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P.O. Box 4699 ◆ Oak Ridge, TN 37831

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April 4, 2016

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Contracting Officer's Representative
Oak Ridge Office of Environmental Management
U.S. Department of Energy, EM-92
Post Office Box 2001
Oak Ridge, Tennessee 37831

Dear Mr. McMillan:

DE-SC-0004645: Transmittal of the *Liquid and Gaseous Waste Operations Engineering Evaluation and Extended Life Study, URS | CH2M Oak Ridge LLC, Oak Ridge, Tennessee* (STJ-02LGWO-D706)

Enclosed for your information, please find a copy of the *Liquid and Gaseous Waste Operations Engineering Evaluation and Extended Life Study, URS | CH2M Oak Ridge LLC, Oak Ridge, Tennessee* (STJ-02LGWO-D706).

If you have questions or need additional information, please contact David Bolling at (865) 712-9582.

Sincerely,

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SAFELY DELIVERING THE DEPARTMENT OF ENERGY'S VISION
FOR THE EAST TENNESSEE TECHNOLOGY PARK MISSION

STJ-02LGWO-D706

Liquid and Gaseous Waste Operations Engineering Evaluation and Extended Life Study, URS | CH2M Oak Ridge LLC, Oak Ridge, Tennessee

This document is approved for public release per review by:

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Strata-G LLC and Excel Engineering contributed to the preparation of this document and should not be considered eligible contractors for its review.

STJ-02LGWO-D706

Liquid and Gaseous Waste Operations Engineering Evaluation and Extended Life Study, URS | CH2M Oak Ridge LLC, Oak Ridge, Tennessee

Date Issued—February 2016

Prepared for the
U.S. Department of Energy
Office of Environmental Management

URS | CH2M Oak Ridge LLC
Safely Delivering the Department of Energy's Vision
for the East Tennessee Technology Park Mission
under contract DE-SC-0004645

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ACRONYMS

BVEST	Bethel Valley Evaporator Service Tanks
CFR	*Code of Federal Regulations*
CIP	Clean-In-Place
D&D	Deactivation and Demolition
DOE	U.S. Department of Energy
EASC	Emergency Avoidance Solidification Campaign
EM	Office of Environmental Management
FFA	Federal Facility Agreement
GAC	Granulated Activated Carbon
GW	Gaseous Waste
HEPA	high efficiency particulate air
LGWO	Liquid and Gaseous Waste Operations
LLLW	Liquid Low-Level Waste
MCC	motor control center
MVST	Melton Valley Storage Tanks
NDE	Nondestructive Examination
NNSS	National Nuclear Security Site
NPDES	National Pollutant Discharge Elimination System
ORNL	Oak Ridge National Laboratory
PW	Process Waste
PWTC	Process Waste Treatment Complex
REDC	Radiochemical Engineering Development Center
ROM	Rough-Order of Magnitude
S&M	Surveillance and Maintenance
SC	Office of Science
TDS	total dissolved solids
TRU	transuranic
TWPC	TRU Waste Processing Center
WAC	Waste Acceptance Criteria
WOCC	Waste Operations Control Center
UCOR	URS | CH2M Oak Ridge LLC
UT-B	UT Battelle
UT	Ultrasonic Testing

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1. PURPOSE

The Liquid and Gaseous Waste Operations (LGWO) organization operates three waste treatment systems at the Oak Ridge National Laboratory (ORNL). Some of the LGWO systems are currently operating years past their expected life, outside of design operating conditions, with increasing frequency and severity of non-routine maintenance. Replacement parts for older systems have become obsolete and training for repair personnel has become more difficult. Although the systems are currently satisfying minimum requirements for process demands and permit obligations, without major repairs and/or replacement, the LGWO system operation and maintenance costs are increasingly higher than available budgets. The current process infrastructure needs refurbishment to maintain system operability. Furthermore, catastrophic failure of even part of the LGWO system would leave users without disposal options, potentially disrupt ORNL research, and could negatively impact the environment and result in fines and penalties.

The purpose of this current conditions report and extended life study is to evaluate the infrastructure and develop recommendations for future operation of the three waste treatment systems that URS | CH2M Oak Ridge LLC (UCOR) operates as part of the LGWO system at ORNL. The current condition evaluation includes a description of the system and users, review of the operating and maintenance history, walkdown results, and testing results. The extended life study includes a forecast of future users and capacity requirements, required maintenance upgrades, new technology evaluation, and life-cycle cost analysis. A major goal of this study is to develop and evaluate alternatives for all three LGWO treatment systems and compare them based on safety, operability, and cost effectiveness. Results from these evaluations were used to identify and prioritize recommendations for near-term and long-term actions to maintain safe and reliable operability of the LGWO systems.

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2. SCOPE

The scope of this current condition evaluation and extended life study includes the Process Waste (PW) System, Liquid Low-Level Waste (LLLW) System, and Gaseous Waste (GW) System that constitute the overall LGWO system. The U.S. Department of Energy (DOE) Office of Environmental Management (EM) prime contractor, UCOR, operates the LGWO systems and several facilities that generate waste discharged to the LGWO system. The DOE Office of Science (SC) prime contractor, UT-Battelle, LLC (UT-B) operates many of the research facilities that generate waste discharged to the LGWO system. The three LGWO systems are interconnected, as illustrated in **Fig. 2-1.**

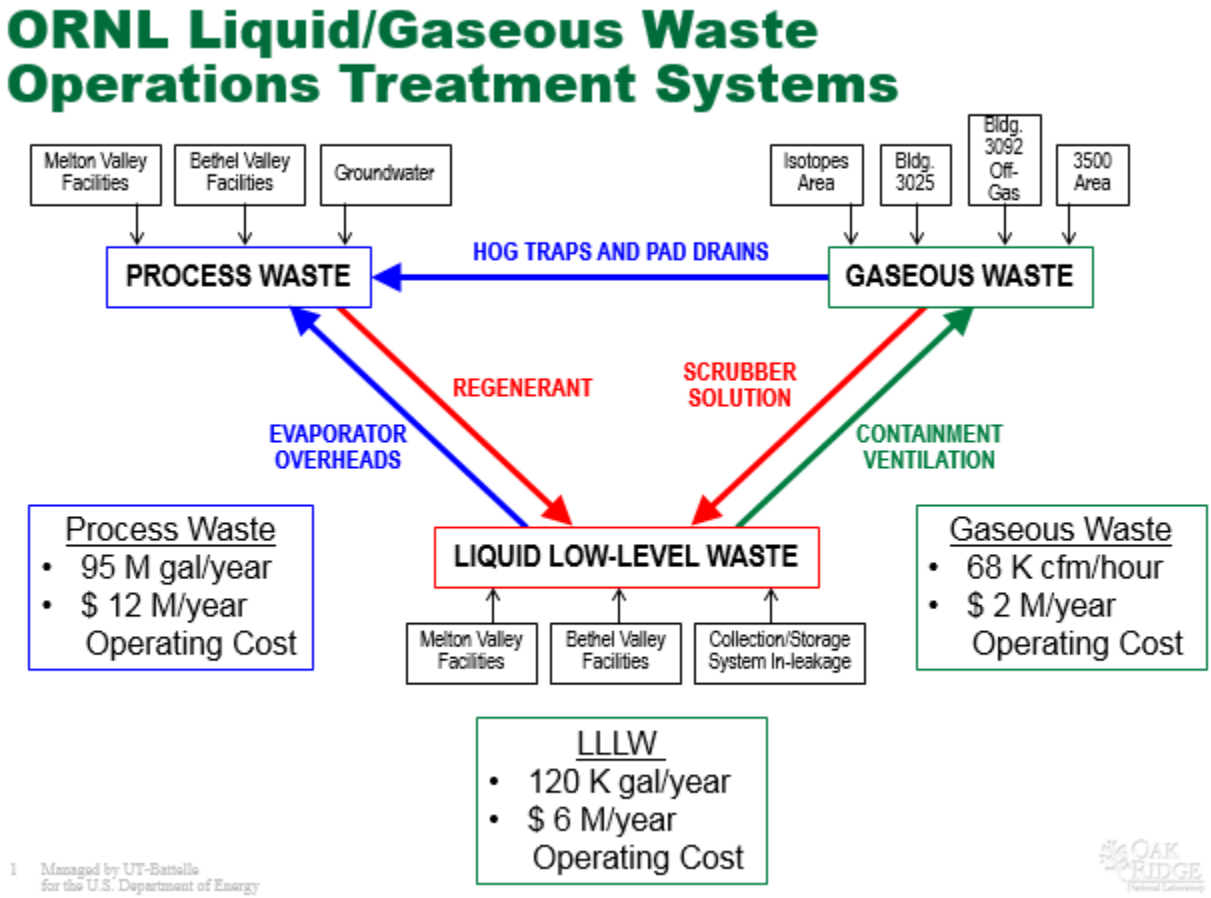

Fig. 2-1. LGWO treatment systems.

- The PW, LLLW, and GW Systems are connected via secondary waste linkages:
- The PW ion-exchange resin regenerant is discharged to the LLLW System for storage and eventual treatment.
- The LLLW Evaporator overheads are discharged to the PW System for treatment prior to release.
- The GW and LLLW are linked through the Cell Vent and Hot Off-Gas service provided to the LLLW Bethel Valley Evaporator Service Tanks (BVEST) and evaporator.
- The GW spent scrubber solution is discharged to the LLLW System.
- The GW vent system groundwater in-leakage is sent to the PW System for treatment.

The current baseline shows all three systems operating until the end of the ORNL cleanup mission; however, system modifications could potentially allow earlier shut down of some of the systems, resulting in operations cost savings. Careful planning, design, and execution is needed to ensure that required services among the three systems are maintained as required for waste generators and to support the DOE ORNL missions in environmental management, science, and energy research.

2.1 CURRENT CONDITION EVALUATION

The scope of the current condition evaluation includes the following:

- **System Descriptions.** A summary of the facilities and equipment associated with each system, including tanks, pumps, piping, valves, filters, and other components as depicted on the LGWO website. The current condition evaluation did not examine the condition of the LGWO maintenance infrastructure (maintenance shops, change houses, and decontamination facilities). These maintenance facilities will need to be evaluated for upgrade/replacement to expedite future LGWO operations and maintenance.
- **System Users.** Generating facilities as documented in the annual LGWO Operations reports from 2005 through 2015.
- **Maintenance.** Non-routine maintenance activities conducted as work packages from 2005 through 2015. Activities associated with routine (preventive) maintenance and instrumentation and control repairs conducted via procedures are up-to-date and are outside the scope of this report.
- **Operations.** Design and actual operating conditions as documented in the annual LGWO Operations reports from 2005 through 2015.
- **Walkdown Results.** Information collected from discussions with LGWO maintenance, operations, and oversight personnel and visual inspection of the accessible system components during system walkdowns conducted during August through December 2015.
- **Testing Results.** Non-destructive examination (NDE) using ultrasonic thickness testing was conducted on select LGWO pipelines, tankers, and tanks during October through December 2015. For the pipelines, a minimum of two locations per exposed section of pipeline were tested, with additional locations around pipe bends. For the 1000-gal tanker, a minimum of eight locations were tested. For the tanks without paneling, a minimum of two locations per 200 ft^2 were tested. For the tanks with paneling, a minimum of two locations per panel were tested. The measured thickness was compared to the original thickness to determine the extent of thinning and/or corrosion. Piping and vessel exteriors were visually inspected to determine corrosion type.

2.2 EXTENDED LIFE STUDY

The scope of the extended life study includes the following:

- **Forecast of Future Users and Capacity Requirements.** An evaluation of the length of time LGWO capabilities will be required to support the EM cleanup mission at ORNL.
- **Discussion of Applicable Technologies.** A review of available technologies with respect to LGWO waste streams and functional requirements to identify three alternatives for each system for the life-cycle cost analysis.
- **Life-Cycle Cost Analysis.** A life-cycle cost estimate, phasing/schedule, and evaluation of the pros/cons associated with each of the alternatives identified. Cost estimates include upgrades/refurbishment, capital projects, operations, and maintenance necessary for near- and long-term operation.

- **Recommendations.** Results from the life-cycle cost analysis were used to develop recommendations for near-term maintenance, refurbishment, and capital projects needed for safe and efficient future operation of the LGWO systems.

2.2.1 Forecast of Future Users and Capacity Requirements

The current LGWO system was designed to serve ORNL operations as they existed 25–50 years ago, including reactors, hot cells, laboratories, and scientific operations. Over the years the SC mission has changed significantly and the many nuclear facilities served by the systems have been reduced to one reactor facility and five hot cells. Many of the laboratories and other research operations that were served by the LGWO have been shut down. The current LGWO system capacity is significantly oversized for the current and projected ORNL SC and EM missions, and most of the facilities are operating beyond their original design life.

The EM mission at ORNL is to minimize environmental risks imposed by outdated facilities and contaminated media that could impact the conduct of advanced energy, neutron, computational, and material research for the DOE. This cleanup mission entails demolition of facilities and remediation of contaminated soil and groundwater in accordance with the requirements of the approved Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) decision documents.

The EM ORNL Cleanup Project Baseline reflects the schedule to meet regulatory and safety requirements based on various funding levels. The Requirements Case, which is based on historical funding levels, shows completion of final cleanup at ORNL by 2047. The Planning Case, which reflects lower annual funding based on recent Presidential Budget requests, shows completion of final cleanup at ORNL by 2067. Regardless of the funding case, it is clear that LGWO capabilities will be needed to support the EM cleanup mission at ORNL for decades. Therefore, 30 years was selected as the design life for this LGWO Extended-Life Study. **Table 2-1 shows the date that each LGWO system is needed to operate for the two baseline cases.**

Table 2-1. LGWO capabilities required to support EM cleanup at ORNL

LGWO system	Requirements Case (Fiscal Year)	Planning Case (Fiscal Year)
Process Waste	2044	2051
Liquid Low-Level Waste	2038	2046
Gaseous Waste	2038	2046
Final Funding of LGWO	2047	2067

2.2.2 New Technology Evaluation

A workshop was held December 2–3, 2015, to discuss and evaluate new technology opportunities for the LGWO systems. Follow-up sessions were held on December 7 and 14, 2015. The purpose of the workshop was to evaluate applicable technologies and system configurations in view of the current conditions and identify alternatives for the life-cycle cost analysis for the PW, LLLW, and GW treatment systems. The workshop participants included; Max Smith (DOE), Jeff Maddox, Brent Griffin, Cameron Wagar, Jim Dunn, and David Bolling (UCOR), Paul Taylor (UT-B), Dirk Van Hoesen and Becca Rogers (Strata-G), Chris Scott (Excel Engineering), Tim Kent (Pro2Serve), and Greg Edwards (Independent Consultant). A detailed narrative of the workshop discussions has been prepared and is available for review.

Treatment technologies were identified by participants' expertise, available reports, and internet research. Detailed information regarding LGWO waste characteristics, potential system reconfigurations, and cost estimates were found in numerous LGWO studies conducted during the past thirty years. These studies focus on three major areas – development of the non-radiological waste water treatment plan, SC focused studies, and EM focused studies and are listed in **Appendix A**. The functional requirements of the LGWO systems are provided as **Appendix B**.

2.2.3 Evaluation Criteria

The evaluation criteria presented in **Fig. 2-2** were used as the basis for evaluating the alternatives in the extended life study. As part of the new technology evaluations, these criteria were used as a basis for screening alternatives that were not considered safe, feasible, or cost effective. For alternatives selected for further evaluation, the criteria were used to define advantages and disadvantages (pros and cons) for each of the alternatives and for developing recommendations for preferred alternatives.

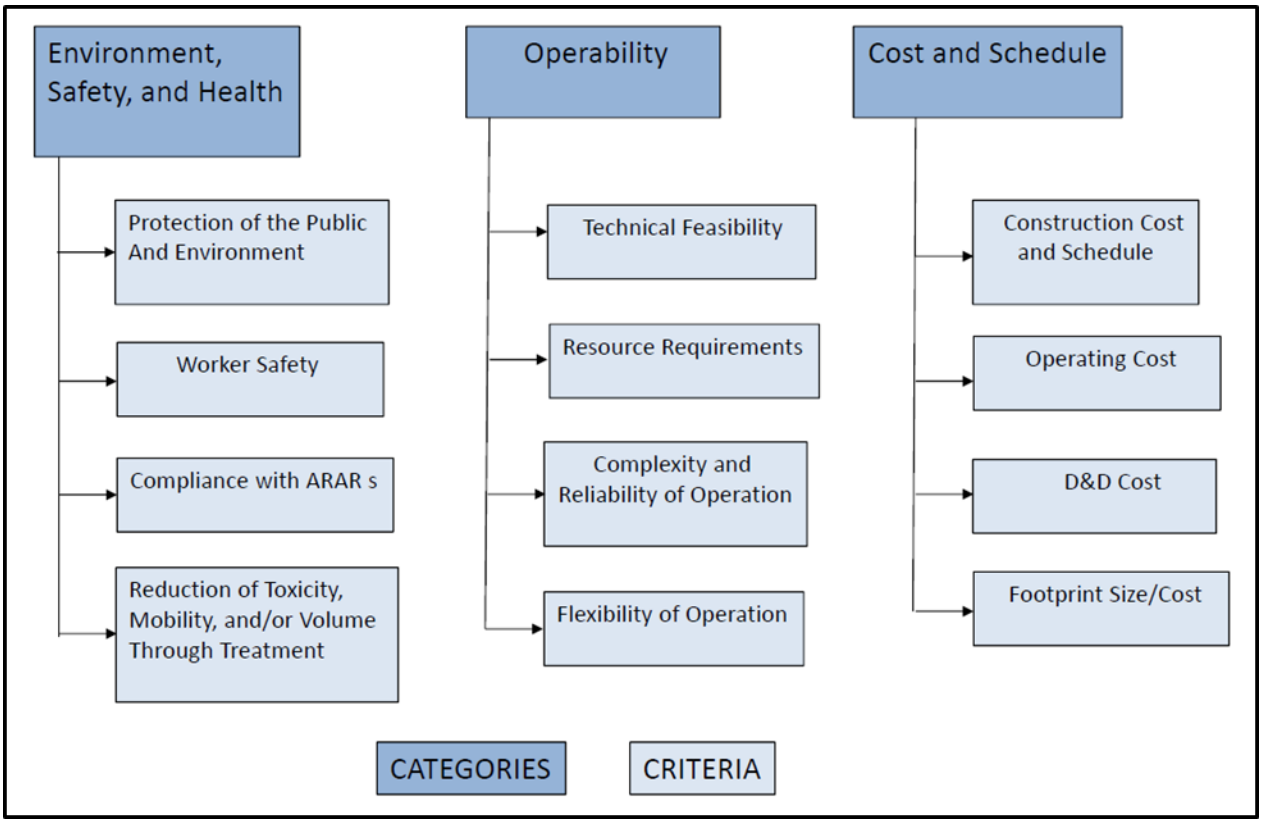

Fig. 2-2. Evaluation criteria for extended life study.

2.2.4 Life-Cycle Cost Analysis

Order-of-magnitude life-cycle cost estimates were developed for the alternatives identified for each system during the new technology evaluation. The cost estimates allow comparison of alternatives on an equivalent cost basis. Cost profiles were developed to calculate the escalated cost and present value. Cost estimates presented in this report were developed to support comparison of project life cycle alternatives.

A combination of cost resources were used to develop the estimates, including:

- Previous estimates
- Vendor quotes for equipment

- Parametric factors for construction, engineering, and project management
- Current operations and maintenance labor requirements and rates
- LGWO management expertise
- Engineering judgement

The following assumptions were used as the basis for the estimates:

- Life cycle duration of 30 years
- Escalation rate of 2.3% per year
- Present value discount rate of 3.1%

Labor costs, incorporated in the operations and maintenance costs, comprise the majority of the life-cycle cost. It is important to note that with the current shared cost and time charging structure within UCOR's Nuclear & High Hazard Operations organization, which includes both LGWO and Surveillance and Maintenance (S&M) activities, that it was not possible for the team to determine precise manpower costs for each of the LGWO systems. LGWO management provided input to determine fair and balanced labor estimates used for waste management operations.

The alternatives analysis also includes an evaluation of pros and cons for each alternate, based on the evaluation criteria. The results of the analyses were used as the basis for recommendations.

2.2.5 Recommendations

Recommendations for continued operation of the LGWO systems fall into two categories: near-term and long-term recommendations. The near-term recommendations are based on the results of the current conditions report and reflect the maintenance repairs needed in the next 3–4 years to maintain operability of the LGWO systems. The long-term recommendations are based on the results of the life cycle costs analysis and reflect the upgrades and/or reconfigurations needed in the future to maintain operation of the LGWO systems for the next 30 years. The recommendations are prioritized according to Environment, Safety, and Health; Operability; and Cost and Schedule.

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3. PROCESS WASTE SYSTEM

3.1 SYSTEM DESCRIPTION AND USERS

The Process Waste Treatment Complex (PWTC) collects, treats, and discharges slightly contaminated process wastewater from generator facilities and groundwater sources throughout ORNL and condensate from the LLLW Evaporator Facility. There is an elaborate collection system consisting of miles of above grade and below grade piping in both the Bethel Valley and Melton Valley areas of ORNL. The collection system also includes large collection tank facilities in both valleys. There are two major treatment facilities, Bldg. 3544 and Bldg. 3608, which are interconnected and include processes for removal of both radiological and hazardous constituents from process wastewater. Radiologically contaminated wastewater is treated to remove Strontium-90 (Sr-90) and Cesium-137 (Cs-137) in order to meet the requirements in DOE Order 458.1, *Radiation Protection of the Public and Environment*. Non-radiological PW is treated to remove hazardous constituents and to meet the requirements of the National Pollutant Discharge Elimination System (NPDES) permit prior to discharge. The single discharge for both systems is located adjacent to Bldg. 3608, a NPDES outfall at White Oak Creek. The Waste Acceptance Criteria (WAC) administratively limits the wastes added to the PW System to a maximum total radiological concentration of the ingestion dose equivalent to $1x10^4$ Bq/L Sr-90.

3.1.1 System Description

The PWTC is categorized as a Radiological facility and includes the following components:

- Source Facilities
- Groundwater collection systems (includes Solid Waste Storage Area leachate collection)
- Collection tanks and piping
  - 66,000 ft of PW piping in Bethel Valley
  - 6800 ft of transfer pipeline between Bldgs. 2600 and 7961
  - Two 6800-ft transfer pipelines between Bldgs. 7961 and 3608
- Monitoring stations
- Neutralization sumps
- Influent pumping station (F-4001)
- Building 2600 Storage Tanks
  - Two 350,000-gal and one 1,000,000-gal “hot” storage tank
- Building 7961 Storage Tanks
  - Two 100,000-gal “hot” storage tanks
  - Two 100,000-gal “cold” storage tanks (one metals, one non-metals)
- Building 3608
  - Equalization tanks (one metals, one non-metals)
  - Water softening and clarification to remove hardness (primarily calcium and magnesium)
  - Alkaline precipitation and clarification to remove heavy metals
  - Filtration to remove suspended solids

- Filter press to dewater sludge from softener/clarifier
- Air stripper to remove volatile organic compounds
  - Granular activated carbon (GAC) to remove mercury and non-volatile organic compounds
  - pH adjustment to meet NPDES discharge criteria
- Building 3544
  - Filtration to remove suspended solids following water softening
  - Ion Exchange to remove Sr-90
  - Zeolite treatment to remove Cs-137

A diagram of the PW System is provided as **Fig. 3-1.**

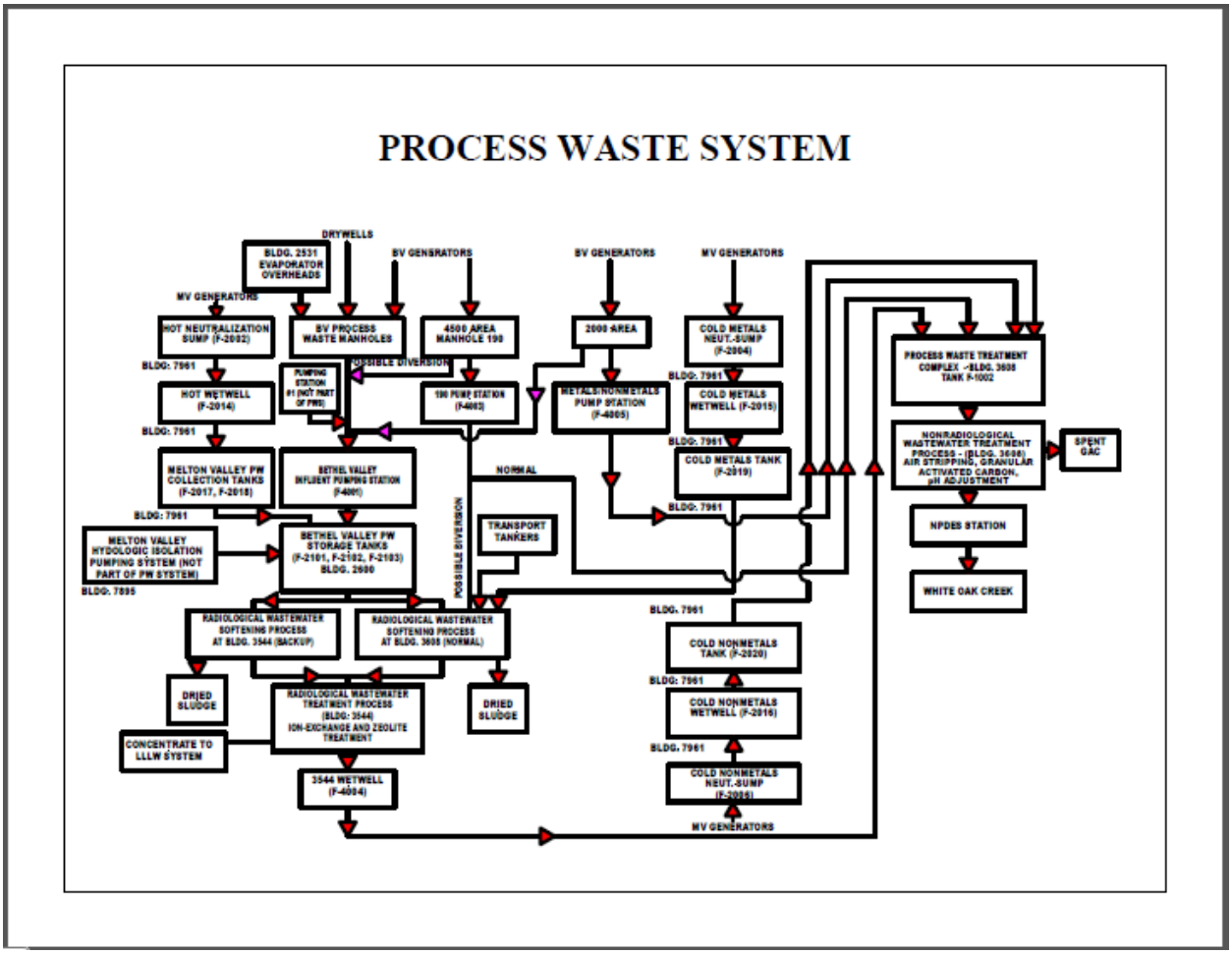

Fig. 3-1. Process waste system flow diagram.

3.1.2 System Users

PW treatment is an essential support function for ORNL. The PWTC system is operated by UCOR for DOE-EM and treats PW generated from UCOR facility operations and waste and groundwater treatment, as well as PW generated by UT-B for SC research and facility operations. Approximately 60% of the radiological PW volume is infiltrated water contaminated with radiological contaminants, mercury, and organics collected from EM facility sumps and underground pipes. The remaining 40% of the PW volume is generated from SC facilities' building foundation drain collection and equipment/process activities.

3.2 OPERATIONS AND MAINTENANCE HISTORY

Building 3544, used for radiological wastewater treatment, was built in 1975 and upgraded in 1996. Building 3608, used for non-radiological wastewater treatment, was built in 1989, along with the two 350,000-gal tank in the 2600 area. The 1,000,000 gal tank was added to 2600 in the early 1990s.

3.2.1 Operating History

Operation of the PWTC includes facility management, wastewater collection and transfer, monitoring, wastewater processing and discharge, secondary waste processing and disposal, repairs, S&M, and documentation. Wastewater is monitored at strategic locations throughout the piping system prior to transfer to a tank farm, which allows for real-time monitoring of pH, alpha and beta-gamma, and flow rate at the Waste Operations Control Center (WOCC). The nominal treatment capacity of the PWTC is designed for 760 gal per minute (gpm). Building 3544 is designed to treat up to 300 gpm of process wastewater for removal of radionuclides. Building 3608 is designed to treat up to 760 gpm of process wastewater prior to discharge to White Oak Creek through the NPDES discharge point. Currently, the maximum flow which can be obtained through Bldg. 3608 is less than 350 gpm, due to flow restrictions between the air stripper and GAC columns. The operational history, showing the volume of PW treated annually through Bldgs. 3544 and 3608 versus rainfall, is shown in **Fig. 3-2**.

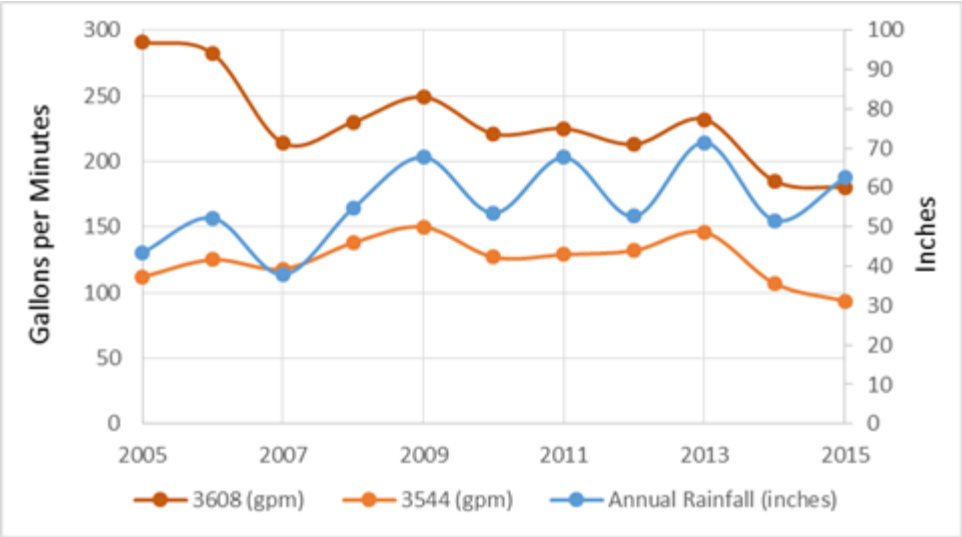

Fig. 3-2. Process waste operational history, 2005–2015.

3.2.2 Maintenance History

As the PWTC facilities continue to operate past their intended design life, the non-routine maintenance continues to increase. In addition to the non-routine maintenance performed, the backlog of deferred maintenance continues to increase as well. Buildings 3608 and 3544 contribute the majority of non-routine maintenance logged for the PWTC. At Bldg. 3608, the majority of work packages are associated with tank maintenance and pump/valve repair or replacement. At Bldg. 3544, the majority of work packages are associated with pump/piping repair or replacement. A summary of logged non-routine maintenance is shown in **Fig. 3-3.**

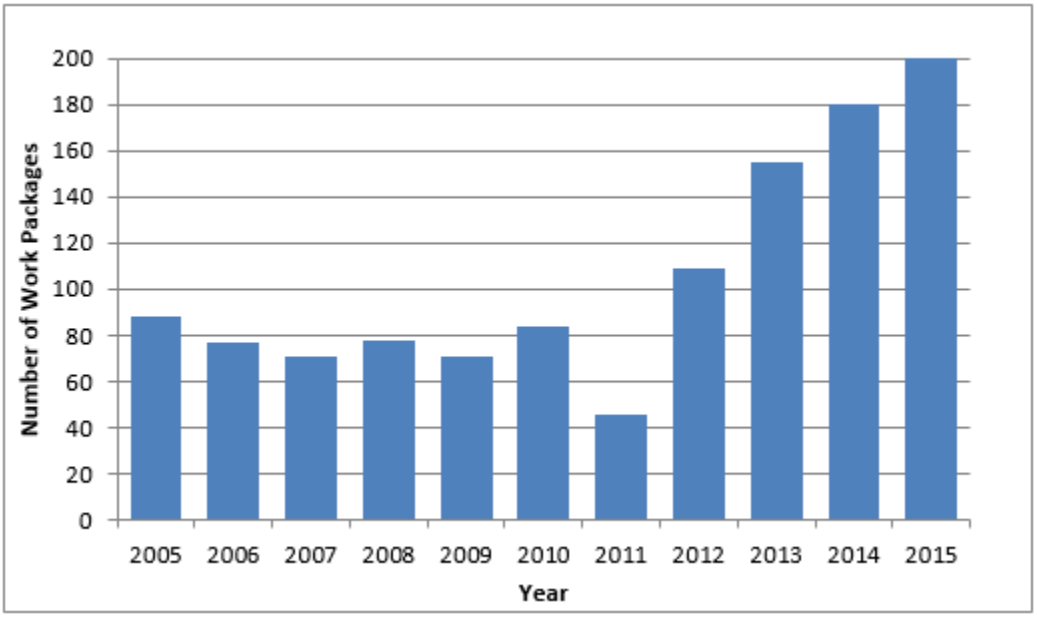

Fig. 3-3. Process waste maintenance history, 2005–2015.

3.3 CURRENT CONDITIONS

3.3.1 Walkdown Results

A walkdown of the PWTC was completed as part of the current condition evaluation and included:

- **Discussions** with plant and facility operators and maintenance support craft;
- **Review** of items currently out of service awaiting maintenance or not operating; and
- **Visual inspection** of Bldgs. 3608, 3544, 2600, and 7961.

During the walkdown, it was apparent that many items require maintenance. The motor control center (MCC) and heat trace controls are obsolete, few valves work, pumps are out-of-service, filters are offline, pipes are broken or leaking, and containment dikes are cracked and filled with vegetation. LGWO personnel also raised concerns regarding the work control process, specifically the time and effort associated with initiating, planning, approving, and executing work packages. Although work packages are being completed effectively, the work control process is not efficient. This inefficiency is a major factor contributing to the steadily increasing maintenance backlog associated with the PWTC. A detailed summary of the PWTC walkdown is provided in **Appendix C**.

3.3.2 Testing Results

NDE testing of the PWTC was performed in October and November 2015 and included ultrasonic testing (UT) of pipelines, tanks, and vessels. A total of 975 readings were collected from pipelines and vessels in and between four facilities (2600, 3544, 3608, and 7961). The NDE results indicated that the malleable iron piping in Bldg. 3608 is severely corroded, to the extent that the majority of the piping is less than the minimum thickness allowed. Significant degradation and corrosion was also detected in the 4001 header, which is also malleable iron. The tanks and vessels are in good condition with additional years of operational life. Despite the age of Bldg.3544, there were no issues with the stainless steel piping and vessels in the facility. Inspection of the underground transfer lines, which are protected with a heavy anti-corrosion barrier and cathodic protection, indicated little or no degradation. The NDE testing results for the PWTC are provided as **Appendix D**.

3.4 EXTENDED LIFE STUDY

3.4.1 Forecast of Future Users and Capacity Requirements

The generation of process wastewater has decreased significantly over the past 5–10 years, from a yearly average of 160 gpm to the current level of 94 gpm for radiological wastewater (Bldg. 3544) and from 250 gpm to 175 gpm for combined radiological and non-radiological wastewater (Bldg. 3608). This is the result of several factors, including:

- Reducing or eliminating discharge to the PW System (e.g. replacement of once through cooling with diversion to storm drain or installation of closed cooling systems);
- Grouting of drains from the source to the main PW header for demolished facilities; and
- Repairing leaking potable water lines in the Central Campus area.

The current PW sources were reviewed and it was determined that additional reduction of PW by source elimination or diversion is likely to be very difficult and/or expensive. The primary sources of PW, infiltration of rainwater into the EM PW piping system and building sumps and groundwater collected in SC building sumps in the 4500 Area, account for 80–90% of the PW generation. It is highly likely that these PW sources will remain until the ORNL Cleanup Project is complete.

The required treatment capacity of the PW System is driven by stormwater flow and the need to have additional treatment capacity available to treat excess water that is diverted to storage. A 500-gpm treatment capacity for combined radiological and nonradiological wastewater is recommended to minimize the potential for exceeding the current storage capacity in storm events. Flow may increase to over 1,000 gpm during periods of heavy rainfall. The system currently is capable of 350 gpm; however, it is designed for 760 gpm.

3.4.2 Maintenance Upgrade Requirements

A number of upgrades are required to maintain operability and secondary containment, including:

- Distributed control system needs to be updated (general LGWO).
- MCC and heat trace controls are obsolete and need to be replaced (general LGWO).
- Dual media filter columns, used to pretreat wastewater for the air stripper and GAC columns, are broken, although the system is functional without them, and should be replaced.
- Piping at Bldg. 3608, including the GAC column piping, is corroded and must be replaced.
- The 4001 header has significantly degraded and was replaced in October 2015 due to risk of failure.

- Valves at 3608 are not functional and should be replaced.
- Tanks and vessels are generally in good condition and expected to remain operational for 30 years as long as cathodic protection is maintained.
- Containment dikes are cracked and filled with vegetation and need to be repaired and resealed.

3.4.3 New Technology Review

3.4.3.1 Applicable Technologies

Applicable technologies for the treatment of the ORNL PW include precipitation, ion-exchange, evaporation, reverse osmosis, ultrafiltration, microfiltration, and solvent extraction. Based on the relative concentrations of the key radiological (Cs-137 and Sr-90) and non-radiological (arsenic, copper, chromium, mercury, and lead) contaminants, five technologies were selected for the detailed evaluation. Detailed information regarding contaminant concentrations and volumes of the process waste water are provided in **Appendix E**. The advantages and disadvantages of the five technologies selected are summarized below:

- **Conventional Treatment.** The current PWTC uses conventional treatment technology, including chemical precipitation, ion-exchanges, and activated carbon.
  - Advantages: The technology is well-developed, widely demonstrated, easily and inexpensively modified to address multiple contaminants, and unit operations can be optimized to minimize secondary waste volumes.
  - Disadvantages: The technology is associated with high construction costs and involves extensive use and handling of hazardous chemicals.
- **Electrocoagulation.** Technology that uses electricity to remove contaminants in water.
  - Advantages: The technology uses no chemicals, which reduces operating costs, hazards associated with chemical handling, and total dissolved solids (TDS) in the treated effluent. The solids handling equipment has a small footprint and low generation of secondary waste solids, which reduces construction, equipment, and waste disposal costs. Treatment units can be constructed off-site by commercial suppliers and delivered as self-contained modules, which reduces installation and commissioning time. Some radionuclide constituents may be significantly reduced, possibly negating the need for ion-exchange.
  - Disadvantages: The technology is not widely used in the DOE complex, would require characterization of waste streams since operating parameters are based on specific waste characteristics and treatability studies to confirm the effectiveness on ORNL process wastewater, and entails periodic anode replacement and cleaning of electrode surfaces.
- **Selective Precipitation.** Technology that uses an ion-specific reagent to precipitate selective contaminants in water.
  - Advantages: Technology is well-developed and widely understood; the solids handling equipment has a small footprint and low generation of secondary waste solids, which reduces construction, equipment, and waste disposal costs; treated water has lower effluent TDS than electrocoagulation or alkaline precipitation alternatives; and treatment units can be constructed off-site by commercial suppliers and delivered as self-contained modules, which reduces installation and commissioning time.
  - Disadvantages: The technology is sensitive to changes in the feed composition; requires multiple chemical feed systems, handling of a range of hazardous chemicals, and multiple types of treatment media; and ion-selective precipitating agents are expensive and can have detrimental aquatic toxicity impacts.

— Issues: Selective precipitation alone is not effective for removal of Cs-137 or Sr-90; therefore, additional unit operations such as ion-exchange would be needed.

- **Membrane.** Technology that uses membranes to physically separate contaminants in water.
  - — Advantages: The technology is not sensitive to constituent type and would produce a very high quality, low TDS effluent stream that is unlikely to impact aquatic life; relies on purely physical means to process wastewater, and requires no chemicals except those needed for periodic cleaning of membranes and evaporator heat transfer surfaces; process equipment is modular and constructed to minimize space requirements, requiring the smallest footprint of the alternatives, which reduces construction/D&D costs.
  - — Disadvantages: There are high costs associated with the membranes and evaporator process equipment, including periodic membrane replacement; the membranes are sensitive to fouling, which can be irreversible; and there are potential maintenance challenges associated with both the membranes and the evaporator system. There are high energy requirements for pumps and evaporator; the high-volume concentrate stream requires evaporation and solidification for disposal; and the operating costs are the highest of the alternatives discussed.
- **Chemical Precipitation.** Technology that uses chemicals to precipitate contaminants in water.
  - — Advantages: The technology is simple, requires a relatively small footprint, has low construction and operating costs, and is applicable for multiple constituents.
  - — Disadvantages: The equipment is not suited for modular construction; process development is necessary for precipitation of Cs-137 and Sr-90; hazards associated with handling large volumes of chemicals; a large volume of secondary waste solids; and high dissolved solids content in the effluent, which may not meet discharge requirements.

3.4.3.2 Discussion

None of the treatment technologies presented a clearly superior potential for treating the ORNL PW compared to the current (conventional) approach, which includes a modification of the current system that was developed in the 1980s and 1990s for removing Cs-137 and Sr-90 using zeolite. The consensus was that the conventional treatment approach offered the best combination of treatment effectiveness, flexibility to handle changing waste characteristics, and years of institutional operating experience. Regardless of the alternative selected, major maintenance upgrades are needed to maintain operability in the near term.

In order to take advantage of the near-term rehabilitation at Bldg. 3608, the discussion focused on the potential for incorporating the modified zeolite operation for removing Cs-137 and Sr-90. The modified zeolite operation would replace the softening and ion-exchange processes currently used to remove radionuclides at Bldg. 3544 and allow for decommissioning of Bldg. 3544. This would also eliminate LLLW generated by the Bldg. 3544 ion-exchange regeneration process. This approach was previously developed and a design package was prepared and documented in DOE/ORO/2340, *Critical Decision-2/3 Technical Baseline for the Integrated Facility Disposition Program Process Wastewater Systems Project at the Oak Ridge National Laboratory*. The study team proposed an improved deployment approach for this project.

The key issues associated with zeolite include the availability of diked areas to locate the equipment and the sequence of near-term maintenance upgrades to maintain continuous operation of the PWTC. Key conclusions from the discussion are summarized below:

- A number of general improvements would be required for any approach for extending the life of LGWO systems (e.g., distributed control system update, MCC component replacement, etc.)

- The existing damaged dual media filters (F-1009 and F-1010) used to prefilter the air stripper and GAC system feed at 3608 should be replaced with new units.
- The existing F-1007 clarifier (utilized for metals removal) will not be required for future operations. Removal of this equipment would provide sufficient area to locate the zeolite columns and pre-filters within the existing 3608 containment area.
- The existing F-1006 water softener will be used for metals precipitation and particulate removal.
- The existing air stripper will not be required and removing it would provide improved access to the area required to remove and replace the F-1009 and F-1010 filters.
- The upgrade would require that radiological wastewater and the low volume of metals wastewater be combined in the F-1001 equalization tank for processing.
- A skid-mounted GAC treatment unit with dual media pre-filters would temporarily replace the existing GAC system while the corroded piping of the GAC system is replaced. The existing GAC columns were determined to be in good condition and would be placed back in service upon completion of the piping repairs.
- With the repaired GAC system back in service, the temporary GAC treatment unit would be repurposed as dual media filters replacing the damaged filters F-1009 and F-1010. Specifications for the temporary GAC system should require functionality (if possible) for using the GAC columns as pre-filters (at a lower flow rate) in a subsequent application. (Note – this may require that vessels designed as dual media filters be used for GAC.)
- Columns designed for zeolite processing for the removal of radioactive Cs-137 and Sr-90 would then be installed in the area the clarifier previously occupied. This use of this zeolite treatment would allow for the shutdown of Bldg. 3544. These columns would have their own set of dual media filters for pre-treatment prior to the zeolite columns.
- NPDES permit modifications with Tennessee Department of Environmental Control approval will be required for both the removal of the 3608 clarifier and air stripper and deployment of the new zeolite system.

The recommended sequencing for this approach is presented in **Table 3-1**.

Table 3-1. Sequence of process waste system modifications

System	Phase 1	Phase 2	Phase 3	Phase 4
General	Support RFP Preparation			
	Replace MCC Components	Reseal/Paint Concrete Dike Area		
	Replace Heat Trace Controls			
	Design, Specify, and Test Distributed Control System (DCS)	Procure, Install, and Test Control System Hardware/Software, Begin Transition of Systems	Transition Remaining Systems to New DCS	
Process Waste	LGWO 4001 Pump Station	Demolish and Replace Non-GAC Piping	Demolish and Replace Non-GAC Piping	Shutdown Bldg. 3544
	Establish Work Area	Demolish and Replace GAC Piping	Apply Corrosion Protection Coatings to Equalization Tanks	
	Demolish Clarifier, Dual Media Filters, and Air Stripper (NPDES permit modification required)	Relocate Temporary GAC and Pipe for Dual Media Service	Install Zeolite Columns and Dual Media Filters	
	Install Temporary GAC System/Piping		Install Dewatering Equipment	
			Rehabilitate SWSA Collection System	

3.4.3.3 Process Waste Treatment System Alternatives

Based on the current conditions and the technology evaluation, the following alternatives were identified for the PW life cycle cost analysis:

- **PW1 – Status Quo.** Continue operation of existing PW System with maintenance and refurbishment as necessary to continue safe and effective operations until completion of EM Cleanup at ORNL.
- **PW2 – Upgrade Bldg. 3608.** Perform near-term maintenance upgrades. Refurbish Bldg. 3608 to include radiological wastewater treatment using zeolite. Deactivate and shut down Bldg. 3544 systems, which will eliminate ion-exchange regenerant going to the LLLW System.
- **PW3 – Build Greenfield Modular Plant.** Perform necessary maintenance upgrades needed to maintain operability until the new plant is commissioned. Construct new facility in Bethel Valley with modular units using the same treatment processes as the Bldg. 3608 Upgrade alternative, treating both radiological and non-radiological wastewater without producing a LLLW waste stream. Deactivate and shut down Bldgs. 3544 and 3608 once the new plant achieves acceptable operating performance.

3.4.4 Process Waste System Alternatives Life-Cycle Cost Analysis

Rough order of magnitude (ROM) life-cycle cost estimates were developed for the PW alternatives based on the following information:

- **Maintenance upgrades.** Fixed-price proposals for the same or similar activities.
- **Additional upgrades.** Engineering studies for zeolite-related costs.
- **Construction.** Vendor quotes for equipment and parametric factors for construction activities.
- **Operation and Maintenance.** Labor costs based on current LGWO rates and anticipated labor requirements. Chemical and materials based on current LGWO usage and rates and anticipated quantities. Energy costs based on anticipated pump, mixer, and fan motor horsepower requirements, kilowatt-hour requirements, and current utility rates.
- **D&D.** Building 3544 D&D cost based on a DOE independent cost estimate as documented in *Critical Decision 2/3 – Performance Baseline for the Integrated Facility Disposition Program Process Wastewater Systems Project* (DOE 2010) and escalated for the anticipated timeframe. Building 3608 (50% larger), upgraded Bldg. 3608 (60% larger), and the Greenfield Plant (25% larger) D&D costs were scaled based on the size relative to Bldg. 3544.
- Additional cost estimate details and assumptions are provided in the *LGWO Extended-Life Study Cost Supporting Data* file, archived in the UCOR Document Control Center.

PW1 – Status Quo. The life-cycle cost estimate for the status quo alternative includes the cost for near-term maintenance upgrades, operations and maintenance, and demolition of Bldgs. 3544 and 3608. The near-term maintenance upgrades are recommended to be performed in three phases, each of which will require approximately one year. The near-term maintenance upgrade costs are summarized in **Table 3-2**.

Table 3-2. Process waste near-term maintenance upgrade costs

Near-term maintenance upgrade activity	2016 Cost ($K)
Support RFP preparation	100
Replace MCC components	1,750
Replace heat trace controls	450
Design specifications for new DCS	225
Establish work area at Bldg. 3608	25
Demolish dual media filters F-1009 and F-1010	475
Demolish air stripper	870
Install temporary GAC columns	1,500
Phase I Total	**5,395**
Reseal/repaint concrete dike area	400
Procure, install, and test new DCS	850
Demolish and replace non-GAC piping	3,600
Demolish and replace GAC piping	1,750
Relocate temporary GAC columns and piping to replace dual media filters F-1009 and F-1010	350
Phase II Total	**6,950**

Table 3-2. Process waste near-term maintenance upgrade costs (cont.)

Near-term maintenance upgrade activity	2016 Cost ($K)
Transition remaining systems to new DCS	375
Demolish and replace non-GAC piping	775
Apply corrosion protection coating on equalization tanks	700
Phase III Total	**1,850**
Replace L-3 granular media filter	752
Replace L-5 basin	276
Reseal plant containment areas	300
Replace MCC and heat trace controls	1,100
Replace/rewire instruments and control panels	168
Replace roof	20
Replace F-4001 sump piping	11
Replace L-10 evaporator (every 10 years)	479
Replace zeolite column	1,112
Replace pump	141
Building 3544 upgrade total	**4,359**

The life-cycle cost estimate for the status quo alternative is provided in **Table 3-3**. For cost escalation and present value determinations, it was assumed that the near-term phased maintenance upgrades would be performed in the first three years of the life cycle, the Bldg. 3544 upgrades would be performed every five years, and the D&D activities would occur in the last two years of the life cycle.

Table 3-3. PW1 – Status quo alternative life-cycle cost estimate

PW1 – Status Quo Cost Elements	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Phase I maintenance upgrades (Year 1)	5.4	5.5	5.3
Phase II maintenance upgrades (Year 2)	7.0	7.3	6.8
Phase III maintenance upgrades (Year 3)	1.9	2.0	1.8
Building 3544 upgrades (Years 5, 10, 15, and 20)	4.4	5.6	4.0
O&M labor, materials, and management (Years 1–28)	156.6	221.5	140.2
Building 3544 D&D (Years 29–30)	9.0	17.6	7.1
Buildings 3608 D&D (Years 29–30)	13.4	26.5	10.6
Life cycle cost	**197.7**	**286**	**175.8**

PW2 – Upgrade Bldg. 3608. The life-cycle cost estimate for the Bldg. 3608 Upgrade alternative includes the cost for near-term maintenance upgrades, additional upgrades to equip Bldg. 3608 for radiological treatment, operations and maintenance, and demolition of Bldgs. 3544 and 3608. The maintenance upgrades would be the same as those identified in Table 3.2 for Phases I, II, and III, along with additional actions necessary for deployment of a new zeolite system within the Bldg. 3608 footprint and placement of Bldg. 3544 in standby mode. The cost summary for the PW2 upgrades is provided in Table 3-4. The F-1007 clarifier, to be demolished during Phase I, has never been used for PW processing and has been deemed unnecessary. The zeolite ion-exchange system, to be installed during Phase III, would be designed for removal of Sr-90 and Cs-137 and include dual media filters to remove suspended solids from the F-1006 clarifier effluent and a dewater bin to remove free water from the spent zeolite. Following

installation and startup of the new zeolite system, Bldg. 3544 would be maintained in a safe standby mode while the new zeolite system is commissioned and achieves acceptable operating performance.

Table 3-4. Process waste additional upgrade costs

Additional upgrades	2016 Cost ($K)
Phase I, II, and III maintenance upgrades	14,195
Demolish F-1007 clarifier	775
Install zeolite columns and dual media filter	1,940
Install spent zeolite dewatering equipment	450
Place Bldg. 3544 in hot standby mode	350
Additional upgrades total	**17,710**

The life-cycle cost estimate for the Bldg. 3608 Upgrade alternative is provided in **Table 3-5**. For cost escalation and present value determinations, it was assumed that the phased maintenance upgrades would be performed in the first three years of the life cycle, D&D of Bldg. 3544 would occur in the fourth and fifth year, and the D&D of Bldg. 3608 would occur in the last two years of the life cycle. Operating costs include operation of the PW System in the current configuration for three years followed by operation of the upgraded Bldg. 3608 for 25 years.

Table 3-5. PW2 – Building 3608 Upgrade alternative life-cycle cost estimate

PW2 – Building 3608 Upgrade cost elements	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Phase I maintenance upgrades (Year 1)	5.4	5.6	5.3
Phase II maintenance upgrades (Year 2)	7.0	7.2	6.9
Phase III maintenance upgrades (Year 3)	1.8	2.0	1.8
Additional upgrades (Years 1 and 3)	3.5	3.7	3.5
O&M labor, materials, and management (Years 1–28)	114.2	159.7	102.7
Building 3544 D&D (Years 4–5)	9.0	10.0	8.6
Buildings 3608 D&D (Years 29–30)	14.3	28.2	11.4
Life cycle cost	**155.2**	**216.4**	**140.2**

PW3 – Build Greenfield Modular Plant. The life-cycle cost estimate for the Greenfield Plant alternative includes the cost for near-term maintenance upgrades needed to maintain operability of the existing PW System until the new plant is online, a capital project to construct the Greenfield Plant, operations and maintenance, and demolition of Bldgs. 3544 and 3608 and the new Greenfield Plant. It is anticipated that nearly all of the near-term PW System maintenance upgrades would be necessary to operate safely and effectively until the Greenfield Plant was commissioned. Only a fraction of the non-GAC piping replacement effort was considered unnecessary for this alternative. Both Bldgs. 3544 and 3608 would be placed in hot standby mode until the Greenfield Plant is commissioned and acceptable operations established. The costs for near-term maintenance upgrades are provided in **Table 3-6**.

Table 3-6. Process waste limited upgrade cost

Limited upgrades	2016 Cost ($K)
Support RFP preparation	100
Replace MCC components	1,750
Replace heat trace controls	450
Design specifications for new DCS	225
Establish work area at Bldg. 3608	25
Demolish dual media filters F-1009 and F-1010	475
Demolish air stripper	870
Install temporary GAC columns	1,500
Reseal/repaint concrete dike area	400
Procure, install, and text new DCS	850
Demolish and replace non-GAC piping at Bldg. 3608	2,000
Demolish and replace GAC piping	1,750
Relocate temporary GAC columns and piping for dual media filter service	350
Transition remaining systems to new DCS	375
Demolish and replace non-GAC piping	775
Apply corrosion protection coatings to equalization tanks	700
Place Bldgs. 3544 and 3608 in hot standby mode	500
Limited upgrades total	**13,095**

A Greenfield Modular Plant would be a capital project and require approximately five and a half years to complete. The first three years would involve site selection, design, and DOE capital project acquisition approvals. The following two and a half years would involve construction and commissioning activities. The cost associated with the major elements for constructing a new plant are provided in **Table 3-7**.

Table 3-7. Capital cost for PW Greenfield Modular Plant

Capital cost elements	2016 cost ($)
Engineering and testing	1,647,727
Equipment	2,162,352
Site development and installation	1,497,411
Piping, electrical, and instrumentation	1,167,017
Building structure	471,200
Construction management and services	1,271,515
Indirect costs (overhead, insurance, taxes)	1,536,414
Commissioning	158,939
Project Management	2,066,212
Contingency at 30% of total	3,593,637
Capital cost total	**15,572,424**

The life-cycle cost estimate for the Bldg. 3608 Upgrade alternative is provided in **Table 3-8**. For cost escalation and present value determinations, it was assumed that maintenance upgrades would be performed in the first three years of the life cycle, D&D of Bldgs. 3544 and 3608 would occur in the seventh and eighth year, and the D&D of the new plant would occur in the last two years of the life cycle. Operating costs include operation of PW Systems in the current configuration for six years followed by operation of the Greenfield Plant for 22 years.

Table 3-8. PW3 – New Greenfield Plant alternative life-cycle cost estimate

PW3 – New Greenfield Plant cost elements	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Maintenance upgrades (Years 1–3)	13.1	13.6	12.9
Capital cost for Greenfield Plan (Years 1–4)	15.6	17.1	15.1
O&M labor, materials, and management (Years 1–30)	118.4	164.0	106.8
Building 3544 D&D (Years 7–8)	9.0	10.7	8.4
Buildings 3608 D&D (Years 7–8)	13.4	16.8	12.4
Greenfield Plant D&D (Years 29–30)	11.2	22.1	8.9
Life-cycle cost	**180.7**	**244.3**	**164.5**

Life-cycle costs for the three PW alternatives are shown in **Fig. 3-4**. The Bldg. 3608 Upgrade is the least expensive alternative, followed by the Greenfield Modular Plant alternative, and the status quo alternative. A sensitivity analysis was performed to evaluate the impact of key cost and schedule risks and opportunities associated with the three PW alternatives. The highest cost impacts are related to unexpectedly high zeolite usage and unanticipated increases in maintenance costs for the Bldg. 3608 Upgrade alternative, and the potential opportunity for reduced maintenance labor requirements for the Greenfield Plant alternative. The sensitivity analysis is provided as **Appendix F**.

The pros and cons of the three PW alternatives are provided in **Table 3-9**.

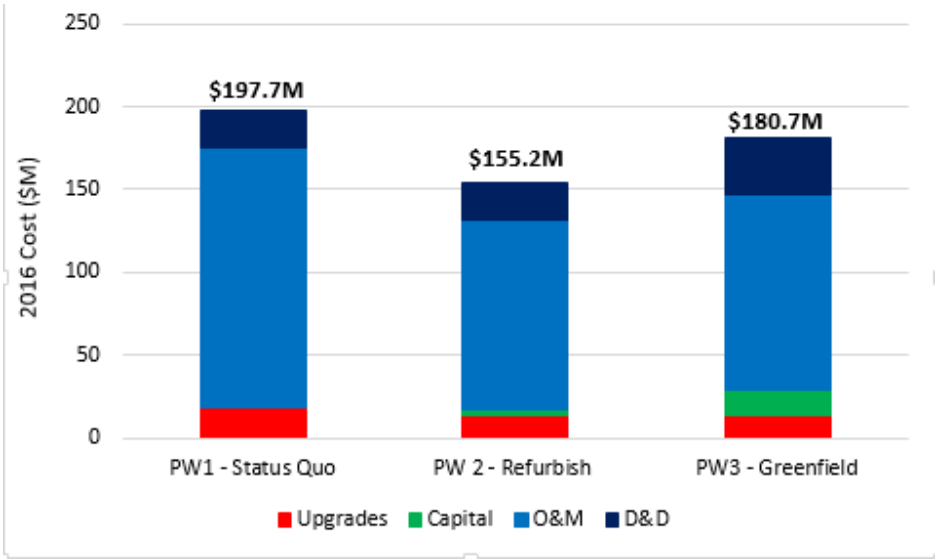

Fig. 3-4. Life-cycle cost estimates for the PW alternatives.

Table 3-9. Pros and cons of the PW alternatives

Category	Process wastewater status quo alternative	Process wastewater 3608 Upgrade alternative	Process wastewater Greenfield Plant alternative
	Continue operation of existing LGWO system with maintenance and refurbishment as necessary to continue safe and effective operations.	**Upgrade Building 3608 to include radiological wastewater processing with zeolite along with required refurbishment actions.**	**Replace Building 3544 and 3608 with a new processing plant located in Bethel Valley. Conduct maintenance and refurbishment activities at Building 3608 as necessary to operate until the new plant is commissioned.**
Environment, Safety, and Health			
Pros	• Avoids risks of accidents during construction of new systems and facilities. • Does not require NPDES permit modifications. • No risk of environmental impacts from new system startup activities. • Does not require additional land space for processing.	• Uses an existing facility for process upgrades. Does not require use of additional land space. • Greatly reduces the quantities of hazardous chemicals used for processing (eliminates nitric acid and greatly reduces sodium hydroxide and sulfuric acid usage). • Eliminates generation of LLLW. • Greatly reduces the quantity of clarifier sludge for dewatering and disposal. • Allows for early D&D of Bldg. 3544 and subsequent environmental restoration activities for underlying soils in that area.	• Greatly reduces the quantities of hazardous chemicals used for processing (eliminates nitric acid and greatly reduces sodium hydroxide and sulfuric acid usage). • Eliminates generation of LLLW. • Greatly reduces the quantity of clarifier sludge for dewatering and disposal. • Allows for early D&D of Bldgs. 3544 and 3608, and subsequent environmental restoration activities for underlying soils in that area. • Majority of construction labor will be “clean,” possibly off-site.
Cons	• Continues storage and handling of large quantities of hazardous chemicals (nitric acid, sulfuric acid, sodium hydroxide) in close proximity to White Oak Creek. • Continues generation of large quantities of dewatered softener sludge. • Continues generating LLLW that must be stored until processing capability is available. • Does not allow for environmental restoration of the Bldg. 3544 area until the end of the project life cycle. • The continued use of aging infrastructure increases the risk of system failures.	• Greatly increases the amount of spent zeolite that requires handling and disposal. • Carries the greatest risk of industrial accidents due to obstructions from existing structures and coordination of multiple contractors within a limited work space. • Majority of construction activities will be “Rad Work” • The continued use of aging infrastructure increases the risk of system failures.	• Greatly increases the amount of spent zeolite that requires handling and disposal. • Requires additional land space for radiological operations. • Requires D&D of an additional facility. • Carries the risk of industrial accidents from construction of a new PW treatment facility.
Operability			
Pros	• Requires no change in operational activities, so additional training of operators is not required.	• Simplifies operations by consolidating at one operating facility, and eliminates the softening and ion-exchange regeneration operations.	• Simplifies operations by consolidating at one operating facility, and eliminates the softening and ion-exchange regeneration operations. • Uses new right-sized systems for processing. • Uses new equipment and updated control systems, which reduces maintenance costs. • No sequencing and coordination of construction activities required to ensure continued operability of 3608 and 3544.
Cons	• Requires the use of older process equipment at Bldgs. 3544 and 3608, which could increase the frequency of maintenance issues.	• Requires optimization of a new unit operation – zeolite ion-exchange. • Requires new operating procedures and operator training for the zeolite system. • Requires the use of older process equipment at Bldg. 3608 which could increase the frequency of maintenance issues. • Requires careful sequencing and coordination of upgrade activities to ensure continued operability of 3608.	• Requires optimization of a new unit operation – zeolite ion-exchange. • Requires new operating procedures and operator training for zeolite system and other new systems.

Table 3-9. Pros and cons of the PW alternatives (cont.)

Category	Process wastewater status quo alternative	Process wastewater 3608 Upgrade alternative	Process wastewater Greenfield Plant alternative
	Continue operation of existing LGWO system with maintenance and refurbishment as necessary to continue safe and effective operations.	**Upgrade Building 3608 to include radiological wastewater processing with zeolite along with required refurbishment actions.**	**Replace Building 3544 and 3608 with a new processing plant located in Bethel Valley. Conduct maintenance and refurbishment activities at Building 3608 as necessary to operate until the new plant is commissioned.**
Cost and Schedule			
Pros	• Does not generate additional equipment or facilities for future D&D.	• Eliminates cost liabilities of LLLW storage and disposal. • Allows early D&D of Bldg. 3544.	• Eliminates cost liabilities of LLLW storage and disposal. • Allows early D&D of Bldgs. 3544 and 3608.
Cons	• Continues generating LLLW that is difficult and expensive to process for disposal. • The continued use of aging infrastructure increases the risk of unplanned maintenance expense. • May require additional costly upgrades of Bldg. 3544.	• Carries the risk of generating greater than expected quantities of spent zeolite. • The continued use of aging infrastructure increases the risk of unplanned maintenance expense.	• Carries the risk of generating greater than expected quantities of spent zeolite. • Requires D&D of an additional facility. • Requires additional time for design and construction. • Carries the risk of delays in capital funding. • Carries the risk of high site development costs due to soil contamination and interferences from legacy underground piping and utility routings.

4. LIQUID LOW-LEVEL WASTE SYSTEM

4.1 SYSTEM DESCRIPTION AND USERS

The LLLW System at ORNL collects, neutralizes, concentrates, and stores aqueous radioactive waste solutions from various sources at the Laboratory. The WAC administratively limits the wastes added to the LLLW System to a total radionuclide concentration of the ingestion dose equivalent to 2 Ci/gal Sr-90.

4.1.1 System Description

The LLLW System consists of a series of dedicated tanks and underground piping used to collect LLLW from generating facilities at ORNL and transfer the waste to the LLLW Evaporator Facility for volume reduction. The overheads are transferred to the PW Treatment System for radionuclide removal and the concentrated LLLW is transferred to storage tanks in Bethel and Melton Valleys for long-term storage. The LLLW System is a Category 2 Nuclear Facility comprised of 16 facilities and includes the following components:

- Collection tanks and piping
  - Tank F-1404, a 1900-gal tank located in Bethel Valley to serve Bldg. 2026 radiochemical laboratory operations
  - Tank F-1800, a 10,000-gal tank located in Melton Valley to serve Bldgs. 7920 and 7930 (the Radiochemical Engineering Development Center [REDC])
  - Three miles of underground piping that connects the waste collection systems to the evaporator system and storage tanks in Bethel Valley and Melton Valley
  - Building 3025E Collection Tank (not part of the LLLW safety basis)
  - Building 3517 Collection Tanks (not part of the LLLW safety basis)
  - Building 3019 Collection Tanks (not part of the LLLW safety basis)
- Evaporator service tanks at Bldg. 2537 (aka Bethel Valley Evaporator Service Tanks [BVESTs])
  - Tanks C-1 and C-2, 50,000-gal feed/collection tanks
  - Tanks W-21,W-22, and W-23 50,000-gal feed/collection tanks
- Evaporator facilities at Bldg. 2531
  - Two 600-gal/hour evaporator systems, each consisting of an evaporator vessel, vapor filter, water-cooled condenser, and condensate catch tank
  - Building 2568 high efficiency particulate air (HEPA) filter facility servicing the Evaporator facilities
  - Buildings 3535 and 2539 cooling towers for the LLLW evaporators
- Melton Valley Storage Tanks (MVSTs)
  - Eight 50,000-gal tanks
- MVST Capacity Increase
  - Six 100,000-gal tanks

LLLW is also transported by motor vehicles to the LLLW Collection System for treatment. Bulk liquid wastes are transported in either the 1,000-gal flatbed mounted tank operated by LGWO personnel or the

Bldg. 7935 dumpster tank operated by UT-B personnel. Smaller quantities of liquid waste are transported in a Department of Transportation Specification 7A Type 1 Equivalent Bottle Package System which consists of a 2.5-gal thick-walled reusable polyethylene bottle with a 20-gal drum overpack.

Engineered safeguards include liquid level measuring devices, combustible gas analyzers, steel liners, secondary containment, leak detection instrumentation, and off-gas and cell ventilation streams treated through HEPA filters. Alarms are telemetered to the WOCC, which is manned around the clock.

A diagram of the LLLW System is provided as **Fig. 4-1**.

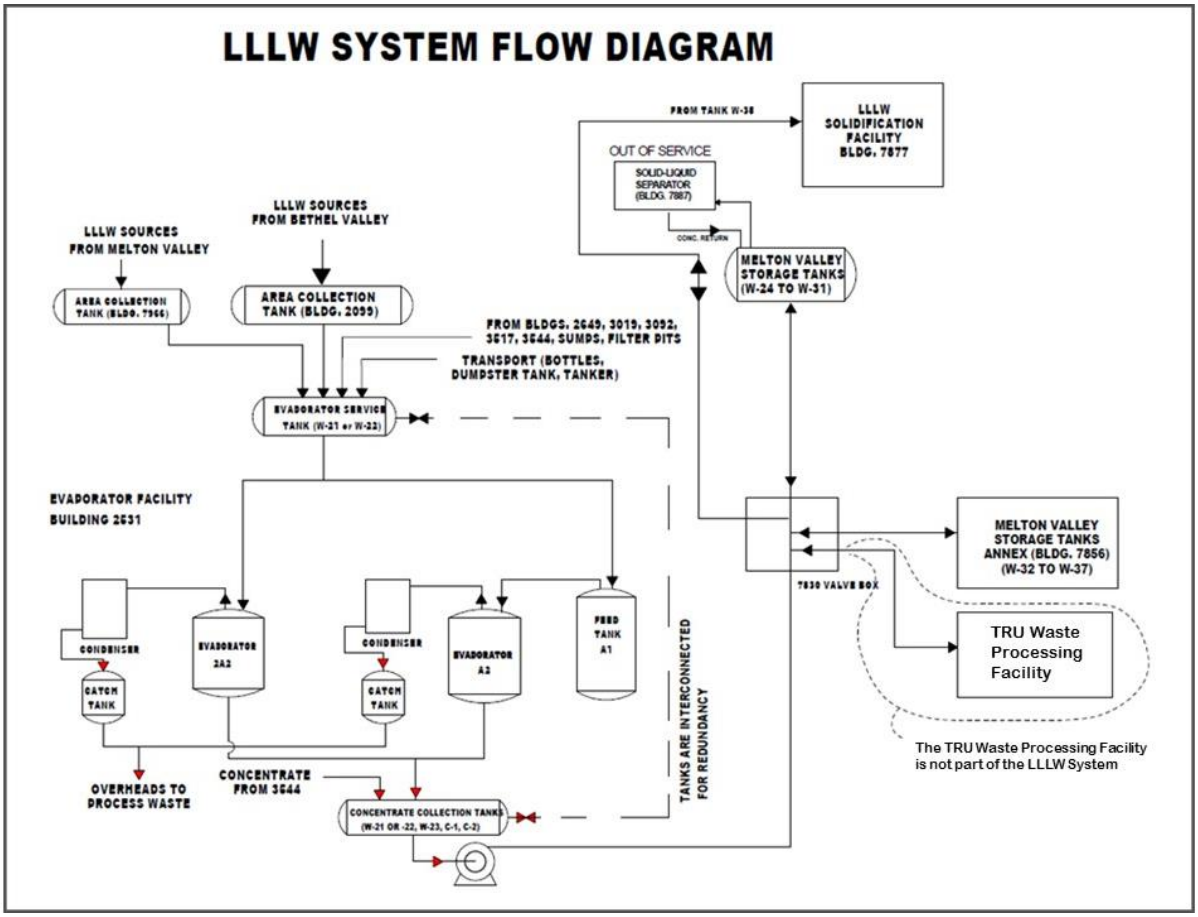

Fig. 4-1. LLLW System flow diagram.

4.1.2 System Users

LLLW treatment is an essential support function that enables key nuclear operations in fuel cycle research and development, isotope development and production, waste operations, and facility S&M. The LLLW System is operated by EM and treats LLLW generated from research laboratories, radiochemical pilot plants, nuclear reactor facilities, and other waste treatment systems at ORNL. Approximately 90% of the LLLW volume, most of which has a low radiological content, is generated from EM activities including Bldg. 3517 sump collection, GW scrubber liquid, Bldg. 3544 ion-exchange regenerant, and other sump locations. The remaining 10% of LLLW, most of which is highly radioactive, is generated from SC activities in Bldgs. 7920, 7930, 7935, and various laboratories. Buildings 7920 and 7930 LLLW (which currently contributes approximately 90% of the total activity in the LLLW System) are currently being segregated and stored in Tank-W33 for future disposition.

4.2 OPERATIONS AND MAINTENANCE HISTORY

The LLLW System was placed in service in the mid-1940s. Treatment and disposal of LLLW was historically accomplished by precipitation of radionuclides in tanks and basins and natural ion-exchange in trenches. Between 1966 and 1984, disposal was accomplished via hydrofracture injections. Since 1984, wastes have been concentrated and stored in BVESTs and MVSTs. As storage space in the tanks became limited, some of the liquid portion was removed from the tanks and processed by solidification for off-site disposal. In 2003, DOE-EM constructed the Transuranic Waste Processing Center (TWPC) to treat the remote-handled transuranic (TRU) and the remaining LLLW supernate that had accumulated.

The LLLW system underwent major upgrades in the 1990s to meet the Federal Facility Agreement (FFA) requirements. Single-contained tanks and piping were removed from service and replaced with double-contained tank facilities and double-contained piping with active leak detection systems. Six 100,000-gal capacity tanks were added to provide additional storage for concentrated LLLW in late December 1998 to support cleanup activities at various inactive tank sites.

4.2.1 Operating History

Operation of the LLLW System includes facility management, LLLW collection and transfers, monitoring, pre-treatment, storage, repairs, S&M, and documentation. The operational history, showing the volume of LLLW treated annually between 2005 and 2015, is provided in **Fig. 4-2**.

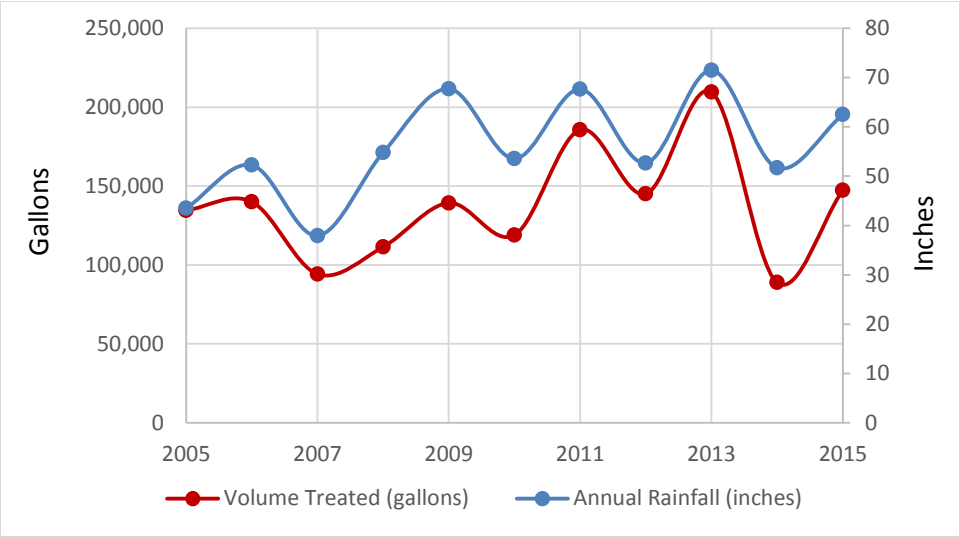

Fig. 4-2. LLLW operational history, 2005–2015.

4.2.2 Maintenance History

As the LLLW facilities continue to operate past their intended design life, the non-routine maintenance continues to increase. In addition to the non-routine maintenance performed, the backlog of deferred maintenance continues to increase as well. The LLLW evaporator facility contributes the majority of non-routine maintenance logged for the LLLW System. Pump, valve, fan, and filter repair/replacement contribute a significant amount of work packages logged. A summary of logged non-routine maintenance are shown in **Fig. 4-3.**

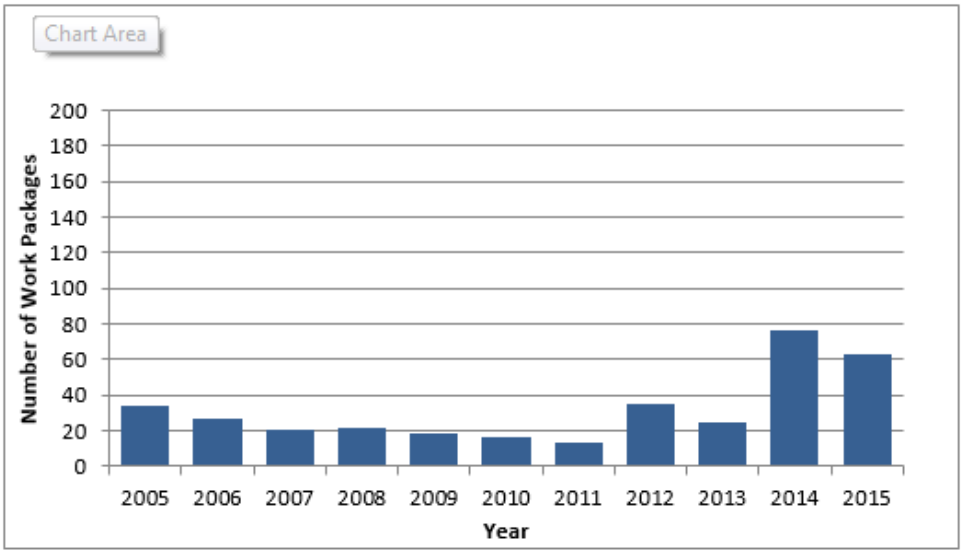

Fig. 4-3. LLLW maintenance history.

4.3 CURRENT CONDITIONS

4.3.1 Walkdown Results

A walkdown of the LLLW System was completed as part of the current condition evaluation. Since much of the LLLW System is underground, only the Evaporator Complex and Bldgs. 7830 and 7856 (sludge storage tank areas) were walked down. The walkdown included:

- **Discussion** with plant and facility operators and maintenance support craft;
- **Review** of items currently broken or not operating; and
- **Visual inspection** of the Evaporator Complex, Bldg. 7830, and Bldg. 7856.

Several items requiring maintenance were identified during the walkdown. The MCC and heat trace controls are obsolete, the Moyno pumps in Bldg. 7966 are inoperable and currently being replaced, and the Cooling Tower is offline due to a leak in the underground piping. LGWO personnel also raised concerns regarding the work control process, specifically the time and effort associated with initiating, planning, approving, and executing work packages. Although work packages are being completed effectively, the work control process is not efficient. A detailed summary of the LLLW System walkdown is provided in **Appendix G**.

4.3.2 Testing Results

NDE testing of the LLLW System was performed in November and December 2015 and included UT of accessible portions of pipelines, valve boxes, and a 1,000-gal tanker, all of which are constructed of stainless steel. A total of 32 readings were collected from the 3092 scrubber circulation line and the 1,000-gal tanker. With one exception, there was no significant corrosion detected. One reading collected from the 3092 line was below the corrosion allowance; however, this result is believed to be inaccurate because the reading was taken at a transition piece. Other readings indicate that the pipelines and tanker are in good condition and have additional years of operational life. The NDE testing results for the LLLW System are provided as **Appendix H**.

4.4 EXTENDED-LIFE STUDY

4.4.1 Forecast of Future Users and Capacity Requirements

The liquids contained in the BVEST and Clean-In-Place (CIP) tanks are scheduled for transfer to the MVST for treatment at the TRU Sludge Processing Facility between 2026 and 2029. The Melton Valley portion of the LLLW storage system is scheduled for shutdown in 2029 to coincide with completion of TRU sludge processing. The SC facilities are anticipated to disconnect from the LLLW System in 2022, pending completion of the proposed treatment system at REDC. LLLW from the GW scrubber may also be eliminated if the scrubber is taken out-of-service as recommended and/or the central stack is shut down. The PW ion-exchange regenerant may also be eliminated if the Bldg. 3608/3544 reconfiguration is pursued as recommended. The remaining LLLW (~100,000 gal/year) will come from EM sumps and is likely to remain until cleanup is complete, unless the liquids are characterized and possibly diverted to the PW System.

4.4.2 Maintenance Upgrade Requirements

Based on the current conditions evaluation of the LLLW System, the Moyno pumps in Bldg. 7966 and the MCCs in all of the LLLW facilities require maintenance upgrades. Both of these issues are being addressed as part of the priority initiatives currently underway.

4.4.3 New Technology Review

4.4.3.1 Applicable Technologies

Applicable technologies for the treatment of the ORNL LLLW waste include evaporators (batch pan, forced circulation, natural circulation, wiped film, rising film tubular, falling film tubular, and rising/falling film tubular), solidification/grout systems (in container paddle mixer and in-line mixer), ion-exchange, and precipitation. Since the SC facilities contribute the majority of the radiological waste and are anticipated to be taken offline in six years, and the EM facilities generate primarily low radiological activity waste, direct grouting or evaporation with grouting are the most attractive treatment approaches.

4.4.3.2 Discussion

LLLW is currently concentrated in an evaporator (Bldg. 2531), stored in the Evaporator Service Tank complex, and eventually transferred by pipeline to waste storage tanks in Melton Valley for ultimate treatment at the TWPC. It is anticipated that the treated waste will be solidified and transported to the National Nuclear Security Site (NNSS) for ultimate disposition. In the late 2020's, TWPC is scheduled for completion of its sludge-related mission, and will no longer accept waste from the LLLW System. The discussion focused on different approaches for processing the LLLW waste streams when TWPC is no longer available, as summarized below:

- Use Existing Collection and Storage Facilities
  - Following completion of the TRU sludge processing campaign in 2029, the LLLW tanks will be empty, providing 1,000,000 gal of storage capacity in Melton Valley and 200,000 gal of storage capacity in Bethel Valley.
  - Based on the project annual generation of evaporator concentration (100,000 gal/year of LLLW concentrated at 40:1 for 2,500 gal/year of concentrate), there is sufficient capacity in the BVEST for 80 years of operation.
  - Normal maintenance would be required. The LLLW pipelines and tanks are in good condition and will likely last for another 30 years. Maintenance upgrades are currently underway as part of the near-term initiatives.

- Eliminate and/or Redirect LLLW
  - The major generators of radioactivity are the SC facilities, which are anticipated to be treated separately by the proposed REDC treatment system.
  - The remaining generator of radioactivity is the Bldg. 3544 ion-exchange regeneration. If the PW System is modified as recommended, this waste stream will be eliminated.
  - LLLW generated from the GW scrubber may also be eliminated, as the scrubber is no longer needed to treat acidic gases (see Section 5).
  - The remaining generators of LLLW are the EM facility sumps. These waste streams have low radiological activity and will likely remain until the facilities are dispositioned. However, some or all of these streams may be able to be re-directed to the PW System for treatment.
  - Waste streams from the various EM facility sumps would need to be characterized to determine whether or not they meet the PW waste acceptance criteria, specifically.
    - 3517 sump collection represents approximately 45,000 gal/year and has never been sampled for characterization.
    - MVST sumps, LLLW valve boxes, and other collection tank vaults may need to be cleaned or the contamination fixed to reduce radioactivity.
    - The GW duct in-leakage could be eliminated if local stacks are installed and the central GW System is shut down.
  - If LLLW cannot be redirected to the PW treatment system, then install a skid-based LLLW treatment operation in the Evaporator facility crane bay and dispose of solids off-site. Evaluate the cost/benefit of grouting with and without evaporation.
  - There is a potential future generation of large quantities of LLLW during the ORNL Cleanup Project from activities such as water decontamination of highly contaminated cells in Bldgs. 3517 and 3019.
    - One option is to require the cleanup contractor to treat any wastes that they generate. However, LLLW treatment may present worker safety, exposure, and containment challenges.
    - Another option is to use the existing LLLW System for collection and storage and send to TWPC or perform a future sludge disposal campaign.

- Provide New LLLW Treatment Capability
  - New technologies and/or reconfiguration will require characterization of various LLLW streams.
  - Potential locations include Transported Waste Receiving Facility, Bldg. 2531 (Evaporator Facility) Crane Bay, Bldg. 7877 Waste Solidification Facility in Melton Valley, or a new Greenfield Facility.
  - The Bldg. 2531 Crane Bay is the most attractive option since it is co-located with the BVEST, which would minimize the distance that LLLW would need to be pumped. However, it would likely require a major expenditure.
- Transport LLLW Off-site for Treatment and/or Disposal
  - Transport LLLW (dilute or concentrated) off-site for treatment and disposal.
    - Processing and Solidification (e.g., Energy*Solutions* or Perma-Fix)
    - Disposal (e.g., NNSS)

— Shipping dilute LLLW would require approximately twenty (20) 5000-gal tanker trucks per year.

— Shipping concentrated LLLW would require fewer truck loads, but may necessitate the use of smaller capacity shielded containers in response to dose issues.

4.4.3.3 LLLW Treatment System Alternatives for Life-Cycle Cost Analysis

Based on the current conditions and the technology evaluation, the following alternatives were identified for the life cycle cost analysis:

- **LLLW1 – Status Quo.** Continue operation of existing LLLW System with maintenance and refurbishment as necessary to continue safe and effective operations until completion of EM Cleanup at ORNL.
- **LLLW2 – On-Site Treatment.** Redirect LLLW to the PW Treatment System where possible and deploy a skid-based LLLW treatment unit in the BVEST Evaporator. Evaluate treating both dilute and concentrated LLLW.
- **LLLW3 – Off-Site Treatment.** Redirection LLLW to the PW Treatment System where possible and ship LLLW off-site for treatment and disposal.

4.4.4 Life-Cycle Cost Analysis

The ROM life-cycle cost estimates were developed for the LLLW alternatives based on the following information:

- **Treatment Volume.** Reconfiguration of the PWTC around 2018–2020 will eliminate generation of 3000–4000 gal per year of high-radiological, highly concentrated nitric acid from the ion-exchange regenerant. Diversion of SC facilities to the new SC LLLW Treatment Facility in 2022 will eliminate approximately 10% of the current LLLW annual volume and 90% of the radionuclide input to the LLLW System.
- **Maintenance.** An urgent special maintenance project, the cooling tower piping modification, is being funded as a high priority initiative and is not included in the life-cycle cost estimate. Significant maintenance upgrades are planned for the existing pumps and pulse-jet mixing systems to support the TWPC sludge processing project and are not included in the life-cycle cost estimate.
- **Liquid Solidification Unit.** Vendor estimates for a liquid solidification equipment at another DOE facility.
- **Truck Loading Station.** 2013 estimate for constructing a truck unloading station at Bldg. 7856. The D&D cost is based on the Bldg. 3544 D&D cost of $1,112 per square foot.
- **Off-Site Transportation and Disposal.** DOE bids for indefinite delivery/indefinite quantity based schedule for treatment and disposal of mixed/radioactive waste streams from DOE sites to commercial radioactive waste processors.
- **Operation and Maintenance.** Labor costs were based on current LGWO rates and anticipated labor requirements. Chemical and materials were based on current LGWO usage and rates and anticipated quantities. Energy costs based on historical electrical costs for the LLLW facilities.
- **D&D.** The D&D costs for the LLLW solidification unit and the truck loading station are based on the Bldg. 3544 D&D cost of $1,112 per square foot. The D&D costs for the LLLW System would be the same for all three alternatives and were; therefore, not included in the life-cycle cost estimates.

A more detailed description of the LLLW alternatives is provided in **Appendix I**. Cost estimate details and assumptions are provided in the *LGWO Life-Cycle Cost Estimate Supporting Data* file, archived in the UCOR Document Center.

LLLW1 – Status Quo. The life-cycle cost estimate for the status quo alternative includes operations and maintenance for 30 years, followed by a solidification campaign. Concentrated LLLW would be stored in the BVEST until transferred to the CIP or MVST for long-term storage until treatment capability is established through a future project.

A final solidification campaign would be performed at the end of the project life cycle. Assuming an annual generation of 2500 gal of LLLW concentrate, the final volume of supernate and sludge accumulated from 2030 to 2045 would be 40,000 gal. The approach for the campaign would be similar to the 1991 Emergency Avoidance Solidification Campaign (EASC) that used a modular system within Bldg. 7877 to solidify 46,615 gal of supernate. The EASC employed a solidification service contractor to provide solidification equipment necessary to process the MVST supernate. It is assumed that systems to be provided for sludge processing in the 2025 time frame would require only minor modifications to accommodate this approach. Collection tanks planned for the TWPC sludge processing facility to be installed adjacent to Bldg. 7880 could be utilized to hold and transfer LLLW to the solidification system. These collection tanks are anticipated to have the capacity to hold the entire volume of the remaining LLLW. The MVST mixing system, presumably a pulse jet system retrofit at Bldg. 7830 as part of the TRU sludge processing campaign, would be maintained as necessary for restart to transfer the remaining LLLW from the MVSTs to the collection tanks at the solidification facility. A crane bay constructed for the sludge processing system would be adequately sized to provide the necessary containment for the solidification system provided by the solidification service contractor. The capital and operating cost for this final campaign are likely to be similar to the EASC, so cost data from the 1991 EASC project (ORNL/TM-11536, *The Emergency Avoidance Solidification Campaign of Liquid Low-Level Waste at Oak Ridge National Laboratory*) were utilized and escalated to 2016 dollar value for this estimate. D&D cost attributed to the final solidification campaign would be insignificant because existing infrastructure would be utilized and solidification systems would be owned and operated by the solidification services contractor.

The life-cycle cost estimate for the status quo alternative is provided in **Table 4-1**. For cost escalation and present value determinations, it was assumed that operations and maintenance will be ongoing for the duration of the life cycle and a solidification campaign will be performed at the end of the life cycle.

Table 4-1. LLLW1 – Status quo alternative life-cycle cost estimate

LLLW1 – Status quo cost elements	**Cost in 2016 dollars ($M)**	**Escalated cost ($M)**	**Present value ($M)**
O&M Labor, Materials, and Management (Years 1–30)	66.1	95.9	58.7
Solidification Campaign Planning (Years 28 and 29)	7.0	13.3	5.6
Processing and Disposal (Year 30)	7.9	15.7	6.3
Life-cycle cost	**81.0**	**124.9**	**70.6**

LLLW2 – On-Site Treatment. The life-cycle cost estimate for the on-site treatment alternative includes the capital costs for a liquid solidification unit, operations and maintenance, and demolition of the liquid solidification unit. The new solidification system would be installed in the Bldg. 2531 crane bay to process approximately 2500 gal per year of newly-generated LLLW beginning in year 15 of the life cycle, following the TWPC sludge solidification campaign. The costs for a liquid solidification process are provided in **Table 4-2**.

Table 4-2. Capital cost for liquid solidification unit

LLLW Liquid Solidification Unit cost element	2016 Cost ($)
Design	63,000
Materials (enclosure and mixer)	100,000
Package HEPA skid	8,000
Cement hopper and feeder	84,700
Fabrication labor	76,000
Fabrication G&A and fee	53,072
Delivery (local)	2,000
Installation	96,693
Direct cost total	483,465
Contractor general conditions, overhead, profit, taxes, and insurance	193,386
Commissioning (8-person team for 2-months)	107,104
Engineering (2 FTE engineers to write specs, test, and develop operating procedures)	77,261
Project management	195,989
Contingency (30%)	317,161
Total cost	**1,374,366**

The life-cycle cost estimate for the redirect and/or eliminate LLLW alternative is provided in **Table 4-3**. For cost escalation and present value determinations, it was assumed that the new solidification unit will be constructed and commissioned by 2030, solidification campaigns will be conducted annually from 2030 to 2045, operations and maintenance would be ongoing for the duration of the life cycle, and the solidification unit would be demolished at the end of the life cycle.

Table 4-3. LLLW2 – On-site treatment alternative life-cycle cost estimate

LLLW2 – On-site treatment cost elements	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Liquid Solidification Unit (Year 15)	1.4	1.9	1.2
On-Site LLLW Treatment and Disposal (Years 16–30)	3.6	6.0	3.1
O&M Labor, Materials, and Management (Years 1–30)	66.1	95.9	58.7
Solidification Unit D&D (Year 30)	0.2	0.4	0.2
Life-cycle cost	**71.3**	**104.2**	**63.2**

LLLW3 – Off-site Treatment and Disposal. The life-cycle cost estimate for the off-site treatment and disposal alternative includes the cost for a transport truck loading station, operations and maintenance and off-site treatment and disposal, and demolition of the truck loading station. There are currently three commercial radioactive waste treatment and disposal facilities capable of processing concentrated LLLW liquids. Transportation of LLLW liquids would be in either tankers or Type A totes. The costs for transportation and disposal of concentrated and as-generated LLLW liquids are provided in **Table 4-4**.

Table 4-4. LLLW off-site transportation and disposal costs

Off-site transportation and disposal	2016 Cost ($)
Treatment (transportation/treatment/disposal for 2,500 gal at $25/gal)	62,500
Profile Charge	20,896
NNSS disposal fee ($18 per cubic foot for 84 drums)	11,340
Total Annual Cost	**94,736**

The transport tanker loading station would be constructed in the BVEST area on the west side of Bldg. 2537. The facility would include a ventilated enclosure with HEPA-filtered exhaust, a diked area for spill containment, and interface piping to allow loading of the tanker or totes with LLLW.

The life-cycle cost estimate for the off-site transportation and disposal alternative is provided in **Table 4-5**. For cost escalation and present value determinations, it was assumed that the truck loading station would be constructed in 2030, off-site transportation and disposal will be performed from 2030 to 2045, operations and maintenance would be ongoing for the duration of the life cycle, and the truck loading station will be demolished at the end of the life cycle.

Table 4-5. LLLW3 – Off-site treatment and disposal alternative life-cycle cost estimate

LLLW3 – Off-site treatment and disposal costs	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Truck loading station (Year 15)	2.5	3.3	2.2
Off-site transportation and disposal (Years 16–30)	2.8	4.7	2.4
O&M labor, materials, and management (Years 1–30)	66.1	95.9	58.7
Truck loading station D&D	0.1	0.2	0.1
Life-cycle cost	**71.5**	**104.1**	**63.4**

The life-cycle costs for the three LLLW alternatives are shown in **Fig. 4-4**. The on-site and off-site treatment alternatives are the least expensive alternatives, followed by the status quo alternative. A sensitivity analysis was performed to evaluate the impact of key cost and schedule risks and opportunities associated with the three LLLW alternatives. The highest impacts are related to greater than anticipated capital costs and LLLW disposal costs. The sensitivity analysis is provided as **Appendix J**.

The pros and cons of the three LLLW alternatives are provided in **Table 4-6.**

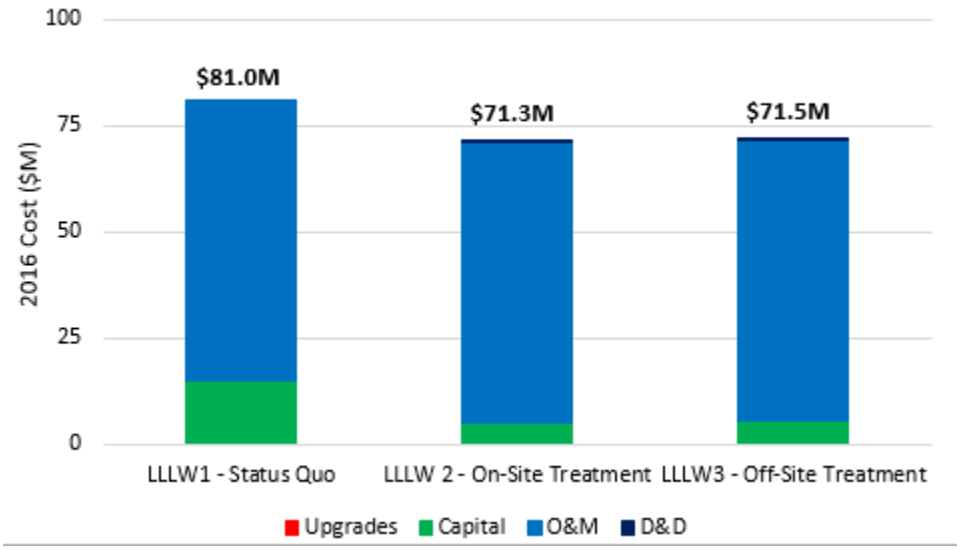

Fig. 4-4. Life cycle-cost estimates for the LLLW alternatives.

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Table 4-6. Pros and cons of the LLLW alternatives

Category	LLLW System status quo alternative	LLLW on-site treatment alternative	LLLW off-site treatment alternative
	Use existing collection and storage facilities with a final solidification campaign.	**On-site LLLW treatment, solidification, and packaging for off-site disposal.**	**Off-site shipment of LLLW for treatment and disposal.**
Environment, Safety, and Health			
Pros	• Avoids risks of accidents during construction of new systems and facilities. • No risk of environmental impacts from new system startup activities. • Does not require additional land space for processing.	• Uses an existing facility for process upgrades. Does not require use of additional land space. • Allows early D&D of the LLLW inter-valley pipeline and Melton Valley storage facilities.	• Reduces LLLW handling to limited interim storage and trucking. • Allows early D&D of the LLLW inter-valley pipeline and Melton Valley storage facilities.
Cons	• Continues generating LLLW that requires long-term on-site storage and management until processing capability is available. • Carries the risk of continued use of the inter-valley pipeline for LLLW transfers.	• Requires additional land space for LLLW processing, packaging, and shipment activities. • Requires future D&D of additional LLLW processing, packaging, and shipment facilities. • Carries the risk of industrial accidents due to construction activities.	• Carries the risk of spills during loading and transportation incidents. • Transfers LLLW handling risks to commercial entities unaccustomed to LLLW management. • Requires additional land space for a trucking station. • Requires future D&D of a trucking station.
Operability			
Pros	• Requires no change in operational activities, so additional training of operators is not required.	• Consolidates operations at one operating facility. • Uses new right-sized systems for processing. • Uses new equipment and updated control systems, which would lower maintenance costs.	• Simplifies operations by eliminating LLLW long-term storage and treatment operations.
Cons	• Stored LLLW creates sludge in tanks that is difficult and expensive to mobilize and process.	• Requires optimization of a new unit operation – LLLW solidification. • Requires operator training for LLLW solidification.	• Requires operator training for new LLLW trucking station.
Cost and Schedule			
Pros	• Does not require additional equipment or facilities. • Could potentially use the existing TWPC facility for future treatment and disposition of accumulated LLLW. • Operations are required for evaporation and storage only. • Allows for the potential use of future SC LLLW treatment facilities for disposition of EM LLLW.	• Eliminates cost liabilities of LLLW storage. • Allows early D&D of Melton Valley storage facilities and inter-valley pipeline.	• Eliminates cost liabilities of LLLW storage and disposal. • Allows early D&D of Melton Valley storage facilities and inter-valley pipeline.
Cons	• Continues collection of LLLW concentrate that requires costly long-term storage with a future capital project for disposition of accumulated LLLW. • May require additional costly upgrades for LLLW evaporator and storage facilities. • Requires continued maintenance of LLLW infrastructure in Bethel Valley and Melton Valley.	• Requires future D&D of an additional LLLW processing facility. • Requires additional time for design and construction. • Carries the risk of additional costs as a capital project. • Carries the risk of delays in capital funding. • Carries the risk of high site development costs due to interferences from existing infrastructure.	• Requires future D&D of an additional trucking station. • Requires additional time for design and construction. • Carries the risk of delays in funding. • Carries the risk of high site development costs due to interferences from existing infrastructure.

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5. GASEOUS WASTE SYSTEM

5.1 SYSTEM DESCRIPTION AND USERS

The GW System at ORNL is a centralized system designed to accept and treat cell ventilation air and off-gas from research facilities in Bethel Valley. Stack 3039, the Central Radioactive Gas Disposal Facility, serves several groups of facilities at ORNL including cell ventilation and off-gas from the Isotopes Area, 3500 Area, and various other active and inactive facilities that must be ventilated to control contamination. Water infiltrating into the GW System collection ducts is directed to the PW System.

The GW System is categorized as Less Than Radiological and includes the following components:

- Collection Systems
  - — Cell ventilation only from Bldgs. 3025E and 3525
  - — Cell ventilation and off-gas from Bldgs. 2531, 2537, 3019, 3028, 3029, 3030, 3031, 3033, 3033A, 3038, 3047, and 3517
- Central Radioactive Gaseous Disposal Facility (Bldg. 3039)
  - — 250-ft high unreinforced radial brick chimney
  - — Stack ventilation system (includes electric fans and steam-driven back-up fans)
- Central Off-Gas Scrubber (Bldg. 3092) (includes a venturi scrubber with electric and steam-driven recirculation pumps, de-mister, drying, roughing, and HEPA filters)

The GW System also includes Bldg. 3125 (Stack Area Diesel Generator) which is categorized as industrial.

A diagram of the GW System is provided as **Fig. 5-1.**

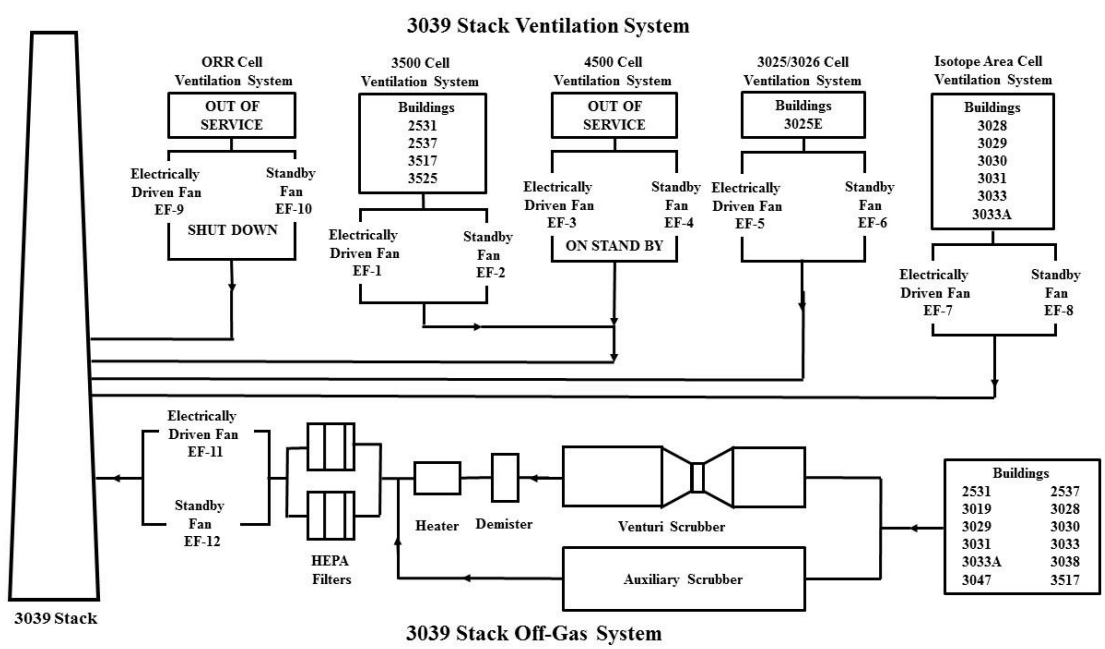

Fig. 5-1. Gaseous waste system flow diagram.

5.2 OPERATIONS AND MAINTENANCE HISTORY

The GW System was originally built in 1950 and was extensively modified and upgraded in 1984 to increase its efficiency and reliability. In 1997, several of the cell ventilation blowers and the off-gas primary blower and backup fan were replaced to increase the system's reliability. Also in early 1997, a new scrubber solution tank and associated transfer equipment was installed that met requirements of the FFA for the LLLW System. The GW System is currently operating at approximately half of its design capacity as facilities have been shut down or replaced their ventilation needs with local filters and stacks.

5.2.1 Operating History

Operation of the GW System includes collection and treatment, sampling, monitoring, repairs, filter replacements, S&M, and documentation. The flow has decreased over time as facilities have disconnected from the GW System, including the Oak Ridge Research Reactor (2005), Bldg. 3026 (2008), multiple Isotope Area facilities (2010), and the 4500 Area facilities (2013). The operational history, showing the volume of gaseous waste treated annually between 2004 and 2014, is provided in **Fig. 5-2**.

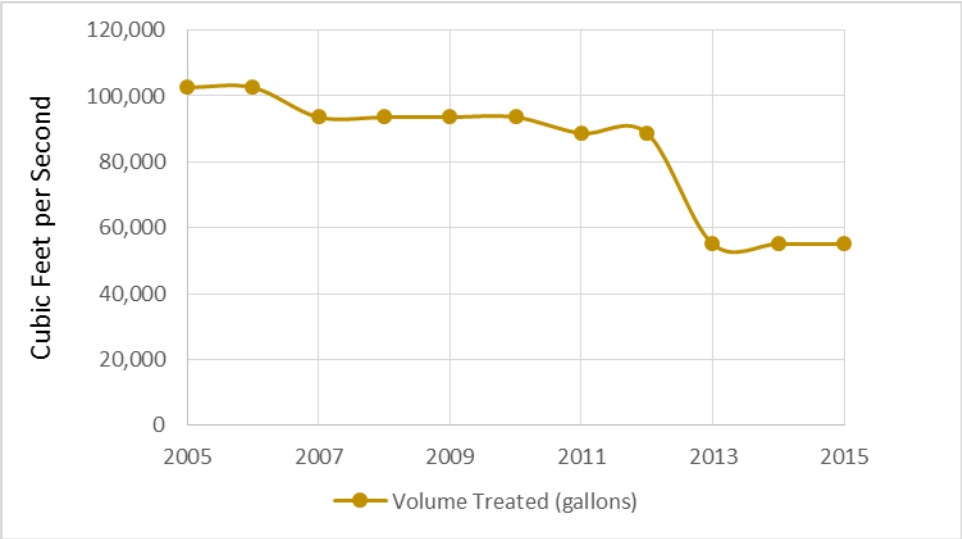

Fig. 5-2. Gaseous waste operational history, 2005-2015.

5.2.2 Maintenance History

The GW System continues to operate past its intended design life. Non-routine maintenance consists primarily of turbine and filter repair/replacement and steam issues. A summary of logged non-routine maintenance are shown in **Fig. 5-3.**

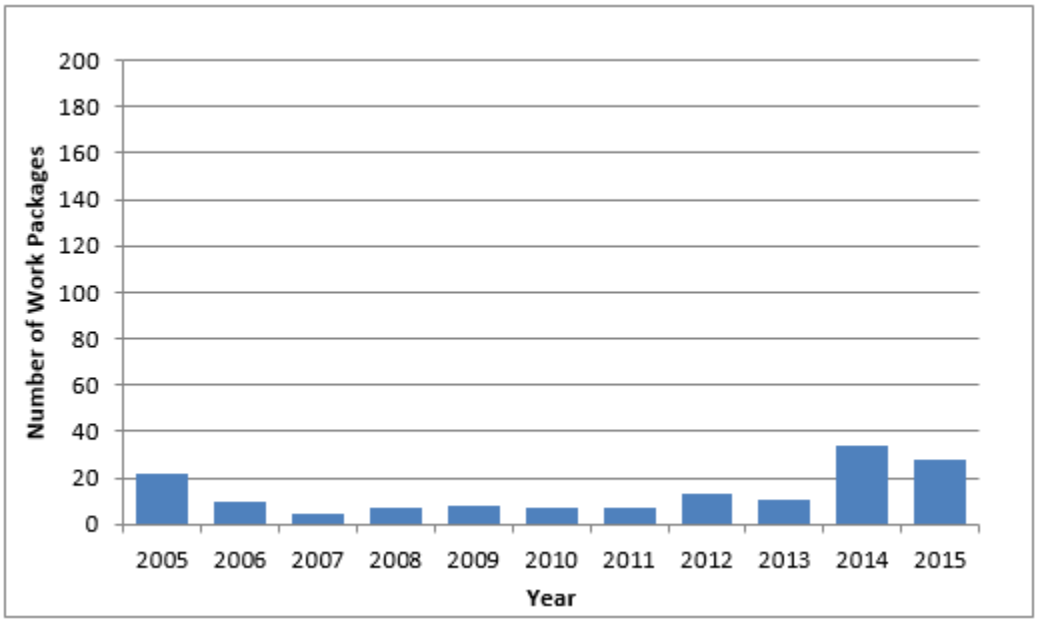

Fig. 5-3. Gaseous waste maintenance history.

5.3 CURRENT CONDITIONS

5.3.1 Walkdown Results

Walkdowns of the GW System were completed during the current condition evaluation. The walkdowns included:

- **Discussion** with plant and facility operators and maintenance support craft.
- **Review** of items currently broken or not operating.
- **Visual inspection** of the 3039 Stack Area and Bldg. 3092.

Several items requiring maintenance were identified during the walkdown. The MCC and heat trace controls are obsolete, the off-gas pressure relief valve and isotope turbine governor in the 3039 Stack Area are offline, and the HEPA filter housings in Bldg. 3092 are degraded. A replacement filter housing has been purchased and is on-site awaiting installation. LGWO personnel also raised concerns regarding the work control process, specifically the time and effort associated with initiating, planning, approving, and executing work packages. Although work packages are being completed effectively, the work control process is not efficient. A detailed summary of the GW System walkdown in provided in **Appendix K**.

UCOR is awaiting Federal Aviation Administration approval to perform an inspection of the central stack using a helicopter drone. The brick masonry stack has not been inspected for nearly twenty years, so there is the potential for non-routine maintenance associated with the stack.

5.3.2 Testing Results

NDE testing of the GW System was performed in November 2015 and included UT of pipelines and duct. A total of 105 readings were collected from ducts and pipelines in the 3039 Stack Area and the 2537 Pit. No significant corrosion was detected. The GW System NDE results are provided as **Appendix L**.

5.4 EXTENDED-LIFE STUDY

5.4.1 Forecast of Future Users and Capacity Requirements

The flow is expected to decrease as the SC and Nuclear Energy facilities disconnect from the GW System in lieu of local units. The facilities are expected to disconnect by the end of the fiscal years as follows:

- Building 3525 – 2017
- Building 3047 – TBD
- Building 3025E – 2019

EM facilities (Bldgs. 2531, 2537, 3019, 3028, 3029, 3030, 3031, 3033, 3033A, 3038, 3047, and 3517) will continue to contribute gaseous waste until sometime between 2038 and 2041. As the flow decreases below 98,000 cfm, modifications to the system (i.e. make up air or flow restriction) will be needed to maintain the flow needed for collecting regulatory requirement samples. The flow is currently below the required flow of 98,000 cfm and a project to add outside air has been identified.

5.4.2 Maintenance Upgrade Requirements

There are no major maintenance issues associated with the GW System. Due to the decrease in flow, some modification of the stack systems will be necessary to maintain the 98,000 cfm to allow for accurate regulatory sampling of the stack. Potential modifications include adding HEPA filtered air intakes with dampers at several duct locations, installing a flow restrictor in the stack to increase flow velocity, replacing the central stack with local units, or replacing the existing stack with a new, right-sized stack.

5.4.3 New Technology Review

5.4.3.1 Applicable Technologies

Applicable technologies for the treatment of the ORNL GW include HEPA filters, cyclones, carbon filters, acid gas filters or scrubbers, and various other specialty blended filters. In addition, technologies were discussed that would accommodate the current reduced flow rates and planned future facility disconnects to maintain the minimum flow velocity needed for accurate regulatory sampling of the stack.

5.4.3.2 Discussion

The discussion focused on ensuring that minimum flow requirements for testing are maintained as facilities are disconnected from the central stack, the need for individual GW System components, and the cost/benefit of switching EM facilities from the central stack to local units.

In addition to identifying alternatives for the life cycle cost analysis, the discussion resulted in a recommendation to shut down the scrubber system. The scrubber was designed to handle acid gases produced during isotope production operations in Bethel Valley. Since these operations are no longer conducted, acid gas removal capability is no longer required. Shutting down the scrubber would reduce operating costs and eliminate the generation of scrubber blowdown that is currently one of the main contributors to the LLLW System.

5.4.3.3 Gaseous Waste Alternatives for Life-Cycle Cost Analysis

The following alternatives were identified for the life-cycle cost analysis:

- **GW1 – Status Quo.** Operate the GW System until completion of EM Cleanup at ORNL. Modify flow (either by providing makeup air or installing a flow restrictor) to maintain the minimum stack flow required for regulatory sampling as facilities are disconnected from the system.

- **GW2 – Local Units.** Accommodate SC facilities moving to local units. Install local fans and stacks to serve Bldg. 3517 and the Evaporator, stabilize the remaining Isotope Area Facilities, and shutdown the central stack.
- **GW3 – Build a New, Right-Sized Central Stack.** Build a new, right-sized central stack, move existing connections, and shut down the central stack.

5.4.4 Life-Cycle Cost Analysis

The life-cycle cost estimates for the GW alternatives were based on the following assumptions:

- **Maintenance upgrades.** Fixed-price proposals for the same or similar activities.
- **Construction.** Vendor quotes for equipment. Parametric factors for engineering and management costs.
- **Operation and Maintenance.** Labor costs based on current LGWO rates and anticipated labor requirements. Chemical and materials based on current LGWO usage and rates and anticipated quantities. Energy costs based on anticipated fan motor horsepower requirements, kilowatt-hour requirements, and current utility rates.
- **D&D.** The 3039 Stack D&D costs were not included in the life-cycle costs because they are already included in the EM baseline and will be the same for all three alternatives. The 3517 and 2531 local unit D&D costs were based on actual cost for deactivation, utility isolation, and demolition of the Bldg. 38 Stack at the Miamisburg Closure Project and similarly sized stack D&D projects.

GW1 – Status Quo. The life-cycle cost estimate for the status quo alternative includes near-term maintenance upgrades and operations and maintenance for 30 years. The near-term maintenance upgrades are needed to provide sufficient make-up air to the 3039 Stack as the SC facilities are taken offline. The near-term maintenance upgrade costs are provided in **Table 5-1**.

Table 5-1. Gaseous waste near-term maintenance upgrade costs

Near-term maintenance upgrades for make-up air	2016 Cost ($)
Total equipment cost	257,610
Site characterization and installation	63,642
Electrical and instrumentation	57,522
Construction management services	147,722
Indirect	53,028
Commissioning	11,363
Engineering and project management	147,722
Contingency (30%)	221,582
Near-term maintenance upgrade total	**960,191**

The life-cycle cost estimate for the status quo alternative is provided in **Table 5-2**. For cost escalation and present value determinations, it was assumed that the maintenance upgrades were performed in the first year of the life cycle.

Table 5-2. GW1 – Status quo alternative life-cycle cost estimate

GW1 – Status quo cost elements	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Maintenance upgrades (Year 1)	1.0	1.0	1.0
O&M labor, materials, and management (Years 1–30)	47.0	60.6	38.3
Life-cycle cost	**48.0**	**61.6**	**39.3**

GW2 – Local Units. The life-cycle cost estimate for the local unit alternative includes the cost for near-term maintenance upgrades, capital costs for local ventilation units at Bldgs. 3517 and 2531, operations and maintenance, and demolition of the local units. The near-term maintenance upgrades are needed to provide sufficient make-up air to the 3039 Stack under the current conditions. The costs for the two local ventilation units are provided in **Table 5-3**.

Table 5-3. GW – Local ventilation unit costs

GW – Local ventilation unit costs	2016 Cost ($)
Total equipment cost	177,429
Site characterization and installation	149,067
Electrical and instrumentation	66,533
Construction management services	190,424
Indirect	68,357
Commissioning	14,648
Engineering and project management	304,678
Contingency (30%)	319,912
Total capital costs	**1,291,048**

The life-cycle cost estimate for local units and shutdown central stack alternative is provided in **Table 5-4**. For cost escalation and present value determinations, it was assumed that maintenance upgraders would be performed during the first year of the life cycle, the two local units would be installed at Bldgs. 3517 and 2531 when the SC facilities go offline in 2022, and demolition of the local stacks would occur during the last year of the life cycle.

Table 5-4. GW2 – Local unit alternative life-cycle cost estimate

GW2 – Local unit cost elements	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Maintenance upgrades (Year 1)	0.1	0.1	0.1
Local ventilation units at 3517 and 2531 (Year 7)	1.3	1.4	1.3
O&M labor, materials, and management (Years 1–30)	37.7	46.2	30.0
3517 and 2531 Stack D&D (Year 30)	1.0	1.9	0.8
Life-cycle cost	**40.1**	**49.6**	**32.2**

GW3 – Build New, Right-Sized Stack. The life-cycle cost estimate for the new, right-sized stack alternative includes the cost for near-term maintenance upgrades, capital cost for a new stack, operations and maintenance, and demolition of the new stack. The near-term maintenance upgrades are needed to provide sufficient make-up air to the 3039 Stack under the current conditions. The capital cost associated with a new, right-sized stack is provided in **Table 5-5**.

Table 5-5. New stack capital costs

New stack capital costs	2016 Cost ($)
Total equipment cost	1,928,653
Site characterization and installation	911,461
Electrical and instrumentation	409,731
Construction management services	779,963
Indirect	942,955
Commissioning	97,495
Engineering and project management	2,027,903
Contingency (30%)	2,129,299
Capital cost total	**9,227,460**

The life-cycle cost estimate for the right-sized stack alternative is provided in **Table 5-6**. For cost escalation and present value determinations, it was assumed that maintenance upgraders would be performed during the first year of the life cycle, the new stack would be constructed when the SC facilities go offline in 2022, and demolition of the new stack would occur during the last year of the life cycle.

Table 5-6. GW3 – New stack alternative life-cycle cost estimate

GW3 – Off-site treatment and disposal costs	Cost in 2016 dollars ($M)	Escalated cost ($M)	Present value ($M)
Maintenance upgrades (Year 1)	0.1	0.1	0.1
Capital cost for new stack (Year 7)	9.2	9.2	9.2
O&M labor, materials, and management (Years 1-30)	44.1	57.2	36.2
New stack D&D (Year 30)	7.6	15.0	6.0
Life-cycle cost	**61**	**81.5**	**51.5**

The life-cycle costs for the three GW alternatives are shown in **Fig. 5-4**. The local stacks alternative is the least expensive alternative, followed by the status quo alternative, and the new stack alternative.

The pros and cons of the three GW alternatives are provided in **Table 5-7.**

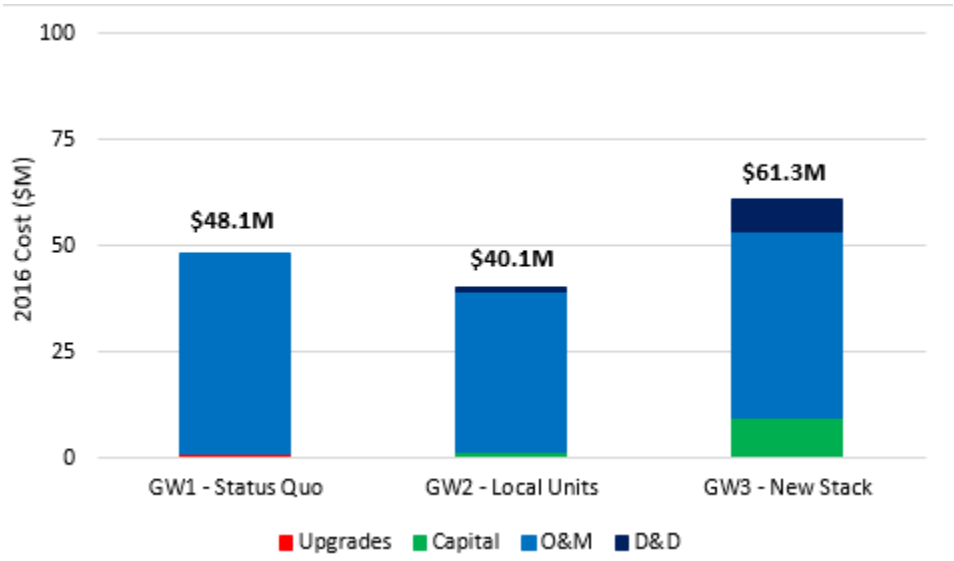

Fig. 5-4. Life-cycle cost estimates for the GW alternatives.

Table 5-7. Pros and cons of GW alternatives

Category	Gaseous Waste System status quo alternative	Gaseous Waste System local ventilation alternative	Gaseous Waste System new central stack alternative
	Continue operation of existing GW System with maintenance and refurbishment as necessary to continue safe and effective operations.	**Provide local ventilation systems for SC and EM facilities, and allow shutdown of the 3039 Stack systems.**	**Replace the 3039 Stack systems with right-sized equipment and stack, and allow continued use by SC and EM operations.**
Environment, Safety, and Health			
Pros	• Avoids risks of accidents during construction of new systems and facilities. • Avoids complications associated with startup of new local ventilation systems.	• Reduces the risk of release of accumulated contaminants from old central ductwork and systems. • Allows for early D&D of 3039 Stack Area systems, reducing the risk of releasing accumulated contaminants, and allowing subsequent environmental restoration activities for underlying soils in that area. • Allows diversion of GW flow from the aging central 3500 Area duct that collects large volumes of groundwater in-leakage. Allows isolation and stabilization of this duct.	• Reduces the risk of industrial accidents associated with construction of multiple local ventilation systems. • Allows for early D&D of 3039 Stack Area systems, reducing the risk of releasing accumulated contaminants.
Cons	• Carries the risk of release of accumulated contaminants from aging central GW ductwork and systems. • Continuous collection of in-leakage from deteriorated underground ducts • Does not allow for environmental restoration of the 3039 Stack Area until the end of the project life cycle.	• Carries the risk of industrial accidents from construction of local ventilation systems.	• Requires future D&D of an additional central stack system. • Carries the risk of industrial accidents from construction a new central stack system. • Continues to carry the risk of releasing contaminants from aging underground ductwork that would continue to be used for routing GW to the new stack.
Operability			
Pros	• Requires no change in operational activities, so additional training of operators is not required.	• Reduces maintenance through the use of new ventilation systems with updated controls.	• Simplifies operations by maintaining centralized GW operations. • Uses new equipment and updated controls which reduces maintenance requirements.
Cons	• Requires the continued use of older systems, ductwork, and controls.	• Requires startup and optimization of multiple local ventilation systems. • Requires training for operators at several facilities.	• Requires startup and optimization of a new central ventilation system. • Requires operator training for a new central ventilation system.
Cost and Schedule			
Pros	• Does not require new equipment or systems.	• Allows early D&D of 3039 Stack Area systems. • Reduced utility and operational costs through the use of right-sized ventilation systems with updated controls.	• Allows early D&D of 3039 Stack Area systems. • Avoids the cost and time necessary for constructing multiple local exhaust systems. • Reduced utility and operational costs through the use of right-sized ventilation systems with updated controls.
Cons	• May require additional costly upgrades to 3039 Stack systems. • Higher utility costs necessary to maintain minimum flow through an oversized central system.	• Requires multiple design and construction projects. • Requires additional time for design and constructing multiple systems. • Carries the risk of delays in funding. • Carries the risk of high construction costs for local systems due to interferences from existing infrastructure.	• Requires additional time for design and construction. • Carries the risk of high construction, demolition, and startup costs due to need for continued operations and interferences from existing infrastructure. • Carries the risk of delays in capital funding. • Requires D&D of additional equipment.

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6. RECOMMENDATIONS

6.1 LGWO GENERAL RECOMMENDATIONS

During the walkdowns conducted as part of the current conditions evaluation, several immediate maintenance repairs were identified. These maintenance repairs are needed to maintain operability of the LGWO system for the near term and are being addressed as high priority initiatives. Some of the initiatives are general LGWO requirements, while others are specific to one of the PW, LLLW, or GW Systems. The general LGWO high priority initiatives needed to keep the system operational include:

- MCC Replacement
- Heat Trace Control Panel Replacement
- Distributed Control System Refurbishment

6.2 PROCESS WASTE RECOMMENDATIONS

Based on the results of the current condition evaluation and extended life study, the following maintenance activities are recommended to maintain operability of the PW System for 30 years:

Near-Term Recommendations – High-Priority Initiatives

- 4001 pump sump overflow piping
- Install temporary GAC columns
- Building 3608 GAC piping repairs
- Install dual media filters prior to GAC columns
- Concrete dike repairs (Bldgs. 3608 and 7961)
- Apply corrosion protection coatings to the Bldg. 3608 equalization tanks
- Shut down and remove the F-1014 air stripper at Bldg. 3608

Long-Term Recommendations

- Remove the F-1007 clarifier at Bldg. 3608
- Install zeolite ion-exchange system with pre-filters and dewatering system at Bldg. 3608 to reduce operating costs by allowing shutdown of Bldg. 3544 and eliminating LLLW generation from ion-exchange regeneration
- Deactivate Bldg. 3544

6.3 LLLW RECOMMENDATIONS

Based on the results of the current condition evaluation and extended life study, the following upgrades are recommended to maintain operability of the LLLW System for the next 30 years:

Near-Term Recommendations – High Priority Initiatives

- Cooling tower piping modifications

Long-Term Recommendations

- Pursue characterization and re-direction of sources, as funds permit
- Re-evaluate storage vs. on-site treatment vs off-site treatment and disposal in the 2022 timeframe

6.4 GASEOUS WASTE RECOMMENDATIONS

Based on the results of the current condition evaluation and extended life study, the following modifications are recommended to maintain operability of the GW System until the remaining facilities are disconnected:

Near-Term Recommendations – High Priority Initiatives

- Provide make-up air capability in phased fashion

Long-Term Recommendations

- Shut down scrubber to reduce LLLW generation
- Stabilize Isotope Row facilities and disconnect from GW System
- Install local units at Bldgs. 3517 and 2531 when PW upgrades are complete and funding becomes available (target completion in 2022 when SC facilities are anticipated to be disconnected)
- Shut down GW System, eliminating approximately 25 years of operating costs

7. REFERENCES

DOE Order 458.1. *Radiation Protection of the Public and Environment,* 2011, U.S. Department of Energy, Washington, D.C.

DOE/ORO/2340. *Critical Decision-2/3 Technical Baseline for the Integrated Facility Disposition Program Process Wastewater Systems Project at the Oak Ridge National Laboratory,* 2010, U.S. Department of Energy, Washington, D.C.

DOE/ORO/2340. *Critical Decision-2/3 Performance Baseline for the Integrated Facility Disposition Program Process Wastewater Systems Project, 2010,* U.S. Department of Energy, Washington, D.C.

ORNL/TM-11536, *The Emergency Avoidance Solidification Campaign of Liquid Low-Level Waste at Oak Ridge National Laboratory, /23,* Oak Ridge National Laboratory, Oak Ridge, TN.

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APPENDIX A.
HISTORICAL LGWO STUDIES

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LGWO STUDIES

- Non-Radiological Waste Treatment Plant
  - *Treatability Studies In support of the Non-Radiological Wastewater Treatment Plant*, ORNL/TM-10046, July 1986
  - *Feasibility Study and Cost Estimate for the Upgrade of the Process Waste Treatment System*, X-OE-795, February 18, 1998
  - *Feasibility Study for the Upgrade of the Process Waste Treatment System*, ORNL/TM-1995/65, May 1999
  - *Evaluation of Alternative Flow Sheets for Upgrade of the Process Waste Treatment Plant*
- Office of Science (SC) Focus
  - *Liquid & Gaseous Waste Treatment System Strategic Plan* (ORNL/TM-2003/197) 2003
  - *LGWTS Strategic Plan Update*, 2005
  - *Waste Operations Evaluation Project, Oak Ridge National Laboratory, Oak Ridge, TN* (MSE) March, 2006
  - *Radioactive Waste Management Strategy and Alternatives Evaluation for Office of SC Generated Gaseous, Process, Transuranic Debris, and Liquid Low-Level Waste Streams* (EPWSD-TECHPAPER-04) September, 2013
  - *LLLW Enterprise Study*, October, 2014
- Office of Environmental Management (EM) Focus
  - *Alternatives Analysis ORNL Reconfigured Capabilities In Support of the Integrated Facility Disposition Project*, May, 2008
  - *Reconfigured and New Facilities Conceptual Design, Integrated Facilities Disposition Project*, Appendix C, *Conceptual Design Report*, November 2008
  - *Environmental Management Waste Management Facility Wastewater Treatment System Alternatives Analysis and Conceptual Design*, BJC/OR-3453, September 2010
  - *Evaluation of Options for ORNL Liquid Low-Level Waste Treatment*, September, 2010
  - 3608 *UPGRADES* (P2S), October, 2013

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APPENDIX B.
LGWO FUNCTIONAL REQUIREMENTS

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1. LGWO Functional Requirements

Identification of key functional requirements for the LGWO systems is necessary in order to identify promising alternatives for short and long-term effectiveness. The overall function of LGWO processing systems is to protect the public, workers, and the environment from the detrimental effects of wastewater and GWs contaminated with hazardous and radiological constituents.

1.1 Process Wastewater Treatment Complex Functional Requirements

The PW System uses various unit operations to remove contaminants from PW to levels that meet applicable regulatory requirements for discharging the treated water to White Oak Creek, a low-flow waterway that intersects the ORNL Main Campus. Principal functions of the system include PW collection, storage, transferring, processing, sampling, and discharging the treated wastewater. As a consequence of PW treatment, secondary waste materials are generated that require additional treatment as necessary, packaging, shipping, and disposal at an off-site disposal facility.

1.1.1 Process Wastewater Effluent Requirements

System functions and requirements for the PWTC system are documented in Requirements for the ORNL Groundwater and Process Wastewater Treatment Facilities (SRD) and in DOE-ORO-2340, *Critical Decision-2/3 Technical Baseline for the Integrated Facility Disposition Program, Process Wastewater Systems Project at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*.

The PW Systems will process wastewater to meet applicable regulatory requirements for discharge to the environment. Table B-1 provides a summary of PW discharge limits at National Pollutant Discharge Elimination System (NPDES) Outfall X12.

Table B-1. Process wastewater contaminant discharge limits

Contaminant	Units	Discharge Limits*
Arsenic (As)	mg/L	0.01
Chromium (Cr)	mg/L	0.44
Copper (Cu)	mg/L	0.11
Cyanide (CN)	mg/L	0.046
Lead (Pb)	mg/L	0.69
Mercury (Hg)	mg/L	Report
Total Toxic Organics	mg/L	Report
Oil and Grease	mg/L	15
pH		> = 6; < = 9
Total Suspended Solids	mg/L	Report
LC50 Static 48Hr Acute for Ceriodaphnia and Pimephales**		> =100%
Cesium-137 (^{137}Cs)	Bq/L	110
Strontium-90 (^{90}Sr)	Bq/L	41

*Discharge limits for non-radiological constituents are regulated by the NPDES permit. Radiological discharges are regulated under DOE O 458.1.
**Toxicity test in which at least 50% of the test species must survive in 100% effluent for 48 hours.

The concentration of hazardous metals as defined in Resource Conservation and Recovery Act (RCRA) such as As, Cd, Hg, Pb, and Ag, are typically low but measurable. Total Toxic Organics is also low and is meant to represent the total concentration of all hazardous organic constituents. The principal influent radionuclides are Cs-137 and Sr-90.

Hazardous metals and organic contaminants must meet the limits given in the existing NPDES permit number TN0002941 issued by the Tennessee Department of Environment and Conservation for the outfall at White Oak Creek. The effluent must also meet the requirements in DOE O 458.1 Chg 3, *Radiation Protection of the Public and the Environment.* Derived Concentration Standards (DCS) are documented in DOE-STD-1196-2011, *Derived Concentration Technical Standard.* The treated effluent must meet the DCS with the sum of the fractional discharges (ratio of actual discharge concentration to the DCS value) for the combined radiological constituents being less than 1.

Though not typically detected in plant feed wastewater at levels that exceed the DCS, radionuclides other than Sr-90 and Cs-137 are sometimes present in trace quantities in wastewater generated by the HFIR and REDC operations that are introduced to the system via the LLLW evaporator condensate. These include ^{241}Am, ^{60}Co, ^{51}Cr, ^{64}Cu, ^{55}Fe, ^{56}Mn, ^{106}Ru, and others. Solubility of these isotopes is low under the current conditions that exist in the PWTC feed wastewater, so they are expected to be present in insoluble colloidal forms that will tend to coagulate and be separated by clarification, filtration, and carbon adsorption. Therefore, the continued use of these unit operations is recommended. The exception to this is tritium (^{3}H) which cannot be separated by best available wastewater treatment technologies. ^{3}H concentration is presently controlled administratively through compliance with WM-LWS-WAC, *Waste Acceptance Criteria for Liquid Waste Systems Operated by the Liquid and Gaseous Waste Operations Project at Oak Ridge National Laboratory*.

1.1.2 General Requirements

General requirements that are not specific to any particular piece of equipment or structure include:

- If a major equipment item (tank, vessel, column, pipeline, etc.) in the existing PWTC is considered for future use, it should be inspected to verify that it has significant remaining useful life (greater than 30 years). Any equipment that does not meet this requirement must be refurbished or replaced.
- Any new facilities built shall be constructed to be consistent with ORNL strategic plans, and must have a design life of 30 years.
- Secondary solid waste from these treatment systems must be suitable (after adequate dewatering and packaging) for direct disposal in an approved sanitary landfill, hazardous waste disposal facility, or low-level waste facility.
- Support functions must be provided operation and maintenance of the facility, including but not limited to control room and supply storage.
- Diked tanker truck unloading stations must be provided, capable of unloading tanker trucks which will transport wastewater from sites such as the EMWMF.
- Systems must comply with all applicable codes and standards.
- Process controls are to be integrated with the LGWO distributed control system, which is scheduled to be upgraded in the near future.
- Confinement of radioactive contamination (airborne and liquid) must be provided as adequate to protect the public, personnel, and the environment.
- Systems must be designed to maintain personnel radiation exposures as low as reasonably achievable (ALARA).

Regulatory requirements from the SRD are given as follows:

All systems, including collection pipelines, storage tanks, and processing facilities, must comply with all applicable codes and standards, including the requirements for confinement and monitoring/leak detection as defined in DOE M 435.1-1, *Radioactive Waste Management Manual*, Chapter IV, M (2)(a) and (2) (e) [7/9/99]).

Additional federal and state regulations governing the handling, treatment, storage, and disposal of the radiological and hazardous waste include:

- 10 *Code of Federal Regulations* (*CFR*) 830, *Nuclear Safety Management*
- 10 *CFR* 835, *Occupational Radiation Protection*
- 10 *CFR* 851, *Worker Health and Safety Program*
- 10 *CFR* Part 1021, *National Environmental Policy Act (NEPA)*
- *Clean Water Act*
- 29 *CFR* 1910, *Occupational Safety and Health Act*
- *Federal Facility Agreement for the Oak Ridge Reservation*, Section 9 and Appendix F.
- DOE P 450.4, *Safety Management System*

Accurate and real-time inventory control systems must be provided to maintain less than Nuclear Hazard Category 3 status per DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*.

Secondary waste materials must be processed, packaged, and certified in compliance with applicable criteria for transport and disposal.

1.1.3 Process Wastewater Technical Requirements

The SRD also defines functional requirements that define specific technical capabilities that must be provided to perform processing functions in a manner that is safe, compliant, efficient, reliable, and verifiable. The necessary capabilities are the basis for design specifications, calculations, and drawings.

The system will be capable of processing wastewater at flows that match or exceed those at which the wastewater is being generated (from the SRD) provides wastewater flows from 2010 and forecasted wastewater generation for the PWTC. Though the forecast in Table B-2 suggests that process wastewater sources from Bethel Valley will decline to zero over time, the system must allow for current quantities and constituents from existing sources such as lab drainage, cooling water, floor drains, and LLLW evaporator system overheads. The projected average flow is expected to be a maximum of 183 gpm; however, a design flow requirement of 300 gpm is designated in the SRD to allow for variability in groundwater flow that is heavily influenced by rainfall. There is enough surge capacity in the existing equalization tanks to maintain a constant average flow to the plant under normal conditions; however, it is necessary at times to increase the flow to the treatment systems in order to maintain an acceptable operating level in the tanks.

Table B-2. Annual process waste flows

Building/Area Served	Manhole	2010		2011		2012		2013		2014		2015 (1)	
		GPM	MG	GPM	MG	GPM	MG	GPM	MG	GPM	MG	GPM	MG
ORR &BSR	112	7.0	3.7	7.4	3.9	7.2	3.8	5.5	2.9	6.8	3.6	7.0	3.7
3047/Reactors (2)	114	9.0	4.7	10.7	5.6	9.0	4.7	6.7	3.7	7.5	3.9	7.5	3.9
3025 and 3026 Pad	149	5.2	2.7	2.3	1.2	1.8	1.0	4.1	2.2	4.6	2.4	5.8	3.0
4500 Complex (7)	190	73.4	38.6	65.8	34.1	54.5	28.7	67.8	35.6	62.0	32.6	63.5	33.4
Isotope Area	234	11.9	5.7	11.3	5.9	14.9	7.8	10.8	5.7	5.6	2.9	3.8	2.0
3525	235	9.8	5.1	10.2	5.4	8.0	4.2	8.2	4.3	4.0	2.1	4.1	2.2
WC-9,10 Drywells (3), (5)	N/A	24.7	13.0	22.8	12.0	22.5	11.8	27.6	14.5	19.8	10.4	22.2	11.7
2026	240	<0.1	<0.1	<0.1	<0.1	1.3	0.7	0.1	0.1	0.2	0.1	<0.1	<0.1
2531 (4)	243	0.6	0.3	0.9	0.4	0.8	0.4	1.2	0.6	0.7	0.3	1.1	0.6
Tank Farm (5)	PS-1	38.4	20.2	23.0	12.1	23.4	12.3	39.0	20.5	32.4	17.1	30.4	16.0
7900	F-2017/2018	6.0	3.1	6.9	3.6	6.1	3.2	5.7	3.0	4.1	2.2	3.1	1.7
7920 &7930 (7)	F2019/2020	4.2	2.2	3.2	1.7	2.5	1.3	3.1	1.6	2.8	1.5	3.2	1.7
SWSA (5)	7895	16.1	8.4	19.3	10.2	17.0	8.9	19.2	10.1	12.0	6.3	8.7	4.6
Corehole 8 (5)	N/A	X	X	X	X	23.2	12.2	18.9	9.9	12.1	6.4	6.9	3.6
EMWMF (7)	Trucked	X	X	14.3	7.5	7.8	4.1	10.6	5.6	12.2	6.4	8.7	4.6
3544 (6)	L-5	127.6	67.1	127.8	67.2	131.6	69.2	145.7	76.6	106.7	56.1	93.6	49.2
3608 To WOC (6)	F-1021	225.3	118.4	224.5	118.0	212.7	111.2	231.8	121.9	184.6	97.0	180.0	94.6

(1) Ave. through 10/25/15 used for year
(2) Bldg. 3047 is MH114 minus MH112
(3) Estimated
(4) LLLW Evaporator Overheads
(5) Groundwater
(6) Includes all of 2015
(7) Non-Rad
X Data Not Available

New or refurbished treatment systems must be designed and installed in a manner that avoids disruption of service to the waste generators. Piping interfaces with the existing system will be constructed in a way that minimizes the time and effort necessary to perform the final connections.

System reliability and redundancy is necessary to ensure the system is available for continuous 24/7 operations. The existing system is designed for continuous operations and provides the necessary collection system capacity to allow for limited-duration shutdown of the processing systems while maintenance (both planned and unplanned) is performed. Equipment is sufficiently sized to allow for a wide range of process flows. In addition, redundant transfer pumps and process vessels are provided to allow for routine maintenance and for equipment malfunctions.

1.2 Liquid Low-Level Waste System Functional Requirements

LLLW System functions include all activities required to collect, process, and store LLLW in a manner which ensures the protection of the health and safety of the workers and the general public as well as the protection of the environment. This is achieved through strict compliance with all federal and state regulations governing the handling, treatment, storage, and disposal of the waste for the PW System.

Principal functions of the system include pipeline transport, pH neutralization, evaporation/concentration, and storage of liquids and sludge. Stored liquids and sludge are staged for later solidification, packaging, and off-site disposal as TRU waste or LLW.

LLLW is collected from glove box and hot cell drains in research laboratories, radiochemical facilities, nuclear reactor facilities, and other systems. LLLW from generators can be collected in several ways, including: 1) direct transfer to the main LLLW collection tanks via the existing piping network, 2) holding in local collection tanks followed by transfer to the main collection tanks via the piping network, and 3) transfer to a transport tanker or bottle carrier for roadway transport to the main collection tanks.

The principal generators for LLLW and annual volumes for 2011–2015 are shown in Table B-3.

Table B-3. LLLW generators and annual volumes

Facility	Volumes (gallons)				
	2011				
2026 (UT-B)	988	156	520	580	963
3019 (Isotek)	0	0	0	0	0
7920 and 7930 REDC (UT-B)	1,612	4,628	3,900	3,536	4,108
7935 Manipulator Shop (UT-B)	1,612	1,872	1,300	2,444	1,508
3039 Stack Area (3092) (UCOR)	36,764	33,332	31,200	19,812	16,640
3517 (UCOR)	68,536	48,152	92,352	30,160	50,076
3544 PWTP (UCOR)	4,262	5,096	5,668	4,680	4,992
TWPC (TRU Waste Processing Center)	0	2,780	2,446	4,559	1,333
HFIR (UT-B)	0	0	0	1,319	0
3525 (UT-B)	0	733	0	0	0
WC-10 Pipeline (UCOR)	0	0	707	825	231
3047 (UT-B)	0	0	0	205	0
Sumps and Valve Boxes (UCOR)	60,220	45,095	72,276	35,549	57,503
7830 MVST Tanks Sumps (UCOR)	8,029	0	0	0	4,223

The composition of the wastewaters sent to the LLLW System must meet the criteria given in WM-LWS-WAC or an approved variance. Generators must evaluate their wastes against the criteria and contact LGWO to arrange for routine acceptance via pipeline or transport tanker.

1.2.1 General Requirements

General requirements for management of LLLW include the following:

- If a major equipment item is considered for future use, it should be inspected to verify that it has significant remaining useful life (greater than 30 years). Any equipment that does not meet this requirement must be refurbished or replaced.
- Any new facilities built shall be constructed to be consistent with ORNL strategic plans, and must have a design life of 30 years.
- Provide nuclear safety controls for Hazard Category 2 inventories of radioactive materials.

- Provide shielding adequate to protect personnel from direct ionizing radiation and to maintain personnel exposures ALARA.
- Process controls are to be integrated with the LGWO distributed control system.
- Provide confinement of radioactive contamination with leak detection capability.
- Facility is to meet or exceed requirements for RCRA permitting.
- Maintain the safety, shielding, and confinement functions throughout normal operations, credible accident scenarios, and post-accident recoveries.
- Provide sampling capabilities to support process operations and waste certification.
- Design allowance for maintenance support functions.
- System reliability and redundancy as necessary for remote operations in high radiation fields.
- System feed storage tanks must have diked tanker truck unloading stations capable of unloading LLLW transport containers.

1.2.2 Technical Requirements

LLLW tank systems must be designed for long-term storage of liquids with capacity large enough to accommodate many years of concentrate generation. Evaporator systems must be designed for shielded, remote operations. Key technical requirements include:

- Evaporator facilities must process up to 100,000-gal of dilute LLLW and reduce the volume by a factor of 30-40:1.
- Evaporator overhead condensate system must provide a decontamination factor that will allow for subsequent processing in the PW System per WM-LWS-WAC or approved variance.
- LLLW must be conditioned to allow long-term storage in the LLLW storage tanks systems.

1.3 Gaseous Waste System Functional Requirements

The GW System functions provide continuous routine transfer and treatment of slightly contaminated radioactive GW in a manner which ensures protection of the health and safety of the workers, the general public, and the environment. Cell ventilation and off-gasses generated by various program activities in multiple laboratory facilities is collected and HEPA filtered locally and/or in transit to the central ORNL stack area, where it is sampled, monitored, and released to the atmosphere via the 250-ft 3039 Stack. The Hot Off-Gas (HOG) generated by various program activities in multiple ORNL facilities is HEPA filtered locally, collected, processed through the 3092 caustic scrubber and HEPA filters at the central stack area, sampled, monitored, and then released to the atmosphere via the 3039 Stack. Flow through the stack is approximately 68,000 cubic feet per minute (cfm).

The GW handling system includes both Cell Ventilation (CV) and HOG treatment. The CV system handles large volumes of air with trace concentrations of radioactive material while the HOG system treats lower volumes of air with higher contaminant content. The system operates continuously and includes collection ducts, exhaust fans, filters, off-gas scrubber, and the 3039 discharge stack. Three different sets of ventilation fans serve the CV system and one central fan system serves the HOG system. Each set includes a primary electric fan and a backup fan that is powered by a steam turbine. A backup generator is available to provide electrical power in the event of a power outage. The steam operated turbines are only needed for the period of time necessary for the backup generator to reach full load.

These systems serve numerous radioactive sources at ORNL, including laboratory hoods, research and development activities, ventilation from out-of-service reactors, potentially contaminated work areas, and other facilities planned for or currently being remediated. The 3092 Scrubber services a number of facilities including many of the same facilities that require cell ventilation. One set of fans services a large number of HOG sources, routing the contaminated air through the scrubber system, demister, heaters, and high efficiency particulate attenuation (HEPA) filters.

Facility managers are responsible for ensuring air handling systems operate appropriately within buildings being serviced by the GW System. Operation of the GW System also involves continuously monitoring the system for pressure changes and flow, replacing HEPA filters, operating and maintaining the off-gas scrubber. Maintenance includes gas sampling, inspection of the 3039 Stack, and ensuring groundwater infiltration is removed and transferred to the appropriate liquid waste treatment facility.

The 3039 Stack Ventilation System, which was originally built in 1950, was extensively modified and upgraded in 1984 to increase its efficiency and reliability. The 1984 upgrades included installation of new ductwork and fans in the 3039 Stack Area, as well as extensive modifications at generator facilities in the Isotope Area of Bethel Valley. Also part of the 1984 upgrades was installation of the off-gas scrubber and HEPA filter banks at Bldg. 3092.

Cell-Ventilation Collection Systems

Each collection system is equipped with an electrically-operated fan for normal operation and a steam turbine driven standby fan with backup diesel generator located near the 3039 Stack. Each backup fan is capable of supplying flow at the required design pressure. Loss of on-site electrical power will activate both the standby fan and the backup diesel generator. As soon as the diesel generator reaches normal operating speed, the sequencing relays will automatically restart the electrically driven fan. The steam turbine-driven fan will automatically reset to its standby condition when the negative pressure at the suction side of the electrical fan returns to normal.

3500 Cell Ventilation Area

The CV requirements for the 3500 Area include hot cell facilities from past radiochemical process operations and processing areas. The air from these facilities passes through local HEPA filters and through a 54-in. diameter concrete duct to the two fans (EF-1 and EF-2) that service these buildings. The total flow requirement for the 3500 Area is about 19,700 cfm and the design flow for each of the fans is about 24,400 cfm. The steam driven backup fan EF-2 operates in the same fashion as other backup fan systems to maintain flow to the 3500 Area should there be a fan failure or loss in electrical power.

3025 Cell Ventilation Area

The CV air from 3025 is collected via above-ground stainless steel ducts ranging from 20 in. to 60 in. in diameter. Filtration of exhaust air from 3025 is not required before combining with the other air streams. The total flow requirement for 3025 and is about 14,900 cfm and the design flow for each of the fans (EF-5 and EF-6) is about 34,000 cfm. EF-6 is the steam driven backup fan for EF-5.

Isotope and Solid State Areas

CV flow from the Solid State Area and Isotope Area combine and are transferred through a 24-in. duct to the 3039 Stack. Fans EF-7 and EF-8 service this area and the discharge from the fans is mixed with the flow from 3042 before entering the stack for discharge. EF-7 has a design flow of about 48,000 cfm and the flow requirement for the Isotope and Solid State Areas is about 31,400 cfm. EF-8 is steam driven backup fan for EF-7.

3092 Hot Off-Gas System
The HOG system services many of the same facilities as the CV system, though the service is connected to sources that are lower in flow requirement, but potentially higher in contamination, both chemical and radiological. The off-gas from the buildings is collected in stainless steel pipes routed underground to a manifold at the scrubber system. Electrically driven blower EF-11 provides a flow of 4000 cfm for the system. EF-11 is backed up by a steam driven blower.

In the past, the off-gas could potentially contain acid gasses such as hydrofluoric or hydrochloric acid that could damage HEPA filter systems and blower components, therefore, a caustic venturi scrubber system is used to neutralize the acids prior to contacting these systems. Since these acidic constituents are no longer present, the caustic scrubber may be taken out-of-service. A demister and heater are located downstream from the scrubber to remove entrained droplets of liquid and dry the air before entering the HEPA filters. The demister is designed with three replaceable mist eliminator elements in parallel that include a bag-in/bag-out replacement system. The system also includes a retaining system for four prefilters and four HEPA filters mounted in parallel.

The jet venture scrubber is designed to remove up to 500 ppm nitric acid in 4000 cfm air using a 3% solution of sodium hydroxide. The caustic solution is circulated through the scrubber at 400 gal/min ambient temperature. The caustic solution is routinely discharged to the LLLW System for disposal. The system includes a backup baffle-type caustic scrubber system should the venturi scrubber system fail for any reason. The pump that services the venturi system uses a steam driven backup pump in case the primary pump fails or power is interrupted.

Filter change outs or switching to other banks of filters are routinely determined based on high pressure drop and scheduled DOP testing of the filters. When a bank of filters exhibits a high pressure drop, a second bank of clean filters may be placed in-service while the first bank of filters is replaced. This operation is typical whether the filters are located at the generator facility or those associated with the HOG

Waste System
An underground stainless-steel piping system collects radioactive condensate from the ventilation system. Process waste such as steam condensate and washdown water is sent to the process drain system. Sumps are located at low points in the system, and liquids that collect in the sumps are pumped or steam-jetted to the PW System. The scrubber solution is discharged to the LLLW System on a routine basis.

Radiation Monitors
A radiation monitoring system is installed on the 3039 Stack at the 50-ft level of the stack. It is designed for continuous monitoring of the radiation level in the exhaust gasses. The signals from the system are recorded and tracked at the Waste Operation Control Center (WOCC, Bldg. 3130).

Turbines
Steam is bled to the steam turbines to maintain proper temperature and to maintain constant slow rotation, thus assuring availability for automatic start-up under loss of electrical power. The turbines are activated upon the loss of static pressure at the inlet to the electric motor driven fan. Pressure sensing switches activate the steam valves that supply steam to the turbines. Each turbine is tested on a weekly basis to ensure proper function should there be a power outage.

Diesel Generator
The backup diesel generator located in Bldg. 3125 is a Caterpillar Model 3508. The fuel tank provides about 1.5 days of operation for 750 kW backup power to the electric fans, Building 3105, and the 3039 Stack monitors. The generator is in good condition with low operating hours.

1.3.1 General Requirements

General requirements for managing ORNL GW include the following:

- If a major equipment item in the existing GW is considered for future use, it should be inspected to verify that it has significant remaining useful life (greater than 30 years). Any equipment that does not meet this requirement must be refurbished or replaced.
- Any new facilities built shall be constructed to be consistent with ORNL strategic plans, and must have a design life of 30 years.
- Secondary liquid waste must be suitable for treatment by the existing ORNL PW System.
- Secondary solid waste from the GW System must be suitable for direct disposal in an approved sanitary landfill, hazardous waste disposal facility, or low-level waste facility.
- Support functions must be provided operation and maintenance of the facility, including but not limited to control room and supply storage.
- Systems must comply with all applicable codes and standards.
- Process controls are to be integrated with the LGWO distributed control system.
- Confinement of radioactive contamination (airborne and liquid) must be provided as adequate to protect the public, personnel, and the environment.
- Continuous flow and contaminant monitoring of the 3039 Stack discharge is required.
- A backup power supply must be available in the event of a power outage. Existing steam operated turbines are only operated for the period of time necessary for the backup power supply to reach full load.

Systems must be designed to maintain personnel radiation exposures ALARA.

Regulatory requirements applicable to GW System design and operations include the following:

- 10 *CFR* 830, *Nuclear Safety Management*
- 10 *CFR* 835, *Occupational Radiation Protection*
- 10 *CFR* 851, *Worker Health and Safety Program*
- 10 *CFR* Part 1021, *National Environmental Policy Act (NEPA)*
- 29 *CFR* 1910, *Occupational Safety and Health Act*
- *Federal Facility Agreement for the Oak Ridge Reservation*
- DOE P 450.4, *Safety Management System*
- *Clean Air Act, Title V requirements*
- *TDEC Air Pollution Control regulations*
- *National Emission Standards for Hazardous Air Pollutants*
- Accurate and real-time inventory control systems must be provided to maintain less than Nuclear Hazard Category 3 status per DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*.

1.3.2 Technical Requirements

The GW facilities must be operated safely and in a manner that prevents adverse environmental impact. The systems are designed to collect, treat, and exhaust facility ventilation and off-gasses in a safe and effective manner. Key performance parameters include:

- Safely collect, process, and exhaust a maximum of 95,000 cfm.
- Meet the requirements of the *Title V Federal Clean Air Act Operating Permit No. 547563*.
- Ensure GW generators comply with the LGWO waste acceptance criteria given in WM-GWS-WAC.
- The 50-year-old central GW treatment system, including the above-ground ductwork in the general vicinity of the central 3039 Stack, was upgraded in the 1980s. The system is oversized for ORNL's future R&D missions. Currently, only about half of the system's capacity is being used. In the future, use is expected to drop to less than 30% of system capacity. Balancing the airflow in the system will become more difficult as inactive facilities are remediated and ORNL consolidates hot cell operations and installs local ventilation systems to allow disconnecting from the GW central system.

  The composition of cell ventilation air or hot off-gas must meet the criteria given in WM-GWS-WAC, which is based on the Title V air permit. The WAC addresses the responsibilities of the generating organization and the generator interface. Generators must evaluate their expected ventilation output against the criteria prior to discharging a new input to the 3039 system. Typically, the gaseous input (whether cell ventilation or process off-gas) must be HEPA-filtered prior to exiting the facility and must meet numerical limits for radionuclide content. The concentrations of other hazardous components must be ALARA before leaving the facility.

APPENDIX C.
PROCESS WASTE WALKDOWN SUMMARY

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Table C-1. Process waste system walkdown

Building	Equipment	Comment
3608	Substation	Half of the substation is currently offline. Roof of metal box housing the substation is known to leak during heavy rains due to drainage issues that result in pooling of water on concrete pad.
	Valves	Based on operator knowledge, very few valves in facility work, most valves are completely open or stuck closed. Many valves cannot be turned. Monthly preventive maintenance should be implemented.
	Containment Dike	Plant and vegetation growth abundant throughout the dike. Multiple cracks in the concrete, chunks of concrete displaced. Sealant cracking, peeling off and piling up in several areas. Chemical spill drain safety valve is stuck in the open position. Main sump has two pumps, one of which does not work.
	Control Room	The motor control system (MCC) and heat trace controls are outdated. Replacement components are hard to find and few technicians are trained to repair old systems. Roof leaks.
	F-1001 & F-1002 (Metals & Non-Metals Tanks)	Hand valve on piping from F-1001 moves at slightest touch, which dramatically alters the flow. No hand valves isolate. Flow control valves work. Jet mixers work. Metals neutralization, caustic addition do not work. F-1001/F-1002 piping leaks, dripping into containment dike.
	F-1003 Rapid Mix Tank	Mixer is broken. Air is used to agitate. Vegetation growing out of overflow box.
	F-1006 & F-1007 (Metals and Non-Metals Clarifier)	F-1006 polymer line consists of a plastic tube zip-tied to the railing and covered in protective foam. F-1007 mixer/rake is broken. J-1007 sludge pump is offline. Sludge is pumped by J-1006 sludge pump through a piping connection. F-1007 has vegetation growing in trough. Both tank troughs have substantial sludge buildup. Tank bottom thickness has not been tested. Rake scrapes sludge around the bottom of the tanks.
	F-1008 Filter Feed Tank	Tank piping is leaking. Pipe insulation has been removed and there is a pipe clamp over the leak. Pumps J-1008A and B both work.
	F-1009 & F-1010 Dual Media Filters	Both filters are offline, limiting the facility's operational load. False bottoms on both vessel need repair. Discharge piping is broken. Being offline limits facility's operational load due to pressure buildup.

Table C-1. Process waste system walkdown (cont.)

Building	Equipment	Comment
3608	F-1014 Air Stripper	Procedure samples are not being collected. Temporary fix on acid addition pipe limits control.
	F-1018, F-1019, F-1020 GAC Columns	Vegetation growing out of the top of the air stripper. Piping/valves need replacement on pipe section that has split down a seam. Only one valve (OPEN/CLOSE) holds. GAC sump level valve is leading, standing water in containment dike. GAC sump has accumulated lots of granulated carbon. F0-1019, filled with Mersorb, is being used as a filter with the dual media offline, reducing the facility's maximum output to half the design gallons per minute. Pressure on lead column builds up to alarm levels and limits facility flow. No backwashing of GAC media has been documented. GAC is not protected by dual media, so carbon gets loaded with contaminants faster and requires more frequent backwashing. Backwash bypass line (painted and indoors) leaks. Previous testing results from 2014 indicate that F-1018 and F-1020 wall thickness is 10-25% below specifications.
	F-1021 Final Effluent Tank	Propeller/shaft issues. Propeller box broke and was repaired. Gearbox broken. No mechanical device in mixing tank. Temporary air hose is used to mix tank. Caustic and acid are added to the top of the tank, the pH probe is located at the bottom of the tank. Overshooting corrections to the pH level of the water. Vegetation is growing on the mixer and water surface.
	F-1022 Sludge Holding Tank	Two pumps to tank, no back-up in case of failure. Recycle pump to F-1070 leaks.
	F-1023 Precoat Tank	Previous testing results from 2014 indicate that wall thickness is 10-25% below specifications.
	F-1025 Caustic Tank	Pumps break down regularly.
	F-1026 Sulfuric Acid Tank	Tank out-of-service. Acid accumulated in bottom of tank needs to be removed.
	F-1027 Polymer Storage Tank	Line to F-1006 is a plastic tube. Diastolic pump breaks roughly once a week requiring maintenance. Persistaltic pump replaced with Randolf pump. Tubing does allow enough polymer to reach clarifier. Polymer is pumped to water softener instead of F-1060 Flash Mix Tank.
	F-1050 Surge Tank	Two of the three pumps do not work. No back-up in case of failure. Flow limited to 180-190 gpm with only one pump to 3544.
3608	F-1051 Ferric Sulfate Tank	One pump leaks, the second pumps works sporadically.

Table C-1. Process waste system walkdown (cont.)

Building	Equipment	Comment
3544	Outdoor Piping	Carbon steel piping has failed in several locations due to age and poor insulation that is retaining water. Large sections have been replaced recently.
	Building	Gutter is rotten, allowing rain to continually drip on the uninsulated pipes on the wall below. Chemical mixing room vessel containment flooring needs to be patched and resealed with epoxy. Column room flooring is in poor shape, nitric acid has eaten away the concrete in multiple places, and needs concrete patched and sealed with spill-alert epoxy. Motor control system works, but is several generations old, and replacement components are difficult to find. Few technicians are trained to perform maintenance on the MCCs.
	L2 Surge Tank	Tank volume is controlled to 50%. Bottom 3-4-ft of tank is silt.
	L3A & L3B Polishing Filters	Filters are offline and have not had resins removed in years. Filter resins have solidified into a concrete-like substance.
	L5 Clearwell	South basin has been shut down, north basin has leaked in the past.
	L7 & L8 Acid Tanks	Both pumps are out-of-service. Pumps/valves require frequent replacement. Vessels appear to be in good shape. Stainless steel and indoors. Acid fume damage to walls near vessels.
	L7A Nitric Acid Tank	Pump does not work. Drained to floor. Valves are cracked to allow acid to creep through.
	L9 Acid Feed Tank	Pump replaced recently. Vessels appear to be in good shape. Stainless steel and indoors. Acid fume damage to walls near vessels.
	L10 Evaporator	Pump replaced recently. There is no backup for supply to online steam coils. Vessels appear to be in good shape. Stainless steel and indoors. Acid fume damage to walls near vessels.
	M-1 Caustic Tank	Tank shell is thinning towards the top. Valves work, but are missing handles.
	L11 LLLW Concentrate Tank	Automatic valves are moved by hand. Block valves work.
	L13 Condenser	One of the condensers has a hole in the cap and has been taken offline.
	PV-101 & PV-102	Backwash pumps need to be replaced. Zeolite in columns needs to be removed and replaced.
2600	Containment Dike	Vegetation needs to be removed from dikes.

Table C-1. Process waste system walkdown (cont.)

Building	Equipment	Comment
2600	F-2101 F-2102 350,000-gal Tanks	Foundation cracks need to be filled.
	F-2103 1,000,000-gal Tank	Foundation cracks need to be filled.
7961	F-2008 Caustic Tank	Overflow alarm going off, but tank was not overflowing. Alarm signal spinning, but no light. Neutralization system does not work, caustic is added through the bypass line.
	F-2017, F-2018, F-2019, F-2020 Tanks	Foundation issues. Observable grout in cracks. Chunks of grout missing around the tank foundations. Jet mixers on the tanks may/may not work due to piping and instrumentation to the DCS. Diversion system does not work, diversion performed manually.

APPENDIX D.
PROCESS WASTE NDE RESULTS

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Table D-1. Process Waste NDE Results

	Area	Initial Thick.	Min Thick.	Allowed Thick.	Corrosion amount	Corrosion %
3608	J-1000B,C 2.5" section	0.2030	0.1440	0.1720	0.0590	29%
	J-1000B suction, 4"	0.2370	0.2410	0.2060	-0.0040	-2%
	HV-603 6" section	0.2800	0.1900	0.2490	0.0900	32%
	HV-330 8" section	0.3220	0.2550	0.2910	0.0670	21%
	HV-330 4" section(LEAK)	0.2370	0.1900	0.2060	0.0470	20%
	F-1006 6" section	0.2800	0.1680	0.2490	0.1120	40%
	F-1006 2.5" section	0.2030	0.1340	0.1720	0.0690	34%
	F-1006 West, 2.5", severe corrosion	0.2030	0.1030	0.1720	0.1000	49%
3544	PV-101	0.3750	0.3520	0.3125	0.0230	6%
	PV-102	0.3750	0.3330	0.3125	0.0420	11%
	L3A, Internal Pitting	0.5000	0.3620	0.4375	0.1380	28%
	L3B	0.5000	0.4540	0.4375	0.0460	9%
	M-1 Top and Bottom	0.3750	0.3580	0.3125	0.0170	5%
	M-1 Side	0.2500	0.1780	0.1875	0.0720	29%
	L-2	0.5000	0.4440	0.4375	0.0560	11%
	L-14 Top and Bottom	0.5000	0.4410	0.4375	0.0590	12%
	L-14 Side	0.3750	0.3840	0.3125	-0.0090	-2%
	M-2	0.1875	0.1850	0.1250	0.0025	1%
	L-7 Top and Bottom	0.3125	0.3880	0.2500	-0.0755	-24%
	L-7 Side	0.2500	0.2510	0.1875	-0.0010	0%
	L-8 Top and Bottom, low reading near bottom weld	0.3750	0.2110	0.3125	0.1640	44%
	L-8 Side	0.2500	0.2530	0.1875	-0.0030	-1%

Table D-1. Process Waste NDE Results (cont.)

	Area	Initial Thick.	Min Thick.	Allowed Thick.	Corrosion amount	Corrosion %
	L-9 Top and Bottom	0.3750	0.3590	0.3125	0.0160	4%
	L-9 Side	0.2500	0.2470	0.1875	0.0030	1%
	L-11	0.2500	0.2640	0.1875	-0.0140	-6%
	L-4A	0.1875	0.1970	0.1250	-0.0095	-5%
	L-4B	0.1875	0.1940	0.1250	-0.0065	-3%
	L-4C	0.1875	0.1900	0.1250	-0.0025	-1%
	L-4D side	0.2500	0.2660	0.1875	-0.0160	-6%
	L-4D bottom	0.3125	0.3300	0.2500	-0.0175	-6%
	L-10 Top Bottom	0.3125	0.3510	0.2500	-0.0385	-12%
	L-10 side	0.2500	0.2910	0.1875	-0.0410	-16%
	L-12	0.1250	0.1190	0.0625	0.0060	5%
	4005 Pit, 2" sch 80	0.2180	0.1830	0.1760	0.0350	16%
	4005 Pit, 4" sch 80	0.3370	0.3080	0.2950	0.0290	9%
	F-2110, 190 Pumps, 6"	0.2800	0.2650	0.2490	0.0150	5%
	7961 Pipeline @ 7961, 6"	0.2800	0.2700	0.2490	0.0100	4%
	7961 Cold Process Waste line, 4"	0.2370	0.2280	0.2060	0.0090	4%
	7961 Pipeline @ 3608, 6"	0.2800	0.2350	0.2490	0.0450	16%
	4003 pump station, 4"	0.2370	0.2290	0.2060	0.0080	3%
	4004 pump station, 6"	0.2800	0.2520	0.2490	0.0280	10%
	3544 Feed Pipeline at 2600, 6"	0.2800	0.2780	0.2490	0.0020	1%
	3608 to 2600 Pipeline at 2600, 4"	0.2370	0.2400	0.2060	-0.0030	-1%
	IPS to 2600 Pipeline at 2600, 8" external Corrosion	0.3220	0.3340	0.2910	-0.0120	-4%
	IPS @ 3544, 4100 pumping station,8", ext corrosion	0.3220	0.2000	0.2910	0.1220	38%

Table D-1. Process Waste NDE Results (cont.)

	Area	Initial Thick.	Min Thick.	Allowed Thick.	Corrosion amount	Corrosion %
	To/From MV Pipeline at 2600, 6"	0.2800	0.2770	0.2490	0.0030	1%
	F-2101, 2600 tanks 1/4"	0.2500	0.2520	0.1880	-0.0020	-1%
	F-2101, 2600 tanks 5/16"	0.3125	0.3170	0.2505	-0.0045	-1%
	F-2101, 2600 tanks 3/8"	0.3750	0.3760	0.3130	-0.0010	0%
	F-2102, 2600 tanks 1/4"	0.2500	0.2430	0.1880	0.0070	3%
	F-2102, 2600 tanks 5/16"	0.3125	0.3110	0.2505	0.0015	0%
	F-2102, 2600 tanks 3/8"	0.3750	0.3660	0.3130	0.0090	2%
	F-2103, 2600 tanks 0.25"	0.2500	0.2530	0.1880	-0.0030	-1%
	F-2103, 2600 tanks 0.2666"	0.2660	0.2660	0.2040	0.0000	0%
	F-2103, 2600 tanks 0.3737"	0.3737	0.3850	0.3117	-0.0113	-3%
	F-2103, 2600 tanks 0.4808"	0.4808	0.4604	0.4188	0.0204	4%
	F-2103, 2600 tanks 0.6143"	0.6143	0.6210	0.5523	-0.0067	-1%
	F-7895,	0.2500	0.2330	0.1880	0.0170	7%
	7961, F-2017	0.2500	0.2460	0.1880	0.0040	2%
	7961, F-2018	0.2500	0.2450	0.1880	0.0050	2%
	7961, F-2019	0.2500	0.2460	0.1880	0.0040	2%
	7961, F-2020	0.2500	0.2420	0.1880	0.0080	3%

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APPENDIX E.
PROCESS WASTE CHARACTERISTICS

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Table E-1. Characterization of process wastewater in 1986 targeted for treatment at the future Non-Radiological Wastewater Treatment Plant (NRWTP)

Locations	**Manhole 190**	**3544 Effluent**	**1500 area**	**2000 area**	**HFIR/REDC**
Parameter	**Concentrations (mg/L)**				
Ca	30	0.5	30	30	35
Mg	10	0.1	10	10	10
Na	7	70	8	7	9
K	2	0.5	2	2	3
Cd	0.66	0.009	0.14	0.011	0.38
Cr	0.45	0.02	0.12	0.01	0.16
Cu	0.28	0.02	0.03	0.03	0.38
Fe	0.21	0.14	0.39	0.058	0.15
Hg	0.006	0.0004	0.0006	0.0005	0.0004
Ni	0.01	0.01	0.039	0.012	0.046
Pb	0.055	0.037	0.004	0.004	0.026
Zn	0.22	0.05	0.16	0.14	0.31
Chloroform	0.018	0.005	0.008	0.010	0.004
Chlorobenzene	0.094	0.005	0.008	0.010	0.004
Methylene chloride	0.53	0.51	0.002	0.002	0.005
Trichloroethylene	0.074	0.062	0.045	0.10	0.047
Total Organic Carbon (TOC)	8	3	9	2	3
Total Suspended Solids (TSS)	5	5	8	5	7
Total Dissolved Solids (TDS)	180	793	178	186	250
Flow (gpm)	125	110	6	10	36

Table E-2. Influent metal concentrations to the reactor clarifier at NRWTP during startup in 1989

Contaminants	Concentrations (mg/L)		
Metal	**Mean**	**Maximum**	**Minimum**
Ca	422	900	23
Mg	55	170	5
Na	301	580	40
Cd	0.007	0.046	0.005
Cr	0.061	0.41	0.011
Cu	0.45	2.7	0.023
Fe	11.6[a]	77	0.13
Ni	0.066	0.35	0.004
Pb	0.21	0.9	0.046
Zn	2.2	22	0.018

[a] Coal yard runoff water was being added temporarily to PWTC

Table E-3. Influent organic concentrations to the air stripper during startup in 1989

Contaminants	Concentrations (mg/L)		
Organic	**Mean**	**Maximum**	**Minimum**
Chloroform	0.018	0.14	0.004
Butylbenzylphthalate	0.010	0.010	0.005
Chrysene	0.010	0.010	0.004
Methylene chloride	0.006	0.026	0.001
1,2-dicloropropance	0.005	0.005	0.004
Trichloroethylene	0.005	0.005	0.001
Tetrachloroethane	0.005	0.005	0.002

Table E-4. Metals concentrations in feed and effluent at NRWTP in 1997-98, and daily NPDES limits

Contaminant	Concentration (mg/L)			
	Nonmetals Tank Influent	Effluent	Removal (%)	NPDES Daily Max
As	< 0.05	0.0015	< 97	0.014
Cd	< 0.003	0.00016	< 95	
Cr	< 0.01	0.0017	< 89	0.44
Cu	0.029	0.0057	80	0.11
Pb	0.090	0.0016	98	0.69
Hg	0.001	< 0.0002	> 80	0.0003
Ni	< 0.05	0.0014	< 97	3.98
Se	< 0.05	0.0025	< 95	0.01
Ag	0.010	0.00017	98	0.008
Zn	0.330	0.046	86	0.95

Table E-5. Metals concentrations in metals tank influent and clarifier effluent at NRWTP in 1997-98

Contaminant	Concentration (mg/L)		
	Metals Tank Influent	Clarifier Effluent	Removal (%)
As	< 0.05	< 0.05	> 0
Cd	< 0.003	< 0.003	> 0
Cr	0.023	0.01	56
Cu	0.570	0.15	74
Pb	0.233	0.09	61
Hg	0.007	0.0007	90
Ni	0.051	< 0.04	> 20
Se	< 0.05	< 0.05	> 0
Ag	0.025	0.01	60
Zn	1.196	0.33	73

Table E-6. PWTC Influent metal and radionuclide concentrations November 2009 and discharge limits

Metal	Mean	NPDES Daily Max	DCS*, Bq/L
Ca (mg/L)	32		
Mg (mg/L)	8.5		
Na (mg/L)	40		
Cd (mg/L)	< 0.04		
Cr (mg/L)	< 0.05	0.44	
Cu (mg/L)	0.083	0.11	
Fe (mg/L)	0.37		
Ni (mg/L)	< 0.07		
Pb (mg/L)	< 0.05	0.69	
Zn (mg/L)	2.96		
^{137}Cs (Bq/L)	1062		110
^{106}Ru (Bq/L)	151		150
^{90}Sr (Bq/L)	420		41
Gross Beta (Bq/L)	1543		

*DCS: Derived Concentration Standard from DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

Table E-7. Mercury concentrations entering and leaving the GAC/Mersorb-LW columns at the PWTC-3608 (formerly the NRWTP)

Location	Mercury Concentration (ng/L)		
	Mean	Max	Min
Lead Inlet	339	1020	77
Lag Outlet	40	72	20

APPENDIX F.
PROCESS WASTE SENSITIVITY ANALYSIS

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Sensitivity Analysis

A sensitivity analysis was performed to evaluate the impact of key cost and schedule risks and opportunities associated with the three PW alternatives. Risk impacts could potentially alter the cost margins between the alternatives and subsequently influence the alternative selection. The alternatives were evaluated for principal cost drivers to determine the impact of a change that has a significant impact on cost. Table F-1 provides key assumptions and risks that could impact each of the three alternatives.

Table F-1. Key risks and opportunities for PW alternatives

Process wastewater system alternative	Key risks (R) and opportunities(O)
Status quo PW alternative	The continued use of aging infrastructure increases unplanned maintenance expense. (R)
3608 Upgrade PW alternative	The continued use of aging infrastructure increases unplanned maintenance expense. (R) Generates greater than anticipated quantities of spent zeolite for disposal. (R)
Greenfield Plant PW alternative	Generates greater than anticipated quantities of spent zeolite for disposal. (R) Delays in capital funding increases operating and maintenance costs with the use of existing facilities, Bldgs. 3544 and 3608. (R) Site development costs are greater than anticipated due to soil contamination and interferences from legacy underground piping and utility routings. (R) Maintenance requirements could be less than anticipated for a new facility with updated equipment and controls. (O)

Data from the PW life-cycle cost analysis was used to estimate the potential cost impact of the identified risks and opportunities. Table F-2 summarizes the potential cost impacts and provides an evaluation of the likelihood that a particular event would be realized.

The risk of higher than anticipated zeolite usage has the relatively high life-cycle cost impact for the 3608 Upgrade and the Greenfield Plant alternatives. The life-cycle cost increases by $4.9M if the zeolite usage is 50% greater than anticipated. The risks of additional unplanned maintenance and unanticipated capital costs have lower impacts on the life-cycle cost for any of the alternatives, in the range of $1.2M to $3.2M.

The Greenfield Plant alternative includes the risk of delayed capital project funding. If the capital project requires nine instead of six years to implement, the life-cycle cost increases by $7.1M due to additional operations maintenance costs for existing systems. The potential opportunity for reduced maintenance costs for the Greenfield Plant alternative (25% reduction in labor cost) could reduce the life-cycle cost by $4.5M.

In the unlikely scenario where $5M unplanned maintenance costs for the 3608 Upgrade alternative is required and the Greenfield Plant alternative maintenance labor cost is reduced by 25%, the Greenfield Plant alternative life-cycle cost would remain $13.3M greater than the 3608 Upgrade alternative.

Table F-2. Summary of sensitivity analysis for PW alternatives

Process wastewater system alternative	Key risks (R) and opportunities(O)	Likelihood*	LCC impact	Description and basis
Status quo PW alternative	The continued use of aging infrastructure increases unplanned maintenance expense. (R)	Likely	+3.1M	Increased maintenance involving $5M in additional Bldg. 3608 and Bldg. 3544 refurbishments at year 15 increases LCC from $175.3M to $178.4M.
3608 Upgrade PW alternative	The continued use of aging infrastructure increases unplanned maintenance expense. (R)	Likely	+3.2M	Increased maintenance involving $5M in additional Bldg. 3608 refurbishments at year 15 increases LCC from $139.4M to $142.6M.
	Generates greater than anticipated quantities of spent zeolite for disposal. (R)	Unlikely	+4.9M	Increasing zeolite usage by 50% increases the LCC from $139.4M to $144.3M.
Greenfield Plant PW alternative	Generates greater than anticipated quantities of spent zeolite for disposal. (R)	Unlikely	+4.9M	Increasing zeolite usage by 50% increases the LCC from $170.5M to $176.2M.
	Delays in capital funding increase required maintenance costs for existing facilities (Bldgs. 3544 and 3608). (R)	Likely	+$7.1M	Due to a 3 year funding delay, it is necessary to operate existing systems longer and replace the MCC components and heat trace controls. This work increases the LCC from $160.4M to $167.5M.
	Site development costs are greater than anticipated due to soil contamination and interferences from legacy underground piping and utility routings. (R)	Likely	+$1.2M	Increasing the cost of site development from 45% to 65% of Total Equipment Cost increases the LCC from $160.4M to $161.6M.
	Maintenance requirements could be less than anticipated for a new facility with updated equipment and controls. (O)	Unlikely	-$4.5M	Reducing the number of maintenance craft by 25% reduces the LCC from $160.4M to $155.9M (present value), which is $3M greater than the 3608 Upgrade alternative.

*Likelihood definitions: Very Unlikely < 10% probability; Unlikely 10-24% probability; Likely 25-74% probability; Very Likely 75-90% probability; Imminent > 90%

APPENDIX G.
LLLW WALKDOWN SUMMARY

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Table G-1. LLLW System walkdown

Building	Equipment	Comment
Evaporator Complex Bldg. 7830 Bldg. 7856	Control Rooms	The Motor Control System (MCC) is several generations old. Although the system works, components are difficult to find and few technicians are trained to perform maintenance on the MCCs. Pipe burst upstairs (Evaporator Complex) caused water to drip into the control room. Plastic is draped over the MCC buckets in order to keep electronics dry.
Bldg. 2535	Cooling Towers	Cooling tower is offline due to a leak in the underground piping from the condenser in the 2531 tunnel to the cooling tower.
Bldg. 7966	Moyno Pumps	Both pumps are inoperable and scheduled to be replaced.

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APPENDIX H.
LLLW NDE RESULTS

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Table H-1. LLLW NDE Results

Area		Initial Thick.	Min Thick.	Allowed Thick.	Corrosion amount	Corrosion %
7966	**Suction**	0.237	0.221	0.206	0.016	6.75%
	Discharge	0.32	0.292	0.289	0.028	8.75%
3321 1000-gal Tanker Shell		0.3125	0.282	0.2815	0.0305	9.76%
3092	**Scrubber Line**	0.28	0.242	0.249	0.038	13.57%
	Scrubber Header	0.337	0.338	0.306	-0.001	-0.30%
Cell Vent	**Isotopes**	0.12	0.117	0.089	0.003	2.50%
	3500-4500	0.12	0.112	0.089	0.008	6.67%
Off-gas	**Stack**	0.1874	0.176	0.1564	0.0114	6.08%
Valve Box	**W6**	0.154	0.147	0.123	0.007	4.55%

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APPENDIX I.
LLLW DETAILED ON-SITE AND OFF-SITE COST EVALUATION

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LLLW System Alternative Descriptions with Off-site and On-site Cost Evaluation

Background

Liquid Low-Level Wastes (LLLWs) at Oak Ridge National Laboratory Laboratory (ORNL) are currently concentrated in an evaporator located at the LLLW Evaporator Facility (Bldg. 2531) and transferred by pipeline to waste storage tanks at Melton/Bethel Valley for ultimate treatment at the TRU Waste Processing Center (TWPC). The treated waste is expected to be a solidified form that will be transported to the National Nuclear Security Site (NNSS) for ultimate disposition. In the late 2020s, it is expected that TWPC will be nearing, if not complete, with its sludge-related mission, and will no longer accept waste from the LLLW System.

In order to plan for the processing of those waste streams once TWPC is no longer available, an alternatives analysis has been conducted. Three potential alternatives have been developed for further consideration, as follows:

- **LLLW System status quo alternative.** Continue operation of existing LLLW System with maintenance and refurbishment as necessary to continue safe and effective operations until completion of EM cleanup at ORNL.
- **LLLW System on-site treatment alternative.** Redirect LLLW to the PW treatment system where possible and deploy a skid-based LLLW treatment unit in the Bethel Valley Evaporator Service Tanks (BVEST) Control Facility. Evaluate treating both dilute and concentrated LLLW.
- **LLLW System off-site treatment alternative.** Redirect LLLW to the PW treatment system where possible and ship remaining LLLW off-site for treatment and disposal. Evaluate shipping both dilute and concentrated LLLW off-site.

Following are cost elements associated with continued operation of the LLLW System "as is," redirection of LLLW where possible, with deployment of skid-based treatment units at the BVEST Crane Facility, and off-site commercial treatment and disposal of LLLW to complete the options analysis. Other factors/costs to be considered when comparing the options are described in the final section.

LLLW Status Quo Alternative

In this alternative, the LLLW System would continue to operate "as is." Current maintenance would be continued with no changes except one urgent special maintenance project, the Cooling Tower Piping Modifications project, that was identified during the condition assessment phase of this study. The concentrated LLLW would be stored in the BVEST until transferred to the Clean-in-Place (CIP) or MVST for long-term storage until treatment capability is established through a future capital project.

Two significant changes would occur in this scenario.

- At some time in the early 2020s, the Office of Science (SC) LLLW Treatment Facility Project would become operational. This would eliminate approximately 10% of the current volume and 90% of the radionuclide input to the LLLW System.
- At some time in the late 2020s, the TWPC sludge processing campaign will be completed. Upon completion of legacy sludge processing, the TWPC facility will be deactivated and prepared for eventual D&D. At that point, no treatment capability would be available and LLLW would be stored in the CIP and MVST until a future capital project is acquisitioned to process the additional LLLW accumulation. At the current generation rate of approximately 5000 gal/year of concentrate, the

storage capacity available after the TRU sludge processing campaign (estimated to be 700,000 gal would last over 100 years. Once the capacity limit (or another driver) was reached, a LLLW solidification campaign would be required.

In order to make this alternative comparable to the other LLLW alternatives, the cost estimate assumes a 30-year duration followed by a solidification campaign. The estimated cost of this alternative would be

- Annual Surveillance and Maintenance (S&M) cost for 30 years
- Cost to build a solidification capability
- Cost to solidify and transport LLLW for disposal

LLLW on-site treatment alternative

Of the potential locations, the Bldg. 2531 crane bay is the best choice. The solidification unit would be contained within a 20-ft Sealand container modified to the specific process requirements. This would allow for movement of the unit should access to the pits below the crane bay, or another temporary use for the truck bay, be required.

Location within the Bldg. 2531 crane bay would facilitate feed of the concentrated LLLW to the drums for solidification/stabilization. Adequate power is available and discharge from the solidification unit high-efficiency particulate air (HEPA) ventilation to the bay would be further processed by the existing building ventilation, eliminating the need for a new air discharge point.

The system consists of a 20-ft Sealand (enclosure) with all painted steel surfaces separated into treatment and donning/doffing rooms. A portion of the Sealand is the drum mixer with rollup doors to feed and discharge conveyors, drum stops and clamps, hydraulically operated in-drum mixer and media/reagent feed. The treatment section of the enclosure is separated from the donning and doffing room by a wall. Air from the donning/doffing room flows to the treatment room and from there through an external package HEPA with pre-filtration and two-stage HEPA capability. If necessary, airlocks are provided on the drum feed and removal ports on the enclosure.

The basis of the estimate is a similar unit designed, fabricated and installed at another DOE facility. The mixer technology has been in use for over 15 years and has proven capability to uniformly mix a wide variety of solidification and stabilization formulations. The unit has also proven to be extremely reliable from an operability and maintenance perspective.

Two commercial waste processors currently use in-drum solidification/stabilization technology. It assumed that either could provide current design specifications, including the parts specifications and recommended vendors, detailed design and fabrication drawings in AutoCAD and supporting engineering documentation for a fee. In addition to that fee, the cost estimate includes engineering to customize the design to meet LGWO requirements in the total Engineering and Design cost, below. With the final design, any number of local fabrication shops could build the system from commercially available parts. The fabrication cost is based on historical materials and equipment costs escalated to current at 3% per year, and fabrication man-hours at commercial rates, plus expected General and Administrative (G&A) and fee from the fabrication company. Table I-1 summarizes the estimated costs associated with fabrication of the system, excluding U.S. Department of Energy (DOE)-provided design support and oversight costs. Limited installation costs at ORNL are also excluded.

Table I-1. Estimated cost for design, fabrication and delivery of an integrated liquid waste solidification enclosure with associated equipment

Cost element	2016 Dollars	Basis
Engineering and Design	$63,000	Vendor estimate
Materials for enclosure and mixer	$100,000	Vendor estimate
Package HEPA skid	$8,000	Vendor estimate
Cement hopper and feeder	$84,700	Vendor estimate
Fabrication labor	$76,000	Vendor estimate
Fabricator G&A and fee	$53,072	Vendor estimate
Delivery (local)	$2,000	Vendor estimate
Total Equipment Cost (TEC)	**$386,772**	Vendor estimate
Installation	$96,693	25% of TEC based on install versus equipment cost ratio for a past Bldg. 2531 project.
Total Direct Cost (TDC)	**$483,465**	
Contractor general conditions, overhead, profit, taxes, and insurance	$193,386	40% of TDC
Commissioning	$107,104	Assumes eight-person commissioning team to train and conduct testing for two months.
Total Construction Cost (TCC)	**$783,955**	
Engineering	$77,261	Assumes two FTE engineers to develop procurement specifications and vendor test requirements, evaluate bids, and develop operating procedures.
Project Management	$195,989	25% of TCC
Total Project Cost (TPC)	**$1,057,205**	
Contingency	$317,161	30% of TPC
Total Estimated Cost for LLLW Solidification System	**$1,374,366**	

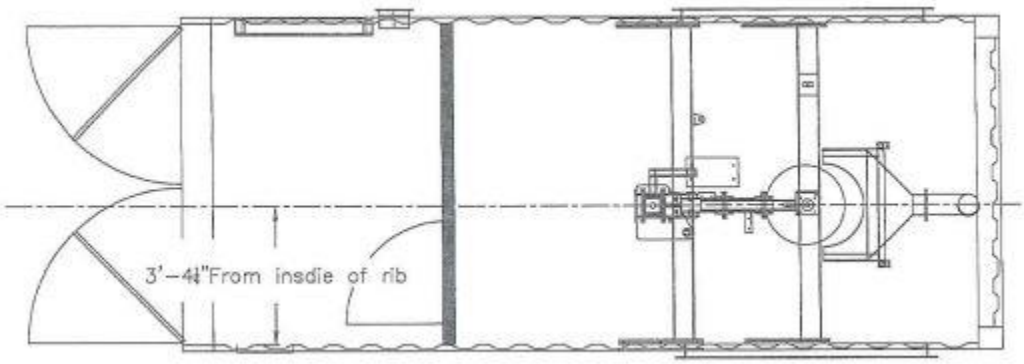

Fig. I-1. Typical stabilization enclosure plan.

Fig. I-2. Enclosure entry to donning/doffing room.

Fig. I-3. Enclosure with hydraulics.

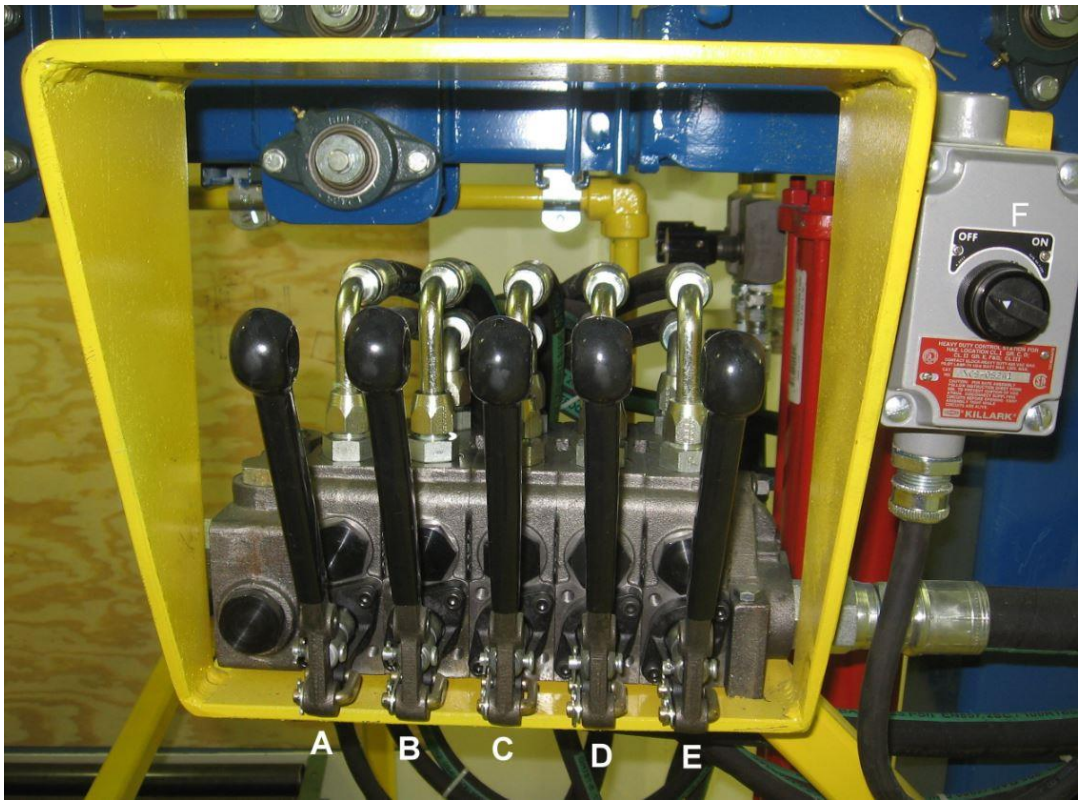

Fig. I-4. Drum mixer controls.

Additional Cost Elements – On-site Solidification

Upon receipt of the enclosure/in-drum mixed package, limited activities would be necessary to complete installation in the LLLW Truck Bay. Electric requirements would be provided by a plug in to an available welding outlet. LLLW concentrate transfer line would be required. If discharge from the enclosure HEPA to the truck bay is acceptable, no connection to building ventilation would be necessary. Connection of the dry-blend cement bin and feeder system and connection to a water source would be required.

If the concentrate is deemed to be RCRA non-hazardous, only limited sampling of the solidified waste would be required. Upon curing of the solidified drums (typically 24 hours), inspection to confirm that the waste has set up and for the presence of liquid on top of the solidified waste would be necessary. Involvement of the site NNSS Waste Certification Officer, including development and approval of NNSS waste profiles and waste package certification throughout the process would be necessary. Once solidification is complete and the packages are certified, routine manifesting, loading and shipment to NNSS would take place.

Processing Rate and Staffing

Assuming an annual receipt rate of 100,000 gal for LLLW and a 40:1 volume reduction, 2500 gal of concentrated LLLW would require solidification. Using a conservative 30-gal liquid loading per 55-gal drum, 84 finished 55-gal drums would result. Table I-2 shows an annual estimate of the materials costs and labor hours required to support on-site processing of 2500 gal of LLLW concentrate per year.

Table I-2. Annual estimated materials and labor for on-site LLLW concentrate treatment and disposal

Materials:	**Quantity**	**Unit Cost**	**Cost**
Drums (ea)	84	$100	$8,400
Grout (bags)(1)	756	$11	$8,316
Labels (sets)	84	$10	$840
Processing Labor:	**FTEs**	**Hours**	**Labor Hours**
Operator	3	210	630
Rad Tech	1	210	210
Supervisor	1	210	210

**Table I-2. Estimated materials and labor–
on-site LLLW concentrate treatment and disposal (cont.)**

Loading Labor:	FTEs	Hours	Labor
Operator	2	20	40
Rad Tech	1	20	20
Waste Specialist	1	20	20
Supervisor	1	20	20
AWCO	1	20	20
Transportation:	**Quantity**	**Unit Cost**	**Cost**
Trips (3)	2	$8,500	$17,000

(1) Assumes that LLLW concentrate is not RCRA hazardous.
(2) Per eight drums, prepare drums (1/2 day), solidify (1 day), finish (1/2 day), 10 hours per day.
(3) Limit 50 drums per shipment.

Summary of on-site treatment costs:

- Annual Operations and S&M cost
- Equipment fabrication
- Equipment installation, operation, and waste disposal

LLLW Off-site Treatment Alternative

Three commercial radioactive waste processors currently have established capabilities for processing either LLLW liquids without pre-concentration or concentrated LLLW liquids. Transportation of those liquids to those processors in either tankers or Type A totes is practical, having no onerous U.S. Department of Transportation (DOT) requirements. Commercial carriers are experienced is transporting similar liquid wastes.

In 2010, DOE Headquarters (HQ) solicited bids for an indefinite delivery/indefinite quantity (IDIQ)-based schedule of prices for treatment on a variety of mixed/radioactive waste forms, the result of which was three contracts issued to three commercial radioactive waste processors for Contract Line Item (CLIN)-based waste processing, available to all DOE sites. Two of the waste categories (CLIN 0006 – liquid waste solidification and CLIN 0007 – Liquid waste thermal treatment) are somewhat related to the LLLW waste streams.

CLIN 0006 is very close to what would be required for the LLLW waste stream after concentration in the LLLW (Bldg. 3521) facility evaporators. The pricing varies greatly from vendor to vendor, driven by the uncertainty of the specifics of the waste streams from a wide variety of DOE sites and the conservatism of the individual companies. The DOE IDIQs expired in June 2015, but are indicative of the relative pricing for the commercial service. They have been replaced with DOE Government Services Administrations (GSAs) that are task-specific, containing no unit rate pricing. The pricing included in the IDIQ's is believed to be on the high end of what could be expected if the service were to be commercially procured. Estimates of competitive prices are included in Table I-3.

CLIN 0007 does not closely correspond with the LLLW waste stream before concentration because it includes liquid wastes requiring thermal treatment that contain hazardous constituents. Those prices are

included in Table I-3, along with an estimate of a reasonable commercial evaporation/solidification price based on the available commercial capabilities and the contract prices for similar services.

Table I-3. LLLW commercial processing cost estimate supporting information

Cost element	Processor 1	Processor 2	Processor 3	Anticipated pricing (1)
Concentrated LLLW				
Treatment, per gallon	$28.73	$6.55	$37.20	$25.00
Per container handling charge	$492.00	$0.00	$0.00	0.00
NNSS certification, per gallon	$10.80	$0.00	$0.00	0.00
Profile charge	$0.00	$20,896.00	$25,789.00	$20,896.00 (2)
As-Generated LLLW				
Treatment, per gallon	$34.14	$13.89	$31.75	$19.00
Per container handling charge	$492.00	$0.00	0.00	0.00
NNSS certification, per gallon	$10.80	$0.00	$0.00	0.00
Profile charge	$0.00	$20,896.00	$25,789.00	$20,896.00 (2)

(1) Reasonable price based on the three Processor options. Assumes the waste is not RCRA hazardous.
(2) Should only be one profile, additional charge if service provided by Processor 2 or 3.

Two packaging/transportation approaches are routinely used for larger volumes of liquid radioactive wastes, estimated costs for which are included in Table I-4, as follows:

- Type A stainless steel totes are available from at least one commercial processor on a rental basis. They are 275-gal capacity, 250 gal when typically filled. There should be no DOT issues with shipping either the concentrate or unconcentrated liquid waste in this package. Once emptied at the processor, the totes are rinsed and made ready for reuse. Those costs are included in the rental price. These totes are recommended as the approach to shipping the concentrated LLLW, up to twelve per shipment.
- Tanker trailers, nominally 5000-gal capacity, are routinely used for DOT-compliant shipping of radioactive liquids. Once the liquids are unloaded at the commercial processor, the tanker is rinsed and radiologically released. Those costs are included in the per gallon price. The hours to accomplish cleaning and release are in the delay charges.
- Analysis of the waste liquids for RCRA constituents will be required before shipping, as well as labor for loading of the shipping conveyance. Processor covers all costs for treatment, analysis, packaging, NNSS certification, loading, and transportation. DOE provides disposal at NNSS.

Table I-4. LLLW transportation costs to commercial processors

Destination	Transport	Delay	Fees	Totes Usage	Total per trip
Oak Ridge, TN					
Tanker	$760	$1,520	$0	$0	$2,280
Totes	$760	$0	$0	$1,800	$2,560
Richland, WA					
Tanker	$12,230	$1,520	$150	$0.00	$13,900
Totes	$9,500	$0.00	$100	$1,800	$10,400

Summary for off-site treatment costs:

- Operation and S&M cost
- Transportation cost
- Processing cost

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APPENDIX J.
LLLW SENSITIVITY ANALYSIS

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LLLW Alternative LCC Sensitivity Analysis

A sensitivity analysis was performed to evaluate the impact of key cost and schedule risks and opportunities associated with the three LLLW alternatives. Risk impacts could potentially alter the cost margins between the alternatives and subsequently influence the alternative selection. Potential cost impacts for the alternatives were evaluated to determine and compare the influence on LCC for the alternatives. Table J-1 provides key assumptions and risks that could impact each of the three alternatives.

Table J-1. Key risks for LLLW alternatives

LLLW System alternative	Key cost and schedule risks
Status quo alternative	• Requires continued maintenance of LLLW infrastructure in Bethel Valley and Melton Valley. • Stored LLLW creates sludge in tanks that is difficult and expensive to mobilize and process. • Carries the risk of delays and cost overruns associated with the final solidification campaign project.
On-site treatment alternative	• D&D costs for the LLLW solidification system are higher than anticipated. • Carries the risk of construction and startup cost increases due to interferences from existing infrastructure and unfamiliar operating characteristics.
Off-site treatment alternative	• The cost of off-site treatment and disposal may be higher than anticipated. • Requires future D&D of a tanker loading station. • Carries the risk of delays and cost overruns during tanker loading station construction.

Data from the LLLW LCC analysis was used to estimate the potential cost impact of the identified risks and opportunities. Table J-2 summarizes the potential cost impacts and provides an evaluation of the likelihood that a particular event would be realized.

The key risks with the greatest potential impact for the alternatives involve greater than anticipated capital costs and LLLW disposal costs. As shown in the table, the potential impacts for the LLLW System status quo alternative are greater than either of the other two alternatives due to greater quantity of LLLW accumulated and the scope of the final solidification campaign. The risk impacts of for the LLLW System off-site treatment alternative are slightly greater than for the LLLW on-site treatment alternative due to the uncertainty associated with commercial off-site treatment and disposal cost.

Table J-2. Summary of sensitivity analysis for LLLW alternatives.

	Key risks (R) and opportunities(O)	Likelihood*	LCC impact	Description and basis
LLLW System status quo alternative	• Requires continued maintenance of LLLW infrastructure in Bethel Valley and Melton Valley.	Unlikely	None	Additional maintenance costs for the Bethel Valley and Melton Valley LLLW storage systems would not be significant for the years following the TWPC sludge solidification project in 2030.
	• Stored LLLW creates sludge in tanks that is difficult and expensive to mobilize and process.	Likely	+$3.1M	Sludge accumulation in the MVSTs requires additional liquid for mobilization and increases the processed volume by 30% from 80,000 to 120,000 gal.
	• Carries the risk of delays and cost overruns associated with the final solidification campaign project.	Likely	+$1.6M	Capital costs for the solidification campaign are 30% higher than anticipated.
LLLW System on-site treatment alternative	• D&D cost for the LLLW solidification facility is higher than anticipated.	Likely	+0.18M	D&D cost is twice the estimated value.
	• Carries the risk of construction and startup cost increases due to interferences from existing infrastructure and unfamiliar operations.	Likely	+0.62	Construction and startup cost is 50% higher than anticipated.
LLLW System off-site treatment alternative	• The cost of off-site treatment and disposal may be higher than anticipated.	Likely	+$1.3M	The cost of off-site treatment and disposal is twice the anticipated cost.
	• D&D cost for the LLLW tanker loading station is higher than anticipated.	Likely	+$0.1M	D&D cost is twice the estimated value.
	• Carries the risk of delays and cost overruns during tanker loading station construction.	Likely	+$1.1M	Construction and startup cost is 50% higher than anticipated.

*Likelihood definitions: Very Unlikely < 10% probability; Unlikely 10-24% probability; Likely 25-74% probability; Very Likely 75-90% probability; Imminent > 90%.

APPENDIX K.
GASEOUS WASTE WALKDOWN SUMMARY

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Table K-1. Gaseous waste system walkdown

Building	Equipment	Comment
3039 Stack Area	Isotope Turbine	The isotope governor is offline. No backup if power is lost.
	Off-Gas	The pressure release valve on the central off-gas does not work.
	HEPA Filter Housing	The HEPA Filter Housings have degraded and are scheduled to be replaced.
Bldg. 3092	Control Room	The MCC is several generations old. The system works, but components are difficult to find and few technicians are trained to perform maintenance on the MCCs.

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APPENDIX L.
GASEOUS WASTE NDE RESULTS

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Table L-1. Gaseous Waste NDE Results

	Piping area	Initial thick.	Min. thick.	Allowed thick.	Corrosion amount	Corrosion %
Cell vent	Isotopes	0.12	0.117	0.089	0.003	2.50%
	3500-4500	0.12	0.112	0.089	0.008	6.67%
	2537	0.1874	0.175	0.1564	0.0124	6.62%
Off-gas	Stack	0.1874	0.176	0.1564	0.0114	6.08%
	W23	0.135	0.124	0.104	0.011	8.15%
	2537	0.154	0.143	0.123	0.011	7.14%

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Date:	Monday, April 04, 2016 9:12:36 AM
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Letter: UCOR-16-0326, dated April 4, 2016

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Attached is your distribution copy of the subject letter. The original correspondence will be sent via plant mail service.

If you have any questions or need additional information, please contact David Bolling at (865) 712-9582.

Thank you.

Ginni Creech

General Plant & Capital Projects

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