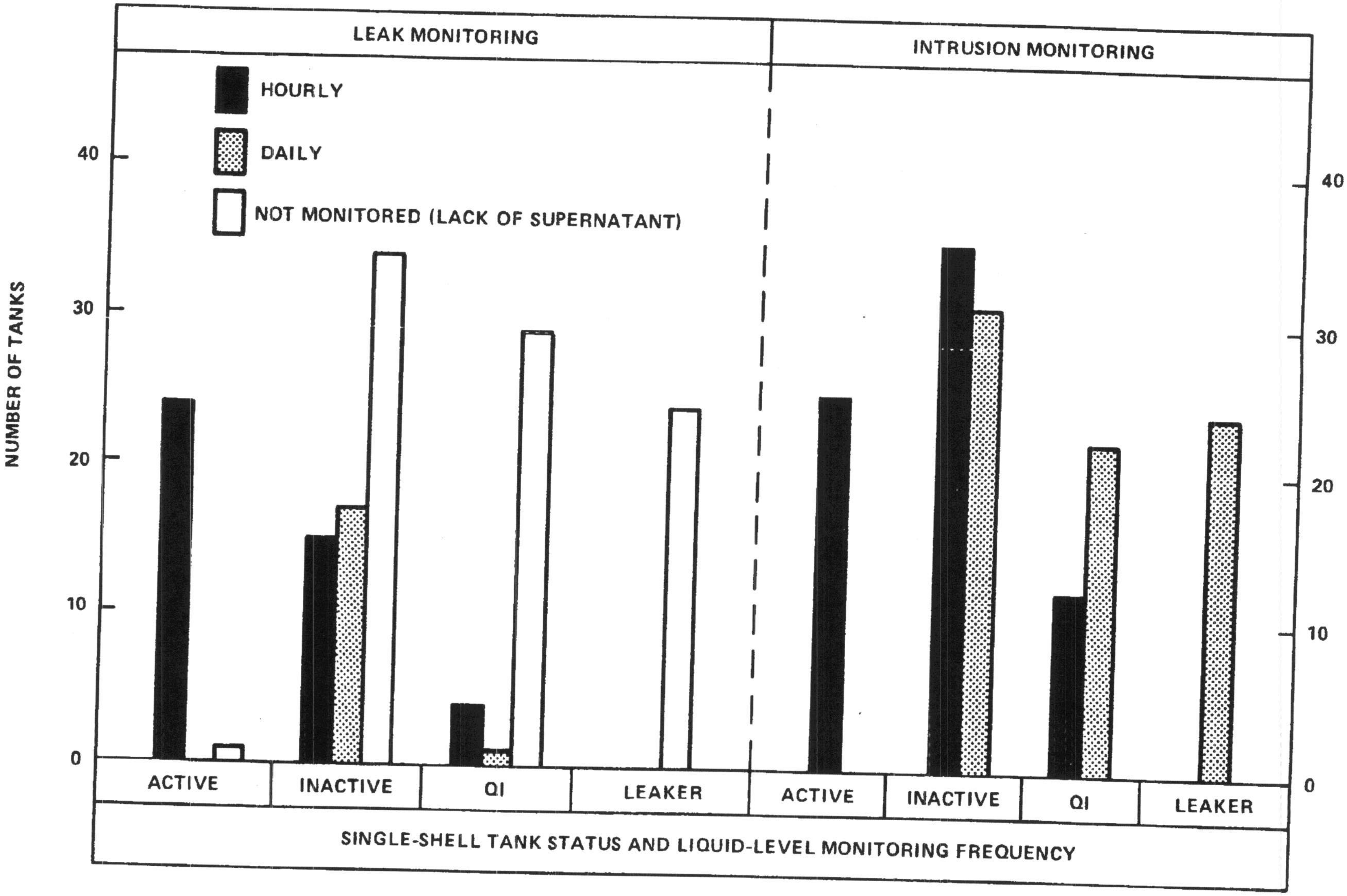

FIGURE 23.
SINGLE-SHELL TANKS – FREQUENCY OF LIQUID-LEVEL MONITORING.

NOTE: QI = QUESTIONABLE INTEGRITY

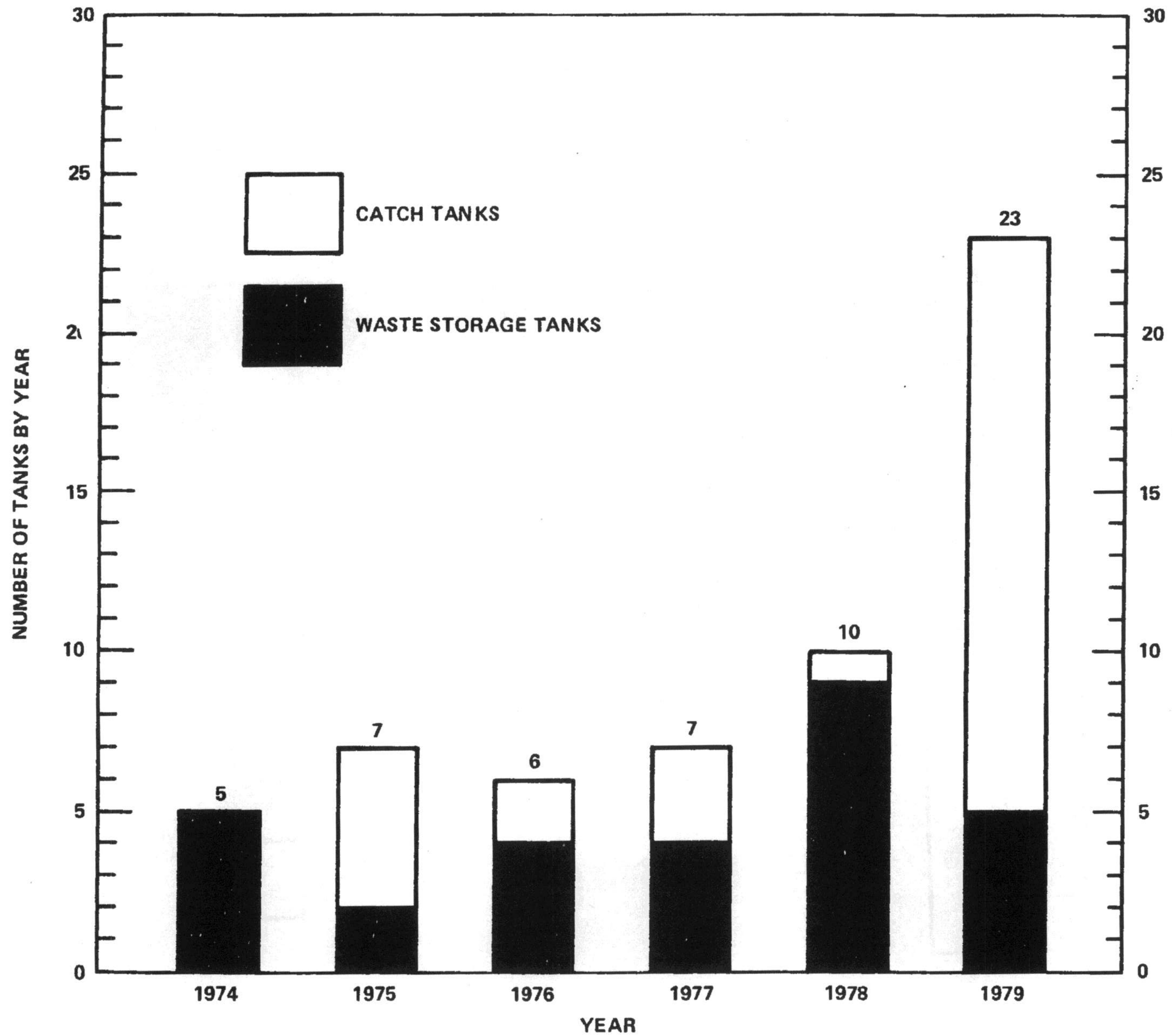

FIGURE 24.
HANFORD 200 AREAS TANK FARM FACILITIES
LIQUID INTRUSION EXPERIENCE – NO. OF TANKS.

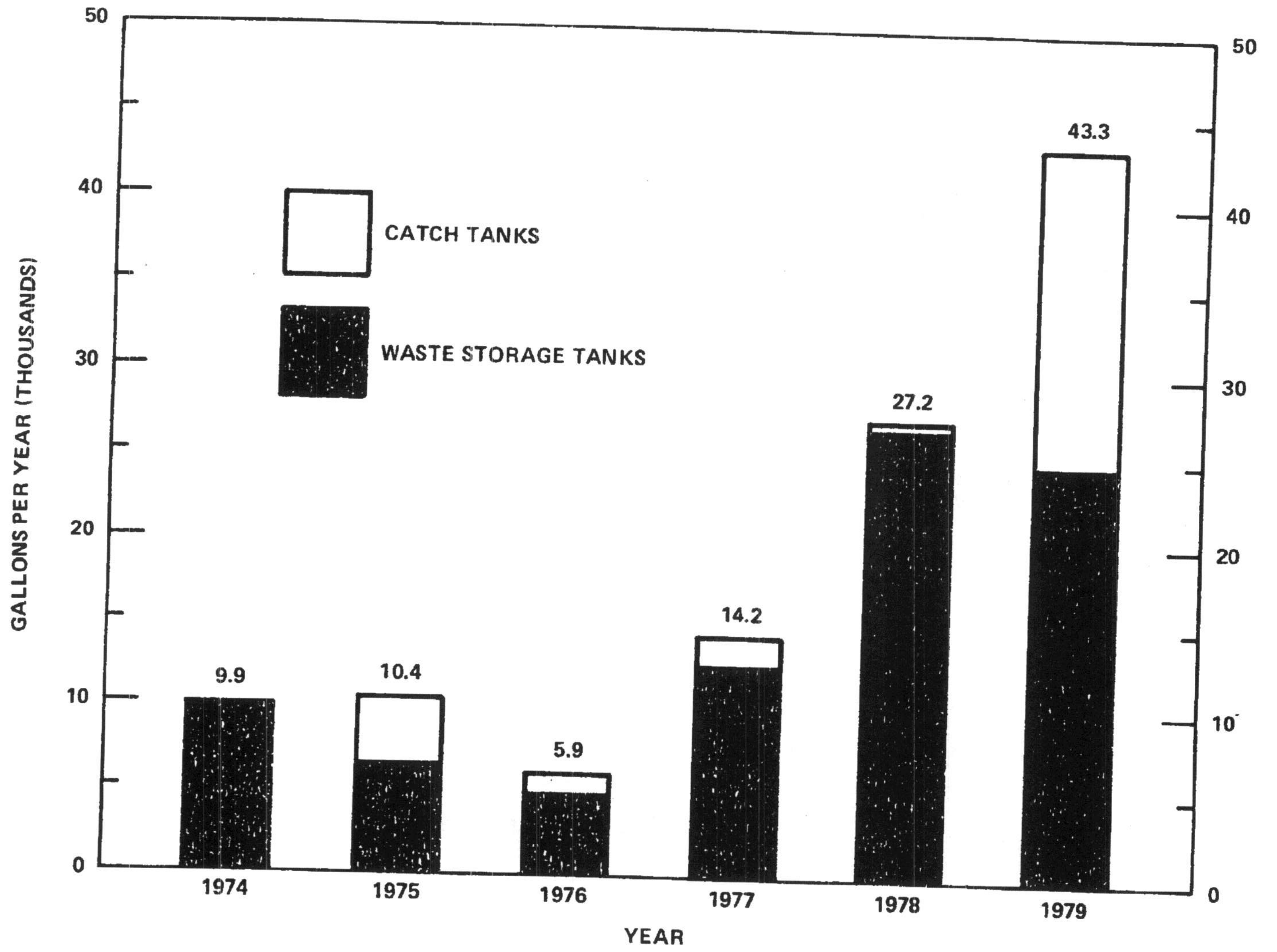

FIGURE 25.
HANFORD 200 AREAS TANK FARM FACILITIES
LIQUID INTRUSION EXPERIENCE – VOLUME.

Chapter 4 Principal Conclusions and Recommendations

4.1 BACKGROUND

Review of the technical adequacy of the surveillance program of the high-level radioactive waste storage tanks cannot be treated independently of the related portions of waste management operations at Hanford from startup through the present or from the policies, procedures, and objectives related to that program.

Detailed examination of the surveillance program in this report is limited to the single-shell tank farms. Surveillance programs for double-shell tanks and for waste processing (e.g., evaporators) and transfer systems differ substantially in certain elements (instrumentation, criteria, etc.) from that for single-shell tanks.

Many of the concerns at Hanford stem from the early design philosophy, which relied on the advantageous characteristics of soil and site hydrology to provide secondary containment for stored radionuclides should the primary containment fail. This philosophy led in large measure to the construction of single-shell waste storage tanks. Leaks to date from these tanks have proven the worth of such characteristics; no significant radiation hazard to public health and safety has arisen from waste management operations at Hanford.

Present design philosophy is to consider the contact of radioactive waste with the soil as environmentally undesirable and has led to the construction of double-shell tanks and eventual elimination of the use of single-shell tanks for storage of high-level radioactive liquid waste.

As a result of the early design philosophy, there are now 149 single-shell waste storage tanks located in 12 tank farms in the Hanford 200 Areas. Of these, 24 have leaked radioactive waste to the soil, and 34 have indications of leakage and are considered to be of questionable integrity. In addition, the 200 Areas have soil contaminated by accidental spills and other failures during tank farm operations and by planned discharges to soil _via_ cribs, ponds, trenches, etc., as documented in environmental impact statements on Hanford operations.

After the first single-shell tank leak in 1958, a program was undertaken to transfer the contents of the leaking tanks to sound tanks and to concentrate waste in tanks by evaporation. This led, in turn, to the waste solidification (in-tank) program in which solids would be left in the single-shell tanks and terminal liquids (nonsolidifiable) would be transferred to double-shell tanks. The success of this program is indicated by the removal of over 120 million gallons of radioactive liquids that might otherwise have been a source of leakage and that would have required additional storage capacity.

As currently conceived, the waste solidification program will not leave dry solids in the tanks but will result in reduced liquid content in sludge or in salt cake. At the end of this program, around the mid-1980's, an estimated 1 million gallons of such drainable liquid (of the estimated 15 million gallons now present) will be left in the single-shell tanks.

Efforts to improve the technology for liquid removal, for stabilization of the liquid and other in-tank contents, and for desiccation of the tank residues have not proven successful, and research and development undertaken for these purposes has not kept pace with the waste solidification programs in meeting needs for advanced in-tank monitoring and drying techniques.

As a result of the waste solidification program, the single-shell tanks are in a transitional state, fully recognized by waste management at Hanford, in which the tanks, one by one, are moving from an active to an inactive state and then to a quasi-storage state. Tank contents are modified by evaporation and pumping, leaving liquid supernatant, damp salt cake, sludge, or various combinations of these in quantities that change during processing. The transitional state is directly affecting the adequacy of policies and procedures, surveillance methodology and practices, and operating objectives to the extent that certain of these waste management program elements are becoming progressively obsolete and require modification.

4.2 POLICIES AND PROCEDURES

One major concern is that, after more than 2 years of DOE existence, Headquarters has not issued a formal health and safety order setting forth requirements and the authorities and responsibilities of DOE officials to its field offices and contractors.

Instead, DOE has issued former ERDA rules (IMD 5001) as non-mandatory guidance. Such directives should be issued promptly. In addition, there is no Department quality control and assurance order. The Richland field office deserves credit for remedying this gap by issuing such rules as mandatory requirements in their field office manual chapter.

In general, all DOE (RL) Operations Directives place on the contractor requirements for prompt detection of tank leaks, redundant notification, and appropriate corrective action of tank leakage. Redundant notification has been established. The directives are inapplicable for most inactive single-shell tanks, however, because the progressive impact of the waste solidifciation program is to render present leak detection methods largely ineffective and corrective action becomes limited if not infeasible. Furthermore, the directives should more completely address the continuing management of leaking or suspected unsound tanks in terms of continuing surveillance, stabilization of contents, or other corrective actions.

The Operations Directives for the past several years also require that the program plan for surveillance and maintenance be implemented to <u>centralize</u> <u>automated</u> surveillance and trend analysis and to place <u>minimum</u> <u>reliance</u> on <u>manual</u> surveillance and analysis. There is an imbalance between policies to reduce liquid levels in the tank farms (thereby reducing the effectiveness of the centralized automated surveillance systems) and policies to maintain knowledge of leakage or migration of tank contents to the soil and to exercise control over these contents. Further policy direction is needed regarding the management of those single-shell tanks, both sound and unsound, that will contain substantial quantities of drainable liquids after the waste solidification and tank isolation programs have been completed.

The incentive type of contract (award fee) provisions given to the contractor in the first half of fiscal 1979 had the effect of imposing a direct conflict between performance criteria for cost effectiveness (related to reduction of surveillance costs, i.e., labor) and criteria for safety of operations and environmental control (related to surveillance and other waste management activities). The 1979 DOE directives to the contractor to revise tank farm surveillance as appropriate, to minimize reliance on manual surveillance, and to optimize surveillance with the need for environmental monitoring, in fact, indicated to the contractor that his award fee would be directly affected by whatever reduction of surveillance he might accomplish. In the Operations Directives for the second half of FY 1979 and first half of FY 1980, the specific requirements to revise tank farm surveillance activities and to provide an analysis of potential surveillance cost reductions has been dropped.

The organizational structures of DOE and the contractor are adequate for policy direction and overview and have provided for redundant evaluation and notification.

Documents relating to the status and history of waste storage tanks and related systems lack consistency. This is due in large measure to updating periods that are staggered up to 1 year or more. The exception to this conclusion is the monthly waste status summary report. A system of quality control for such documents is needed to prevent misunderstandings and misinterpretations.

4.3 TANK FAILURE EXPERIENCE

Failure experience with single-shell tanks has been examined statistically for possible correlation with tank size, years of construction, and service life. This population is statistically small, and the tanks have been subjected to nonuniform stresses from operations. No significant distinction in performance was found between tanks classified as leakers and those classified as of questionable integrity; hence, they were combined into one class of unsound tanks. No significant difference was found between tanks grouped by tank size and those grouped by years of construction. When tanks were grouped by service life, however, the relationship was found to be normally distributed, with an estimated mean service life of 425 months and a standard deviation of 174 months, extrapolated from present findings that 40% of the single-shell tanks are unsound; extrapolation to 50% indicates that an additional 10-15 tanks will become unsound in the next several years. This projected failure of additional tanks may occur without prompt detection by leak monitoring systems; leak indications may be delayed, depending on the contents of the affected tank (including volumes of supernatant and interstitial liquids), or the leaks may be too small to be detected.

A group of seven more tanks that have limitations on fill level were not included in the analysis of tank failure experience. These tanks are considered unsound above the fill limit but sound below. Classifying them as unsound in the failure analysis could result in a reduced estimated mean service life for these tanks and a larger number of tanks now considered unsound.

4.4 TANK CLASSIFICATION AND LEAK DETECTION CRITERIA

At least nine categories have been used at Hanford to classify tank operational status and soundness. Four or five of these classifications are used at present. The purpose and utility of such categories should be reexamined as they pertain to operations accounting, management of tank use, and surveillance requirements. A clear distinction must be made between categories relating to the operational status of tanks and those relating to tank soundness. Furthermore, because they differ in construction and in ease of surveillance, separate categories need to be established for classifying the soundness of double-shell and single-shell tanks.

No formal criteria exist for classifying waste storage tanks as to soundness. Some working guidelines have been in common use for many years, but none have been applied uniformly or consistently. The need for flexible criteria, recognized at Hanford, must be matched by formal documentation of such criteria for uniform and consistent tank classification. Existing working guidelines may serve as the foundation for formal criteria, but in their present form they are too inflexible and incomplete, as evidenced by classification practices to date. For example, these guidelines refer to only two of the several available leak monitoring systems, are based on fixed set points (e.g., drop in liquid level) but not trends, and make no distinction between single-shell and double-shell tanks.

The working guidelines also have been used to determine whether or not a tank is leaking, but there is no compelling rationale for using identical guidelines for these two purposes. Direct, prompt evidence of tank leakage has occurred in only a few cases. The majority of tank leaks have had to be inferred indirectly from monitoring evidence over a period of time. During this time other liquid removal processes (such as vaporization into off-gas) may have been significant. Anomalies observed by one of the tank monitoring systems have triggered the prompt removal of tank contents, thus possibly preventing the configuration of the leak by additional data. The lack of a formal objective system for determining if a tank is leaking has led to inconsistent and non-uniform evaluations, which are compounded to some degree by the limitations of the inferential process. Criteria for determining leakage in double-shell tanks should include direct observation, i.e., visual inspection of the tank annulus.

Furthermore, the working guidelines also have been used to set remedial action points for leakage, but, again, there is no compelling reason why these guidelines should be the same as those for tank classification or determination of leakage. Evidence shows that other informal criteria, such as rates of change (in liquid level or dry well radiation level) below the levels of the working guidelines, have also been used as action points; this contributes to non-uniform actions. Criteria need to be developed separately for single-shell and double-shell tanks to provide action points for the graded sets of response commonly taken in tank farm operations (e.g., notification, investigation, precautionary measures, and prompt actions).

4.5 SURVEILLANCE PROGRAM: SINGLE-SHELL TANKS

The primary elements affecting the adequacy of the surveillance program for waste storage tanks are:

1. The contents of each tank and the nature of those contents; i.e., how such contents are expected to change over time.

2. The functional capability of the monitoring systems at each tank to monitor leaks, unwanted intrusions, and the movement of radionuclides in the soil.

3. The frequency of monitoring and its appropriateness to the status of the tank and to its contents.

The source of leakage of greatest concern is liquid supernatant, which has a mobility comparable to water. The mobility of interstitial liquid is comparable to supernatant in soil but initially is about one order of magnitude lower in the interstitial spaces of salt cake and sludge. During pumping to remove interstitial liquid, the mobility of the remaining liquid is progressively reduced. Salt cake and sludge free of interstitial liquid are dense solids considered to be relatively stable. Thus the source term for leakage depends on the constituents of the tank contents and the tank soundness relative to those constituents.

All 149 single-shell waste storage tanks are equipped with at least two leak-detection systems, and 20 tanks have an independent third system. Liquid-level monitoring by conductivity probe is the most direct leak detection system. Such systems become nonfunctional when supernatant is removed yet remain functional for detecting unwanted intrusions. Because supernatant has been removed in the waste solidification program, leak detection by liquid-level measurement is functional in only 61 of the single-shell tanks. The technology for measuring liquid levels in salt cake without supernatant is not presently developed, and the research and development for this purpose has not kept pace with the waste solidification program in meeting needs to monitor loss of interstitial liquids.

Between two and eight dry wells are located in close proximity to most of the single-shell tanks. These wells are used for monitoring soil radioactivity levels as indicators of possible tank leakage as well as movement of radioactivity in the soil. The 16 small storage tanks have essentially no dry well monitoring system installed but contain very little drainable liquid. Of the remaining 133 single-shell tanks, 74 have functional dry-well systems, 20 have systems that are nonfunctional because of insufficient drainable liquid content, and 23 tanks classified as leakers or of questionable integrity have one or more dry wells contaminated by tank contents. Contaminated dry wells are considered functional to a limited degree for monitoring further indications of leakage or migration of radionuclides in the soil.

The functional capability of any dry well system to detect leaks from a given tank is highly dependent on the geometric relationship between point of failure, leakage migration path, and dry well location. Thus, under ideal conditions, small leaks can be and have been detected by dry well monitoring, but, in theory, under unfavorable conditions leaks may not be observed. Nevertheless, all dry well systems, even those considered nonfunctional for detecting tank leakage, continue to be of value in determining the migration and decay of radionuclides already in the soil and in monitoring unplanned releases in their vicinity from interconnecting piping for routing of liquids and gases.

Horizontal lateral (dry well) leak monitoring systems are installed for 16 of the 149 single-shell tanks. The systems are functional for six of the tanks but they are nonfunctional for four because of insufficient liquid in the tanks. For the other six tanks, the systems are considered functional to a limited degree because of soil contamination.

Leak detection pits located at four of the single-shell tanks are considered fully functional, although one of these tanks was classified to be of questionable integrity as a result of dry well contamination rather than leakage into the leak detection pit system. In this particular case, liquid-level measurements did not indicate that leakage had occurred.

Adequacy of surveillance for detecting leakage is directly related to the number of functional monitoring systems for each tank and to the tank contents. Most of the drainable liquids (70%) are located in 46 sound active and inactive tanks monitored by two, and in some cases three, functional leak monitoring systems at present. An additional 12.6% of the drainable liquids is presently located in 33 sound inactive tanks with one functional leak detection system. About 0.5% (80 thousand gallons) of drainable liquid is in salt cake in sound, inactive tanks with no functional monitoring systems. Thus approximately 83% of the drainable liquid inventory in single-shell tanks is located in 79 sound tanks monitored by at least one functional leak detection system. These ratios will change over time as liquids are removed from the tanks under the waste solidification program.

Monitoring of sound tanks by a single functional leak detection system is marginally adequate. If no leak detection system is functional, monitoring is clearly inadequate unless the tank contents can be shown to be fully stabilized so that leakage is not possible. Of the sound, inactive tanks, 22 (containing about 1.9 million gallons of drainable liquid) have no functioning liquid-level monitoring systems because of supernatant removal and are monitored only by dry wells. If the pumping program proceeds on schedule, this number will increase to 37 tanks by the end of fiscal 1981.

Hanford practice is to treat both tanks classified as leakers and those classified as of questionable integrity as unsound, to transfer supernatant liquid to sound tanks, and to schedule the removal of drainable interstitial liquid—subject to limitations of pump availability and the state of technology for liquid removal from salt cake and sludge. Nevertheless, about 2.2 million gallons of drainable liquid remains in the 34 tanks of questionable integrity, and about 0.4 million gallons is in the 24 confirmed leakers.

Only one tank of questionable integrity has two fully functional leak-monitoring systems, and only 11 tanks have at least one such system. A substantial quantity of drainable liquid (about 1.6 million gallons) is stored in 14 other questionable-integrity tanks that have at best a marginal leak monitoring capability. The procurement and installation of more sophisticated pumping equipment, scheduled for these tanks through the next several years, should be expedited. Practically no drainable liquid is left in the questionable-integrity tanks that have no functional leak monitoring systems.

In the 24 confirmed leaking tanks, the lack of leak monitoring is offset by the fact that all supernatant has been removed and that in 22 of these tanks half the drainable interstitial liquid is held tightly in sludge. The other 200 thousand gallons held in salt cake is scheduled for jet pumping starting in fiscal 1981. Present efforts to monitor these tanks are adequate, considering the status of the tanks and their contents.

Frequency of monitoring is an equally important parameter of the surveillance program. Liquid-level monitoring systems for each tank are either automated [connected to the Computer Automated Surveillance System (CASS)] or manual. Some single-shell tanks have both automated and manually operated conductivity probes; others have one or the other. On a routine basis, automated sensors are read on an hourly basis. Manual probes are read daily by an operator. If a tank has no supernatant or has excessive salt cake at the surface, these readings measure only intrusions; otherwise the measurements detect both leakage from and intrusions into the tanks.

All the 25 active single-shell tanks are connected to CASS; 24 tanks are monitored hourly for leakage and intrusions, and one tank is monitored hourly for intrusions but not for leakage because of temporary lack of supernatant. During liquid transfer operations, when liquid levels are changing and tank contents are being distrubed, materials-balance procedures must replace the liquid-level measurements.

The liquid-level monitoring systems of 35 of the 66 inactive single-shell tanks are tied into CASS, and hourly intrusion information is provided. Daily intrusion determinations are made manually for the other 31 tanks. For leak detection, however, 34 of the inactive tanks have insufficient supernatant to be monitored, 15 tanks are monitored hourly on CASS, and 17 tanks are monitored manually on a daily basis.

Liquid-level monitors for 12 of the 34 questionable integrity tanks are tied into CASS for hourly intrusion determinations; such determinations are made manually for the other 22 questionable integrity tanks on a daily basis. Most (29) of the questionable integrity tanks cannot be monitored for loss of liquid because they lack supernatant liquid. As a result, only five such tanks are monitored for leakage—four tanks hourly on CASS and one tank manually on a daily basis.

All 24 confirmed leaking tanks are monitored manually for liquid intrusions on a daily basis, but none of these tanks are monitored for loss of liquid since the lack of supernatant liquid renders the conductivity probes nonfunctional.

The frequency of liquid-level monitoring of all single-shell tanks for intrusion is adequate. About half (72) of the liquid-monitoring systems are automated and checked hourly by CASS; the other half (77) are read manually once a day. The frequency is adequate for leak monitoring of all 25 active tanks and for the other 37 inactive tanks that have functional liquid-level leak monitoring systems, despite the fact that one half the tanks (containing about half the drainable liquid contents) in this latter group is monitored hourly and the other half is monitored daily.

The appropriate frequency for monitoring by dry wells and horizontal lateral wells depends on many factors and therefore is difficult to determine. Because of the transitional state of the single-shell tanks, frequency should be determined on a tank by tank basis. For example, as noted previously, the 25 active single-shell tanks contain 57% of the estimated 15.3 million gallons of drainable liquids now in single-shell tanks. One tank (101-AX) holds 188 thousand gallons of drainable interstitial liquid that is not monitored by liquid-level measurements due to lack of supernatant. Other active tanks have periods ranging from days to weeks when the liquid-level monitoring systems are non-functional because of continuing transfer operations that preclude establishing level baselines in the tanks. Thus, dry well monitoring is the primary leak detection method during these periods. Generally, active tanks have substantial drainable liquid inventories that are relatively more mobile in the event of tank failure, are more readily amenable to transfer in the event of leakage, and many of these tanks are approaching the estimated mid-point service life for becoming unsound. Formal criteria are needed to redetermine the surveillance frequency for each tank and the development of such criteria is recommended, taking into account pertinent technical factors such as available monitoring systems, tank contents and their relative mobility. Until formal tank by tank criteria are developed, which may result in some tanks being read more frequently than biweekly for certain periods of time and some less frequently, tanks with redundant monitoring systems can remain on a biweekly frequency; but active tanks in a dynamic state and inactive tanks monitored only by dry wells and containing substantial quantities of drainable liquids should be monitored more frequently than every two weeks.

The situation is somewhat different for 21 of the 66 inactive tanks; these tanks contain 1.9 million gallons of drainable liquids and are functionally monitored for leakage by both liquid-level probe and dry wells. In these tanks the supernatant surfaces are stable. A second group of 22 inactive tanks, which also contain 1.9 million gallons of drainable liquids, is monitored for leakage by dry wells alone. For these 43 tanks, especially those monitored only by dry wells, a 2-week dry well monitoring schedule may be too infrequent. Furthermore, as the waste solidification program proceeds, an estimated 15 tanks in the first group will lose liquid-level monitoring because of supernatant removal and will be monitored only by dry wells by the end of fiscal 1981. Formal criteria are needed to redetermine the surveillance frequency for each tank and the development of such criteria is recommended, taking into account pertinent technical factors such as available monitoring systems, tank contents, and their relative mobility. As an interim measure until formal criteria are established, monitoring frequency for inactive tanks monitored only by dry wells and containing substantial quantities of drainable liquids should be more frequent than every two weeks. The remaining 23 inactive tanks, which contain relatively small quantities of drainable liquids (below the maximum levels undetectable by dry wells), may be left on a biweekly dry well monitoring schedule, or this schedule may be lengthened because the dry wells serve primarily to monitor environmental movement of radionuclides.

Only five of the 34 questionable integrity tanks have a functional liquid-level leak monitoring system, and the bulk of the drainable liquid remaining (about 2 million gallons) is stored in 20 tanks that are wholly dependent on dry wells for leak monitoring (liquid-level measurement systems are no longer functional). A prudent approach indicates that these tanks with relatively large volumes of drainable liquid need to be monitored on a frequent dry well schedule, unless credit can be taken for the degree to which interstitial liquid has been removed by pumping (thereby affecting the ability of that liquid to leave the salt cake). When dry wells or horizontal laterals are already indicating soil contamination (as is the case for 14 of these tanks), the appropriate frequency for monitoring is directly related to the rate of change of radiation levels and should be set on an individual tank basis. A similar approach applies to the two or three confirmed leaking tanks containing relatively large quantities of drainable liquid. All other questionable integrity and confirmed leaking tanks would probably be monitored adequately on a biweekly basis or at longer intervals.

In view of the necessity of using dry wells and horizontal lateral wells as either sole or secondary source for detection of leaks, the formal criteria proposed are needed to establish surveillance frequency for individual tanks during the transitional period until final tank stabilization is complete. These criteria should take into account the many conditions just reviewed. Such frequency criteria must be flexible and must reflect not only the established numerical action criteria for these monitoring systems but also the early trend analysis presently in use and its relationship to frequency sampling. What is envisaged is not a cookbook of sampling but rather a set of principles for guiding the selection of monitoring frequency in view of the leak detection systems that are available and functional.

The conclusion that sampling frequency criteria are needed should not be interpreted as unrestricted endorsement of dry well or horizontal lateral well monitoring systems. All leak monitoring systems in single-shell tanks at best provide indirect evidence, but in-tank monitoring is more direct and less inferential than monitoring soil outside the tank. Where dry wells provide the sole input to leak detection, they must be used to a greater extent than they would be if in-tank monitoring were available. Moveover, review of leak detection experience for a limited number of tanks indicates that, for low average leak rates (on the order of 1 to 20 gallons per day), there is a lag time of 1 year or more between leak identification by liquid-level measurements and the observance of related dry well radiation level increases. This lag time could increase as the volume and mobility of liquid from the tank change during the waste solidification program. Improved in-tank liquid-level monitoring systems capable of replacing present conductivity probe devices and of measuring interstitial liquid levels are needed to provide knowledge of tank behavior and to indicate where remedial or preventive control actions should be focused. Research and development efforts to this end are under way but need to be augmented and accelerated.

Development of in-tank monitoring for loss of interstitial liquid is not meaningful unless control actions can be taken in the event of tank failure. As stated previously, the end point of the present waste solidification (pumping) program is an estimated inventory of about 1 million gallons of drainable but nonpumpable interstitial liquid in the single-shell tanks. Some techniques have been evaluated for further solidification of the tank residues, but none has proven successful. It is essential that the program to develop and implement an adequate technology for waste stabilization be intensified.

Eleven of the single-shell tanks contain high-heat solids and must be monitored for temperature level. Without auxiliary cooling, these tanks would likely exceed the maximum allowable temperature set to protect the tank concrete from degradation and subsequent failure. Another 19 tanks with heat-generating solids may present similar problems without cooling. Temperature monitoring is also important for maintaining adequate process control during the waste evaporation process. Initially, thermocouple temperature-monitoring systems were installed in all single-shell tanks, but because of failure these are presently nonfunctional in 11 tanks. As thermocouples fail, they are replaced on an as-needed basis related to the heat-generation status of the tank involved. Temperatures are monitored routinely each day in 40 of the single-shell tanks by the CASS operations. The other 98 tanks are monitored manually—those with high heat content (11 tanks), on a monthly basis and the others, quarterly. Temperature monitoring is adequate for the single-shell tanks because the heat-up rates for their contents have been well established.

Single-shell tanks are inspected by in-tank photography to observe contents, measurement anomalies, and anomalies or defects at the tank walls. The 25 active tanks that are scheduled for yearly photography are full of liquids and will not be photographed until pumped down. Minimal information is gathered from photographs of full tanks unless there is a surveillance or process control problem in which photographs may be useful. The 72 tanks classified as primary stabilized tanks are photographed every 2 years. Photography for the 26 inactive tanks, including 22 questionable integrity and confirmed leaker tanks, which have been interim stabilized is scheduled every 3 years. The remaining 26 tanks are photographed on a yearly basis.

Under development is a dome survey program to evaluate the physical and structural integrity of the steel-reinforced concrete tank domes; to monitor internal dome loadings, anomalies, and defects on a selective schedule; and to survey structural movement or deflections as indicators of stress. An initial pilot program is under way which uses visual survey techniques to examine certain tanks with dome suspended equipment, with a history of heavy salt loadings, or with dome anomalies or defects. This program is augmented by periodic sampling and analysis of dome concrete.

4.6 SURVEILLANCE PROGRAM: DOUBLE-SHELL TANKS

All seven active double-shell tanks are monitored at three locations for the detection of leaks: inside the primary tank (shell), within the annulus between the primary tank and the secondary tank (shell), and at the leak detection pit located adjacent to each tank which collects any leakage through the secondary tank through a system of slots in the base slab. Liquid level in the primary tank is measured by a conductivity probe system that detects both leaks from and intrusions into the tank. The liquid-level probes in primary tanks are automated on CASS for three double-shell tanks and are read hourly; for the other four double-shell tanks, the primary-tank liquid level monitors are manually operated and are read daily. Ultimately, all double-shell primary-tank liquid level monitors will be tied into CASS, including the 13 new double-shell tanks in the final stages of construction.

Leaks from the primary tanks and other intrusions into the annulus are monitored in two ways: (1) by liquid-level conductivity probles which are activated by the presence of liquid in the annulus and which sound an alarm in the instrument building, and (2) by radiation monitors used to detect airborne radioactivity in annulus ventilation air. These systems are adequate, but a far more sensitive technique (in addition to these) is used at the Savannah River Plant; this technique which is planned for use at Hanford is remote visual imagery by photography or television. This latter technique can detect minute pinpoint or hairline penetrations through the primary tank and the degree to which crystallized penetrations at those locations become self-sealing, stabilize, or grow. Even though to date such penetrations have been found only in tanks that were not stress relieved by heat treatment, the power of the method suggests that this monitoring system should be used routinely at Hanford at it is at Savannah River.

Conductivity probes and radiation monitors located in the leak detection pits for each double-shell tank monitor the underside of the secondary shell in a manner identical to that of the annulus monitors. All these systems collectively provide in depth leak monitoring and are adequate.

Temperature-monitoring systems (thermocouples) are installed on all seven double-shell tanks; systems for four of the tanks are on CASS and are monitored daily, and the other three, now monitored manually on a monthly basis, will be added to the CASS operation, as will the 13 new double-shell tanks now entering their final construction period.

One area of concern regarding the seven double-shell tanks presently in use and the 13 additional double-shell tanks under construction is the lack of dry wells to monitor the soil around these tanks for spills, possible transfer line failures, and migration of radioactive materials from adjacent areas. The complex of multiple tank containment and monitoring systems has been assumed to justify this lack. A similar lack of dry wells exists at the evaporator-crystallizer facilities, where an older, singly encased transfer line failed just recently, and a loss of about 500 gallons was detected only by its presence at the surface. Experience at the Savannah River Plant has demonstrated the value of dry wells near double-shell tanks and evaporators. Indeed, one of two major leaks there, which resulted from a failure in a doubly encased transfer line next to a double-shell tank, was detected by dry well measurements. A certain number of dry wells should be located both in the double-shell tank farms and close to the evaporators to provide adequate surveillance of these facilities.

4.7 MATERIAL BALANCES

Transfers of liquids are carried out for a variety of reasons. Generally, these are planned operations, but occasionally emergency transfers may be required when a tank or pipe fails. Material balances provide one accountability input for transfers of radioactive wastes for the period of time when such materials have left a tank or process vessel under surveillance until they are fully accountable in the receiving tank or vessel. Other accountability inputs include establishing proper routing; periodic testing of transfer lines; liquid-level monitoring during transfer, including line flush; and final accounting, considering the various material balances made during the operation. Material balance methods at Hanford are adequate, taking into account the physical limitations of the measurement systems. Balances are performed by a combination of manual and computer (CASS) system activities.

4.8 QUALITY ASSURANCE

The importance of an independent quality assurance (QA) program in connection with the tank farm surveillance program is recognized in requirements established by the DOE Richland Operations Office, and this function is outlined in the contractor's procedures. Organizationally, the contractor has provided staff and the authority to perform this important independent function. Verification of the QA program was not extensive during this review because of the priority of other surveillance matters. Procedurally and organizationally, however, the program appears to be adequate.

4.9 PROCEDURES, RECORDS, AND REPORTS

As noted previously, a lack of consistency has been observed in documentation of the status and history of the waste storage tanks and associated systems, the one exception being the monthly waste status summary report. This situation extends more broadly to other procedures, records, and reports; however, a number of inquiries into confusing or erroneous information obtained during the course of this review indicate that record data used in direct waste management operations are maintained fully correct and up-to-date. Full cooperation was obtained from DOE and contractor staffs in correcting deficiencies and confusion in information. Nevertheless, the discrepancies between documents, out-of-date data, and absence of formal criteria for decision making in certain critical areas led to misunderstandings and misinterpretations in the past and will continue to do so until some system of quality control over these operational aids is established. Specifically, what is needed to ensure the adequacy of the surveillance program includes the updating of data on a periodic, timely basis; periodic audit of data, procedures, records, etc., as needed; establishment of orders, procedures, criteria, and standards as noted previously for tank classification, leak determination, surveillance, trend analysis, graded remedial actions, etc.; simplification and combining of records and reports wherever possible; and elimination of data and records that cannot be kept meaningful.

4.10 HEALTH RISK CONSIDERATIONS

In the 1978 independent technical review of the radioactive waste management at Hanford, performed by an ad hoc panel on Hanford Wastes of the Committee on Radioactive Waste Management of the National Academy of Sciences (NAS) at the request of the former U.S. Energy Research and Development Administration and the Council on Environmental Quality, the Panel reached "...a firm conclusion that current practices effectively minimize radiation hazards to workers on the Hanford Reservation and persons living in the surrounding area." Specifically, the panel concluded that "...the off-Reservation intensity of radiation caused by Hanford operations is no more than a trivial fraction of the natural background radiation; monitoring of all parts of the environment is adequate; and provision has been made for prompt remedial action in case of credible accidents or natural calamities." The portion of that review pertinent to risks associated with radioactive wastes in the waste storage tanks was reviewed and brought up to date by Dr. Patricia Durbin, one of the consultants to this review and a member of the original NAS Panel on Hanford Wastes. In her summary, Dr. Durbin concluded (see Appendix A): "The laboratory research and field experience at Hanford confirm quantitatively that the dryness of the sediment zone above the water table, the sorption properties of the tank farm sediments, dilution in groundwater, and the long flow paths of groundwater to the Columbia River constitute a series of independent barriers which prevent radionuclides deposited in subsoil by leakage from the waste tanks from moving to the Columbia River before their radiologic hazard has been eliminated by decay. Imposition of any or all of those barriers to radionuclide migration serves to reduce still further the low risk (two times background) which would result from complete dispersal of all the radionuclides in the drainable liquid left in the single-shell waste tanks."

4.11 LIQUID INTRUSIONS

Intrusions (unwanted additions) of liquids into the waste tanks and catch tanks associated with the waste management operations at Hanford are occurring with increasing numbers and volume. The significance of intrusions to the surveillance program is twofold; first, intrusion monitoring, which is excellent, must be continued despite the degree of stabilization or degree of isolation of any tank or related system as long as there is a finite possibility for further intrusions to occur, and, second, considering the fact that some 54 single-shell tanks are unsound and that the remaining single-shell tanks will ultimately become unsound, every intrusion represents a potential leaching agent to remove tank contents to the soil outside. The causes of intrusion are varied—leaks at valves and jumpers, misroutings, leakage during transfers, snowmelt runoff, etc. The number of tanks involved, as well as the total volume, doubled from 1978 to 1979; during January of 1980, 10 thousand gallons of snowmelt runoff apparently entered two tanks classified as leakers and one tank of questionable integrity. The net impact of this worsening situation raises the question of whether the proposed elimination of liquid-level monitoring for interim isolated tanks can be effected in the near future.

4.12 FUTURE CONCERNS - IMPLICATIONS FOR SURVEILLANCE

This review has by necessity focused on the management of radioactive wastes in the single-shell tank farm and on the surveillance programs and activities directly associated with the operations involving those tanks. Environmental surveillance extending outside the perimeters of the tank farms and beyond the limits of the 200 Areas was not a subject of this review; an extensive treatment of the subject may be found in the final environmental statement "Waste Management Operations - Hanford Reservation, Richland, Washington" (ERDA-1538, Vols. 1 & 2) published December 1975. Nevertheless, there are circumstances of environmental contamination in the 200 Areas that bear directly on future management and surveillance of the single-shell tank farms. Details of planned and unplanned releases to the soil in these areas are treated exhaustively in the reference and will not be repeated here except for updating.

To date, the estimated volume of leakage to the soil from all single-shell waste storage tanks is on the order of 500 thousand gallons. Currently an estimated 15 million gallons of drainable liquids remain in the single-shell tanks. This volume is predicted to drop to about 1 million gallons at the end of the present waste solidification program. Eventually, as single-shell tanks become unsound over time, this million gallons may be released to the soil. Past unplanned releases to soil are not known; owing to the philosophy of using soil as a secondary containment, spills and other accidental releases within the tank farm boundaries were not recorded routinely until 1972. Moveover, in the early years of Hanford operations, the soil of the 200 Areas was used for direct absorption of perhaps 30 to 50 million gallons of intermediate- to high-level liquid waste discharged to cribs, ditches, etc., directly adjacent to or near the tank farm areas in several instances. The existence of these areas has been well documented, and they are under continuing surveillance for evidences of migration through the soil. According to recent reviews, the projected migration of this soil contamination presents no future concern with regard to risk to health. Looking at the locations of radioactive material, as shown in Table 23, almost all the beta-gamma activity of the radioactive wastes remains in the waste storage tanks, with perhaps 1 percent in the burial grounds waste and 0.1 percent in the soil at liquid waste disposal sites. Plutonium and other transuranic elements are distributed somewhat differently: 42 percent in burial grounds (including 9 percent in a readily retrievable storage mode), 20 percent in soil at liquid waste disposal sites, and 38 percent in waste storage tanks. This means that future surveillance of waste storage tanks must be viewed in the light of the overall environmental monitoring effort and that future planning for management of wastes in those tanks must likewise take into account the feasibility and relative risks and benefits of further actions to contain those wastes in their present location as contrasted to their relocation, perhaps to another, deeper site at Hanford. Decisions on final disposition of the storage tanks should be accelerated before more tank failures occur so that the ease of fixation in place or transfer of tank contents may be improved and the amount of further environmental contamination may be lessened. The problem is not a simple one: for example, consideration must be given to factors that may affect the ability to transfer tank contents, in view of some of the unique contents listed in Table 24.

TABLE 23.

SUMMARY OF HANFORD 200 AREAS RADIOACTIVE WASTE (1)

SITE	NUMBER OF SITES	Pu (kg)	BETA-GAMMA (Ci)
LIQUID WASTE DISPOSAL SITES	223	202	1.2×10^5
TANK FARMS	17 (2 Under Construction)	388 (2)	1.1×10^8 (2)
BURIAL GROUNDS	28	431 (3)	1.5×10^6
UNPLANNED RELEASES	35	< 0.1	3.1×10^4
TOTAL	303	1,021	1.1×10^8

(1) Ref: RHO-LD-42, Revision 2, November 1979 (Some Figures Estimated on Limited Data)

(2) Ref: RHO-CD-7946, December 1979 (Unclassified Figures From Classified Report)

(3) 95 kg of the Pu in Burial Grounds is in a Retrievable Storage Mode

TABLE 24.

HANFORD SS TANK FARM FACILITIES
UNIQUE CONTENTS

STATUS AS OF 1-25-80

TANK	STATUS	CONTENTS
101-BX	QI	~ 1,800 GALLONS OF ARC-359 ORGANIC ION EXCHANGE RESIN ADDED IN 1972
102-BX	L	DIATOMACEOUS EARTH ADDED
105-BY	QI	63 TONS PORTLAND CEMENT ADDED
107-SX	L	41 BOTTLES OF NEUTRALIZED WASTE FROM 100F AREA, EACH WITH LESS THAN 1 GRAM PU-239
110-SX	QI	16 PLASTIC BOTTLES OR CONTAINERS (3" DIA. BY 54" LONG) CONTAINING FOLLOWING TOTAL VOLUMES: 113 G U NAT 52 G U DEP 6 G ENRICHED U 204 G PU
113-SX	QI	1,400 FT^3 DIATOMACEOUS EARTH ADDED
116-SX	QI	DIATOMACEOUS EARTH ADDED
117-TX	QI	DIATOMACEOUS EARTH "MOUNDED" IN TANK
106-TY	L	DIATOMACEOUS EARTH ADDED
101-U	L	TANK USED FOR DISPOSAL OF SOLID WASTE: – SIX CASK LOADS OF EXPERIMENTAL FUEL ELEMENTS, SHROUD TUBES AND SAMARIUM "POISON" CERAMIC BALLS. 1,530 G OF 4.5% ENRICHED U AND 6 G OF PU; PLUS 180 KCi CO-60 AND 130 Ci MIXED FISSION PRODUCTS – COBALT-60 SLUGS WITH 70 KCi CO-60
104-U	L	DIATOMACEOUS EARTH ADDED

KEY: L = leaker; QI = questionable integrity

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Glossary

The glossary used in this report gives preference to definitions used in the Hanford Operations. Exceptions used in this report are noted.

Active tank - a tank which contains greater than a minimum heel of liquid and/or for which future material additions are planned.

Annulus - a vessel space in the form of a ring; the space between concentric walls.

Background - the amount of radiation that is present at a given location due to natural or induced radiation.

Baseline - a reference point, specified liquid level or radiation level against which new information is compared.

Burial ground - a land area specifically designated for storage or disposal of containers of radioactive solid wastes and obsolete or worn out equipment in shallow land burial.

Caisson - a structurally secure chamber installed within an excavation for the purpose of supporting the excavation sidewalls. As applied to waste tank surveillance, caissons are in place as housings for leak detection lateral tubing in the A and SX Farm Tanks.

CASS - Computer Automated Surveillance System.

Catch tanks - small capacity single-shell tanks, associated with diversion boxes and diverter stations. The tanks are designed to receive any transfer line leakage from these boxes or adjacent pipe encasements.

Conductivity probe - a device which completes an electrical circuit when contacted by a conductive material.

Confirmed or declared leaker - the designation of any underground waste storage tank which has leaked per the conclusion reached after a review of accumulated data. These tanks are also classified and tabulated "inactive" by Hanford. In this report, confirmed leaker tanks are discussed and totaled separately.

Crust - a hard surface layer which has formed in many waste tanks that contain concentrated solutions.

Decommissioning - the management or disposition of worn out or obsolete nuclear facilities or contaminated sites. Decommissioning operations remove facilities such as reprocessing plants and burial grounds from service and reduce or stabilize radioactive contamination.

Decontamination - the selective removal of radioactive material from a surface or from within another material.

Deliquescent - a solid capable of absorbing moisture from the air and becoming a liquid.

Desiccant - a drying agent.

Diatomaceous earth - diatomite, a light friable siliceous material derived chiefly from diatom (algae) remains which is added to selected underground waste storage tanks to absorb and thereby immobilize residual heels.

Disposal - the planned release of radioactive and other waste in a manner that precludes recovery, or its placement in a manner which is considered permanent so that recovery is not provided for.

Diversion box - a below grade concrete enclosure containing the remotely maintained jumpers and spare nozzles for diversion of waste solution to storage tank farms.

Double-shell tanks - the new one-million gallon underground waste storage tanks, consisting of a complete free standing, carbon steel primary tank within a secondary shell, which is in turn contained within a reinforced concrete structure.

Dry well - (In-Tank) - a sealed casing within a tank that is attached to a riser, and used for access of a neutron or an acoustical probe to determine the level of drainable interstitial liquor.

Dry well - a steel casing, generally 6 inches in diameter, drilled into the ground to various depths, and used for access of monitoring instruments to measure the presence of radioactivity or moisture content.

Environs - area immediately surrounding.

Evaporator-crystallizers - 242-A and 242-S waste concentration facilities that operate at a reduced pressure (vacuum) and are capable of producing a slurry containing about 30 volume percent solids and a specific gravity of greater than 1.6.

Functional capability - as used in this report, is defined as the ability of a monitoring system to achieve its design purpose. Lack of functional capability may be caused by system malfunction or to factors causing an operable system to become unresponsive (e.g., insufficient source or too much source).

Heel - the amount left in a vessel or container after the bulk of the contents has been removed.

Inactive tank - a tank which has been removed from liquid-processing service, pumped to minimum supernatant liquid heel, and is waiting to be or is in the process of stabilized and interim isolated. Hanford includes all tanks as inactive that are not in an active category. In this report, confirmed leaker and questionable integrity tanks are discussed and totaled separately.

Interim isolation - completion of the physical effort required to minimize the inadvertent addition of liquids into an inactive storage tank, auxiliary tank, process vault, sump, catch tank or diversion box.

Interim stabilized - the condition of an inactive waste storage tank after all liquid technically practical has been removed by a salt well system using a jet pump. Tanks not requiring salt wells and jet pumps will be interim stabilized by other methods. Tank evaluations will be performed during the interim stabilization effort to determine the status and eventually when a tank will be considered "interim stabilized."

Interstitial liquor - the liquid which fills the voids in the solids in the waste tank. This liquid is estimated to be about 50 percent of the solids volume. In salt cake, approximately 60 percent of the liquor is drainable and about 40 percent is held in place by capillary forces (nondrainable). In the sludge portion of the tank farm waste this liquor is not considered pumpable or drainable, but may contain pockets of liquid which cannot be estimated. Interstitial liquor may be evaporator feed or terminal liquor.

Isolation - the act of sealing a tank against liquid intrusion from any creditable source and confining the atmosphere in the tank, except for filtered airways for normal tank breathing and ventilation for temperature control where necessary.

Jet pump - a modified commercially available jet pump used as a very effective salt well pump. A centrifugal pump in the pit recirculates a stream to serve as the motive fluid for the jet located at the bottom of the well which draws additional solution into the loop at a rate equal to the discharge rate that is controlled by a diaphragm operated valve (DOV).

Lateral - horizontal dry well under A Farm and certain SX Farm waste storage tanks.

Leak detection pit - collection point for any leakage from AX Farm tanks. The pits are equipped with radiation and liquid detection instruments.

Liquid level - level of liquid present in a tank.

Open hole salt well - a pump inserted into a waste tank with the suction at or below the solids level, frequently used to remove the bulk of the liquid, particularly in tanks containing less than 2 feet of sludge.

Primary stabilization - the condition of an inactive waste storage tank after all liquid above the solids, other than isolated surface pockets, has been removed. Isolated surface pockets of liquid are those not pumpable by conventional techniques.

Probe - an instrument package designed to be inserted in dry wells, tank risers, or other access ports to measure conductivity, radiation, moisture, temperature, etc.

Psychrometry - determination of the humidity or dew point of a gas from wet and dry bulb temperatures that is used in conjunction with flow rate data to calculate evaporation rates.

Questionable integrity - any tank which has a small decrease in liquid level or a radiation increase in an associated dry well, for which the data are insufficient to support a conclusion that the tank is sound. Hanford also classifies and tabulates these tanks as "inactive." In this report, questionable integrity tanks are discussed and totaled separately.

Salt cake - nondeliquescent crystals (at average Hanford air conditions) formed by evaporation, cooling, and/or settling.

Salt well - a screened casing inserted into a waste tank containing solids that extends to within about 2 inches of the bottom. The larger solid particles are rejected by the screen while liquid is allowed to migrate into the well for pumping.

Salt well pump - a low capacity pump used to remove interstitial liquor from salt wells.

Service life - the period of time from the date a tank was put into service to the date of removal from service because of unsoundness.

Sludge - solids formed by precipitation without additional concentration.

Slurry - watery mixture of insoluble material, coming from an evaporator, before the salt crystals have grown.

Storage - retention of waste in some type of man-made device in a manner permitting retrieval.

Supernate - (supernatant) - the liquid phase lying above solids that have settled to the bottom of a vessel.

Tank farm - area containing a number of storage tanks; i.e., underground waste tank storage of radioactive waste.

Terminal liquor - the liquid product from the evaporation-crystallization process which upon further concentration forms an unacceptable solid for storage in single-shell tanks. Terminal liquor is characterized by a caustic concentration of approximately 5.5M (the caustic molarity will be lower if the aluminum salt saturation is reached first).

Thermocouple - a probe for measuring temperature, consisting of two dissimilar metal wires joined at one end (hot junction) with the free ends joined to a measuring instrument. Electrical potential changes due to temperature changes at the hot end are measured and calibrated to read out as temperature.

Thermocouple tree - a group of thermocouples assembled in a pipe and inserted into a waste tank for measuring temperatures at regular (normally two foot) vertical intervals.

Vadose zone - the unsaturated region of soil between the ground surface and the water table.

Appendix A Addressing the Hazards of Hanford Radioactive Wastes (Patricia Durbin)

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I.a. Assessing the Hazards of Radioactive Wastes to Human Health

Several methods are available to provide insight into the kinds and magnitudes of the hazards to human health posed by the radioactive residues accumulated in the course of various applications of nuclear fission. The first and most direct method is a simple listing of the amounts (in curies) of the constituent radionuclides in the various waste forms or at specific locations or the amounts of wastes that have been generated from nuclear activities such as worldwide fallout from atmospheric weapons testing, plutonium production, and electric power reactors.

Because each radionuclide has a unique time of existence—described by its decay constant ($0.693/T_{\frac{1}{2}}$, where $T_{\frac{1}{2}}$ is the physical half-life)—the quantity of the radionuclides in the waste inventory changes with time. Graphs can be used to describe the time-dependent changes in inventory (as shown in Figs. 3.3 and 3.4, Ref. 1). The decay curves show which radionuclides will be important contributors to the total potential radiological hazard at specific times after fuel has been removed from a reactor.

However, the radioactive species present would not be equally hazardous to human beings were they all to escape from confined storage. In addition to its decay rate, each radionuclide has a unique set of physical properties—the kinds and energies of the particles and/or electromagnetic radiations that are emitted as its decays. Those properties have an important influence on the amounts and spatial patterns of energy deposition in tissue and, consequently, on biological effects. Equally important are the chemical properties of each radioelement, for the chemistry of an element determines how it will behave in aqueous solution, in the presence of other elements in soils and sediments, in the ion transport systems of plants, and in the gastrointestinal tracts and internal chemical milieu of animals.

I.b. Hazard Index

Most analyses of the mechanisms by which stored radioactive wastes can reach the biosphere conclude that the likeliest pathway is entrainment or solution in waters, either on the earth's surface or belowground. A third and more illuminating method of examining the health hazards of radioactive wastes, the so-called Hazard Index, was developed so that the relative hazards of the different waste nuclides could be compared, assuming that all were dissolved in drinking water. The Hazard Index [volume of water required to dilute the radionuclides in the inventory to a level which can be released into the public domain (Refs. 2, 3)] utilizes the large body of physical and biological data that were compiled by the International Commission on Radiological Protection (ICRP) (Ref. 2) for the purpose of setting intake limits for the protection of workers from radionuclides in the workplace.

That body of data includes: (a) the fraction of an ingested radionuclide that is absorbed into the blood from the gastrointestinal tract; (b) the amounts of the absorbed radionuclide that are deposited in important tissues (either those deemed especially radiosensitive, such as red bone marrow and gonad, or those in which the radionuclide concentration is high and imparts a large radiation dose; (c) the temporal pattern of retention of the radionuclides in tissues (described by biological half-life); and (d) the energy from each decay deposited in the tissue of interest. (See the footnotes to Table A-1 for definitions of these terms and the equations used to calculate radiation dose.) The biological factors, along with the appropriate energies and quality factors (QF, which takes account of the different microscopic distributions of energy of the particles and radiations), and a set of limits on radiation doses in tissues were used by ICRP to calculate the amount of each radionuclide that could be ingested daily by adults for 50 years without exceeding the established annual dose limits of 5 rem/year to whole body, red bone marrow, or gonads; 30 rem/year to bone or thyroid; and 15 rem/year to other organs. Those intake limits for workers were given as Maximum Permissible Concentrations in water (MPC_w). The ICRP recommended and later the Atomic Energy Commission, which was superseded by the Nuclear Regulatory Commission, adopted a tenfold reduction in those limits when applied to the general population. The Hazard Indices (using MPC_w for the general population) of the radionuclides in the 20-year-old wastes in the Hanford tanks (as of 1978) appear in Fig. E-1, Ref. 9.

The dose limits on which the MPC_w's were based were derived from a composite of clinical radiological experience, industrial and medical experience with ^{226}Ra and uranium, and a body of animal toxicological experiments (chiefly rodents), and they imply that, per unit of radiation dose, whole body, red marrow, and gonads are three times more sensitive than other organs and six times more sensitive than bone or thyroid, but without specifying endpoints.

I.c. Quantitation of Radiation Effects on Human Health

The dominant biological action of ionizing radiation is currently believed to be structural alternations of DNA molecules in the cell nucleus, which are essential for normal cell function and successful cell replication. When the radiation dose is large and/or the dose rate is high, the major early effect is depletion of cell numbers caused by failure of severely damaged cells to proliferate (Ref. 10). Acute radiation death is the result of proliferative failure of vital cells in the intestinal tract and/or bone marrow (Ref. 11). In mammals, the most radiosensitive of the vertebrates, the 30 to 60 day LD_{50} (lethal dose for 50% of the population within 30 to 60 days) for high dose rate x- or gamma-radiation ranges from 150 rad (sheep) to 1500 rad (desert mice), with that for man estimated to be about 250 rad (Ref. 12). Larger doses can be tolerated if the dose rate is low (in which case only a few cells are hit), if the dose is delivered over an extended interval (allowing some damaged DNA molecules to be repaired or selected out), or if only part of the body is exposed.

At the low dose rates and low accumulated doses expected in the vicinity of nuclear facilities during normal operations and all except the most catastrophic accidents, acute radiation effects are absent, but there is a finite probability of the persistence of a small amount of transmissible unrepaired DNA damage in some cells, which can be manifested early as a mutation or after many years as a "late effect," particularly cancer. The major late radiation effect that has been observed in human beings is an increased frequency of malignancies (somatic effect) among exposed individuals. An increase of heritable health defects (genetic effect) in the descendants of exposed individuals has been inferred from animal experiments.

The so-called linear hypothesis, which states that the probability of induction of a cancer by radiation is linearly related to total radiation dose and independent of dose rate, and the available human radiation experience on cancer induction have been used by committees of the U.S. National Research Council (Ref. 12) and the United Nations (Ref. 13) to predict the risk per unit of accumulated radiation dose of incurring a fatal cancer. Data developed in mice have been used by those organizations to predict the number of inheritable health defects in all subsequent generations per unit of radiation dose to the gonadal tissues of the first generation. Table A-2 shows the radiation "risk estimates" for human health effects developed by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (Ref. 13) as adopted for radiation protection purposes by ICRP (Ref. 6).

I.d. Adverse Health Effects Method of Hazard Assessment

In the 20 years since ICRP issued their major compilation of biological data and limits for radionuclide intakes by workers (Ref. 2), a large amount of new information on metabolism of many radionuclides by human beings has been accumulated and much new information has become available on the effects of radiation in man (Refs. 12, 13). The latter information is summarized in Table A-2. The new biological data have appeared in a series of ICRP reports (Refs. 4-8).

All of that new information and new methodology has been used here to develop a more refined and more informative assessment of the risk to human health (designated here as Adverse Health Effects, AHE) of the constituents of radioactive wastes ingested with water or foods. First, the most recent biological data and metabolic models were used to calculate the radiation doses to specific target tissues and to gonads from ingestion of 1 μCi of a waste radionuclide. A 70-year dose commitment was used to approximate the average human lifetime in the United States, and a 30-year integrated dose to the gonads was calculated as an approximation of the genetically significant time. Second, the total lifetime risk was obtained for each radionuclide from the product of the dose commitment per microcurie ingested and the appropriate risk factor for each target tissue (obtained from Table A-2), summed for several target tissues when required. Thus, as shown in Table A-1, it is possible to estimate for ingestion of any amount of a radionuclide (in this case 1 μCi) the total lifetime risk to an individual (or a population of any size) of developing a fatal cancer or of passing a heritable defect to all subsequent generations of descendants.

The lifetime risk of Adverse Health Effects that can be attributed to natural background radiation [average 0.1 rem/year in the United States, Ref. 14)] can also be calculated:

Somatic effects: 0.1 rem/year x 70 years x 1 x 10^{-4}/rem =	7 x 10^{-4}
Genetic effects: 0.1 rem/year x 30 years x 2 x 10^{-4}/rem =	6 x 10^{-4}
Total Adverse Health Effects	1.3 x 10^{-3}

The highest calculated potential risk from ingesting a radionuclide is 4.2 x 10^{-4} from ingestion of 1 μCi of ^{241}Am, and that risk is about one-third that which could be attributed to natural background.

Both kinds of estimates, the Hazard Index and the Adverse Health Effects, yield high values for the potential hazards of stored radioactive wastes because they imply that the entire radionuclide inventories will be ingested by people. Neither method accounts for the chemical forms or the actual amounts that will be taken into the bodies of people or animals. Several geochemical processes, which will not be discussed here, tend to reduce substantially the amounts of the radionuclides that could exist in solution in a drinking water supply or that could be accumulated by plants or animals and transferred to man in food chains. There are also two important biological processes which are not taken into account in these estimates: first, there is roughly a tenfold lower gastrointestinal absorption of insoluble forms of most of the heavy metal constituent radionuclides (Refs. 2, 5, 6), and, second, the effectiveness is reduced for producing somatic effects, at least from sparsely ionizing gamma rays and beta particles, when the rate of dose delivery and total doses are low (Refs. 12, 15, 16).

II.a. Residual Liquor in the Hanford Tanks

When the present plan for stabilization of the single-shell Hanford waste tanks is complete in about 1984, it is estimated that the total volume of drainable, but not pumpable, residual liquid in the single-shell tanks will be about 10^6 gal (3.8×10^3 m^3). The total amount of residual liquor from the evaporation process estimated to be on hand is 11×10^6 gal, of which 10×10^6 gal will be either in the process of further evaporation or stored in the new double-shell tanks. The major radionuclides in the residual liquor inventory as of 1990 and the chemical composition of the solution are shown in Tables 3.2 and 3.1, respectively (Ref. 1). The nuclide composition of a similar alkaline supernatant at the Savannah River Plant (SRP) (Table III-5, Ref. 17) includes concentrations of some additional minor radioactive constituents, and these have been inferred also to be present in the same proportions in the residual liquor at Hanford (see Table A-3 of this report). The radionuclide concentrations shown in that table are three times those shown in Ref. 17 to account for water loss in the evaporation processing of the original supernatant to obtain salt cake. On the average, the Hanford wastes were estimated to be 20 years out of the reactor in 1978 (Ref. 9) and, therefore, would be about 25 years old in 1984. The inventories show that the oldest wastes at SRP are 10 years out of the reactor. For the purpose of this discussion, both sets of data have been converted to a common age of 25 years.

II.b. Adverse Health Effects—A "Worst Case Analysis"

The concentrations of the radionuclides in the Columbia River at Pasco can be calculated from the data in Table A-4, assuming that all 10^6 gal of residual liquor remaining in the single-shell tanks at the end of pumping were placed directly into the river in 1984—clearly an impossible situation. Table A-3 shows the results of those calculations in terms of amounts ingested (microcuries per person) for dumping in 1 day or steadily during 1 year. Table A-5 gives the applicable water concentration standards (Refs. 2, 3) and the new limits on intake recommended by ICRP reduced by a factor of 10 (Ref. 6). If the nuclides were diluted in 1 day's flow, only the concentrations of ^{90}Sr and ^{137}Cs would exceed either the prevailing or the recommended standards, and the concentration of ^{241}Am would equal the recommended standard. If the nuclides were diluted in 1 year's flow, only the concentration of ^{137}Cs would equal the standards. When the total intake (intake is the same; only the rate differs) is compared to the new ICRP limits on annual intake, the only nuclide that would equal the limit is ^{137}Cs (12 μCi ingested, compared to an annual limit of 11 μCi). Tables A-1 to A-3 can be used to estimate the health consequences to the exposed individuals and their progeny (and by simple multiplication to an estimated population of any size). The total risk (see Table A-6) to an individual of developing a fatal cancer or transmitting a genetically based disease to all subsequent generations is 1.65×10^{-4} as a result of drinking Columbia River water at Pasco contaminated with the entire radionuclide inventory of the drainable alkaline liquor, and ^{137}Cs contributes about 97% of that risk. For comparison, the lifetime (70-year) risk attributable to natural background radiation of 0.1 rem/year is 1.3×10^{-3}, and natural background radiation makes a minor contribution to the total U.S. cancer incidence (about 25% of all deaths are related to cancer) or to the amount of genetically related disease [estimated to be about 20% of all noninfectious illnesses (Ref. 20)].

In addition to a single-pass of radionuclides downriver used as municipal drinking water, the Columbia River furnishes a large amount of irrigation water. That water is spread over large areas; its ^{137}Cs content would create an external gamma-ray field; and its ^{90}Sr and ^{137}Cs content would be partially incorporated into foods.

II.b.1 Gamma-Ray Field. If 47,600 acres are irrigated with water taken above the confluence of the Columbia and Snake Rivers during 1 year at a rate of 4.2 acre-ft of water per acre (see Table A-4), the yearly use is (acre-ft = 1.23×10^3 m^3 and acre = 4.05×10^3 m^2):

$$4.76 \times 10^4 \text{ acre} \times 4.2 \text{ acre-ft/acre} \times 1.23 \times 10^3 \text{ m}^3\text{/acre-ft} = 2.46 \times 10^8 \text{ m}^3 \text{ of water}$$

the area of irrigated land is:

$$4.76 \text{ acre} \times 4.05 \times 10^{-3} \text{ km}^2\text{/acre} = 1.93 \times 10^2 \text{ km}^2$$

and the areal distribution of ^{137}Cs is:

$$1.7 \times 10^{-2} \text{ mCi/m}^3 \times 2.46 \times 10^8 \text{ m}^3\text{/}1.93 \times 10^2 \text{ km}^2 = 2.1 \times 10^4 \text{mCi/km}^2$$

From Ref. 21, it can be calculated that the gamma radiation level in the first year from distributed ^{137}Cs would be:

$$2.1 \times 10^4 \text{ mCi/km}^2 \,[0.12(0.63e^{-1.15} + 0.37e^{-0.03})] = 1420 \text{ mrad/year}$$

For a farmer working 8 hours per day, 5 days per week, 50 weeks per year, a work year is 2000 hr or 2×10^3/24 hr/day x 365 days/year = 0.228 year. His dose would be 1420 mrad/year x 0.228 = 326 mrad, or about 3 times background. If he worked in those fields for 50 years, his total exposure can be calculated by integrating the UNSCEAR equation, and his total dose would be 26 rad.

For a total lifetime risk from whole-body external radiation of 3×10^4, the added risk for continuous out-of-doors occupancy would be 26 rem $\times 3 \times 10^{-4} = 7.8 \times 10^{-3}$, or about 6.5 times the risk conferred by natural background radiation. For work occupancy only, the risk would be $0.228 \times 7.8 \times 10^{-3} = 1.8 \times 10^{-3}$, or about 1.5 times the risk of natural background.

II.b.2. <u>^{90}Sr in Foods.</u> ^{90}Sr is the major contributor to internal dose from eating foods grown on soil contaminated by this group of radionuclides. The ^{90}Sr concentration on this land would be:

$$5.5 \times 10^{-7}\ \text{Ci/m}^3 \times 2.46 \times 10^8\ \text{m}^3\ \text{water}/1.93 \times 10^2\ \text{km}^2 = 7 \times 10^2\ \text{mCi/km}^2$$

UNSCEAR (Ref. 21) has calculated that the concentration of ^{90}Sr in foods is, on the average, 4.5 pCi/year/g Ca/mCi ^{90}Sr/km^2. For an average U.S. diet, the annual intake of Ca is 100 g/year (Ref. 8). From a ground contamination of this level, individual ingestion would be:

$$7 \times 10^2\ \text{mCi/km}^2 \times 4.5 \times 10^2\ \text{pCi/mCi}\ ^{90}\text{Sr/km}^2 = 0.31\ \mu\text{Ci}$$

of which 0.12 is transferred to bone. The Adverse Health Effects attributable to this intake of ^{90}Sr (from Table A-2) would be:

$$0.31\ \mu\text{Ci} \times 1.2 \times 10^{-5}\ \text{AHE}/\mu\text{Ci ingested} = 3.8 \times 10^{-6}\ \text{for 1 year's intake}$$

Assuming no weathering (loss from soil by runoff or migration below the plant root zone) and loss only from radioactive decay, intake over 50 years would be 9 μCi, and the Adverse Health Effects would be 1.1×10^{-4} per person.

Thus, the most significant consequence, in terms of effects on human health, of placing the drainable liquid from the Hanford waste tanks directly into the Columbia River would be the external radiation from ^{137}Cs spread over land surface in irrigation water (work occupancy for 50 years confers a risk of 1.8×10^{-3}). Drinking Columbia River water would confer an individual risk of 1.6×10^{-4} per person, and eating foods grown on the irrigated land for 50 years (as the sole source of dietary Ca) would confer a risk of 1.1×10^{-4} per person. The total risk to the maximum individual, a farmer who worked the irrigated land, drank untreated Columbia River water, and ate only foods grown on the contaminated land, over his lifetime would be 2.1×10^{-3}, roughly twice the risk from natural background.

These risk estimates are independent of any assumptions about the sizes of the exposed populations; however, all would be subject to the same natural background level and its associated calculated risk of 1.3×10^{-3} per person.

A larger area, 2.77×10^5 acres, is irrigated in the 65-mile reach of the Columbia River beyond the 75-mile radius of the Hanford Reservation and below the entry of the Snake River but above the points of entry of most of the remaining important tributaries. The flow from the Snake River increases the total to 1.42 times the main stem flow. For the purpose of this discussion, the annual flow through this downstream irrigated area will be assumed to be 1.5 times the flow at Pasco, or 1.64×10^{11} m^3/year. The intensity of gamma fields created by the

^{137}Cs would be proportionately less because of the greater dilution: for the first year, 220 mrem/year for a 40-hr work week and 17 rem a lifetime of continuous out-of-doors occupancy. The ^{90}Sr content of foods grown on that land would be lower, leading to annual intakes of 0.2 μCi in the first year and 6 μCi over 50 years. Thus, individual doses would be less, but in both cases the potential number of exposed persons must be considered to be larger. Doses from drinking Columbia River water taken in or below this reach would also be lower; however, no record is immediately available on the use of Columbia River water downstream from Pasco for municipal purposes. All available evidence points to reliance on other sources (J. Soldat, private communication).

III.a. Health Consequences of Leakage of Fluid from Waste Tanks

Leakage of the drainable fluid from the Hanford single-shell waste tanks into the subsoil is a likely event, in contrast to the direct dumping of liquid into the Columbia River, which was examined as a "worst case" in the preceding section. The sediments provide several important barriers that prevent or retard emergence of the radionuclides into the biosphere. The only available vehicle for transport of the radionuclides is groundwater, which provides some initial dilution and moves slowly enough to permit some radioactive decay of the shorter-lived nuclides before it enters the river. The second barrier is the chemical reaction of the nuclides with the subsoil minerals, which act to retard nuclide movement with respect to the flow of groundwater. The third barrier is the almost dry, unsaturated vadose zone above the water table.

Those three barriers—movement of water in the vadose zone, sorption on and reaction with the Hanford tank farm sediments, and the patterns and rates of groundwater movement—can now be considered to have been well studied in the laboratory and the field, and research on the many remaining details and refinements is in progress. The results that were available before 1974 were reviewed in the Hanford Waste Management Environmental Impact Statement (Ref. 19) and by a National Academy of Sciences-National Research Council study panel (Ref. 9). The work done since then has been directed toward reducing the number of uncertainties about the behavior of fluids added to the vadose zone (Refs. 22-24), the movement of groundwater beneath the Hanford tank farm (Ref. 23), and the sorption of cationic waste constituents from solutions of varying composition (Ref. 25). Those studies, which are summarized below, comprise a body of theoretical and experimental evidence strongly supportive of the view that, unless very large amounts of water are placed on the soil surface (considered to be highly unlikely as a natural event), there is little probability that any of the leaked radionuclides below the tanks will ever reach the water table and further that, even if waste liquid were to reach the water table, the radioactive cations (Sr, Cs, lanthanides, and actinides) which are potentially most hazardous to man will be so delayed by precipitation and sorption that little or none will reach the Columbia River by groundwater flow.

III.b. Postulated 800,000 Gallon Tank Leak

An analysis of the possible consequences of leakage into the subsoil of 800,000 gal of liquid from a waste tank (all of the drainable fluid from neutralized fresh waste) was prepared for the Waste Management EIS (Ref. 19,

p. III.2-3) issued in 1975. The time required for preparation and processing of that report precluded use of any materials published after 1973. The following assumptions were used:

1. The fluid wets a circular area 38.5 m in diameter (126 ft), and all fluid drains in a cylindrical volume of soil 52 m high (170 ft).

2. The average porosity of the sediments is 0.35, and the specific retention is 0.06 of the pore volume, i.e., 0.02 of the total column volume.

3. The percolation rate was determined by the presence of a silt layer typical in the 200W Area, as calculated with the Percol Model.

4. The shortest direct flow path of groundwater to the river led to a travel time of 20 years.

The assumed column volume was $19^2 \times \pi \times 52 = 6 \times 10^4$ m^3, and the volume of specific retention (volume of fluid that will be held against gravity, by capillarity, etc.) is $0.02 \times 6 \times 10^4 = 1.2 \times 10^3$ m^3. The fluid volume is 3×10^3 m^3 (800,000 gal); thus, 1.8×10^3 m^3 of fluid (60% of the total) was assumed to move downward to the water table and to arrive there in 2 to 12 years.

The high empirically determined sorptive capacities of certain subsoil layers in the 200W Area for isotopes of Cs, Sr, lanthanides, and actinides were assumed to prevent those nuclides from reaching the groundwater.

On the basis of the above assumptions, all of the ^3H, ^{99}Tc, and ^{129}I, and part of the ^{125}Sb and ^{106}Ru were postulated to be diluted in the Columbia River in 22 years, and 22 years of radioactive decay were accounted for when appropriate. Doses to the maximum individual were calculated, and, after the risk factors in Table A-2 of this report are applied, they add up to 6×10^{-8} per person, or 0.02 of the 1 year risk from natural background.

In that analysis a conservatively small specific retention volume was used deliberately to examine the consequences of some flow of fluid to the water table.

III.c.1 Hanford Groundwater Transport. In 1977, Arnett et al. (Ref. 23) presented a mass transport model of groundwater flow which took account of two important factors and permitted a more realistic description of the behavior of groundwater beneath the Hanford tank farms. First, volume flow was calculated rather than the restricted and fictitious linear direct path that was considered in the EIS (Ref. 19), and, second, certain direct (shortest straight-line) pathways to the river were found to be essentially eliminated by the presence of poorly permeable basalt outcrops. The minimum travel time calculated by that method was 43 years for nondecaying, nonsorbing ions introduced into the water table below the A tank farm located at the eastern edge of the 200E Area. About one-half of the material was calculated to travel as a peak and emerge at 43 years; the remainder emerged at a declining rate over a period of about 300 years. (Note: the minimum travel time is about twice the estimated value used for the 200W Area in the 800,000 gal tank leak analysed in the EIS.)

III.c.2 Vadose Zone Analysis. An appendix to the report by Arnett et al. (Ref. 23) contains an analysis of the movement of water through the vadose (unsaturated) zone, in which it is pointed out that fluid movement in that zone depends on the following:

1. Volume and chemical composition of the solution.

2. Permeability and pre-existing moisture content of the sediments.

3. Relationship between relative permeability and saturation for each sediment type.

4. Sorption characteristics of each sediment type for ions.

5. Presence of lithologic changes (discontinuities) between the release point and the groundwater.

Because fluids introduced into these sediments move laterally as well as downward (see Fig. D-10, Ref. 24), it was assumed in this analysis that the wetted volume would be conical rather than cylindrical, as was assumed in the 800,000 gal analysis in the EIS (Ref. 19). The assumptions used in the vadose zone analysis are as follows:

1. Fresh neutralized waste (the same as in the EIS case) leaked from a double-wall tank in the 200E Area, where layering of sediments is not pronounced and sediment properties are relatively uniform.

2. The leak occurred rapidly through a 40-m^2 rupture in the tank bottom, and 800,000 gal of liquid penetrated the sediments, with a spreading ratio of 1:1 (an increase in the radius of the wetted area by 1 m for each 1 m movement downward). If the tank bottom was 70 m above the water table, the total volume of soil within such a conical volume would be $2.9 \times 10^5\ m^3$.

3. The moisture content of the sediments was 6 to 8% by volume.

4. Sorptive properties were uniform throughout the hypothetical volume.

5. The composition of the leaked wastes was uniform and had the fluid flow properties of distilled water. The latter assumption is conservative in that (a) density and viscosity of the waste fluid are greater than pure water and it will flow more slowly than water and (b) the

alkalinity of the fluid retards movement of some ionic species. It is not conservative in that the high Na^+ content of the waste solution reduces the soil:water distribution coefficients of some of the radionuclides, particularly Sr (Ref. 25).

In order to reach the water table, the volume of fluid in the wetted volume must exceed the specific retention of the soil. The hypothetical conical volume was 2.9×10^5 m^3, and the volume of fluid was 3×10^3 m^3. The waste liquid would occupy about 1% of the cone volume, and, as the authors stated, "an increase in moisture content in Hanford sediments of up to 4 - 6% has shown little tendency to migrate downward to a significant degree." They concluded, "that arrival of any portion of the waste liquid at the water table is unlikely under normal circumstances."

III.c.3. Cation Sorption in Hanford Sediments. A summary was included of several papers, including a review by Routson (Ref. 26), describing measurements of distribution coefficients (sorption coefficients, K_d) and column studies of leaching of various waste nuclides in Hanford sediments. Sorption coefficients measured under a variety of solution conditions, including the caustic solutions in the Hanford wastes, were for Sr, 5 to 38; Cs, 12 to 200; Pu, 200; and Am, 1200. ^{99}Tc was sorbed poorly, if at all. The sorption of Ru was variable, because it exists in the wastes in at least two different chemical forms. Usually the low K_d values (higher mobility in soils) were associated with acidic conditions.

III.d.1. Review of the T-106 Tank Leak. In mid-1973 an estimated 115,000 gal of supernate (Purex waste about 5 years old, partly stripped of ^{137}Cs and ^{90}Sr) leaked from tank T-106 into the subsoil below the 200W Area tank farm. Reports were prepared on the circumstances of the leak (Ref. 27) and on early measurements using monitoring wells drilled to assess the extent of movement of the leaked radionuclides (Ref. 28). The measurements have been repeated periodically, and the methods have been refined. All the pertinent data are contained in a 1979 update and review of the status of the leaked wastes (Ref. 24). That report also contains useful new data and concepts of vadose zone water movement, groundwater movement below the Hanford site, and ion sorption, which were applied to the re-evaluation of the tank leak accident. Conversely, the field observations of the T-106 leak tend to confirm theoretical and laboratory studies of certain of the waste radionuclides (gamma-ray emitters and Pu) in the unsaturated Hanford tank farm sediments.

Several kinds of data have been obtained chiefly by means of 24 dry wells drilled to investigate the leak: Total gamma-ray intensities at depth were obtained with NaI or G-M detectors; intensities of specific gamma-ray emitting nuclides were obtained by gamma spectrometry of the original drilling cores (1973-74) and recently by means of in-well Ge-Li detectors; and Pu and Am concentrations in sediments have been obtained by taking advantage of the γ-n reactions of Pu and Am isotopes in high intensity gamma fields (metal foils are exposed at depth, and the induced radioactivity is measured). Those measurements have been used to define the extent and kinetics of movement of the contaminated zone and to define the locations and/or movement of specific radionuclides— ^{106}Ru, ^{137}Cs, ^{144}Ce, and Pu isotopes. The fate of ^3H, ^{90}Sr, ^{99}Tc, and ^{129}I in these wastes could not be measured by the above methods. If the original drilling cores are still available, however, some information about the initial status of those nuclides might be obtained by radiochemical analysis.

In general terms the findings were as follows.

III.d.2. Spreading. There was substantially more horizontal than vertical movement of the waste fluid, as defined by the ^{106}Ru front. A roughly circular area 52 m in diameter (Fig. 11, Ref. 24) was wetted, whereas the front moved downward 12 to 14 m. That is a much greater degree of spread than was assumed by Arnett et al. (Ref. 23) in their study of hypothetical leaks in the 200E Area.

III.d.3. Movement of Wetted Front, ^{106}Ru. After 1974 there was very little additional movement, in any direction, of the leading edges, as determined from measurement of ^{106}Ru, the fastest moving and least sorbed nuclide that could be measured. The deepest pentetration of ^{106}Ru was to about 34 m above the local water table. None of the waste nuclides has been detected in groundwater monitoring wells near the leak site. The ^{106}Ru front is now receding as a result of radioactive decay.

III.d.4. Movement of ^{137}Cs and ^{144}Ce. Since 1974 there has been no significant downward movement of ^{137}Cs, and the location of the ^{137}Cs peaks and zones containing readily detectable amounts of ^{137}Cs (>1 $\mu Ci/\ell$) lag behind the ^{106}Ru peaks and areas of concentration by several meters. The ^{144}Ce is confined to a still smaller volume, but the low concentration impeded accurate measurements from the outset, and radioactive decay has now reduced ^{144}Ce to barely detectable levels. Initially, the ^{144}Ce was moving close to the ^{106}Ru front, but recent measurements suggest greater retardation.

III.d.5. Movement of Plutonium. Pu and Am isotopes appear to be confined to the first 3 to 4 m below the leak point. Their concentrations in that zone are several times greater than in the original leaked fluid; this suggests that these actinides were sorbed or "filtered out" by the sediments first encountered.

Although the detectable front (defined by the 1 $\mu Ci/\ell$ isopleth of ^{106}Ru) has expanded slightly, the bulk of the waste nuclides has remained in the volume permeated in 1973-74. That lack of movement tends to substantiate the several theoretical treatments of fluid movement in the vadose zone. The lag of the ^{137}Cs and ^{144}Ce peaks well behind the ^{106}Ru front and the fixation of Pu and Am isotopes near the point of origin provide additional field information in an "order of magnitude" sense of the soil:solution distribution coefficients (K_d's) obtained for those elements in the laboratory.

The authors concluded, on the basis of the field evidence supported by new theoretical studies, that there is little probability that any of the waste radionuclides will reach the water table, the Hanford groundwater, or the Columbia River.

III.e.1. Groundwater Flow Paths and Rates. A new mathematical model of groundwater flow was developed to predict minimum flow times to the boundary of the Hanford site, and a summary of the theory and procedures is included in the T-106 review document (Ref. 24). The new model builds on and is a major improvement of the straight-line volume flow model developed earlier by the Hanford group (Ref. 23) because it calculates flow in a contoured three-dimensional space. This model predicts that the average flow distance for groundwater below the 200W Area to the boundary at the Columbia River is 26 km and the average travel time is 117 years at an average rate of flow of 0.61 m/day. Distances from the 200E Area were not presented, but from the figures they appear to be somewhat shorter. [Note that the above calculated distances and flow times are five times greater than the shortest path used in the EIS (Ref. 19) study of a hypothetical 800,000 gal tank leak in the 200W Area and about 2.5 times the values obtained from the earlier (VTT) model for emergence of peaks of nonsorbed nuclides if leaked into the 200E Area (Ref. 23).]

III.e.2. Wetting Frontal Movement. Laboratory studies were conducted of the movement downward of a liquid pulse introduced at the top of a dry, closed column of homogenized Hanford tank farm sediments (Ref. 29). A pulse of water equal of 10% of the empty column volume was added to soil columns 25 to 200 cm long, and the distance traveled by the wetting front was recorded as a function of time. The results could be described empirically by:

$$S = ET^F \tag{1}$$

where S is the length of column wetted, T is the elapsed time in hours, and E and F are constants that depend on sediment type (E also depends on column length). To make Eq. 1 independent of column length, we can normalize it by dividing both sides by the column length, L:

$$S' = S/L = ET^F/L = E'T^F \tag{2}$$

For mixed Hanford tank farm sediments E' and F have the values 0.37/hr and 0.13, respectively. Eq. 2 can be used (as described in Ref. 24) to predict the time required for the wetting front of a pulse 10% of a column volume to travel to the bottom of a dry column of any specified length and diameter.

In the T-106 case, 115,000 gal (4.35×10^2 m^3) of waste leaked, and, according to Fig. 11, Ref. 24, a roughly circular area 52 m in diameter (area: 2.12×10^3 m^2) was wetted at a height about 50 m above the water table. That fluid volume would fill an empty column to a height of $4.35 \times 10^2\ m^3/2.12 \times 10^3\ m^2 =$ 0.21 m and would represent a 10% pulse in a column 2.1 m long. Solving Eq. 2 for T, where S' is the number of 2.1-m column lengths to arrive at the water table, $50/2.1 = 0.37/hr \times T^{0.13}$, and $T = 9.3 \times 10^9$ years. This kind of analysis of fluid movement in a dry column indicates that, if the sediments below the tank remain dry, even the poorly sorbed nuclides, ^{99}Tc and ^{129}I, will not reach the water table.

The authors of Ref. 24 deliberately chose a much smaller diameter for the wetted area below the T-106 tank (23 m) and calculated an arrival time of the wetting front at the water table of 2.3×10^4 years. (Note: In that case the ^{99}Tc and ^{129}I, which are assumed to move with the solvent front, would be delayed.

They would eventually emerge to the Columbia River at the same low concentrations with the same low health consequences that were calculated in Ref. 23. The authors pointed out that the column model they considered is conservative for several reasons other than the choice of a small wetted area: (a) Discontinuities (not present in the homegeneous laboratory sediment columns) will tend to enhance lateral flow. (b) The viscosity of the leaked fluid is greater than that of distilled water (used in the laboratory experiments), and more viscous solutions tend to flow more slowly. (c) In the laboratory studies, all moisture was conserved in the closed system, and that tends to maximize liquid flow by avoiding the evaporative losses expected in the field.

III.e.3. Sorption Effects. Movement of solutes in the presence of a solid phase is retarded according to the equation:

$$V_i/V_w = 1/(1 + K_d \rho/\theta) \qquad (3)$$

where V_i is the velocity of the sorbed ion (length/time), V_w is the velocity of the liquid phase (length/time), K_d is the equilibrium distribution coefficient of the ion between the solid and liquid phases (ml/g), ρ is the bulk density of the solid phase (g/cm^3—1.6 on the average for Hanford tank farm sediments), and θ is the pore fraction of the solid phase (for Hanford sediments, about 0.4). For the subsoil environment of the Hanford tank farm, Eq. 3 reduces to:

$$V_i/V_w = K^{-1} = 1/(1 + 4K_d) \qquad (4)$$

Laboratory studies of the equilibrium distribution of ions between homogenized Hanford tank farm sediments and aqueous solutions have been conducted for many radioelements under a variety of conditions of pH and solution composition. There is no complete review of that work, but many of the results appear in Refs. 23 - 26. The ranges of values obtained for K^{-1} for the major cations in the Hanford waste tanks are as follows: Cs, 0.04 to 0.001; Sr, 0.47 to 0.002; and Am and Pu, 0.001 to 0.0002. The smallest values for K^{-1} were usually obtained for dilute alkaline solutions; the largest values of K^{-1} (poorest sorption and retardation) for Cs and Sr were obtained for solutions containing high concentrations of competing ions—0.2 M K^+ or Ca^{++}, or 3 M Na^+ (Ref. 25).

The poor sorption of Sr in the presence of high concentrations of Na^+ or Ca^{++} might be cause for concern if the Hanford tank farm subsoil should be sufficiently wetted to move the matrix solution to and through the water table essentially unchanged in composition. A statistical equation (Eq. 9, Ref. 25) was developed to estimate for ^{90}Sr K_d in the presence of macroions. For the solution composition of the leaked T-106 liquid (4 M Na^+, 0.0022 M Ca^{++}; K^+ is assumed to be equal to Ca^{++}), K_d = 0.43 and K^{-1} = 0.37 for Sr. If groundwater travel time is 117 years as calculated in Ref. 24, a retardation factor of 0.37 would increase travel time for ^{90}Sr to 117 years/0.37 = 316 years in which time the 1.3×10^{10} µCi (1.13×10^5 µCi/gal x 1.15×10^5 gal) of ^{90}Sr estimated to have leaked from tank T-106 would decay to 5.3×10^6 µCi (0.0004 of the initial value). An estimate of the annual groundwater flow under the Hanford Reservation can be obtained from Ref. 23. That volume, 1.5×10^7 m^3, would have diluted the ^{90}Sr to 3.5×10^{-7} µCi/ml. Thus, even with the poorest sorption conditions, ^{90}Sr concentrations in emerging groundwater contaminated by the T-106 leaked waste volume would be below the standards shown in Table A-5 before dilution by the 1.1 x 10^{17} ml annual flow of the Columbia River.

In the static laboratory studies, limited amounts of sediments were equilibrated with a fixed amount of matrix solution, and the proportions were such that the ion exchange reactions between soil and solution would not change the bulk composition of the solution significantly (Ref. 25). In the dynamic conditions of the field, however, the bulk composition of the solution will be changed by dilution in groundwater and by sorption of the macroions onto the vast amounts of mineral surfaces encountered in transit. Thus, as some point, as the macroion concentrations in the solution are reduced, Sr sorption will improve, and Sr will begin to lag even farther behind the solvent front, thus permitting additional radioactive decay before emergence into the river.

The laboratory studies of the effect of macroions on radionuclide sorption were conducted at pH 7, and the influence of both composition and high alkalinity (characteristic of real waste solutions) was not evaluated. In addition to altering K_d's, reactions can be expected between the alkaline liquids (about 8 M NaOH in the residual alkaline liquor in the stabilized single-shell tanks) and the siliceous components of the sediments. Such reactions can lead to formation of new phases in which some of the radionuclides are effectively trapped at the site (J.A. Apps, private communication). The kinds and extent of such alkaline reaction products seems not to have been studied for the Hanford sediments. The chemical reactions, wetting behavior, and radionuclide movement (particularly of ^{90}Sr) on sediment columns of the residual alkaline liquor need to be investigated. The cores of the wells drilled to investigate the T-106 leak would be a promising set of starting materials.

III.e.4. Soil Moisture Transport. The climate at the Hanford Reservation is generally described as cool mid-latitude desert; i.e., the temperature range is mild, and the annual precipitation is 13 to 26 cm of winter snow and summer rain (Ref. 9). The unsaturated sediment zone is about 100 m thick and is generally classified as dry. The continuing dryness of that zone is an important barrier to movement of leaked radioactive wastes into the groundwater. There was some uncertainty about the fate of the annual precipitation (meteoric water) in the vadose zone sediments; about 10 years ago, on the advice of an NAS committee, several experiments were initiated.

Measurements of ^{3}H from atmospheric weapons test fallout indicated a depth of penetration of meteoric water of about 5 m. Below that depth, ^{3}H concentrations indicated a water age of 25 years or older. Those results suggested that in recent times annual precipitation was not moving from the surface to the water table.

A major progress report of several other experiments is available (Ref. 22). The most recent results of the lysimeter studies are presented in detail. The lysimeters are two columns of uniformly mixed Hanford sediments 3 m in diameter and 18 m high. One is closed at the bottom to intercept percolated water; the control lysimeter is open at the bottom. They are provided with a variety of instruments that measure temperature, water content, and, it is hoped, eventually, local pressure in soil pores. The major finding, which confirms the ^3H measurements, is that annual precipitation penetrates during the cool months to a depth of 4 to 6 m, and then in the warm dry months, it is eliminated upward. A very dry zone (1.4% moisture by weight) was identified at the 15- to 18-m depth (at the level of the waste tank bottoms); the authors suggest that this is an additional barrier to deep penetration of surface waters.

Some questions still remain. A puzzling aspect of the 1973-74 lysimeter studies that were reported was the finding of a stationary "perched" envelope of the annual precipitation at the 6-m depth of the open lysimeter. Early publication of the more recent data is strongly encouraged. The entire set of experiments should be summarized and published in an open literature.

On the basis of their measurements as of 1974, the authors concluded that the Hanford site was one of the best suited for storage and/or disposal of radioactive wastes.

III.f. Environmental Monitoring

Annual environmental reports (Refs. 29, 30, for example) are published of the measurements of external radiation levels and the radionuclide contents of air, water, groundwater, soil, natural vegetation, crops and foodstuffs, and wild vertebrates on and in the neighborhood of the Hanford site. In some locations on the Columbia River shoreline in the Hanford reach area, thermoluminescent dosimeters show radiation levels 2 to 6 times background. The highest readings are obtained at N-trench springs and are attributable to the continued operation of N-reactor. Radiation levels and radionuclide concentrations off site have not been increasing, but rather have been declining, as the levels of worldwide fallout from atmospheric tests have declined, and the nuclides produced by the earlier operations of the once-through-cooled reactors decay or are cleared from the river by burial or scouring. By 1977 radiation levels from the old Hanford reactor operations had declined enough to open the entire Columbia River shoreline and islands to public access.

IV.a. General Comments, Studies of the Hanford Site

Steady progress has been made to define quantitatively for the Hanford site the moisture transport behavior in the unsaturated zone, the sorption characteristics of the Hanford sediments, and the ability to predict movement of local groundwater in a realistic way. Some of that work has been published in scientific journals as well as in internal documents; the project reports continue to the best sources of original data. External publication should be encouraged because the work is of good quality, and much of it, in particular the groundwater modeling studies, is applicable to the general problems of disposal of toxic wastes.

IV.b. Biological Effects of Radionuclides

Research on the behavior of the important radionuclides in fission wastes has more precisely defined their absorption and temporal distribution after oral intake by people and the amount of radiation dose that will be absorbed in critical tissues. Continued observation of irradiated human populations and closer definition of their radiation doses have led to development of a set of quantitative estimates of the risk to human health of an exposure to ionizing radiation.

The new biologic parameters and dose calculation methods recommended by ICRP (Refs. 4, 6) and the radiation risk factors adopted by ICRP (Ref. 4) have been combined in this report to provide a way to judge the risk to human health incurred by ingesting radionuclides in fission wastes. These risks may be compared to the risk that can be calculated for natural background radiation.

A "worst case" analysis was presented in which it was assumed that all the residual alkaline liquor remaining in the single-shell tanks after stabilization (drainable but not pumpable fluid) was dumped directly into the Columbia River in 1984. That analysis led to estimates of the risks to health of the users of that water (for drinking, growing, and eating irrigated crops), which were about two times natural background risk.

IV.c. Concluding Remarks

The laboratory research and field experience at Hanford confirm quantitatively that the dryness of the sediment zone above the water table, the sorption properties of the tank farm sediments, dilution in groundwater, and the long flow paths of groundwater to the Columbia River constitute a series of independent barriers which prevent radionuclides deposited in subsoil by leakage from the waste tanks from moving to the Columbia River before their radiologic hazard has been eliminated by decay. Imposition of any or all of those barriers to radionuclide migration serves to reduce still further the low risk (two times background) which would result from complete dispersal of all the radionuclides in the drainable liquid left in the single-shell waste tanks.

/s/ Patricia W. Durbin, PhD
Berkeley, California
Feb. 24, 1980

TABLE A-1

Individual radiation dose commitment and the associated risk of adverse health effects (AHE), fatal cancer in the exposed individuals, or genetically-based disease in all subsequent generations of their descendants, as a result of ingestion of 1 microcurie of a radioactive constituent of unseparated high level fission waste.

Nuclide	Target Tissue[a]	Risk Factor[b] (AHE/rem-70 yr)	E_{eff}[c] (MEV)	Mass[d] (g)	f_w[e]	T_{eff}[f] (day)	Decay[g] k_D	Dist.[h] k_d	Dose-70yr[i] (rem/μCi ingested)	Risk / μCi ingested
^{79}Se	Body	3×10^{-4}	0.05	7×10^4	0.9	11	1	1	5.2×10^{-4}	1.6×10^{-7}
^{90}Sr	Bone	5×10^{-6}	1.13	5×10^3	(	0.2 x 580	)[j]	0.71	0.95	4.8×10^{-6}
	Redmarrow	2×10^{-5}	1.13	5×10^3				0.28	0.38	7.6×10^{-6}
	Total									1.2×10^{-5}
^{93}Zr	LLI	1×10^{-5}	0.02	150	-	0.75	-	0.28	2.6×10^{-3}	2.6×10^{-8}
^{99}Tc	LLI	1×10^{-5}	0.094	150	-	0.75	-	0.28	1.2×10^{-2}	1.2×10^{-7}
^{106}Ru	LLI	1×10^{-5}	1.3	150	-	0.75	-	0.28	0.17	1.7×10^{-6}
^{126}Sn	LLI	1×10^{-5}	0.3	150	-	0.75	-	0.28	3.8×10^{-2}	3.8×10^{-7}
^{129}I	Thyroid	5×10^{-6}	0.068	20	0.3	1.4×10^2	1	1	10.4	5×10^{-5}
^{134}Cs	Body	3×10^{-4}	1.1	7×10^4	1.0	65	1	1	7.6×10^{-2}	2.3×10^{-5}
^{135}Cs	Body	3×10^{-4}	0.066	7×10^4	1.0	70	1	1	4.9×10^{-3}	1.5×10^{-6}
^{137}Cs	Body	3×10^{-4}	0.59	7×10^4	1.0	70	1	1	4.4×10^{-2}	1.3×10^{-5}
^{144}Ce	LLI	1×10^{-5}	1.3	150	-	0.75	-	0.5	0.17	1.7×10^{-6}
^{147}Pm	LLI	1×10^{-5}	0.069	150	-	0.75	-	0.5	8.8×10^{-3}	8.8×10^{-8}
^{151}Sm	LLI	1×10^{-5}	0.041	150	-	0.75	-	0.5	5.2×10^{-3}	5.2×10^{-8}
^{152}Eu	LLI	1×10^{-5}	0.65	150	-	0.75	-	0.5	8.3×10^{-2}	8.3×10^{-7}
^{154}Eu	LLI	1×10^{-5}	0.69	150	-	0.75	-	0.5	8.8×10^{-2}	8.8×10^{-7}
^{226}Ra	Bone	5×10^{-6}	220	5×10^3	(	0.18 x 125	)[j]	0.4	30	1.5×10^{-4}
^{230}Th	Bone	5×10^{-6}	96	5×10^3	1.4×10^{-4}	3.6×10^4	0.37	10	26	1.3×10^{-4}

TABLE A-1 (Continued)

Nuclide	Target Tissue[a]	Risk Factor[b] (AHE/rem-70 yr)	Eeff[c] (MEV)	Mass[d] (g)	fw[e]	Teff[f] (day)	Decay[g] k_D	Dist.[h] k_d	Dose-70yr[i] (rem/μCi ingested)	Risk μCi ingested
^{230}Th	Liver	1×10^{-5}	96	1.7×10^{3}	8×10^{-6}	7×10^{2}	1.0	1	2.4×10^{-2}	2.4×10^{-7}
	Gonads	2×10^{-4}	96	$(2 \times 10^{-9})^{k}$		(1.1×10^{4})		1	1.1×10^{-1}	2.2×10^{-5}
	Total									1.5×10^{-4}
233, 235 ^{238}U	Bone[1]	5×10^{-6}	92	5×10^{3}	1.2×10^{-3}	5×10^{3}	0.97	0.36	2.8	1.4×10^{-5}
	Kidney[1]	1×10^{-5}	92	150	2.6×10^{-5}	1.5×10^{3}	1	-	1.6	1.6×10^{-5}
	Body[1]	2.8×10^{-4}	92	6.5×10^{4}	2.6×10^{-5}	1.5×10^{3}	1	-	7.8×10^{-3}	2.2×10^{-6}
	LLI	1×10^{-5}	0.92	150	-	0.75	-	0.5	1.2×10^{-1}	1.2×10^{-6}
	Total[1]									3.4×10^{-5}
^{237}Np	Bone	5×10^{-6}	100	5×10^{3}	2.2×10^{-4}	3.6×10^{4}	0.37	10	45	2.2×10^{-4}
	Liver	1×10^{-5}	100	1.7×10^{3}	5×10^{-6}	1.5×10^{4}	0.7	1	0.22	2.2×10^{-6}
	Gonads	2×10^{-4}	100	$(1 \times 10^{-9})^{k}$		(1.1×10^{4})		1	5.6×10^{-2}	1.1×10^{-6}
	Total									2.2×10^{-4}
^{238}Pu	Bone	5×10^{-6}	110	5×10^{3}	4.5×10^{-5}	1.7×10^{4}	0.64	10	8.2	4.2×10^{-5}
	Liver	1×10^{-5}	110	1.7×10^{3}	4.5×10^{-5}	1×10^{4}	0.82	1	1.8	1.8×10^{-5}
	Gonads	2×10^{-4}	110	$(1 \times 10^{-9})^{k}$		3.3×10^{4}	0.20	1	5.6×10^{-2}	1.1×10^{-5}
	Total									7.1×10^{-5}
239, ^{240}Pu	Bone	5×10^{-6}	110	5×10^{3}	4.5×10^{-5}	3.6×10^{4}	0.37	10	9.6	4.8×10^{-5}
	Liver	1×10^{-5}	110	1.7×10^{3}	4.5×10^{-5}	1.5×10^{4}	0.70	1	2.2	2.2×10^{-5}
	Gonads	2×10^{-4}	110	$(1 \times 10^{-9})^{k}$		(1.1×10^{4})		1	6×10^{-2}	1.2×10^{-5}
	Total									8.2×10^{-5}
^{241}Pu	Bone	5×10^{-6}	2.8	5×10^{3}	4.5×10^{-5}	4.2×10^{3}	1	10	1.6×10^{-1}	8×10^{-7}
	Liver	1×10^{-5}	2.8	1.7×10^{3}	4.5×10^{-5}	3.6×10^{3}	1	1	4×10^{-2}	4×10^{-7}
	Gonads	2×10^{-4}	2.8	$(1 \times 10^{-9})^{k}$		4.8×10^{3}	0.80	1	1.6×10^{-3}	3.2×10^{-7}
	Total									1.5×10^{-6}

TABLE A-1 (Continued)

Nuclide	Target Tissue[a]	Risk Factor[b] (AHE/rem-70 yr)	Eeff[c] (MEV)	Mass[d] (g)	fw[e]	Teff[f] (day)	Decay[g] k_D	Dist.[h] k_d	Dose-70yr[i] (rem/μCi ingested	Risk / μCi ingested
^{242}Pu	Bone	5×10^{-6}	100	5×10^{3}	4.5×10^{-5}	3.6×10^{4}	0.37	10	9.0	4.4×10^{-5}
	Liver	1×10^{-5}	100	1.7×10^{3}	4.5×10^{-5}	1.5×10^{4}	0.70	1	2.0	2×10^{-5}
	Gonads	2×10^{-4}	100	(1×10^{-9})[k]		(1.1×10^{4})		1	5.6×10^{-2}	1.1×10^{-5}
	Total									7.5×10^{-5}
^{241}Am	Bone	5×10^{-6}	110	5×10^{3}	2.2×10^{-4}	3×10^{4}	0.45	10	50	2.6×10^{-4}
	Liver	1×10^{-5}	110	1.7×10^{3}	2.2×10^{-4}	1.3×10^{4}	0.73	1	10	1×10^{-4}
	Gonads	2×10^{-4}	110	(5×10^{-9})[k]		(1.1×10^{4})		1	3.2×10^{-1}	6.2×10^{-5}
	Total									4.2×10^{-4}
^{244}Cm	Bone	5×10^{-6}	120	5×10^{3}	2.2×10^{-4}	5.7×10^{3}	1.0	10	22	1.1×10^{-4}
	Liver	1×10^{-5}	120	1.7×10^{3}	2.2×10^{-4}	4.6×10^{3}	0.98	1	5.2	5.2×10^{-5}
	Gonads	2×10^{-4}	120	(5×10^{-9})[k]		6.7×10^{3}	0.68	1	2×10^{-1}	4×10^{-5}
	Total									2×10^{-4}
^{3}H	Body	3×10^{-4}	0.01	6.3×10^{4}	1.0	10	1	1	1.2×10^{-4}	3.5×10^{-8}

Footnotes - Table A-1

[a] The chemical properties of each radioelement determine its site of deposition in the body and, consequently, the site in which its decay energy will be absorbed. The target tissue contains the cells in which an adverse health effect may be induced by the ionizing radiation from a specific radionuclide deposited in tissue.

[b] Risk factors were taken from ICRP Pub. 26 (Ref. 4). See also Table A-2 of this report.

[c] E_{eff} is the decay energy absorbed in the cells of the target tissue, E_{eff} = E x QF, and QF = 20 has been used for alpha particles. Data for E are taken from ICRP Pub. 2 (Ref. 2). For alpha emitters that irradiate the lower large intestine (LLI), only 1% of the decay energy is assumed to be absorbed in the proliferating intestinal epithelial cells.

[d] Mass of the target tissue; data are taken from ICRP Pub. 23 (Ref. 5).

[e] f_w is the fraction of ingested nuclide that is deposited in the target tissue, $f_w = f_1 \times f_2$, where f_1 is the fraction of the radionuclide absorbed via the intestinal tract into blood and f_2 is the fraction of total body content initially deposited in the target tissue (or in adjacent tissues constituting a radiation source to the critical cells of the target tissue) data are taken from ICRP Pub. 30 (Ref. 6), where available, otherwise from ICRP Pub. 2 (Ref. 2) or ICRP Pub. 19 (Ref. 7).

[f] T_{eff} is the effective half-life of the radionuclide in the target tissue, $T_{eff} = (T_b \times T_p)/(T_b + T_p)$, where T_b and T_p are the biological and physical half-lives, respectively data taken from ICRP Pub. 30 (Ref. 6) where available, otherwise from ICRP Pub. 2 (Ref. 2) and ICRP Pub. 19 (Ref. 7).

[g] k_D is the fraction of total decay events that occur in the target tissue. For all tissues except gonads, $k_D = (1 - e^{-1.77 \times 10^4/T_{eff}})$, where the constant = 70 years x 365 days/ year x 0.693. For gonads, an average genetically significant time of 30 years was assumed, and $k_D = (1 - e^{-7.6 \times 10^3/T_{eff}})$.

[h] k_d is a dimensionless dose distribution factor required to convert average dose in the target tissue to the dose to critical cells.

[i] Radiation dose calculations:

Lower large intestine, Dose (rem) = (51.2 rad/day/μCi/g) x 1 μCi ingested x E_{eff} x (k_d/m) x 0.75 day

Dose commitment (integrated dose) to tissues containing radionuclides, 30 years for gonads, 70 years for all other tissues

Dose (rem) = (51.2 rad/day/μCi/g) x 1 μCi ingested x E_{eff} x (k_d/m) x f_w x $(T_{eff}/0.693)$ x k_D.

[j] For the alkaline earth elements in bone, (^{90}Sr and ^{226}Ra) f_1 and the fraction retained in bone (integrated for 70 years) were taken from ICRP Pub. 20 (Ref. 8).

[k] For actinide elements in gonads, ICRP Pub. 30 (Ref. 6) gives a combined term, $f_2/m = 10^{-5}/g$, for the average concentration on either testes or ovaries. It is further assumed that in gonads $T_b = \infty$; so, for nuclides with $T_p \gg 30$ years, the product, $(T_{eff}/0.693) \times k_d$, is replaced by $t = 1.1 \times 10^4$ day. For the shorter lived actinide nuclides, $T_{eff} = T_p$.

[l] The long-lived uranium isotopes pose some special problems for this presentation. ICRP Pub. 30 (Ref. 6) recommends use of two-component exponential terms to describe uptake and retention of U in bone, kidney, and whole body. Only the parameters of the longer-lived components are shown here. The shorter-lived components, which contribute 3.5% to the bone dose and 48% to the kidney and whole body doses, have been included in the total doses given here.

ICRP Pub. 30 (Ref. 6) also recommends, and it has been used here, $f_1 = 0.05$ for most soluble U compounds. However, the intestinal absorption of U is dependent on the amount ingested. The specific activity of ^{238}U, the dominant isotope, is 3×10^6 g/Ci, and 1 μCi of U weighs about 3 g. For a 70-kg man, that is an intake of 43 mg/kg, for which, from experiments, f_1 is only 0.0015, about 1/35 of the recommended value. Thus, the values given for the doses and associated risks from ingestion of 1 μCi of U isotopes are probably at least 35 times too large.

TABLE A-2

Risk of Adverse Health Effects (fatal cancer or genetic defects) from exposure of an individual to ionizing radiation.

Malignancy in Tissue	Lifetime risk/rem[a]
Bone marrow (leukemia)	2×10^{-5}
Lung	2×10^{-5}
Female breast	2.5×10^{-5} (x 0.5)[b]
Thyroid	5×10^{-6}
Bone (surfaces)	5×10^{-6}
Other tissues	1×10^{-5} (x 5 for whole body)
Total risk of malignancy for whole-body irradiation	11.25×10^{-5} (about 1×10^{-4})
Genetic effects	
First two generations	1×10^{-4}
All subsequent generations	1×10^{-4}
Total generic risk	2×10^{-4}
Total health effects	3×10^{-4}

[a] ICRP concludes that these risk factors for radiation-induced malignancy are appropriate average values for both sexes and all ages (Ref. 6).

[b] Assuming one-half the population is female.

TABLE A-3

Radionuclides in residual liquor in Hanford waste tanks as of 1984. Concentration in water and individual human intakes, if 10^6 gal. of drainable liquor were placed directly into Columbia River in one day or during one year.

Nuclide	1990[a]	11 x 10^6 gal. 1984		1 x 10^6 gal. drainable[c]	Inventory place directly in River: Concentration in water (μCi/ml)[d]		Inventory place directly in River: Individual intake (μCi)[e]
	(Ci)	(Ci)	(Ci/gal.)	(Ci)	1 day	1 year	
^{3}H	1.1×10^{4}	1.4×10^{4}	1.3×10^{-3}	1.3×10^{3}	4×10^{-6}	9×10^{-9}	8.3×10^{-3}
^{90}Sr	6×10^{5}	6.8×10^{5}	6.2×10^{-2}	6.1×10^{4}	2×10^{-4}	6×10^{-7}	4×10^{-1}
^{99}Tc	3.1×10^{4}	3.1×10^{4}	2.8×10^{-3}	2.8×10^{3}	1×10^{-5}	2.5×10^{-8}	1.9×10^{-2}
^{106}Ru	3.7×10^{1}	1.2×10^{3}	1.1×10^{-4}	1.1×10^{2}	4×10^{-7}	1×10^{-9}	7×10^{-4}
^{129}I	4.7×10^{1}	4.7×10^{1}	4.3×10^{-6}	4.2	1×10^{-8}	4×10^{-11}	2.8×10^{-5}
^{134}Cs	4.3×10^{2}	2.5×10^{3}	2.3×10^{-4}	2.2×10^{2}	8×10^{-7}	2×10^{-9}	1.4×10^{-3}
^{135}Cs	1.6×10^{2}	1.6×10^{2}	1.4×10^{-5}	1.4×10^{1}	5×10^{-8}	1×10^{-10}	9.4×10^{-5}
^{137}Cs	1.8×10^{7}	2×10^{7}	1.9	1.8×10^{6}	6×10^{-3}	2×10^{-5}	1.2×10^{1}
^{93}Zr[b]	-	8×10^{2}	7×10^{-5}	8×10^{1}	2.5×10^{-8}	6×10^{-11}	5×10^{-5}
^{147}Pm[b]	-	3.3×10^{4}	3×10^{-3}	2.2×10^{3}	8×10^{-6}	2×10^{-8}	1.4×10^{-2}
^{151}Sm[b]	-	1.2×10^{5}	1.1×10^{-2}	1.1×10^{4}	4×10^{-5}	1×10^{-7}	6.9×10^{-2}
^{154}Eu[b]	-	5.5×10^{1}	5×10^{-6}	5.2	2×10^{-8}	5×10^{-11}	3.1×10^{-5}
$^{239,\ 240}Pu$[b]	-	4.3×10^{1}	3.9×10^{-6}	3.9	1×10^{-8}	4×10^{-11}	2.8×10^{-5}
^{241}Am[b]	-	1×10^{2}	1×10^{-5}	9.	3×10^{-7}	6×10^{-10}	5.6×10^{-4}
^{244}Cm[b]	-	5.5×10^{1}	5.4×10^{-6}	5.6	2×10^{-8}	5×10^{-11}	3.4×10^{-5}

[a] Radionuclide content of residual liquor, major constituents as of 1990 (Table 3.2, Ref. 1) in 11 x 10^6 gal. total volume.

TABLE A-3 (Continued)

[b] Minor radionuclide constituents of alkaline supernate at Savannah River Plant shown for 10 years out of reactor (Table III-5, Ref. 17). Concentrations in Hanford residual liquor is estimated to be 3 times greater and of average age 25 years as of 1984.

Estimated concentration at Hanford = $\text{Ci/gal.}_{\text{SRP-10y}} \times 3 \times e^{-0.693 \times 15/T_{1/2}}$
Estimated inventory at Hanford = 11×10^6 gal. x estimated concentration (Ci/gal.)

^{93}Zr, lanthanides, and actinides are likely to be entrained, nonsettled, colloidal particles rather than in solution and are, therefore, less well absorbed from the human tract than is assumed in these calculations.

[c] Assumes drainable residual liquor in all retired, stabilized Hanford single-shell waste tanks is 10^6 gal. in 1984 at the end of the present pumping schedule.

[d] Columbia River flow at Pasco, $3 \times 10^8 m^3$/day, $1.1 \times 10^{11} m^3$/year main stem plus Ya ima River, with no water treatment.

[e] Individual intake is the same over 1 year (annual intake by ingestion) regardless of whether passage is a one-day pulse or a uniform concentration during 1 year. Assumes total daily fluid intake (only from this source) of 1950 ml, 7.1×10^5 ml) year (Ref. 5).

TABLE A-4

Average annual flow rate of the Columbia River and its tributaries and major municipal and irrigation uses of Columbia River water as of 1970[a].

Annual average flow rate	ft^3/sec
Columbia River main stem at Vernita Bridge	117,000
Yakima River	5,650
Flow rate at Pasco	122,650
Snake River	50,850
Flow rate above McNary Dam	173,500
Other downstream tributaries	75,500
Flow rate at Vancouver, Wash.	249,000
Municipal water use	
Tri-Cities (Richland, Pasco, Kennewick)	60,000 people
No other apparent major municipal use[b]	
Irrigation use	
Within 75 miles of Hanford Reservation	4.6×10^4 acres[c]
(Estimated water use)	2×10^5 acre-ft[d]
Next 65 miles downstream	2.8×10^5 acres
(Estimated water use)	1.2×10^6 acre-ft[d]

[a] Sources: Ref. 18 and Ref. 19, p. II.3-13.

[b] As of 1970, the major communities downstream (Portland, Vancouver, and cities in Washington) appear to use groundwater or tributaries for drinking water.

[c] Calculated area based on authorized use (acre-ft/acre) downstream, i.e., about 4.3 acre-ft/acre, which would be the requirement for a high water crop such as alfalfa.

[d] Authorized use; as of 1970 about one-half was being taken.

TABLE A-5

Limiting concentrations in water and on annual intake by one general public for radioactive constituents of alkaline liquor at Hanford, as recommended by ICRP.

Nuclide	ICRP, 1959 (Ref. 2 and 3)[a]		ICRP, 1979 (Ref. 6)[b]	
	MPC_w (µCi/ml)	Annual intake (µCi)	Annual limit on intake (µCi)	DWC (µCi/ml)
^{3}H [d]	3×10^{-3}	2×10^{3}	8×10^{3}	1×10^{-2}
^{90}Sr	3×10^{-7}	2×10^{-1}	3	4×10^{-6}
^{99}Tc	3×10^{-4}	2×10^{2}	10^{2} c	10^{-4} c
^{106}Ru	1×10^{-5}	8×10^{-1}	10^{1} c	10^{-5} c
^{129}I [d]	6×10^{-8}	5×10^{-2}	5×10^{-1}	8×10^{-7}
^{134}Cs	9×10^{-6}	7	8	1×10^{-5}
^{135}Cs	1×10^{-4}	8×10^{1}	8×10^{1}	1×10^{-4}
^{137}Cs	2×10^{-5}	1×10^{1}	1×10^{1}	2×10^{-5}
^{93}Zr	8×10^{-4}	6×10^{2}	10^{3}	10^{-3}
^{147}Pm	2×10^{-4}	2×10^{2}	10^{2} c	10^{-4} c
^{151}Sm	4×10^{-4}	3×10^{2}	10^{2} c	10^{-4} c
^{154}Eu	2×10^{-5}	2×10^{1}	10^{1} c	10^{-5} c
$^{239, 240}Pu$	5×10^{-6}	4	5×10^{-1}	8×10^{-7}
^{241}Am	4×10^{-6}	3	1×10^{-1}	2×10^{-7}
^{244}Cm	7×10^{-6}	6	2×10^{-1}	3×10^{-7}

[a] MPC_w, Maximum Permissible Concentration in water. Annual intake for continuous use by general public calculated assuming total fluid intake of 8×10^{5} ml/year (Ref. 2).

[b] Annual limit on intake (ALI) given in Ref. 6. Derived Water Concentration (DWC) calculated for continuous use assuming the newer value for fluid intake of 7.1×10^{5} ml/year. Values given by ICRP were for workers, and those have been reduced by 0.1 to conform to earlier applications to protection of the general public.

[c] No data were given by ICRP (Ref. 6) for these radionuclides. By analogy to isotopes of ^{144}Ce, intakes are limited to the Lower Large Intestine. Values shown are approximate and are based on the energies and half-lives of the isotopes.

[d] These amounts of ^{3}H and ^{129}I are maximal and are probably over estimates of the quantities remaining in the liquor in the waste tanks. Much of the ^{129}I would have been lost during the original dissolution of the fuel and most of the ^{3}H should have followed the water in the process of evaporation.

TABLE A-6

Summary of risk/person of Adverse Health Effects incurred by drinking untreated Columbia River water contaminated in 1984 by direct dumping of 10^6 gal. of residual alkaline liquor in Hanford wastes.

Nuclide	Intake (μCi)[a]	Adverse Health Effects (AHE)/μCi ingested[b]	Risk of AHE/person
^{3}H	8×10^{-3}	3.5×10^{-8}	2.9×10^{-10}
^{90}Sr	4×10^{-1}	1.2×10^{-5}	4.8×10^{-6}
^{99}Tc	1.9×10^{-2}	1.2×10^{-7}	2.3×10^{-9}
^{106}Ru	7×10^{-4}	1.7×10^{-6}	1.2×10^{-9}
^{129}I	2.8×10^{-5}	5×10^{-5}	1.4×10^{-9}
^{134}Cs	1.4×10^{-3}	2.3×10^{-5}	3.2×10^{-8}
^{135}Cs	9.4×10^{-5}	1.5×10^{-6}	1.4×10^{-10}
^{137}Cs	1.2×10^{1}	1.3×10^{-5}	1.6×10^{-4}
^{93}Zr	5×10^{-5}	2.6×10^{-8}	1.3×10^{-12}
^{147}Pm	1.4×10^{-2}	8.8×10^{-8}	1.2×10^{-9}
^{151}Sm	6.9×10^{-2}	5.2×10^{-8}	3.6×10^{-9}
^{154}Eu	3.1×10^{-5}	8.8×10^{-7}	2.7×10^{-11}
$^{239,\ 240}Pu$	2.8×10^{-5}	8.2×10^{-5}	2.3×10^{-9}
^{241}Am	5.6×10^{-4}	4.2×10^{-4}	2.4×10^{-7}
^{244}Cm	3.4×10^{-5}	2×10^{-4}	6.8×10^{-9}
		Total risk	1.65×10^{-4} [c] (97% from ^{137}Cs)

[a] From Table A-3.

[b] From Table A-2.

[c] Lifetime risk from natural background of 0.1 rem/year = 1.3×10^{-3} (see text).

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Appendix B Correspondence: K. Cartwright

Illinois Institute of Natural Resources

State Geological Survey Division

Natural Resources Building
Urbana, IL 61801
217/344-1481

March 13, 1980

Dr. Robert J. Catlin
Deputy Director of Environmental Compliance
and Overview
U.S. Department of Energy
Mail Stop E-201
Washington, DC 20545

Dear Dr. Catlin:

I have had the opportunity today to review the draft "Assessment of the Surveillance Program of the High-Level Waste Storage Tank at Hanford." I am in general agreement with the report; however, much of the discussion lies outside my area of technical expertise, and I rely on your expertise and that of the other consultants on these matters.

In the area of my technical expertise, I believe your conclusions are correct. I may point out one item: the question continues to arise concerning the frequency of dry well monitoring. I reviewed the technical data provided by Rockwell International, but do not feel it is conclusive. I refer you to my statements in my letter of February 29, 1980, and point out that, in part, the recommendation of more frequent monitoring for some tanks is based on my professional judgment. I must also point out that this applies to only a limited number of tanks.

Thank you for the opportunity to review the draft.

Very truly yours,

Keros Cartwright
Geologist and Head
Hydrogeology and Geophysics Section

Illinois Institute of Natural Resources

State Geological Survey Division

Natural Resources Building
Urbana, IL 61801
217/344-1481

February 29, 1980

Dr. Robert J. Catlin
Deputy Director of Environmental Compliance
and Overview
U. S. Department of Energy
Mail Stop E-201
Washington, DC 20545

Dear Dr. Catlin:

I would like to modify some of the comments in my letter of December 21, 1979, in light of the reply and comments received from Rockwell International (Internal letter from W. H. Price to W. F. Heine dated January 29, 1980). In general, Mr. Price adequately answered my questions.

Mr. Price's point concerning the buffering of fluids which may leak from the waste tanks by the Hanford soils is well taken (answer to question #1). I do not have any serious concerns about the calculations made for the possible discharge in the Columbia River of radioactive ions in the Environmental Statement (ERDA 1538), the National Research Council Report, and Mr. Price's letter.

There are two questions, however, that still need to be considered and were not answered in the Price letter due to, I am sure, poor wording of question #4 in my original letter: 1) What is the initial migration rate of leaking fluid in the vicinity of the tank? and 2) How fast can fluid leak from the tank once the supernatant is pumped out, i.e. drainage from the salt cake and sludge?

The initial rate of migration will be dependent on the earth materials surrounding the tank and the discharge rate and volume of the leak. It was my impression from the discussion with Mr. Price at Richland and reading of the literature that this rate of migration could be quite rapid if there were a large leak from a tank. This point is especially important when considering the frequency of dry well monitoring. This initial rate has not been documented. However, no matter what this initial rate is, it will have little, if any, effect on the long-term migration rates expressed in the reports and Mr. Price's letter.

Once the supernatant is removed, the discharge rate of fluid from a tank (via a leak) probably will change. The control of the initial migration rate outside the tank will be the same. However, the discharge rate from the tank will, very likely, be significantly reduced and thus the initial migration rates outside the tank will also be reduced. The fluid conductivity of the salt cake and sludge and the "fluid table" in the tank will control, along with the size of the hole, the discharge rate. It is clear that the detection of such a leak by dry wells will be less definitive and take a longer time following a leak occurrence.

This leads me to conclude that active tanks, or inactive tanks with large amounts of supernatant still present, should be monitored much more frequency and thoroughly than tanks which have been pumped. Concerning the frequently of dry well monitoring in the active tanks and those with supernatant, we do not have a good estimation of the possible transport rates, but do know they could be quite rapid. I suggest the previous weekly schedule may be appropriate. However, a much longer period between monitoring of dry wells is appropriate after the tanks have been pumped down. I think the dry well monitoring program should be re-tailored on a priority basis to monitor the tanks for which the system will be the most effective; this probably should include the completion of the dry well network around appropriate tanks.

There is a second point which continues to arise in the literature and discussions that bothers me. That is, the statements concerning the lack of ground-water movement in the vadose zone (unsaturated zone) and that moisture from tank leaks will be incorporated in the vadose zone. This concept makes the implicit assumption that the vadose zone, below the upper 5 or 6 meters of active moisture transport, is severely moisture-depleted. However, this is not stated nor is the mechanism for this depletion suggested.

While it is moisture-deficient, I see no reason to assume the sediments below the area of active evaporation are significantly below field capacity (the moisture which a rock or soil will hold against gravity drainage - this is time dependent). Indeed their moisture contents are very stable. Undoubtedly, these sediments were completely saturated with water in the recent geologic past, at the end of the Pleistocene 10,000 to 12,000 years ago. Since that time, (the period of time is unknown) they have lost moisture by gravity drainage to the water table and by vapor transport to the surface. Eventually the system will stabilize and moisture contents of the sediments will become stable, as gravity drainage ceases (in a few years) and vapor from the water table equals that lost to the surface. The data at Hanford suggest that this may be the case there. The final moisture content will be primarily a function of the sediment properties.

In such circumstances the addition of fluid in the subsoil, well below active zones, will cause fluid potentials and movement of contaminants. This will occur until the moisture contents return to a "stable" condition, and water will reach the water table in the process. This rate of movement has not, to my knowledge, been documented, but certainly is very slow, on the order of much less than a centimeter per year and would have an extremely low flux.

Thus, the conclusions drawn by the Hanford studies are not significantly affected; i.e. few radioelements will reach the water table unless other events have or will occur to accelerate the moisture movement. In this regard, it is my understanding that some of the tank farms have a crib in close proximity or associated with the farm. If this is so, the moisture content of the soils could already be increased and moisture movement enhanced.

Dr. Robert J. Catlin
February 29, 1980
Page Three

Let me reiterate that the conclusions drawn in ERDA 1538, the NRC report, and Price's letter are not seriously affected by these comments. That is, the ultimate affect on the Columbia will be negligible.

Very truly yours,

Keros Cartwright
Geologist and Head
Hydrogeology and Geophysics Section

Internal Letter

Rockwell International

Date January 29, 1980

No. 72710-80-023

TO: (Name, Organization, Internal Address)

W. F. Heine
Surveillance & Maintenance
2750-E Bldg., 200 East Area

FROM: (Name, Organization, Internal Address, Phone)

W. H. Price
Earth Sciences Group
MO-028 Trlr., 200 West Area
2-2141

Subject: Earth Sciences Group Reply to Keros Cartwright's Questions

Ref: Letter, December 21, 1979, K. Cartwright to R. J. Catlin

We have reviewed the comments and questions posed to Rockwell Hanford Operations (Rockwell) by Dr. Keros Cartwright of the Illinois State Geological Survey. In this letter, we first address two of Dr. Cartwright's statements that we take partial exception with, followed by our replies to the questions posed by Dr. Cartwright. Dr. Cartwright stated "...The data from the T-106 Tank (RHO-ST-14) suggest that radionuclides are still migrating. The Ruthenium-106 is migrating at a velocity about equal to its decay resulting in an apparent zero rate. Cesium-137 is continuing to migrate both downward and outward."

With the exception of the 1978 movement, there is no evidence of detectable Ruthenium-106 (Ru-106) migration. The 1978 movement was probably caused by an addition of water to the system. In-well total gamma profiles are the only continuous 1973 through 1978 radioactivity data for the leak plume. Total gamma essentially represents a summation of Ru-106 and Cesium-137 (Cs-137) gamma activities for wells 106 - 121. A comparison of profile changes from year-to-year is the only indication of radionuclide migration. These data are provided in Figures K3 through K10 of RHO-ST-14. We believe that these data show that from 1973 to 1978 total gamma levels increased in some sediment layers in all wells. The increased activity levels were due to the lateral movement of the waste in the various sediment layers. In contrast to the 1973 - 1974 period, there is no evidence that the lateral movement of waste has continued at a measurable rate below the backfill since 1974, although limited redistribution may have occurred in the backfill from 1975 to 1976. In fact, the levels have steadily decreased since 1974. This is primarily due to the radioactive decay of Ru-106. Ruthenium-106 was a major gamma activity contribution (>82%) in the 241-T-106 tank supernatant when the leak occurred and has a 1-year half-life. Thus, since 1973, Ru-106 has decayed through several half-lives. In addition, Ru-106 is the most mobile of the readily detectable radionuclides and is the best waste solution tracer. Since 1974, the waste solution has generally moved so slowly that its movement cannot be detected because the rate of radioactive decay of Ru-106 <u>exceeds</u> the rate of further lateral spreading of moisture. This does not indicate, however, that the movement has totally ceased. These statements are true both for Ru-106 and Cs-137.

In wells containing appreciable Cs-137 (106, 107, 109, 110, and 111), total activity can be seen to decay after 1974 until the cesium gamma activity exceeded the ruthenium gamma and total gamma activity then essentially remained constant after this time. In no case did the Cs-137 activity increase in these wells. Examples of this is the 10 - 13 meter level of well 106, the 10 - 12 meter level of well 109, the 10 - 13 meter level of well 110, and the 10 - 15 meter level of well 111.

A second statement that we do not agree with is "..experimental distribution coefficients have been obtained for the Hanford soils; however, these were determined using neutral solutions." This is not true. The sorption work for the T-106 leak was done using a simulated waste solution which was approximately at the pH measured in the T-106 tank supernatant (pH 11.9).

Below are provided our answers to the four specific questions asked by Dr. Cartwright.

1. What will be the effect of pH change, either alkaline or acidic, of the solution on the distribution coefficients (Kd) measured in the laboratory?

   Acid waste solutions are neutralized before storage in tanks at Hanford, therefore, only alkaline wastes may reach the sediments in the event of a tank leak.

   Solution pH is important in determining radionuclide distributions between the groundwater and Hanford sediments. Several attempts have been made to measure the pH effect by adjusting the pH with acids, bases, and buffers. These experiments illustrate that the sediments themselves are effective pH buffers. The groundwater solution in contact with Hanford sediments will gradually approach a pH of 7 - 8 regardless of the starting pH. Adding chemical buffers (sodium acetate, etc.) can also interfere with sorption of radionuclides. To overcome these difficulties, many Kd measurements are made at the pH values dictated by the sediments under study. The pH is always measured, but is not considered a variable. It would seem reasonable that this measured pH is representative of that existing in the field.

2. Do these Kd values represent actual solutions in the tanks? Of particular concern here are the trace concentrations of such ions as plutonium which may be in the solution.

   The composition of tank solutions are altered as they pass through Hanford sediments. Reactions such as precipitation, ion exchange, mineral transformation, dissolution and dilution continuously alter the composition of waste solution plumes. To simulate this changing composition, laboratory Kd measurements have been performed (RHO-LD-87) with widely varying concentrations of macroions such as sodium (Na^+), potassium (K^+), calcium (Ca^{++}), and magnesium (Mg^{++}), which are major cations in both tank solutions and Hanford sediments. In addition, selectivity coefficients for these major cations are being measured for Hanford sediments. This data is required for operation of the PERCOL

Program. Distribution coefficients for all of the important radionuclides in the tanks (including plutonium, americium, and neptunium) have been measured. However, recent emphasis has been on those radionuclides which are known to be most mobile in Hanford subsoils - strontium, cesium, cobalt, ruthenium, neptunium, and technetium. Americium and plutonium have little tendency to migrate except when complexed with chelating agents or in strongly acid solutions.

3. How well do the models, using the available coefficients, predict the Cesium-137 distribution from the T-106 tank leak in the unsaturated zone?

Model predictions of the Cs-137 distribution in the T-106 tank leak plume were made by Intera Environmental Consultants (RHO-CD-790) in 1979. The Cs-137 was predicted to have a nearly symetrical distribution about the horizontal plume through the leak center. This symmetry has not been found in the field and the actual plume is better described as being nearly spheroidal and hanging from the point of leak. There has been no systematic comparison of Intera predictions with actual field values. Since the Intera code is proprietary and not readily available, Rockwell has instead acquired a set of finite element codes.

These Rockwell codes have been used to predict T-106 moisture distribution with good agreement. The modeling of solute transport is underway, and when available a statistical comparison of Cs-137 predictions vs measured will be undertaken. This will be initiated in FY 1980. Also, a field test will be undertaken in FY 1981 that will utilize a buried point source and field observation wells to generate precise data to compare with predictions and evaluate a set of field methods to estimate the hydraulic parameters required by models. Tracers included in this field test include Strontium-85 (Sr-85) and Cesium-134 (Cs-134).

4. What is the velocity and direction of ion transport in the unsaturated zone of the 200 East Area? Of the 200 West Area? Since the geology is different, there may be significant differences in transport. (I also would like to distinguish clearly between ion velocity and rate, which frequently is defined as the discharge per unit area per unit time - i.e., flux. I am interested in the time it takes the chemical front to arrive.)

Soil water flux is determined by the hydraulic conductivity and moisture potential gradient. If one assumes a similar gradient for both the 200 East and 200 West areas, soil water flux in the 200 West Area would be less than in the 200 East Area. More layers containing silts with a low hydraulic conductivity occur in the 200 West Area (including at least one indurated calcic horizon), however, the only long term observations of moisture movement on the Hanford Site were made near the 200 East Area in 20 m long backfilled columns (commonly called lysimeters). The conclusion drawn from these field observations (RHO-ST-15) was that if there were any net liquid flow downward it would be less than 1.0 cm/year.

The average rate and direction of ion transport in the unsaturated zone depends on the ion, season of the year, and depth being considered. For example, lysimeters near the 200 East Area were monitored for five years and it was found that natural moisture could penetrate to the 5 m. depth over the winter and then apparently move back to the atmosphere by evapotranspiration processes. Most soil physicists deny that this can be done by evaporation from the soil surface and plant roots must have extracted moisture from the deeper depths. Field studies are underway to more accurately establish the soil surface boundary condition during the evaporative process and calibrate models for this application.

Below the seasonal zone of wetting and drying, it has been established that the direction of moisture flow is downward at a rate of less than 1 cm/year and probably less than 0.1 cm/year. This gives an estimated pore water velocity less than 10 cm/year. (This figure will undoubtedly be adjusted as field data is obtained and analyzed.) Hence, for Cs-137 with a conservatively estimated retardation factor of 200, the migration rate of the breakthrough $(\frac{C}{Co} = .5)$ front would be less than 0.2 cm/year.

We hope the above responses will sufficiently answer Dr. Cartwright's questions. If further clarification is required, do not hesitate to contact us.

WHP

W. H. Price, Manager
Earth Sciences Group

WHP/RCR/GSB/JBS/ejm

Information:
G. S. Barney
A. G. Law
P. G. Lorenzini
R. C. Routson
J. B. Sisson

Illinois Institute of Natural Resources

State Geological Survey Division

Natural Resources Building
Urbana, IL 61801
217/344-1481

December 21, 1979

Dr. Robert J. Catlin
Deputy Director of Environmental
Compliance and Overview
U. S. Department of Energy
Mail Stop E-201
Washington, DC 20545

Dear Bob:

I am writing concerning my thoughts on the migration of contaminants at the Hanford Reservation. This is not a complete analysis of the problem; however, it describes the situation as I understand it and relay to you the concerns I have at this time. At the meeting in Berkeley, I gave you a list of all the documents I reviewed; I am attaching another copy of that list with this letter. The following discussion is based on those documents and information gathered during our visit to Hanford in October.

At Richland, they have studied the possible transport pathways of radioactive nuclides in the ground-water system. Much of the theoretical work was done by Battelle Northwest while ARCO and Rockwell have done most of the applications. The PERCOL, VTT and MMT-DPRW models are excellent models of the saturated ground-water system, and with adequate input parameters will predict the nuclide transport with as much accuracy as is possible with today's technology. (Modeling technology today far exceeds our capability to measure all the input parameters necessary for the models.)

In addition, work has been carried on in studying the unsaturated ground-water movement from the tank areas to the ground-water table. This provides the contaminant input to the model of the saturated ground-water system. The unsaturated system is not as well understood as the saturated system and, therefore, the modeling of the system is more tentative.

To overcome this latter weakness, any environmental protection afforded by this zone is partially discounted in the hypothetical leaks discussed in ARH-LD-162, and they assumed a percentage of liquid leaked would reach the water table. The result, I believe, is a relatively conservative (worst case) approach to the problems which will occur at the Columbia River.

I am somewhat concerned, however, about the very long-lived nuclides present in the waste. The data from the T-106 tank (RHO-ST-14) suggest that radionuclides are still migrating. The Ruthenium-106 is migrating at a velocity about equal to its decay resulting in an apparent zero rate. Cesium-137 is continuing to migrate both downward and outward. This would be the case for any ion with a half-life significantly longer than the Ruthenium-106. This does not seem to be adequately delt with in any of the reports. There is an assumption, based on some studies, that the unsaturated zone will not transport fluids to the water table, and if any fluid should arrive at the water table, the contaminants will have been held in the "soil" by cation exchange or other processes.

Exchange, and other processes contained in the distribution coefficient, are related to the concentration of the ion in the solution and to its relative concentration in the solution. Thus, it is possible for an ion, which one might think would be easily removed from solution as it passes through the soil, to pass almost unattenuated because other ions are being absorbed. Experimental distribution coefficients have been obtained for the Hanford soils; however, these were determined using neutral solutions (pH 7.0±).

This leads me to several questions which I have of the people at Hanford:

1) What will be the effect of pH charge, either alkaline or acidic, of the solution on the distribution coefficients (Kd) measured in the laboratory?

2) Do these Kd values represent actual solutions in the tanks? Of particular concern here are the trace concentrations of such ions as Plutonium which may be in the solution.

3) How well do the models, using the available coefficients, predict the Cesium-137 distribution from the T-106 tank leak in the unsaturated zone?

4) What is the velocity and direction of ion transport in the unsaturated zone of the 200 E Area? Of the 200 W Area? Since the geology is different, there may be significant differences in transport. (I also would like to distinguish clearly between ion velocity and rate, which frequently is defined as the discharge per unit area per unit time - i.e. flux. I am interested in the time it takes the chemical front to arrive.)

These questions deal primarily with migration of contaminants in the unsaturated zone. Clearly the transport phenomenon is less well known in this zone and it is the most important barrier to contaminant migration from the 200 Areas. They also deal with the speed which the contaminants will travel, and therefore, with the basic question of frequency of monitoring. The impression I have of the data and from discussions at Hanford is that the initial migration of ions will be quite fast, and decrease as the driving head decreases; e.g., moisture contents decrease between the source area and surrounding soil. It also appears that the concentrations assumed to reach the water table in ARH-LD-162 are conservative as they say for the ion calculated.

Dr. Robert J. Catlin
December 21, 1979
Page Three

I think it would be better for Rockwell to reply in writing to these questions, after which some discussion could also be helpful. However, I realize there might not be sufficient time for this approach.

I hope this is helpful to you when you visit Hanford in January. Please call me if you think any of the discussion or questions are unclear or need expanding.

Very truly yours,

Keros Cartwright
Geologist and Head
Hydrogeology and Geophysics Section

Enclosure

Documents Obtained and Reviewed During This Inquiry of the High Level Waste Tanks

Document	ID Number
Disposal of Radioactive Liquid Wastes From the Uranium Recovery Plant	HW-54721
Hanford Groundwater Transport Estimates for Hypothetical Radioactive Waste Incidents	ARH-LD-162
No name given; listed by number and section heading - Introduction - Waste Storage Tank Status - A, AX, AY & AZ Farms - Composit Section - AX Farm Tank - Action Criteria - 241-AY Tank Farm - Action Criteria - 241-AZ Tank Farm - Waste Storage Tank Status - B Farm - Waste Storage Tank Status - BX Farm - Waste STorage Tank Status - BY Farm - Waste Storage Tank Status - C Farm - Action Criteria: 200-East Area Diversion Box Catch Tanks and Diverter Station Catch Tanks - Waste Storage Tank Status - S Farm - Waste Storage Tank Status - SX Farm - Waste Storage Tank Status - SY Farm - Waste Storage Tank Status - T Farm - Waste Storage Tank Status - TX Farm - Waste Storage Tank Status - TY Farm - Waste Storage Tank Status - U Farm - Action Criteria: 200-West Area Diversion Box Catch Tanks and TK-141 and KT-142-S	RHO-CD-213
Waste Status Summary	RHO-CD-14
Alternatives for Long-Term Management of Defense High-Level Radioactive Waste	ERDA 77-44
Interim Report on Status of Containment Integrity Studies for Continued In-Tank Storage of Hanford High-Level Defense Waste	RHO-CD-773
Trace Strontium and Cesium Equilibrium Distribution Coefficients: Batch and Column Determinations	BNWL-SA-843
High-Level Waste Leakage from the 241-T-106 Tank at Hanford	RHO-ST-14
A Column Cation-Exchange-Capacity Procedure for Low-Exchange-Capacity Sands	
^{241}Am, ^{237}Np, and ^{99}Tc Sorption on Two United States Subsoils from Differing Weathering Intensity Areas	
Leach and Soil Column Tests with Stored Redox Sludge	ARH-1733

Document	ID Number
One-Dimensional Model of the Movement of Trace Radioactive Solute Through Soil Columns: The Percol Model	BNWL-1718
A Procedure for Estimating Capacity of a Ground Disposal Facility for Radioactive Waste	HW-57897
Experimental Methods for Obtaining Percol Model Input and Verification	BNWL-1721
Percol User's Manual	BNWL-1720
Sorption of ^{99}Tc, ^{237}Np and ^{241}Am on Two Subsoils from Differing Weathering Intensity Areas	BNWL-1889
Radioactive Wastes at the Hanford Reservation - A Technical Review	
Waste Management Operations - Volume 1 of 2	ERDA-1538
Waste Management Operations - Volume 2 of 2	ERDA-1538
Geology of the Separation Areas, Hanford Site, South-Central Washington	RHO-ST-23
Measurement of Fission Product Sorption Parameters for Hanford 200 Area Sediment Types - Progress Report	RHO-LD-73 Informal Report
Radioactive Waste Management at Hanford	
Sediment Moisture Relations: Lysimeter Project - 1976-1977 Water Year	RHO-ST-15
Hanford Groundwater Modeling - Review of Parameter Estimation Techniques	RHO-C-19
Stratigraphy of the Late Cenozoic Sediments Beneath the 216-A Crib Facilities	RHO-LD-71

Hanford Documents Previously in Personal Files;

Reviewed Where Pertinent to the Question of the High Level Waste Tanks

Document	ID Number
Conceptual and Mathematical Modeling of the Hanford Groundwater Flow Regime	ARH-ST-140
Hanford Pathline Calculational Program - Theory, Error Analysis and Applications	ARH-ST-149
Multicomponent Mass Transport Model: Theory and Numerical Implementation (Discrete-Parcel-Random-Walk Version)	BNWL-2127
A Graphic Degitizer Program to Interpolate Matrix Grid Values: User's Manual	BNWL-1652
Variable Thickness Transient Groundwater Flow Model User's Manual	BNWL-1704
Information Storage and Retrieval System for Well Hydrograph Data User's Manual	BNWL-1705
The Transmissivity Iterative Calculation Routine - Theory and Numerical Implementation	BNWL-1706
The Transmissivity Iterative Programs on the PDP-9 Computer A Man-Machine Interactive System	BNWL-1707
Transmissivity Iterative Program User's Manual	BNWL-1708
Collection and Analysis of Pump Test Data for Transmissivity Values	BNWL-1709
Calculation of Soil Hydraulic Conductivity from Soil-Water Retention Relationships	BNWL-1710
A Study of Soil Matric Potential and Temperature in Hanford Soils	BNWL-1712
Transport Model User's Manual	BNWL-1716
Methods for Estimating Transport Model Parameters for Regional Groundwater Systems	BNWL-1717
Experimental Support Studies for the Percol and Transport Models	BNWL-1719
Graphic Display of Three-Dimensional Surfaces User's Manual	BNWL-1722

Appendix C Correspondence: A. Schneider

DR. ALFRED SCHNEIDER
PROFESSOR OF NUCLEAR ENGINEERING
CONSULTING ENGINEER

GEORGIA INSTITUTE OF TECHNOLOGY
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February 21, 1980

Mr. Robert J. Catlin
Office of Environmental Compliance
and Overview
Mail Stop; E-201
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Catlin:

As previously agreed, I reviewed the following in connection with the evaluation of the surveillance of Hanford waste tanks:

Material balance procedures
Quality assurance
Interstitial liquid level measurement
Techniques for the intensive drying of salt cake and sludges

My writeups on these subjects are enclosed.

During our meeting in Germantown on February 7th, I gave you orally a list of items which I considered to be essential in enabling the Group to answer the questions posed to it. Your outline dated 1-31-80 indicates that the Report which you are preparing is quite comprehensive. Please let me know if I can be of further help to you. I look forward to receiving a draft of the Report for my final comments.

Sincerely yours,

A. Schneider

Alfred Schneider

Enclosures
AS/f

MATERIAL BALANCES

Transfers of liquids are carried out for a variety of reasons. In most cases, these transfers are planned operations and individual procedures are written by Tank Farm Process Engineering for each transfer. Occasionally, emergency transfers may be necessary in case of tank or pipe failures.

At the time liquids are transferred, leak detection and surveillance methods used for quiescent conditions are not generally applicable and careful material balances must be performed at frequent intervals. Material Balance Procedures are defined in TO-025-1 through 50.

There are four types of tank farm transfers: general inter-tank transfers, transfers between farms and processing plants, operation of salt well pumping systems, and transfers within active bottoms systems.

Some transfers lines, both direct buried and encased, failed in the past. Recent experience has shown that line failures are usually not detected during transfers but are found in the course of pressure testing.

The allowable discrepancy between sending and receiving tanks levels after completion of the transfer and line drain is ± 0.5 in., which means that a leak of less than 1,500 gallons could not be detected.

Very detailed material balance procedures have been worked out for the 242-A and 242-S Evaporator Systems. The daily material balance data sheets are reviewed and approved by supervisory personnel. Allowable discrepancies are -5,000 to +9,000 gallons. For the 242-S System there is an additional 10-day average allowable discrepancy of less than negative 2,000 gallons.

Material balances are also performed by the CASS and discrepancies in excess of the established limits are alarmed.

In conclusion:
Material balances are the major surveillance method during transfers. This could be supplemented by leak detection sensors for transfer lines, but detection sensitivities obtainable at present may not be adequate. Operator involvement in material balances is decisive, but some functions (e.g. calculations, recall of previous measurements or results, comparisons with allowable limits, statistical and experience analyses) should be incorporated in a computer system.

QUALITY ASSURANCE

The function of an independent Quality Assurance program in connection with tank farm leak detection is outlined in QA Procedure No. 4-110, issued June 28, 1979.

The requirements cover a wide range of activities, including participation in specific steps aimed at assuring the adequacy of the tank farm leak detection systems. This includes audits of routine measurements and data recording; calibration of instruments; review and approval of new designs, modifications and design changes; and review and approval of procedures.

Organizationally, the Director of Quality Assurance reports to the Vice-President and General Manager of RHO, which should provide the necessary level of authority for the independent conduct of this function.

Verification of QA field performance was not possible as part of this Group's investigation. Mr. H. Spanheimer, QA Representative, stated on November 20, 1979 that "Quality Engineers have received CASS training, quality audits have been conducted on the dry well monitoring procedures, and design reviews were performed on the portable exhauster".

In conclusion:
The importance of an active role for Quality Assurance has been recognized and procedures exist for the implementation of a QA program. Samples of procedures and sign-off sheets show active participation of QA personnel. The limited information available indicates, however, that implementation of the QA program with regard to the surveillance program may have been quite limited.

INTERSTITIAL LIQUID LEVEL MEASUREMENT

The liquid level measurements currently used are based on contact of a pair of electrodes, suspended from a measuring tape with a liquid surface. This method is not applicable in the absence of a liquid surface, as is the case for those tanks where the liquid level has receded below the solid salt cake or sludge, as a result of concentration, crystallization , and pumping out of the supernate.

The measurement of the level of interstitial liquid is important for process control during tank pumping, for estimating the volume of "drainable" liquid which may leak during subsequent tank failures, and for monitoring the tank contents during various stages of stabilization.

Two types of measuring techniques have been proposed:

A dip tube - pressure differential method which can be carried out using the salt well screen provided for the jet pump assembly.

Non-contact instruments installed in dry wells inside the tanks. The interface sensor may consist of a neutron source and detector, an accoustic probe, or a collimated gamma detector.

It appears that none of these probes are operational at this time (RHO 65260-79-06890).

RHO informed in February that by April 15, 1980, six prototype dry wells will be installed in six tanks. An accoustic probe was satisfactorily tested in a laboratory tank containing simulated waste and an instrument suitable for field use will be available by July 1, 1980. Neutron and gamma probes are ready for field use and will be installed by July 1, 1980.

In conclusion:
Interstitial liquid level monitoring is necessary for the assessment of the efficacy of the tank stabilization program, the surveillance of an increasing number of tanks, and the compilation of radioactive waste inventory estimates.
Current estimates of drainable liquid volumes may be quite inaccurate, as evidenced by the progressive increase of the estimates for sludges (zero - five years ago vs. over 12 % at present).
The adoption of interstitial level measurements as part of routine surveillance shouldbe considered.

DRYING OF SALT CAKE AND SLUDGES

It has been recognized that pumping does not achieve complete removal of drainable liquid from tanks containing sludge and salt cake. Thus, there remains the potential for the release of thousands of gallons of radioactive liquids from stabilized tanks. To remedy this situation, RHO has investigated means to remove the residual liquid by intensive desiccation of the tank contents. Four techniques were investigated:

- Microwave drying
- A-C resistance heating
- Induction heating
- Electrokinetic water migration

The last two methods were rejected because of technical difficulties or risk of tank dammage. The studies ranged from literature surveys to laboratory investigations on a pilot scale, at a cost of "several hundred thousand dollars".

Microwave drying and A-C resistance heating are considered feasible, but further work would require the construction of prototype equipment at a cost of 1-2 million dollars. DOE requested that RHO submit by March 15, 1980 the following information before any further work is authorized:

- Estimates for the total volume of interstitial liquid remaining after jet pumping is completed.

- Criteria by which jet pumping is considered to have been completed.

- Evaluation of the consequences of total release of the residual interstitial liquid by leakage to the soil.

In conclusion:
While it is recognized that salt well pumping does not achieve the anticipated full immobilization of wastes in tanks, insufficient information at this time makes the justification of additional drying methods difficult. R & D of intensive drying methods should be continued on a laboratory scale, but prototype testing must await the outcome of the evaluation requested by the DOE. The implication of in-tank drying for long-term waste management programs shouldbe evaluated.

Appendix D Interim Management Directive: IMD No. 5001

Form DOE 3.5
(10-77)

IMD

SERIAL NO 19 IMD NO 5001

DISTRIBUTION CODE

DATE September 29, 1977

APPROVED BY ORDER OF THE SECRETARY

Interim Management Directive

United States Department of Energy

SUBJECT

SAFETY, HEALTH, AND ENVIRONMENTAL PROTECTION

I. PURPOSE

This directive provides general guidance for discharging the safety, health, property, and environmental protection responsibilities in DOE and DOE-controlled operations.

II. POLICY AND OBJECTIVES

It is the policy of the DOE to assure that DOE-controlled operations are conducted in a manner that will minimize undue risks to the safety and health of the public and employees and will provide adequate protection of property and the environment.

The objectives of DOE's health, safety, property, and environmental protection efforts are anticipation and control of the impact of DOE activities upon the environment and compliance with environmental, safety, and health (ES&H) requirements, including applicable statutory requirements affecting Federal facilities and operations.

III. APPLICABILITY

The policy and procedures outlined in this directive are applicable to all DOE and DOE-controlled operations. The extent to which procedures are applicable in those various operations is identified in the section of this directive titled "Procedures."

IV. RESPONSIBILITIES AND AUTHORITIES

The Secretary exercises ultimate authority and responsibility for the Department with respect to assuring safety, health, property, and environmental protection in DOE operations. Operational safety, health, property, and environmental protection is assigned as a basic line management responsibility within DOE and extended to DOE-controlled activities as appropriate through the respective ES&H contract clauses.

Authority for ES&H policy development, standards, safety and environmental reviews, and audits relating to DOE operations is delegated to the Assistant Secretary for Environment.

V. PROCEDURES

Pending the development and promulgation of DOE management directives pertaining to environmental, safety, and health matters, the following references may be used as guideline procedures and standards in the discharge of the Department's safety, health, and environmental protection responsibilities under the Occupational Safety and Health Act of 1970, Executive Order 11807, Executive Order 11752, Atomic Energy Act of 1954, as amended, Energy Reorganization Act of 1974, as amended, and the general Federal environmental and safety laws.

ERDAM 0502, NOTIFICATION, INVESTIGATION, AND REPORTING OF OCCURRENCES (OSHA, EO 11807, operational safety assurance, keeping Congress informed).

ERDAM 0504, OPERATIONAL SAFETY PROGRAM APPRAISALS (Safety assurance through programmatic efforts).

ERDAM 0505, CONSTRUCTION SAFETY PROGRAM (Health and safety during construction).

ERDAM 0506, OCCUPATIONAL SAFETY AND HEALTH PROGRAM FOR ERDA GOCO CONTRACTOR EMPLOYEES (Atomic Energy Act of 1954 provisions for AEC exercise of safety and health statutory authority and agreement with DOL regarding OSHA).

ERDAM 0507, FEDERAL EMPLOYEE SAFETY AND HEALTH PROGRAM (EO 11807) (Revised August 12, 1977).

ERDAM 0510, PREVENTION, CONTROL, AND ABATEMENT OF AIR AND WATER POLLUTION (EO 11752).

ERDAM 0511, RADIOACTIVE WASTE MANAGEMENT (Minimize radioactive exposure and associated risk to man and environment).

ERDAM 0513, EFFLUENT AND ENVIRONMENTAL MONITORING AND REPORTING (To determine compliance with environmental protection standards and to determine the effectiveness of effluent treatment and control, environmental protection, and efforts to achieve levels of radioactivity which are as low as practicable).

ERDAM 0521, MEDICAL INVESTIGATION OF ALLEGED DISABILITIES FROM SPECIAL HAZARDS (Investigation of injuries and illnesses common to nuclear operations).

ERDAM 0524, STANDARDS FOR RADIATION PROTECTION (Assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable).

ERDAM 0525, OCCUPATIONAL RADIATION EXPOSURE INFORMATION (Gather information to determine that radiation doses to individuals are maintained at the lowest levels technically and economically practicable).

ERDAM 0527, RESPONSE TO ACCIDENTS INVOLVING NUCLEAR WEAPONS IN THE CUSTODY OF THE DOD (AEC-DOD Memorandum of Understanding, June 10, 1970).

ERDAM 0528, CONTRACTOR OCCUPATIONAL MEDICAL PROGRAM (Protect contractor employees against health hazards in their work environment).

ERDAM 0529, SAFETY STANDARDS FOR THE PACKAGING OF FISSILE AND OTHER RADIOACTIVE MATERIALS (Assurance of the protection of the public health and safety during transportation of such materials).

ERDAM 0530, NUCLEAR CRITICALITY SAFETY (Protect the health and safety of the public and of Government and contractor personnel working in plants that handle fissionable materials).

ERDAM 0531, SAFETY OF NONREACTOR NUCLEAR FACILITIES (Assure that identifiable risks are no greater than those for comparable licensed nuclear facilities).

ERDAM 0510, PREVENTION, CONTROL, AND ABATEMENT OF AIR AND WATER POLLUTION (EO 11752).

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Appendix E U.S. Atomic Energy Commission Manual Chapter 0511

Form AEC-489
(Rev. 3-73)

U.S. ATOMIC ENERGY COMMISSION
AEC MANUAL

TRANSMITTAL NOTICE

Chapter 0511 RADIOACTIVE WASTE MANAGEMENT

SUPERSEDED:

	Number	Date
Chapter		
Page(s)		
Appendix	IAD 0511-21	3/20/70

TRANSMITTED:

	Number	Date
TN	0500-106	
Chapter	0511 (complete)	9/19/73
Page(s)		
Appendix	0511 (complete)	9/19/73

REMARKS:

This new chapter assigns responsibilities and authorities and establishes procedures for radioactive waste management.

Chapter 0511 RADIOACTIVE WASTE MANAGEMENT

0511-01 POLICY

It is the policy of the AEC to manage radioactive waste in such a manner as to minimize the radiation exposure and associated risk to man and his environment over the lifetime of the radionuclides.

0511-02 OBJECTIVE

To assure safe long-term management of all radioactive waste generated by AEC operations and of that radioactive waste which is delivered to the AEC by licensed operations as required by regulations.

0511-03 RESPONSIBLITIES AND AUTHORITIES

031 **The General Manager** approves the AEC radioactive waste management plan submitted by the Division of Waste Management and Transportation (WMT) and determines compatibility of field office waste management plans with the AEC plan if questions as to compatibility raised by WMT are not resolved by the Assistant General Managers concerned.

032 **The Director, Division of Waste Management and Transportation**:

a. is responsible for program direction and fiscal control of the long-term management of high-level radioactive wastes at AEC facilities.

b. is responsible for program direction and fiscal control of all near-surface radioactive solid waste burial grounds at AEC facilities, and of engineered storage vaults at AEC facilities for interim storage of solid radioactive wastes from licensed activities.

c. is responsible for program direction and fiscal control of operations of Federal repositories for the disposal or long-term storage of radioactive wastes, to include: developing, performing studies for, designing, constructing, demonstrating, and obtaining necessary external reviews and approvals.

d. coordinates the development and annual updating of an overall plan for the management of radioactive waste from AEC operations.

e. calls for field office waste management plans, reviews them with advice of program divisions, and determines their compatibility with the overall plan.

f. exercises overall cognizance, coordination, and review of waste management activities, including the degree of progress in meeting schedules and objectives, to assure compliance with AEC policies and requirements; coordinates with appropriate program divisions to assure that field office waste management planning and budgeting are consistent with the AEC overall plan.

g. develops, recommends, and promulgates policies, guides, and requirements for treatment and storage of liquid, solid, and gaseous wastes at AEC facilities, including the definition of categories of waste; assists the Division of Operational Safety in the development of safety policies, guides, standards, and requirements for the release of radioactive effluents to the environment.

h. determines or approves criteria and specifications, including those relating to packaging and transport, for wastes which are to be stored in near-surface land burial grounds or engineered storage vaults at AEC facilities, or are to be stored in Federal radioactive waste repositories.

i. prepares in cooperation with appropriate field offices and contractor staff, environmental assessments and statements for major AEC waste management facilities, in accordance with IAD-0510-29.

j. maintains: (1) central records of the capabilities and capacities of AEC facilities and Federal repositories for accepting, processing, storing, burying, and disposing of radioactive waste; and (2) central inventories of radioactive waste being stored, buried, or disposed of at AEC facilities and Federal repositories.

k. provides program direction and fiscal control of a research and development program for

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(1) techniques for long-term storage or disposal of commercial and AEC high-level waste; (2) compaction, incineration, or other improvements in handling practices for contaminated solid waste; and (3) improvements in air cleaning or liquid effluent treatment.

l. develops and defends budget estimates for its waste management responsibilities and activities, including facility requirements, and exercises fiscal control over such activities; provides staff assistance to other divisions in the budget submissions of waste management items for which they are responsible.

m. provides advice on applicability or interpretation of the provisions of this chapter and approves exceptions, where warranted, coordinating these actions with appropriate Headquarters divisions.

n. sponsors and coordinates testing and development of improved products and systems (such as High Efficiency Particulate Air Filters) for reducing to the lowest economically and technically practical[1] level radioactive material releases to the environment.

o. with regard to the above assigned responsibilities, acts as the General Manager's staff liaison and point of contact with the Office of Regulation and with other Federal, state, or local groups with regard to activities concerning (1) AEC-generated wastes and (2) commercially generated wastes to be delivered to the AEC as required by regulations.

033 The Director, Division of Operational Safety:

a. develops, recommends, and promulgates policy, standards, and requirements relevant to (1) the protection of man and the environment from radiation or contamination, and (2) safety of systems and system components used for controlling radioactive material discharge to the environment.

b. exercises overall surveillance, evaluation, and appraisal of AEC site effluent and environmental monitoring programs to assure compliance with. AEC safety standards and policy relating to protection of man and his environment in accordance with AECM 0513, and coordinates such monitoring programs with comparable programs of other agencies.

c. in cooperation with WMT, evaluates radioactive waste management programs to assure that the AEC policy of controlling the release of radioactive materials to the lowest levels[2] technically and economically practical is being implemented.

d. appraises the safety aspects of field office waste managment programs and activities.

e. reviews waste management plans in relation to their impact on man and the environment and recommends any appropriate modifications to the Director, Division of Waste Management and Transportation.

f. coordinates with appropriate directors of program divisions prior to establishing policy standards which may have a programmatic impact.

034 Directors of Program Divisions, Headquarters:[3]

a. consistent with programmatic responsibilities and the provisions of sections 032 above and 044 below, provide direction of operations involving radioactive waste generated in their programs.

b. within programmatic responsibilities, may provide direction and guidance consistent with appendix part II for the preparation of waste management plans to be submitted by field office managers under 038(c).

c. review waste management plans submitted by field office managers relative to each site at which they have programmatic responsibilities, including related comments of other program divisions which have activities at those same sites, and consult with the Director, WMT, concerning his review function described in 032(e).

d. as requested by the Director, WMT, review inquiries on the applicability or interpretation of the provisions of this chapter and requests for exemptions.

e. consult with the Director, OS, in matters relating to policy, standards, and requirements relevant to the protection of man and the environment from radiation or contamination.

035 The Director, Division of Naval Reactors, assumes the same responsibilities as managers of field offices for its respective program activities.

036 The Director, Office of Information Services, assumes responsibilities for waste generated in connection with nuclear exhibits not under direction of any field office manager.

037 The Director, Division of Construction:

a. develops or approves in conjunction with WMT, and other concerned Headquarters divisions, design criteria for facilities to be constructed or modified for the purpose of processing or storing radioactive wastes or of controlling the release of radioactive wastes to the environment.
b. reviews waste management plans relative to their planned construction activities and advises the Director, Division of Waste Management and Transportation, on the estimated costs and schedules and conformance with design criteria.

038 Managers of Field Offices:

a. assure that the relevant criteria in 044, below, are followed in developing practices for routine and emergency operations at AEC installations under their jurisdictions and that current practices, where differing, are revised to comply with the criteria.
b. refer questions as to applicability, interpretation, or exemption from the criteria (see 044, below) to the Director, Division of Waste Management and Transportation, through the appropriate program divisions.
c. prepare and submit to WMT, with copies to the appropriate program divisions, annually updated waste management plans for their sites, following the general guidance in appendix 0511, part II.
d. maintain suitable approval control over key waste managment decisions of operating contractors, such as the establishment or major modification of:
   (1) operating limits for quantities or concentrations of radioactive materials released to the environment.
   (2) release locations and timing of releases.
   (3) methods of treatment of effluents to minimize release of radioactive materials.
   (4) methods of conversion of high-level liquid waste for interim storage or disposal.
   (5) process flowsheets, to the extent that they determine the quality or quantity of wastes.
   (6) methods of interim storage of solid wastes.
e. assure that for AEC operational situations, calculations related to burial/storage operations include full cost, exclusive of land, depreciation, added factor, and perpetual care costs. For purposes of comparative cost evaluations of solid waste burial or storage with and without additional processing for volume reduction, all costs are included, e.g., depreciation of facilities, cost of land, and present worth of perpetual care costs.
f. maintain records of radioactive waste stored or buried at their sites.
g. conduct a program of annual appraisals of contractor radioactive waste management activities.

0511-04 BASIC REQUIREMENTS

041 Applicability. This chapter applies to divisions and offices, Headquarters, field offices, and contractors who operate AEC-owned or -controlled facilities and whose contracts contain the Standard Safety, Health, and Fire Protection Clause (see AECPR 9-7.5006-47).

042 Coverage. This chapter and its appendix specify the responsibilities, requirements, and procedures which shall govern the management of radioactive waste.

043 Appendix 0511. Appendix 0511 contains definitions (part I) and guidance (part II) for use in implementing the policies and responsibilities of this chapter. The detail of the appendix is not to be taken as all-inclusive nor should it preempt the use of good judgment by knowledgeable field office and contractor staff in the development of safe practices and controls in the management of radioactive waste.

044 Operating Criteria. To assure an effective program for the management of radioactive waste, the following criteria shall be observed:

a. **General**
   (1) Field offices and their contractors shall conduct their operations and dispose of and store radioactive waste in such a manner as to assure that present and future radiation exposures to individuals and population groups will be at the lowest levels technically and economically practical not exceeding limits established in AECM 0524 appendix parts I and II.
   (2) Continuing efforts shall be made to develop and use improved technology for reducing the radioactivity releases to

the lowest technically and economically practical level.

(3) High-level liquid radioactive waste shall not be transported offsite.

(4) The extent and degree of radioactive contamination of land by AEC waste management activities shall be minimized.

b. **High-Level Radioactive Waste**

(1) High-level liquid wastes shall be converted to suitable physical and chemical forms and confined in a manner which shall provide high assurance of isolation from man's environment with minimal reliance on perpetual maintenance and surveillance by man under conditions of credible geologic, seismic, and other naturally occurring events.

(2) High-level liquid radioactive wastes may be initially stored in carefully engineered systems equipped with adequate provision for leak detection and control. Tanks and transfer systems shall be designed to resist credible internal and external forces. Technology shall be developed and employed as soon as practical to reduce the volume and mobility of the high-level liquid wastes placed in initial storage facilities.

(3) High-level liquid wastes in initial storage and high-level wastes in long-term storage, or in pilot plant facilities shall, in each case, be contained and emplaced so as to be retrievable for removal and transfer elsewhere. The method of storage and the physical and chemical forms of the stored waste shall be predicated on safety and not on possible retrieval for recovery of fission products for beneficial uses.

(4) The radioactivity and the chemical and physical characteristics of all high-level wastes in initial, long-term, or pilot plant storage shall be determined for each condition of storage.

(5) Spare tanks shall be maintained providing volume in excess of initial storage requirements for high-level liquid wastes. Each tank farm holding high-heat liquid waste shall have available, in tanks empty except for a residual heel, space equivalent to the largest volume of such wastes stored in any one tank. Each tank farm holding low-heat liquid waste shall have available reserve storage capacity to accommodate the contents of the largest tank in the system. Where interconnected tank farms are sufficiently close that the times required to transfer tank contents between farms are similar to the times required to transfer tank contents within a farm, such interconnected tank farms may be considered as a single tank farm for purposes of the above requirements.

c. **Other Liquid Radioactive Waste**

(1) Liquid radioactive waste not meeting the definition of "high-level waste" shall be converted into two fractions, one consisting of liquids which can be discharged to the environment pursuant to AECM 0524 (i.e., persons in uncontrolled areas will not be exposed to concentrations in excess of those prescribed in table II, annex A, appendix 0524) and the other consisting of either: (a) high-level liquid waste, which would be handled in accordance with the policies of b., above; or (b) solid waste which would be handled in accordance with the policies in d., below.

(2) As soon as technically and economically practical, the use of natural-soil columns (such as cribs, seepage ponds, and similar facilities) for liquid streams that exceed established standards for release of radioactivity to uncontrolled areas shall be replaced with other treatment systems. It should be recognized that liquid which meets established standards and is released to soil columns still may result in a buildup (at a slower rate) of radioactivity in the soil column. Thus, it would be advantageous to design soil column structures so either the soil can be retrieved and relocated or the points of release are separated to the extent that the buildup of radioactivity in the soil column will not exceed an acceptable level.

(3) Adequate diversion systems shall be provided to assure that normally releasable streams, which, as a consequence of accident or operational upset, exceed established standards (cited in AECM 0524) for releases to uncontrolled areas, are automatically

detected and diverted to controlled holding areas and are recycled or processed to yield a releasable stream.

d. **Radioactive Solid Waste Other Than That Generated by Solidification of High-Level Liquid Waste**

(1) Technical and administrative efforts shall be directed toward a marked reduction of (a) the gross volume of solid waste generated in AEC operations and (b) the amount of radioactivity in such waste.

(2) Volume-reduction technology, such as compaction and incineration, shall be adapted for use with radioactive solid waste and placed in operation wherever practical.

(3) Except as dictated by (4), below, solid radioactive waste may be stored in conventional burial grounds approved by the AEC.

(4) Solid waste generated at AEC sites and containing significant U-233 or transuranium nuclide contamination shall be stored at AEC sites, segregated from other radioactively contaminated solid waste and with combustible and noncombustible transuranium-contaminated waste packaged separately. The packaging and storage conditions shall be such that the packages can be readily retrieved in an intact, contamination-free condition for 20 years. The packages shall be suitably labeled so the waste they contain can be identified by cross-reference to permanent records.

e. **Airborne Radioactive Effluents**. Gaseous and other airborne radioactive effluents shall be controlled at the lowest level below the limits of AECM 0524 consistent with the state of the technology and good economic practices.

f. **Other**. Radioactive waste generated by underground nuclear tests, and remaining underground shall be considered as a special case.

045 References

a. AECM 2401, "Physical Protection of Classified Matter and Information," for additional protection required for classified radioactive waste.
b. AECM 0510, "Prevention, Control, and Abatement of Air and Water Pollution."
c. AECM 0513, "Effluent and Environmental Monitoring and Reporting."
d. AECM 0524, "Standards for Radiation Protection."
e. AECM 0529, "Safety Standards for the Packaging of Fissile and Other Radioactive Materials."
f. AECM 0530, "Nuclear Criticality Safety."
g. AECM 0544, "Planning for Emergencies in AEC Operations."
h. AECM 6301, "General Design Criteria."
i. AECM 7401, "Safeguards Control and Management of Nuclear Materials."
j. WASH-1202, "Plan for the Management of AEC-Generated Radioactive Wastes."
k. AEC Property Management Instructions Subpart 109-45.50, "Excess and Surplus Radioactively Contaminated Personal Property."

0511-05 NATIONAL EMERGENCY APPLICATION

In the event of a national emergency, as defined in AECM 0601-04, the provisions of this chapter and its appendix shall continue in effect.

[1] In the context of the policy statement in AECM 0524-012.

[2] In the context of the policy statement in AECM 0524-012.

[3] For purposes of this chapter, program divisions are those Headquarters divisions that provide functional direction of activities which generate radioactive waste.

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PART I

TERMINOLOGY

A. PURPOSE

This part provides terminology to be used in interpreting and implementing this chapter. For consistency, its use is recommended in other communications concerning radioactive waste management.

B. USAGES

1. **Airborne Radioactive Effluents**—Radioactive particulates, mists, vapors, fumes, and/or gases, contained or entrained in air effluents. (Note: The special case of materials such as Kr-85 removed from effluents and packaged for retention, should be described as "Compressed radioactive gases" or "Adsorbed radioactive gases.")

2. **Combustible (for purposes of AECM 0511-044 d.(4)**—Organic material capable of being burned, except that if the only combustible content of a package is plastic lining or wrapping used for contamination control purposes around incombustible objects or materials, the contents of the package as a whole may be considered noncombustible.

3. **Contamination-Free (for purposes of AECM 0511-044 d.(4)**—A condition of the outer surfaces of stored containers, as determined by appropriate swipe surveys or direct radiation instrument surveys, sufficiently free of contamination so that under standard radiation work procedures for the site in question respiratory protection will not be required during container handling.

4. **Crib**—An underground framework or structure into which liquid wastes are discharged, located so that the radioactivity (other than tritium) is sorbed on the soil before the liquid reaches groundwater.

5. **Disposal**—The planned release of radioactive waste in a manner that precludes recovery, or its placement in a manner which is considered permanent so that recovery is not provided for. (Note: If recovery is planned, or could be provided for easily as in the case of conventional surface burial grounds, the term "storage" should be used.)

6. **Diversion**—As applied to nominally uncontaminated fluid streams, the capability of automatically detecting excessive radioactivity and diverting the stream to a retention system for treatment.

7. **Effluents**—Airborne and liquid streams discharged from a facility after all engineered process waste treatment and effluent controls have been effected. Releases offsite or into groundwater and surface streams which leave the site or go to the atmosphere from engineered systems such as stacks, lagoons, retention ponds, or injection wells are to be considered as effluents. The term does not include solid waste or other waste which is contained (e.g., underground nuclear test debris), stored (e.g., in lagoons, retention ponds, trenches, tanks), or shipped offsite.

8. **Storage**—Retention of radioactive waste in some type of man-made device, such as a tank or vault, in a manner permitting retrieval.

9. **Long-Term Storage**—The status of radioactive waste under control and surveillance, and readily retrievable, but in such a form and location that no further processing or manipulation is considered necessary for a period of time which is very long compared to other periods of time in the nuclear fuel cycle; an example would be storage in a high-quality near-surface storage vault with an expected durability of many decades.

10. **Federal Repository**—A Federally owned and operated facility for storage or disposal of specific types of radioactive waste from AEC sites and/or licensees.

11. **Federal Reservation**—An AEC site requiring long-term control and restrictions because of stored or buried waste or decommissioned facilities.

12. **High-Heat Liquid Waste**—Liquid waste containing sufficient thermal energy to require some supplemental means of cooling, such as cooling coils.

13. **High-Level Liquid Waste**—The aqueous waste resulting from the operation of the first-cycle extraction system, or equivalent concentrated wastes from subsequent extraction cycles, or equivalent wastes from a process not using solvent extraction, in a facility for processing irradiated reactor fuels.

14. **High-Level Waste**—(a) high-level liquid waste, or (b) the products from solidification of high-level liquid waste, or (c) irradiated fuel elements if discarded without processing.

15. **Other Liquid Waste**—Liquid waste, not within the definitions of high-level liquid waste.

16. **Liquid Radioactive Waste**—Solutions, suspensions, and mobile sludges, contaminated with radioactive materials.

17. **Management (Waste)**—The planning (including design and process improvement), execution, and surveillance of essential functions related to control of radioactive waste, including treatment, solidification, initial or long-term storage, and disposal.

18. **Radioactive Waste**—Materials of no value consisting of, including, or contaminated with radioactive material in excess of the levels or concentrations permitted in AEC Property Management Instructions for unconditional release of excess property. This includes (a) stored liquid, solid, or gaseous residues from chemical or metallurgical processing of radioactive materials; (b) discarded items such as defective equipment and building rubble, not radioactive in themselves but contaminated with radioactive materials; and (c) discarded items containing induced radioactivity. Treated as a separate category are: (1) irradiated fuels stored for possible processing; (2) radioactive scrap stored for possible recovery of useful values; and (3) materials and equipment stored for possible future use following decontamination.

19. **Retention Basin**—A watertight basin in which liquid waste is held for any one or more of the following reasons: (a) the decay of short-lived radioactivity; (b) analysis to verify activity levels permitting release; (c) recycle for treatment; (d) evaporation.

20. **Seepage Basin**—A basin in permeable earth through which liquid percolates and in which radioactivity, except for tritium, is sorbed.

21. **Settling Basin**—A watertight basin designed for separating sludges and sediments as a layer on the bottom. The water is disposed of by overflow or solar evaporation.

22. **Solid Radioactive Waste**—Material that is essentially dry but may contain sorbed radioactive fluids in sufficiently small amounts to be immobile when buried in dry soil.

23. **Transuranium-Contaminated Solid Waste**—Those contaminated with certain alpha-emitting radionuclides of long half-life and high specific radiotoxicity to greater than 10 nanocuries/gram (10 microcuries/kilogram), subject to the following conditions and understandings:
    a. The radionuclides included are U-233 (with its daughter products), plutonium, and transplutonium nuclides except Pu-238 and Pu-241. (Note that Pu-238 and Pu-241 waste should be handled as transuranium-contaminated waste when so indicated by Pu-239 impurities or when required by local burial criteria.)
    b. The value of 10 nCi/g is derived from the upper range of concentrations of radium-226 in the earth and is subject to modification based on long-term studies of nuclide migration in soil.
    c. The activity density may be averaged over the contents of individual shipping containers, such as 55-gallon drums, including materials added for shielding or sorption of liquids. Late discovery (for example, on recalculation of data) that an individual container is above this level will not be considered as necessitating its retrieval provided there is reasonable assurance that the average of the container and the balance of the associated containers is below the level.

d. For typical Pu-239 waste at this activity density, it is recognized that indirect measurements or estimates and administrative controls must be used instead of direct external measurements. An example of such administrative controls is the establishment of specific in-plant working areas from which typical wastes have been established by suitable studies as being either above or below the control value.

e. It is recognized that under present technology certain waste, primarily bulky discarded process equipment, with transuranium content above this value may not lend themselves to practical storage in full compliance with AECM 0511-044 d(4). However, these items should be recorded as transuranium wastes.

f. Requests for exception for applying the 10 nCi/g value on a package-by-package basis, with substitution of an equivalent quantity limit applicable to a burial facility, or requests for exemption for specific short half-lived transplutonium wastes, will be considered on a case-by-case basis, as per AECM 0511-032(m).

g. The 10 nCi/g value is a criterion for choosing different methods of handling different kinds of radioactive waste; it should not be confused with a value below which excess materials may be unconditionally released, as per AEC Property Management Instructions 109-45.50.

PART II

WASTE MANAGEMENT PLANS

A. PURPOSE

This part provides guidance on the development of a radioactive waste management plan for each site, as required by AECM 0511-038c.

B. DISCUSSION

Existing conditions at the various facilities will require different types and degrees of effort to meet the operating criteria of AECM 0511-044. Accordingly, the plans submitted under AECM 0511-038c need not be identical in degree of detail. Appropriate references to supplement or substantiate the information or conclusions stated in the plan should be provided. The outline of a waste management plan in C, below, is to be followed.

C. FORMAT FOR THE SITE WASTE MANAGEMENT PLANS

1. **Program Administration**

   1.1 Site
   1.2 Office Responsible
   1.3 Contractors
   1.4 Lead Responsibility for Site Plans
   1.5 Source of FY 1972 Funds for Waste Management

2. **Description of Waste Generating Processes**

   2.1 Process Flowcharts

3. **Description of Waste Management Facilities**

   3.1 Identification and Location of Facilities
   3.2 Description of Waste Treatment Facilities
   3.3 Description of Waste Storage Facilities
   3.4 Description of Effluent Control Systems
   3.5 Site Administrative Limits on Effluents

4. **Radioactive Waste Stored**

   4.1 High-Level Waste From Chemical Processing Operations
   4.2 Solid Radioactive Waste Other Than Solidified High-Level Waste
   4.3 Other Radioactive Materials

5. **Plans and Budget Projections**

   5.1 Interim Storage of High-Level Liquid Waste
      5.1.1 Milestone Charts
      5.1.2 Expected Accomplishments in FY 1972
      5.1.3 Proposed Program for FY 1973
      5.1.4 Proposed Program for FY 1974 and Beyond
      5.1.5 Five-Year Budget Projects for FY 1974 and Beyond
   5.2 Long-Term Storage of High-Level Waste
   5.3 Management of Low- and Intermediate-Level Liquid Waste
   5.4 Management of Solid Waste Contaminated With Radioactivity
   5.5 Management of Airborne Radioactive Waste
   5.6 Recapitulation of Budget Projection

Detailed Instructions for site waste management plans will be forwarded periodically to field office managers.

Appendix F Correspondence: L. M. Richards to A. G. Fremling

(Original letter typed on ARHCO letterhead; retyped for readability.)

Richland, Washington 99352
Telephone 509 942 7411

AUG 31 1973

U. S. Atomic Energy Commission
Richland Operations Office
Richland, Washington 99352

Attention: Mr. A. G. Fremling, Manager

Subject: WASTE STORAGE TANK LEAK DETECTION METHODS AND CRITERIA
Contract AT(45-1)-2130

References: (1) Letter, August 16, 1973, R. L. Ferguson to L. M. Richards, "Status Report on Atomic Energy Commission Recommendations"

(2) Letter, August 17, 1973, L. M. Richards to R. L. Ferguson, same subject

Gentlemen:

The Atlantic Richfield Hanford Company has been reviewing and revising operational controls for monitoring the integrity of the 200 areas waste storage tanks since the Tank 106-T leak incident. In addition to these actions, ARHCO has initiated studies to establish new technical criteria for leak detection, based on our best assessment of current capabilities, and to upgrade leak detection capability in a systematic manner whereby the maximum gain can be obtained in the minimum time.

Battelle-Northwest personnel were asked to consult with ARHCO, and leak detection studies were requested. The BNW preliminary reports were reviewed by ARHCO, and were incorporated with, and reinforced by, internal ARHCO analyses on liquid-level measurement, dry-well monitoring, and material-balance techniques. These studies are continuing, and changes of criteria for leak detection may be possible when the detailed investigations are completed.

During the interim period, before new criteria are implemented, limits on tank farm primary leak detection measurements have been established for all categories of tanks. When these limits are reached, the Manager, Manufacturing Department, and the Manager, Operations Support Engineering Department, are notified that the leak detection limit has been reached. These managers have the responsibility for determining the corrective action to be taken, and will carefully consider the available data prior to ordering partial or complete pumping of the suspect tank.

The notification limits for the four present waste storage tank categories are listed as follows:

- The static storage tanks are monitored by the Food Instrument Company (FIC) electrical continuity liquid-level instrument as the primary leak detection control. In-tank repeatability of these FIC gauges is about $\pm$0.25 inches. These liquid levels are presently being manually read and recorded once per shift, but the automatic data acquisition system, which is being tested in the 200 East Area, should be operational in both the 200 East and 200 West areas by October 1, 1973.

  Unexplained discrepancies of greater than 0.5 inch (equivalent to 1,375 gallons) from baseline levels in these static tanks are required to be promptly reported, for corrective action, to the responsible department managers. The electrode tape manual gauges and dry-well readings are used as backup to the more accurate FIC gauges, and are monitored monthly or as requested to supplement FIC gauge data.

- The static bottoms tanks are monitored by manually-operated electrode tape gauges as the primary leak detection control mechanism. In-tank repeatability of these gauges is $\pm$0.5 inch. The liquid levels are read once per shift, and an unexplained discrepancy of greater than one inch (equivalent to 2,750 gallons) is required to be reported to the responsible department managers for pumping decision. The dry-well monitoring readings are used as a backup to the liquid-level monitoring and are taken on a weekly or monthly frequency.

- The operating bottoms tanks are monitored by calculating the overall material balances around the evaporator system on a daily basis. Material-balance discrepancies of more than 3.5 inches (equivalent to 9,600 gallons) must be reported to the responsible section managers, and accumulative discrepancies indicating potential loss of ten inches (equivalent to 27,500 gallons) are required to be reported to the responsible department managers, for evaporator shutdown, in order to allow for static tank liquid-level monitoring of the suspect tanks pending a decision for pumping. The dry wells surrounding these tanks are used as a backup to the material-balance calculation and are monitored on a minimum weekly frequency.

- The only boiling-waste tank now containing self-boiling waste (101-AY) is protected from leak release by double-wall construction. The primary leak detection mechanism for this tank is the continuous monitoring of the annular space for radioactive solutions, which would indicate failure of the inner liner.

  The remaining tanks in this use category contain strontium sludge and/or nonboiling supernatants. The primary leak detection method for the tanks in this use category in the SX and A farms are the horizontal laterals drilled under the tanks. The primary leak detection mechanism for the tanks in the AX farm is the grid system sump measurement and alarm equipment.

  The laterals in the SX and A farms are monitored on a daily-to-weekly basis, depending on radioactivity and location. The responsible section managers are notified immediately when radiation levels increase. The maximum undetectable leak for this system has been calculated at 5,500 gallons, which is equivalent to a two-inch loss of liquid. The grid-drainage leak detection pits in the AX and AY farms are checked twice per shift. The responsible section managers are notified immediately when liquid levels or radiation readings increase. In the AY farm, the tank annulus liquid levels are recorded once per shift, and supervision is notified immediately in the event of system alarms or recorded liquid-level increases. The responsible department managers are notified for decision as soon as the recorded increases are verified by the responsible section managers.

The backup leak detection system for these tanks is the liquid-level measurement taken once per shift, and the dry-well monitoring reading taken on a weekly or monthly frequency.

The dry-well system is no longer considered to be the primary leak detection method for any tank category. The measurement capability of the dry-well system in place around bottoms tanks was evaluated by BNW, and the calculations were refined by ARHCO experts, taking into account the most recent geological and hydrological data. The average volume of a maximum undetectable leak for all tanks presently in, or available for, bottoms loop service is 51,000 gallons, and ranges from 14,000 to 145,000 gallons. While small leaks can be, and have been, detected by the dry-well monitoring system, when the leak is near the dry well, the possibility of large undetected leaks still remains. To some extent, the large maximum undetected leaks are a result of insufficient wells around tanks, but, additionally, the present asymmetric placement of the wells allows large areas for leaks to remain undetected. With symmetrical spacing of wells around tanks, the maximum undetected leak calculation results are as follows:

Number of Symmetrical Dry Wells	Maximum Undetected Leak (gallons)	
	200 East	200 West
2	168,000	110,000
3	64,000	43,000
4	30,000	20,000
5	17,500	11,500

The asymmetry of dry-well placement was caused by the incremental drilling over a period of years, with each drilling aimed at obtaining the maximum benefit for the least cost, and by drilling around existing equipment. It should be noted that once a given number of wells are drilled symmetrically around a tank, the maximum undetected leak can only be reduced by doubling the number of wells around the tank.

In the dry-well monitoring system, the number of wells would have to be approximately doubled to reduce the maximum undetectable leak to 10,000 gallons. However, seven additional dry wells located near four of the waste tanks would reduce the maximum undetectable leak from the 145,000 gallons, cited previously, to 75,000 gallons. We are continuing a program to improve the dry-well monitoring system as a backup leak detection mechanism. Our aim will be to lower the maximum undetectable leak, through careful placement of additional wells.

Both the BNW and ARHCO studies indicate the dry wells should be monitored as frequently as possible, in order to limit the leak volume. However, it is not feasible to monitor all the bottoms loop tank dry wells more frequently than once per week with existing or ordered equipment. If leaks are indicated in a particular tank, by the primary leak detection system, the dry wells associated with that tank are monitored on an accelerated schedule. Investigations to improve dry-well monitoring equipment and procedures are continuing and will possibly allow some increase in monitoring frequency.

AUG 31 1973

Additional programs are under way to improve leak detection methods. Additional FIC gauges are being procured and installed in boiling waste and bottoms loop tanks for evaluation. Battelle-Northwest will provide assistance to ARHCO, through detailed investigations of commercially available liquid-level sensors for crusted liquids, material-balance techniques for evaporator systems, modifications to provide for liquid-level gauge failure notification, and dry-well monitoring capabilities. Waste tank inspection is being evaluated by Westinghouse Hanford Company's nondestructive testing group. Such inspection, if available, could determine possible leakers or identify probable leak levels before refilling tanks with waste solutions.

You will be kept advised of the progress of the above-mentioned studies and other ARHCO evaluations, and notified of any change in the decision criteria listed.

Very truly yours,

/s/

L. M. Richards
President

LMR:GEB:ap

cc: RL Ferguson, AEC-RL

October 18, 1973

LEAK CATEGORIZATION SUMMARY

REVISION 1

STATIC STORAGE TANK

Suspect Leaker

- Limit

  Liquid level decrease ≥ 0.5 inch below baseline by FIC gauge or drywell radiation readings increase above the 50,000 counts per minute (15 milliroentgens per hour) background limit.

- Action

  Pump out supernatant to below suspect liquid level, if one can be determined, or pump out the same as a confirmed leaker. If liquid level does not stabilize during partial pumpout, declare and treat as confirmed leaker.

Restricted-Use Tank

If monitoring indicates that a partial pumpout of a suspect leaker stops all indications of possible leakage, the tank will be put in a restricted-use category with a maximum liquid level limit established below the suspect level. If inspection of tank interior indicates a suspected breached liner, a liquid level limit will be established below the suspect level.

Confirmed Leaker

- Limit

  Liquid level decrease ≥ 0.5 inch below baseline by FIC gauge,

  and drywell readings increase above the 50,000 counts per minute (15 milliroentgens per hour) background limit;

  or definite and continuing liquid level change ≥ 0.5 inch such that no doubt exists that a leak has occurred.

- Action

  Pump out supernatant liquid. Install salt well and pump interstitial liquid or stabilize residual liquid with dessicant. Isolate tank from tank farm systems. Maintain surveillance. Investigate leak extent.

STATIC BOTTOMS TANK

Suspect Leaker

. Limit

Unexplained liquid level decrease ≥ 1.0 inch below baseline by manual electrode tape gauge,

or drywell radiation readings increase above the 50,000 counts per minute (15 milliroentgens per hour) background limit.

. Action

Pump out supernatant to below suspect liquid level, if one can be determined, or pump out the same as a confirmed leaker. If liquid level does not stabilize during partial pumpout, declare and treat as confirmed leaker.

Restricted-Use Tank

If monitoring indicates that a partial pumpout of a suspect leaker stops all indications of possible leakage, the tank will be put in a restricted-use category with a maximum liquid level limit established below the suspect level. If inspection of tank interior indicates a suspected breached liner, a liquid level limit will be established below the suspect level.

Confirmed Leaker

. Limit

Liquid level decrease ≥ 1.0 inch below baseline by manual electrode tape gauge,

and drywell readings increase above the 50,000 counts per minute (15 milliroentgens per hour) background limit,

or definite and continuing liquid level change ≥ 1.0 inch such that no doubt exists that a leak has occurred.

. Action

Pump out supernatant liquid. Install salt well and pump interstitial liquid or stabilize residual liquid with dessicant. Isolate tank from tank farm systems. Maintain surveillance. Investigate leak extent.

OPERATING BOTTOMS TANK

Suspect Leaker

- Limit

Accumulative material balance discrepancy of ten inches (27,500 gallons):

followed by shutdown of evaporator bottoms loop for a minimum of 48 hours for static tank measurements,

with subsequent liquid level decrease in a tank, of one inch, by manual electrode tape gauge;

or drywell radiation reading increases above the 50,000 counts per minute (15 milliroentgens per hour) background count.

- Action

Pump out supernatant to below suspect liquid level, if one can be determined, or pump out the same as a confirmed leaker. If liquid level does not stabilize during partial pumpout, declare and treat as confirmed leaker.

Restricted-Use Tank

If monitoring indicates that a partial pumpout of a suspect leaker stops all indications of possible leakage, the tank will be put in a restricted-use category with a maximum liquid level limit established below the suspect level. If inspection of tank interior indicates a suspected breached liner, a liquid level limit will be established below the suspect level.

Confirmed Leaker

- Limit

Liquid level decrease $\geq$ 1.0 inch below baseline by manual electrode tape gauge,

and drywell readings increase above the 50,000 counts per minute (15 milliroentgens per hour) background limit,

or definite and continuing liquid level change $\geq$ 1.0 inch such that no doubt exists that a leak has occurred.

- Action

Pump out supernatant liquid. Install salt well and pump interstitial liquid or stabilize residual liquid with dessicant. Isolate tank from tank farm systems. Maintain surveillance. Investigate leak extent.

BOILING WASTE STORAGE TANK
DOUBLE SHELL

Confirmed Leaker

- Limit

  Liquid in the leak detection pit and/or radiation in the annular space.

- Action

  Recycle waste in annular space, back into tank, while evaluating the specific incident and deciding on action. Pump to spare double-shell tank if warranted.

BOILING WASTE STORAGE TANK
SINGLE SHELL

None are in use for boiling waste storage. Treat the same as static bottoms tanks; except when sluicing, the laterals are used as the primary detection method.

Appendix G Correspondence: Stephen Stalos

13133 Larchdale Road
Laurel, MD 20811
February 5, 1980

Mr. Robert Catlin
Department of Energy
Office of the Environment
Mail Stop E201
Washington, DC 20545

Dear Mr. Catlin:

Thank you for sending me the Inspector General's report. I appreciate your patience, kindness and thoughtfulness during this investigation.

I wish to summarize and to comment upon the events which led to my request for the assistance of your office.

In November 1978, Rockwell Hanford Operations (RHO) reduced its efforts to detect leaks in underground nuclear waste storage tanks at Hanford. This step was recommended by the Waste Tank Monitoring Revision Group (WTMRG) of RHO, and was approved by the Department of Energy's Richland Operations Office (DOE-RL). The WTMRG had been formed by Don Cockeram, General Manager of RHO, at the request of Alex Fremling, Manager of DOE-RL.

I hope your report will clearly state whether this reduction was justified or unjustified. If the reduction was justified, for what reasons? If the reduction was not justified, what steps should be taken?

In the references, I have enclosed, three reasons are presented for the reduced tank surveillance:

1) A fortnightly frequency for dry well monitoring is adequate to detect radiation changes "in the most dynamic case."

2) The use of neutron probes within selected tanks will improve surveillance and will offset reduced dry well monitoring.

3) Reduced dry well monitoring will reduce radiation exposure to personnel.

Additionally, Mr. Cockeram, in his press conference following my resignation, implied that surveillance competed with the solidification program. Thus, a reduction in surveillance, one is led to believe, might actually minimize environmental risk by enhancing the solidification effort.

The second and third reasons given for reduced surveillance are never mentioned in the minutes of the WTMRG. Nor is Mr. Cockeram's suggestion of enhancing the solidification program. In fact, the first reason given for reduced surveillance is only mentioned once--in the minutes of the August 23, 1978, meeting--and without justification. Graphs and charts describing the proposed change exist, but I know of no other presentation of reasons for reduced surveillance than those I have enclosed and referenced. At the very least, the rationale for reduced surveillance is poorly documented.

As we have discussed, I believe all the reasons presented for reduced surveillance are without merit and lack any technical justification.

To justify the statement that fortnightly dry well monitoring is adequate to detect radiation changes "in the most dynamic state," plots were made of peak dry well radiation readings as a function of time. It was noted that in the case of the most rapid increase examined--a dry well near tank 110-U--the amount of time between the radiation peak leaving background level and exceeding 200 counts per second was greater than two weeks. Mr. Deichman and Mr. Roecker argued that, under fortnightly monitoring, one dry well reading would have detected the non-standard condition and appropriate action could have been taken. Thus, they conclude, fortnightly dry well monitoring is adequate. This conclusion is erroneous since weekly dry well monitoring would have detected the non-standard condition earlier, allowing the investigation and any necessary remedial to begin earlier. The net result of reducing dry well monitoring is to increase the time-integrated amount of leaked high level waste. Thus, the proper goal of surveillance, to minimize the risk to man and the environment by minimizing the total volume of leaked material, through prompt leak detection, is undermined by reduced dry well monitoring.

Many other points could be made concerning this argument. Even RHO admits that 200 counts per second is only a report writing threshold; that count rate does not define a problem. A tank may leak and never produce that count rate, or an agency other than direct tank leakage might far exceed that count rate. Too, from my argument it follows that if monitoring dry wells weekly is better than monitoring them fortnightly, daily monitoring would be even better. True, but I have always acknowledged budgetary restraints and worked to be more efficient with given resources. The point is that the Operations Directive requires prompt detection of leakage, and that any move away from promptness should be justified.

No use of neutron probes as an in-tank monitoring device was made by Tank Farm Surveillance during my tenure. Tests of the probe were made in the only tanks possessing the capability for their use: six out of 149 single shell tanks. Mr. Cockeram, in his press conference, committed RHO to establishing the use of neutron probes in 32 tanks by September 30, 1979. I do not know whether this goal was met. The neutron probe measures local moisture content, the moisture concentration within a two-foot radius of the probe. That concentration may not represent the overall liquid concentration in the tank. Further the concentration may increase, decrease, and then increase again with increasing depth of the neutron probe in the tank: It is false to think of a flat, uniform, "liquid level" within the tank solids. Too, the neutron probe presents unique calibration problems due to the varying chemical constituents of each tank: the concentration of boron and many other neutron absorbers is critical.

In spite of these considerations, RHO reduced the monitoring of liquid levels in many tanks, as well as reducing the dry well frequency. Mr. Deichman and Mr. Roecker, in their December 1, 1978, letter (p. 2) seem to believe in-tank measurements a priori preferable to dry well measurements. I believe each case should be judged on its merits, but all leak detection methods are leak detection methods: No method, inside or outside the tanks, gives any warning that a leak is about to occur. Liquid level decreases may occur from agencies other than tank leakage, e.g., evaporation, just as dry well radiation peaks may form from agencies other than tank leakage. Thus, I can see no reason why in-tank measurements a priori should be given precedence.

Concerning the reduction of radiation exposure to personnel from dry well monitoring by reducing the surveillance schedule:

This reason was a cynical attempt to appear concerned about radiological safety where evidence for such a concern did not previously exist. Far, far less than one person-rem is directly attributable to dry well monitoring, for the entire group for an entire year. More personnel exposure is obtained in one week's usage of a neutron probe--which, as you know, contains a millicurie Pu-Be source--than in a year's dry well monitoring. Further, duties assigned to monitoring personnel in lieu of dry well monitoring, such as swab-riser readings, present far higher exposure and contamination risks than does dry well monitoring.

I wish to add two comments reflecting upon the concern of RHO to reduce radiation exposure. Until I ordered the practice stopped, tank liquid level plummets were cleaned by personnel holding the plummet in hand while rubbing it with an abrasive cloth. Second, I discovered that the source for the neutron probe was kept in a large, hydrogenous shield between usages, but that when the source was removed and placed in the unshielded probe for use, no neutron shield was provided and the probe was simply placed on a holder on the side of the monitoring van, then used by the monitor. When I ordered a halt to use of the neutron probe until a shield could be provided, Mr. G. T. Dukelow countermanded my order. The reason given to justify this unnecessary exposure was a commitment by RHO to DOE-RL to demonstrate the possible use of the probe in a certain tank by a given date. No programmatic or technical program would have been adversely affected by postponing usage until adequate shielding could have been provided. To this date, I do not know that proper shielding has been provided.

Mr. Cockeram's view of surveillance as competing with the solidification program is very disturbing. The solidification program is not enhanced by a reduction in tank monitoring. The entire environmental monitoring program, chiefly air monitoring, does consume a signficant part of RHO contract dollars: the tank monitoring program does not. The entire Tank Farm Surveillance budget is less than 1 percent of RHO's budget. Too, both surveillance and solidification are aimed at the same goal; minimizing radioactive material released to the environment. Surveillance is not an irrelevant record-keeper, as he would seem to imply. Indeed, I urged in August 1978 that phase two salt well pumping of TX Farm be accelerated, on the basis of surveillance data, but to no avail. The fact is that the two programs are too separated. Even the schedules for pumping are not set on the basis of surveillance data.

Finally, all statements about the adequacy of surveillance are judged against the necessity for surveillance: What are the risks to man and the environment from tank leakage? Certainly, I can not give a definitive answer, and I believe the only attempt to give a definitive answer, ERDA-1538, is inadequate. The model and methods used in the hypothetical tank accident presented in ERDA-1538 are not conservative. D'Arcian diffusion and absorption coefficients were used to determine the relative isotopic abundance of material reaching the ground water, and a number was picked out of the air to determine the quantity of leaked materials to actually reach the ground water from a tank originally holding 800,000 gallons. Even so, the MPC for water, for one radionuclide, was exceeded. Do we really know the microgeology of the Hanford Reservation so well that we can preclude a large amount of strontium or cesium from reaching groundwater? The number of water wells in this area alone, fairly direct access paths, places some doubt in my mind. So I think, at the very least, we should assume surveillance is very important, until a more careful study is conducted and more experience is gained. The beta-emitter pollution of the Columbia River from the Hanford plume is increasing, not decreasing.

I acknowledge our discussion of many of these points previously, and thank you for your patience in being so long-suffering.

Sincerely,

Stephen Stalos

Enclosures
Letter, Stephen Stalos to D. J. Cockeram, 11/15/78
Letter, D. J. Cockeram to S. P. Stalos, 12/1/78
Meeting Minutes, Waste Tank Monitoring Revision Group, 7/18/78, 7/26/78, 8/2/78, 8/9/78, 8/18/78, 8/23/78
Press Conference, D. J. Cockeram, 12/6/78

Appendix H Hanford SS Tank Farm Facilities — Functional Capability of Leak Monitoring Systems

TANK	STATUS†	CRITERIA FOR STATUS CLASSIFICATION	DRAINABLE LIQUID INVENTORY: SUPERNATANT (KGAL)	DRAINABLE LIQUID INVENTORY: DRAINABLE INTERSTITIAL LIQ. (KGAL)	DRAINABLE LIQUID INVENTORY: TOTAL DRAINABLE LIQ. (KGAL)	LIQUID LEVEL MONITORING CAPABILITY: MONITORING LEAK DETECTION CRITERIA: DECREASE	MONITORING LEAK DETECTION CRITERIA: INCREASE	CONDUCTIVITY PROBE: MANUAL	CONDUCTIVITY PROBE: AUTOMATIC	FUNCTIONAL LIQ. LEVEL PROBE: LEAK	FUNCTIONAL LIQ. LEVEL PROBE: INTRUSION	DRY WELL MONITORING CAPABILITY: MAX. LEAK UNDETECTABLE (KGAL)	DRY WELL MONITORING CAPABILITY: FUNCTIONAL LEAK DETECTION	HORIZONTAL LA[…] MONITORING CA[…]: MAX. LEAK UNDETECTABLE (KGAL)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(200 EAST AREA)														
101-A	A	–	11	146	157	YES	YES	X	X	YES	YES	10	YES	5
102-A	A	–	85	4	89	YES	YES	X	X	YES	YES	17.5	YES	5
103-A	A	–	324	90	414	YES	YES	X	X	YES	YES	17.5	YES	5
104-A	L	LATERAL	0	4	4	NO	YES	X		NO	YES	17.5	NO	5
105-A	L	DRY WELL	0	4	4	NO	YES	X		NO	YES	17.5	NO	5
106-A	A	–	607	6	613	YES	YES	X	X	YES	YES	10	YES	5
101-AX	A	–	0	188	188	YES	YES	X	X	NO	YES	17.5	YES	
102-AX	A	–	500	11	511	YES	YES	X	X	YES	YES	10	YES	
103-AX	A	–	882	1	883	YES	YES	X	X	YES	YES	17.5	YES	
104-AX	QI	DRY WELL	3	0	3	NO	YES	X	X O/S	NO	YES	17.5	NO	
101-B	QI	DRY WELL	0	10	10	NO	YES		X	NO	YES	17.5	NO	
102-B	I	–	14	9	23	YES	YES	X	X	YES	YES	17.5	YES	
103-B	QI	DRY WELL	24	20	44	YES	YES		X	YES	YES	17.5	*	
104-B	I	–	14	66	80	YES	YES	X		YES	YES	30	YES	
105-B	QI	DRY WELL	0	81	81	NO	YES	X		NO	YES	30	*	
106-B	I	–	14	16	30	YES	YES	X	X	YES	YES	30	YES	
107-B	L	LIQ. LEVEL & DRY WELL	0	7	7	NO	YES	X		NO	YES	30	NO	
108-B	I	–	33	21	54	YES	YES		X	YES	YES	17.5	YES	
109-B	I	–	14	36	50	YES	YES	X	X O/S	YES	YES	30	YES	
110-B	QI	LIQ. LEVEL	0	0	0	NO	YES	X		NO	YES	17.5	NO	
111-B	QI	DRY WELL	3	31	34	YES	YES		X	YES	YES	30	*	
112-B	QI	DRY WELL	6	5	11	YES	YES	X	X	YES	YES	17.5	NO	
201-B	L	LIQ. LEVEL & DRY WELL	1	0	1	YES	YES	X		NO	YES	55	NO	
202-B	I	–	0	3	3	YES	YES	X		NO	YES	55	NO	
203-B	I	–	3	6	9	YES	YES	X		YES	YES	55	NO	
204-B	I	–	3	6	9	YES	YES	X		YES	YES	55	NO	
101-BX	QI	DRY WELL	0	1	1	NO	YES	X		NO	YES	30	NO	
102-BX	L	LIQ. LEVEL & DRY WELL	0	5	5	NO	YES	X		NO	YES	17.5	NO	
103-BX	I	–	0	10	10	YES	YES		X	NO	YES	17.5	NO	
104-BX	A	–	80	17	97	YES	YES	X	X	YES	YES	17.5	YES	
105-BX	A	–	39	11	50	YES	YES	X	X	YES	YES	17.5	YES	
106-BX	I	–	14	4	18	YES	YES	X	X	YES	YES	30	NO	
107-BX	I	–	0	47	47	YES	YES	X	X	NO	YES	30	YES	
108-BX	L	LIQ. LEVEL & DRY WELL	0	1	1	NO	YES	X	X O/S	NO	YES	17.5	NO	
109-BX	I	–	0	26	26	NO	YES	X	X	NO	YES	17.5	YES	
110-BX	QI	DRY WELL	0	42	42	YES	YES	X		NO	YES	17.5	*	
111-BX	QI	DRY WELL	22	51	73	YES	YES	X		YES	YES	17.5	*	
112-BX	I	–	0	22	22	YES	YES		X	NO	YES	17.5	YES	

KEY: A = Active Tank
I = Inactive Tank (Not Questionable Integrity Or Confirmed Leakers)
QI = Questionable Integrity Tank
L = Confirmed Leaker Tank
K. GAL. = Thousand Gallons
O/S = Out Of Service

†Status Of Tanks 107-B, 201-B, 101-C and 112-U Changed To L On 1-25-80
*Functional To A Limited Degree For Monitoring Further Indications Of Leakage Or Buildup, Migration And Decay Of Radionuclides In The Soil

LIQUID LEVEL MONITORING CAPABILITY					DRY WELL MONITORING CAPABILITY		HORIZONTAL LATERALS MONITORING CAPABILITY		LEAK DETECTION PITS MONITORING CAPABILITY	
LEAK ITERIA	CONDUCTIVITY PROBE		FUNCTIONAL LIQ. LEVEL PROBE							
NCREASE	MANUAL	AUTOMATIC	LEAK	INTRUSION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
YES	X	X	YES	YES	10	YES	5	YES		
YES	X	X	YES	YES	17.5	YES	5	YES		
YES	X	X	YES	YES	17.5	YES	5	YES		
YES	X		NO	YES	17.5	NO	5	NO		
YES	X		NO	YES	17.5	NO	5	NO		
YES	X	X	YES	YES	10	YES	5	YES		
YES	X	X	NO	YES	17.5	YES			0.1	YES
YES	X	X	YES	YES	10	YES			0.1	YES
YES	X	X	YES	YES	17.5	YES			0.1	YES
YES	X	X O/S	NO	YES	17.5	NO			0.1	YES
YES		X	NO	YES	17.5	NO				
YES	X	X	YES	YES	17.5	YES				
YES		X	YES	YES	17.5	•				
YES	X		YES	YES	30	YES				
YES	X		NO	YES	30	•				
YES	X	X	YES	YES	30	YES				
YES	X		NO	YES	30	NO				
YES		X	YES	YES	17.5	YES				
YES	X	X O/S	YES	YES	30	YES				
YES	X		NO	YES	17.5	NO				
YES		X	YES	YES	30	•				
YES	X	X	YES	YES	17.5	NO				
YES	X		NO	YES	55	NO				
YES	X		NO	YES	55	NO				
YES	X		YES	YES	55	NO				
YES	X		YES	YES	55	NO				
YES	X		NO	YES	30	NO				
YES	X		NO	YES	17.5	NO				
YES		X	NO	YES	17.5	NO				
YES	X	X	YES	YES	17.5	YES				
YES	X	X	YES	YES	17.5	YES				
YES	X	X	YES	YES	30	NO				
YES	X	X	NO	YES	30	YES				
YES	X	X O/S	NO	YES	17.5	NO				
YES	X	X	NO	YES	17.5	YES				
YES	X		NO	YES	17.5	•				
YES	X		YES	YES	17.5	•				
YES		X	NO	YES	17.5	YES				

TANK	STATUS†	CRITERIA FOR STATUS CLASSIFICATION	DRAINABLE LIQUID INVENTORY: SUPERNATANT (KGAL)	DRAINABLE LIQUID INVENTORY: DRAINABLE INTERSTITIAL LIQ. (KGAL)	DRAINABLE LIQUID INVENTORY: TOTAL DRAINABLE LIQ. (KGAL)	LIQUID LEVEL MONITORING CAPABILITY: MONITORING LEAK DETECTION CRITERIA: DECREASE	MONITORING LEAK DETECTION CRITERIA: INCREASE	CONDUCTIVITY PROBE: MANUAL	CONDUCTIVITY PROBE: AUTOMATIC	FUNCTIONAL LIQ. LEVEL PROBE: LEAK	FUNCTIONAL LIQ. LEVEL PROBE: INTRUSION	DRY WELL MONITORING CAPABILITY: MAX. LEAK UNDETECTABLE (KGAL)	DRY WELL MONITORING CAPABILITY: FUNCTIONAL LEAK DETECTION	HORIZONTAL LA[TERAL] MONITORING CA[PABILITY]: MAX. LEAK UNDETECTABLE (KGAL)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(200 EAST AREA) – (CONT'D)														
101-BY	I	–	8	70	78	YES	YES	X		YES	YES	17.5	YES	
102-BY	I	–	0	103	103	YES	YES	X		NO	YES	17.5	YES	
103-BY	L	DRY WELL	0	133	133	NO	YES	X		NO	YES	17.5	*	
104-BY	I	–	11	179	190	NO	YES	X		NO	YES	17.5	YES	
105-BY	QI	DRY WELL	0	171	171	NO	YES	X		NO	YES	30	*	
106-BY	QI	TAR RINGS	0	157	157	YES	YES	X		NO	YES	17.5	YES	
107-BY	QI	DRY WELL	0	18	18	NO	YES	X		NO	YES	17.5	*	
108-BY	L	DRY WELL	0	74	74	NO	YES	X		NO	YES	17.5	*	
109-BY	I	–	33	116	149	YES	YES	X		YES	YES	17.5	YES	
110-BY	I	–	61	119	180	YES	YES	X		YES	YES	17.5	YES	
111-BY	I	–	0	172	172	YES	YES	X		NO	YES	17.5	YES	
112-BY	I	–	0	89	89	NO	YES	X		NO	YES	17.5	YES	
101-C	L	LIQ. LEVEL & DRY WELL	0	9	9	NO	YES	X		NO	YES	30	NO	
102-C	I	–	0	37	37	NO	YES		X	NO	YES	64	NO	
103-C	I	–	25	22	47	YES	YES		X	YES	YES	17.5	YES	
104-C	A	–	146	38	184	YES	YES	X	X	YES	YES	17.5	YES	
105-C	I	–	22	21	43	YES	YES	X	X	YES	YES	10	YES	
106-C	I	–	22	25	47	YES	YES	X	X	YES	YES	17.5	YES	
107-C	I	–	0	21	21	NO	YES	X	X	NO	YES	17.5	YES	
108-C	I	–	0	4	4	NO	YES	X		NO	YES	17.5	NO	
109-C	I	–	6	3	9	NO	YES	X		NO	YES	17.5	NO	
110-C	QI	DRY WELL	2	20	22	NO	YES	X	X O/S	NO	YES	17.5	*	
111-C	QI	LIQ. LEVEL	0	2	2	NO	YES	X		NO	YES	17.5	NO	
112-C	I	–	0	12	12	NO	YES	X		NO	YES	17.5	NO	
201-C	I	–	4	0	4	YES	YES	X		YES	YES	55	NO	
202-C	I	–	2	0	2	YES	YES	X		YES	YES	55	NO	
203-C	I	–	4	1	5	YES	YES	X		YES	YES	55	NO	
204-C	I	–	3	0	3	YES	YES	X		YES	YES	55	NO	
(200 WEST AREA)														
101-S	A	–	253	57	310	YES	YES	X	X	YES	YES	11.5	YES	
102-S	A	–	108	152	260	YES	YES	X	X	YES	YES	10	YES	
103-S	A	–	555	48	603	YES	YES	X	X	YES	YES	11.5	YES	
104-S	QI	LIQ. LEVEL	0	14	14	NO	YES	X		NO	YES	11.5	YES	
105-S	I	–	53	26	79	NO	YES	X	X	NO	YES	11.5	YES	
106-S	I	–	0	78	78	NO	YES	X	X	NO	YES	11.5	YES	
107-S	A	–	349	52	401	YES	YES	X	X	YES	YES	11.5	YES	
108-S	I	–	58	48	106	NO	YES	X	X O/S	NO	YES	11.5	YES	
109-S	I	–	0	57	57	NO	YES	X	X	NO	YES	11.5	YES	
110-S	I	–	0	0	0	NO	YES	X	X	NO	YES	11.5	NO	
111-S	I	–	0	160	160	NO	YES	X	X	NO	YES	11.5	YES	
112-S	I	–	0	76	76	NO	YES	X	X	NO	YES	11.5	YES	

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K. GAL. = Thousand Gallons
O/S = Out Of Service

†Status Of Tanks 107-B, 201-B, 101-C and 112-U Changed To L On 1-25-80
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LIQUID LEVEL MONITORING CAPABILITY					DRY WELL MONITORING CAPABILITY		HORIZONTAL LATERALS MONITORING CAPABILITY		LEAK DETECTION PITS MONITORING CAPABILITY	
LEAK ITERIA	CONDUCTIVITY PROBE		FUNCTIONAL LIQ. LEVEL PROBE		MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION
NCREASE	MANUAL	AUTOMATIC	LEAK	INTRUSION						
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
YES	X		YES	YES	17.5	YES				
YES	X		NO	YES	17.5	YES				
YES	X		NO	YES	17.5	•				
YES	X		NO	YES	17.5	YES				
YES	X		NO	YES	30	•				
YES	X		NO	YES	17.5	YES				
YES	X		NO	YES	17.5	•				
YES	X		NO	YES	17.5	•				
YES	X		YES	YES	17.5	YES				
YES	X		YES	YES	17.5	YES				
YES	X		NO	YES	17.5	YES				
YES	X		NO	YES	17.5	YES				
YES	X		NO	YES	30	NO				
YES		X	NO	YES	64	NO				
YES		X	YES	YES	17.5	YES				
YES	X	X	YES	YES	17.5	YES				
YES	X	X	YES	YES	10	YES				
YES	X	X	YES	YES	17.5	YES				
YES	X	X	NO	YES	17.5	YES				
YES	X		NO	YES	17.5	NO				
YES	X		NO	YES	17.5	NO				
YES	X	X O/S	NO	YES	17.5	•				
YES	X		NO	YES	17.5	NO				
YES	X		NO	YES	17.5	NO				
YES	X		YES	YES	55	NO				
YES	X		YES	YES	55	NO				
YES	X		YES	YES	55	NO				
YES	X		YES	YES	55	NO				
YES	X	X	YES	YES	11.5	YES				
YES	X	X	YES	YES	10	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X		NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X	X O/S	NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	NO				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				

TANK	STATUS†	CRITERIA FOR STATUS CLASSIFICATION	DRAINABLE LIQUID INVENTORY: SUPERNATANT (KGAL)	DRAINABLE LIQUID INVENTORY: DRAINABLE INTERSTITIAL LIQ. (KGAL)	DRAINABLE LIQUID INVENTORY: TOTAL DRAINABLE LIQ. (KGAL)	LIQUID LEVEL MONITORING CAPABILITY: MONITORING LEAK DETECTION CRITERIA: DECREASE	LIQUID LEVEL MONITORING CAPABILITY: MONITORING LEAK DETECTION CRITERIA: INCREASE	LIQUID LEVEL MONITORING CAPABILITY: CONDUCTIVITY PROBE: MANUAL	LIQUID LEVEL MONITORING CAPABILITY: CONDUCTIVITY PROBE: AUTOMATIC	LIQUID LEVEL MONITORING CAPABILITY: FUNCTIONAL LIQ. LEVEL PROBE: LEAK	LIQUID LEVEL MONITORING CAPABILITY: FUNCTIONAL LIQ. LEVEL PROBE: INTRUSION	DRY WELL MONITORING CAPABILITY: MAX. LEAK UNDETECTABLE (KGAL)	DRY WELL MONITORING CAPABILITY: FUNCTIONAL LEAK DETECTION	HORIZONT… MONITORIN…: MAX. LEAK UNDETECTABL… (KGAL)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(200 WEST AREA) – (CONT'D)														
101-SX	A	–	143	99	242	YES	YES	X	X	YES	YES	11.5	YES	
102-SX	A	–	371	129	500	YES	YES	X	X	YES	YES	11.5	YES	
103-SX	A	–	71	208	279	YES	YES	X	X	YES	YES	11.5	YES	
104-SX	A	–	110	213	323	YES	YES	X	X	YES	YES	10	YES	
105-SX	A	–	64	210	274	YES	YES	X	X	YES	YES	11.5	YES	5
106-SX	A	–	745	43	788	YES	YES	X	X	YES	YES	11.5	YES	
107-SX	L	DRY WELL	0	14	14	NO	YES	X		NO	YES	11.5	*	5
108-SX	L	LIQ. LEVEL & DRY WELL	0	11	11	NO	YES	X		NO	YES	11.5	NO	5
109-SX	L	DRY WELL	0	32	32	NO	YES	X		NO	YES	10	*	5
110-SX	QI	LIQ. LEVEL	0	8	8	NO	YES	X		NO	YES	10	NO	5
111-SX	L	LATERAL	0	10	10	NO	YES	X		NO	YES	10	NO	5
112-SX	L	LIQ. LEVEL & DRY WELL	0	13	13	NO	YES	X		NO	YES	10	*	5
113-SX	L	BULGED LINER	0	1	1	NO	YES	X		NO	YES	43	NO	5
114-SX	QI	DRY WELL	0	25	25	NO	YES	X		NO	YES	11.5	*	5
115-SX	L	LIQ. LEVEL & DRY WELL	0	1	1	NO	YES	X		NO	YES	11.5	NO	5
101-T	I	–	143	13	156	YES	YES	X	X	YES	YES	11.5	YES	
102-T	I	–	0	1	1	YES	YES	X	X	NO	YES	11.5	NO	
103-T	QI	LIQ. LEVEL	0	4	4	NO	YES	X	X	NO	YES	11.5	NO	
104-T	I	–	0	14	14	NO	YES	X		NO	YES	11.5	YES	
105-T	I	–	0	14	14	YES	YES	X	X	NO	YES	11.5	YES	
106-T	L	LIQ. LEVEL & DRY WELL	0	3	3	NO	YES	X		NO	YES	11.5	NO	
107-T	QI	DRY WELL	28	19	47	NO	YES	X	X	NO	YES	43	YES	
108-T	QI	LIQ. LEVEL	0	6	6	NO	YES	X	X O/S	NO	YES	11.5	NO	
109-T	QI	DRY WELL	0	14	14	NO	YES	X	X	NO	YES	11.5	*	
110-T	I	–	0	43	43	NO	YES	X	X	NO	YES	20	YES	
111-T	QI	LIQ. LEVEL	0	56	56	NO	YES	X	X	NO	YES	11.5	YES	
112-T	I	–	6	8	14	YES	YES	X	X	YES	YES	11.5	YES	
201-T	I	–	0	0	0	YES	YES	X		NO	YES	55	NO	
202-T	I	–	0	0	0	YES	YES	X		NO	YES	55	NO	
203-T	I	–	0	0	0	YES	YES	X		NO	YES	55	NO	
204-T	I	–	0	4	4	YES	YES	X		NO	YES	55	NO	
101-TX	A	–	96	9	105	YES	YES	X	X	YES	YES	11.5	YES	
102-TX	I	–	0	137	137	YES	YES	X	X	NO	YES	11.5	YES	
103-TX	A	–	467	18	485	YES	YES	X	X	YES	YES	11.5	YES	
104-TX	I	–	8	12	20	YES	YES	X	X	YES	YES	11.5	YES	
105-TX	QI	DRY WELL	0	121	121	YES	YES	X		NO	YES	11.5	*	
106-TX	I	–	0	136	136	YES	YES	X		NO	YES	11.5	YES	
107-TX	QI	DRY WELL	0	12	12	YES	YES	X	X	NO	YES	11.5	YES	
108-TX	I	–	0	39	39	NO	YES	X	X	NO	YES	20	YES	

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LIQUID LEVEL MONITORING CAPABILITY					DRY WELL MONITORING CAPABILITY		HORIZONTAL LATERALS MONITORING CAPABILITY		LEAK DETECTION PITS MONITORING CAPABILITY	
IG LEAK CRITERIA	CONDUCTIVITY PROBE		FUNCTIONAL LIQ. LEVEL PROBE							
INCREASE	MANUAL	AUTOMATIC	LEAK	INTRUSION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION
(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
YES	X	X	YES	YES	11.5	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X	X	YES	YES	10	YES				
YES	X	X	YES	YES	11.5	YES	5	YES		
YES	X	X	YES	YES	11.5	YES				
YES	X		NO	YES	11.5	*	5	*		
YES	X		NO	YES	11.5	NO	5	*		
YES	X		NO	YES	10	*	5	*		
YES	X		NO	YES	10	NO	5	YES		
YES	X		NO	YES	10	NO	5	*		
YES	X		NO	YES	10	*	5	*		
YES	X		NO	YES	43	NO	5	NO (NOT USED)		
YES	X		NO	YES	11.5	*	5	*		
YES	X		NO	YES	11.5	NO	5	NO		
YES	X	X	YES	YES	11.5	YES				
YES	X	X	NO	YES	11.5	NO				
YES	X	X	NO	YES	11.5	NO				
YES	X		NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X		NO	YES	11.5	NO				
YES	X	X	NO	YES	43	YES				
YES	X	X O/S	NO	YES	11.5	NO				
YES	X	X	NO	YES	11.5	*				
YES	X	X	NO	YES	20	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X		NO	YES	55	NO				
YES	X		NO	YES	55	NO				
YES	X		NO	YES	55	NO				
YES	X		NO	YES	55	NO				
YES	X	X	YES	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X	X	YES	YES	11.5	YES				
YES	X		NO	YES	11.5	*				
YES	X		NO	YES	11.5	YES				
YES	X	X	NO	YES	11.5	YES				
YES	X	X	NO	YES	20	YES				

TANK	STATUS†	CRITERIA FOR STATUS CLASSIFICATION	DRAINABLE LIQUID INVENTORY: SUPERNATANT (KGAL)	DRAINABLE LIQUID INVENTORY: DRAINABLE INTERSTITIAL LIQ. (KGAL)	DRAINABLE LIQUID INVENTORY: TOTAL DRAINABLE LIQ. (KGAL)	LIQUID LEVEL MONITORING CAPABILITY: MONITORING LEAK DETECTION CRITERIA: DECREASE	LIQUID LEVEL MONITORING CAPABILITY: MONITORING LEAK DETECTION CRITERIA: INCREASE	LIQUID LEVEL MONITORING CAPABILITY: CONDUCTIVITY PROBE: MANUAL	LIQUID LEVEL MONITORING CAPABILITY: CONDUCTIVITY PROBE: AUTOMATIC	LIQUID LEVEL MONITORING CAPABILITY: FUNCTIONAL LIQ. LEVEL PROBE: LEAK	LIQUID LEVEL MONITORING CAPABILITY: FUNCTIONAL LIQ. LEVEL PROBE: INTRUSION	DRY WELL MONITORING CAPABILITY: MAX. LEAK UNDETECTABLE (KGAL)	DRY WELL MONITORING CAPABILITY: FUNCTIONAL LEAK DETECTION	HORIZONT… MONITORI…: MAX. LEAK UNDETECTABLE (KGAL)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(200 WEST AREA) – (CONT'D)														
109-TX	I	–	0	135	135	YES	YES	X	X	NO	YES	11.5	YES	
110-TX	QI	DRY WELL	0	132	132	YES	YES	X		NO	YES	11.5	*	
111-TX	I	–	33	111	144	YES	YES	X		YES	YES	11.5	YES	
112-TX	I	–	9	155	164	YES	YES	X		YES	YES	11.5	YES	
113-TX	QI	DRY WELL	0	204	204	NO	YES	X		NO	YES	43	*	
114-TX	QI	DRY WELL	0	194	194	NO	YES	X		NO	YES	20	*	
115-TX	QI	DRY WELL	0	192	192	NO	YES	X		NO	YES	20	*	
116-TX	QI	DRY WELL	0	189	189	NO	YES	X		NO	YES	20	*	
117-TX	QI	DRY WELL	0	188	188	NO	YES	X		NO	YES	43	*	
118-TX	A	–	261	128	389	YES	YES	X	X	YES	YES	11.5	YES	
101-TY	QI	LIQ. LEVEL	0	15	15	NO	YES	X	X	NO	YES	20	NO	
102-TY	I	–	5	9	14	YES	YES		X	YES	YES	11.5	YES	
103-TY	L	LIQ. LEVEL & DRY WELL	0	21	21	NO	YES	X	X	NO	YES	43	NO	
104-TY	QI	LIQ. LEVEL	0	6	6	YES	YES	X	X	NO	YES	20	NO	
105-TY	L	LIQ. LEVEL	0	36	36	NO	YES	X		NO	YES	110	NO	
106-TY	L	LIQ. LEVEL & DRY WELL	0	3	3	NO	YES	X		NO	YES	20	NO	
101-U	L	LIQ. LEVEL	0	5	5	YES	YES	X		NO	YES	20	NO	
102-U	I	–	0	121	121	YES	YES	X	X	NO	YES	11.5	YES	
103-U	I	–	42	118	160	YES	YES	X	X	YES	YES	11.5	YES	
104-U	L	BULGED LINER	0	16	16	NO	YES	X		NO	YES	20	NO	
105-U	I	–	25	124	149	YES	YES	X	X	YES	YES	11.5	YES	
106-U	QI	LIQ. LEVEL	16	59	75	YES	YES		X	YES	YES	11.5	YES	
107-U	A	–	335	58	393	YES	YES	X	X	YES	YES	11.5	YES	
108-U	I	–	17	128	145	YES	YES		X	YES	YES	20	YES	
109-U	I	–	11	125	136	YES	YES		X	YES	YES	11.5	YES	
110-U	L	LIQ. LEVEL & DRY WELL	0	20	20	NO	YES	X	X	NO	YES	11.5	*	
111-U	A	–	116	127	243	YES	YES	X	X	YES	YES	11.5	YES	
112-U	L	LIQ. LEVEL & DRY WELL	2	6	8	NO	YES	X		NO	YES	11.5	NO	
201-U	I	–	1	1	2	YES	YES	X		YES	YES	55	NO	
202-U	I	–	1	1	2	YES	YES	X		YES	YES	55	NO	
203-U	I	–	1	0	1	YES	YES	X		YES	YES	55	NO	
204-U	I	–	1	0	1	YES	YES	X		YES	YES	55	NO	

KEY: A = Active Tank
I = Inactive Tank (Not Questionable Integrity Or Confirmed Leakers)
QI = Questionable Integrity Tank
L = Confirmed Leaker Tank
K. GAL. = Thousand Gallons
O/S = Out Of Service

†Status Of Tanks 107-B, 201-B, 101-C and 112-U Changed To L On 1-25-80
*Functional To A Limited Degree For Monitoring Further Indications Of Leakage Or Buildup, Migration And Decay Of Radionuclides In The Soil

FUNCTIONAL LIQ. LEVEL PROBE		DRY WELL MONITORING CAPABILITY		HORIZONTAL LATERALS MONITORING CAPABILITY		LEAK DETECTION PITS MONITORING CAPABILITY	
LEAK	INTRUSION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION	MAX. LEAK UNDETECTABLE (KGAL)	FUNCTIONAL LEAK DETECTION
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
NO	YES	11.5	YES				
NO	YES	11.5	•				
YES	YES	11.5	YES				
YES	YES	11.5	YES				
NO	YES	43	•				
NO	YES	20	•				
NO	YES	20	•				
NO	YES	20	•				
NO	YES	43	•				
YES	YES	11.5	YES				
NO	YES	20	NO				
YES	YES	11.5	YES				
NO	YES	43	NO				
NO	YES	20	NO				
NO	YES	110	NO				
NO	YES	20	NO				
NO	YES	20	NO				
NO	YES	11.5	YES				
YES	YES	11.5	YES				
NO	YES	20	NO				
YES	YES	11.5	YES				
YES	YES	11.5	YES				
YES	YES	11.5	YES				
YES	YES	20	YES				
YES	YES	11.5	YES				
NO	YES	11.5	•				
YES	YES	11.5	YES				
NO	YES	11.5	NO				
YES	YES	55	NO				
YES	YES	55	NO				
YES	YES	55	NO				
YES	YES	55	NO				