Operations Research Modeling in Support of the Hanford Direct Feed Low Activity Waste Program – 15538

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ABSTRACT

Operations Research (OR) modeling is a supplemental system planning tool for the Hanford Tank Farm Contractor. OR models are designed to quantify the impact of equipment failures and other constraints on mission duration; to determine overall system performance; and to identify any potential bottleneck areas and identify any potential improvement areas. OR models are being developed to provide critical insights into the expected operational performance of current and planned facilities and to help identify any operational risks which impact performance of plant and equipment. This information is used to aid decision making on facility design and operations. A new OR model is being developed in support of the Direct Feed Low Activity Waste (DFLAW) Program and will be a valuable tool in the development of overall operational and management strategies as well as providing input to facility design. The OR model will identify predicted system availability, process bottlenecks, and key equipment influencing system performance. The OR model will also test proposed solutions to improve system availability by resolving process bottlenecks and provide this information to the design agent for incorporation into the DFLAW process design.

INTRODUCTION

The US Department of Energy (DOE), Office of River Protection (ORP) manages the River Protection Project (RPP). The RPP mission is to retrieve and treat Hanford's tank waste and close the tank farms to protect the Columbia River. The waste is stored in 177 underground tanks, 149 single shell tanks (SST) and 28 double shell tanks (DST). Retrieval and treatment of this waste poses a significant technical challenge and requires robust and comprehensive planning tools to ensure successful mission completion. The Department of Energy Hanford Waste Retrieval, Treatment, and Disposition Framework [1], released in 2013 described an approach to allow waste immobilization to begin as early as practicable. This approach includes early treatment of Low Activity Waste (LAW) to produce an immobilized glass product for disposal.

In order to begin early LAW treatment and immobilization, upgrades to the Hanford Tank Farms are required as well as new facilities and modifications to the Waste Treatment and Immobilization Plant (WTP) LAW vitrification facility. The tank farms upgrades will supply supernatant tank waste to a new Low Activity Waste Pretreatment System (LAWPS) where suspended solids and Cs-137 are removed to meet WTP LAW acceptance criteria. The suspended solids and Cs-137 will be returned to the Tank Farms and the treated supernatant will be sent to WTP LAW vitrification. Modifications to the WTP to handle liquid effluents from the LAW vitrification facility off-gas treatment system (among other sources) will allow WTP LAW vitrification to operate independently from WTP Pretreatment. Finally, the Immobilized Low

Activity Waste (ILAW) containers will be transported to the Integrated Disposal Facility for burial.

Strategic planning at the Hanford Site is a complex and iterative process. Strategic planning includes the use of system planning tools to plan and evaluate the RPP mission. The Hanford Tank Waste Operations Simulator (HTWOS) model, a dynamic flowsheet simulation and mass balance computer model, simulates the current RPP mission. However, HTWOS does not explicitly account for equipment failures or performance issues which may result in overly optimistic predictions of mission durations. The OR model is intended to supplement HTWOS as a system planning tool to improve the understanding of the expected performance of systems, structures and components important to RPP mission execution.

HANFORD OPERATIONS RESEARCH MODELS

Several OR models have been developed at Hanford to examine various aspects of the RPP mission. They are listed in Table I.

TABLE I. Hanford Operations Research models

Model Name	Scope	Status
Waste Feed Delivery Phase 3.1	Simulates retrieval, 242-A evaporator campaigns and delivery of tank waste to WTP, uses RPP System Plan 6 (ref) as basis	Operational
Single-Shell Tank Retrieval	Simulates four primary single-shell tank retrieval technologies including retrieval and transfer to planned waste retrieval facilities and receiver DSTs	In development
222-S Laboratory	Simulates the movement, manipulation, preparation and analysis of tank waste samples through the laboratory mission, uses RPP System Plan 6 as a basis	Operational
WTP Logistics and Infrastructure	Simulates the WTP logistics and infrastructure including process chemical/reagent supply, storage and consumption, equipment spares replacement, support services, ILAW canister and secondary solid waste storage	Operational
WTP Operations	Simulates Pretreatment Facility, HLW Vitrification and LAW Vitrification Facility and Glass Formers Facility operations and is used to assess overall facility availability.	Operational

These models have been developed using the Witness™ process simulation software. Results from these models have been used to inform facility operating plans through the identification of process bottlenecks. This provides insight into improvements necessary to transition from a safe storage to a waste feed delivery mission.

DIRECT FEED LOW ACTIVITY WASTE OPERATIONS RESEARCH MODEL

Model Design

The scope of the DFLAW OR Model includes the AP Farm Waste Feed Delivery and LAW feed staging, LAWPS, WTP LAW feed receipt, certain LAW operations and secondary liquid waste returns, and 242-A Evaporator campaigns [3]. The model is being developed using a phased approach. The initial phase of the model development focuses on the LAWPS, with subsequent phases incorporating 241-AP tank farm feed delivery operations, 242-A evaporator operations supporting DST space management activities and WTP LAW secondary liquid waste returns. This approach was selected to more effectively support time-sensitive LAWPS project design activities.

The LAWPS configuration in the initial DFLAW OR Model is based upon the LAWPS conceptual design. Figure 1 illustrates the LAWPS process configuration in the model. Unit operations and equipment modeled include solids removal using cross-flow filtration, return of solids to the tank farms, Cs-137 removal by ion exchange, ion exchange regeneration and return of the Cs-137 to tank farms, and treated LAW lag storage. In addition to the LAWPS process equipment, supporting equipment such as the vessel and vault ventilation systems, electrical distribution, cooling water and plant air systems is modeled. Only failure modes which will cause processing to stop are simulated. As examples, modeled failure modes include waste transfer pump failure to start, failures of the process ventilation system fans, leaking jumpers, et al. Equipment failure frequencies and restoration times are based on a variety of sources. These sources include Hanford-specific data, data from other nuclear sites such as Savannah River and Sellafield, and industry data bases. Hanford specific date are preferred and are used where they exist. If not, other nuclear site data bases are utilized. Finally, if no nuclear industry data are available, generic industry reliability data are used.

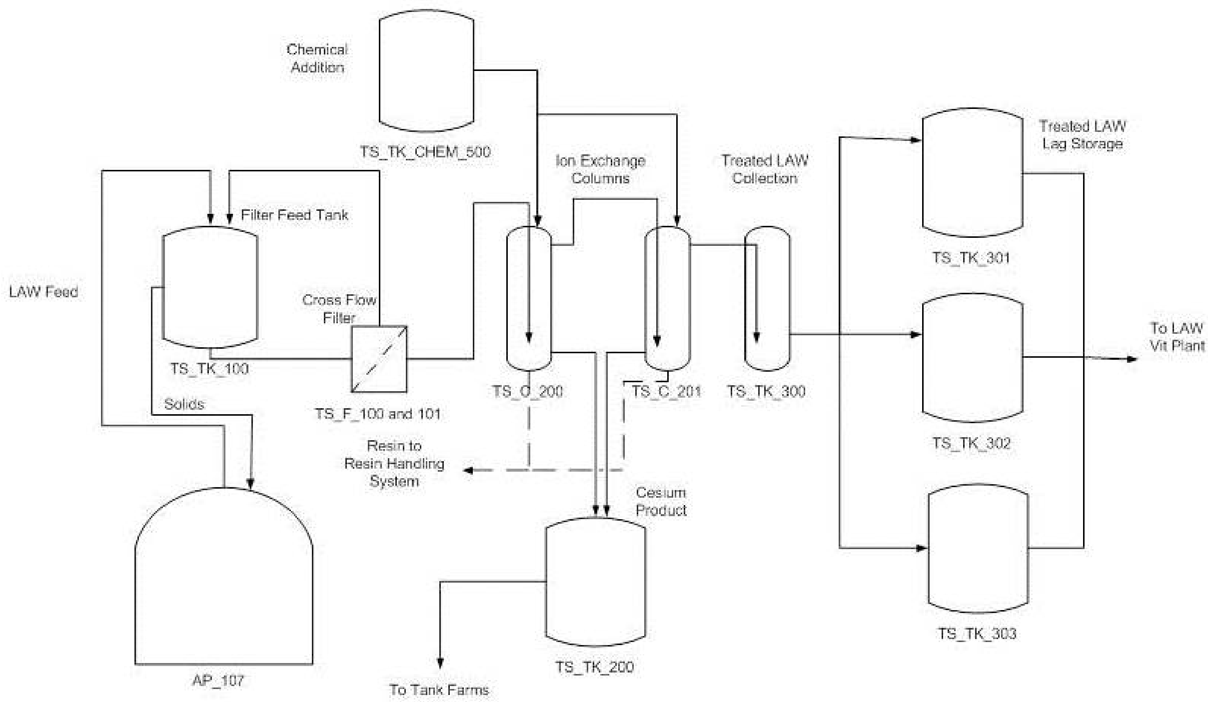

Figure 1. LAWPS OR Model Process Configuration

The supernatant feed from tank farms (241-AP-107) and LAW vitrification operations are conservatively modeled in this phase. They are unconstrained such that they do not impact LAWPS operations, i.e. feed and LAW vitrification feed tank space are available whenever LAWPS requires them. There are no equipment failures in the tank farms or the LAW vitrification facility that could slow down the feed to LAWPS or throttle the output of treated LAW to vitrification. This allows a more explicit assessment of the LAWPS availability and identification of process bottlenecks since the only events that could slow down LAWPS processing occur within LAWPS itself. LAWPS process steps and sequences are based on the conceptual design. Flow rates, vessel volumes, batch sizes as well as the timing of such activities as ion exchange resin regeneration and waste acceptance sampling are all consistent with the current LAWPS operations and maintenance concepts. Figure 2 provides a screenshot of the DFLAW (LAWPS) OR model.

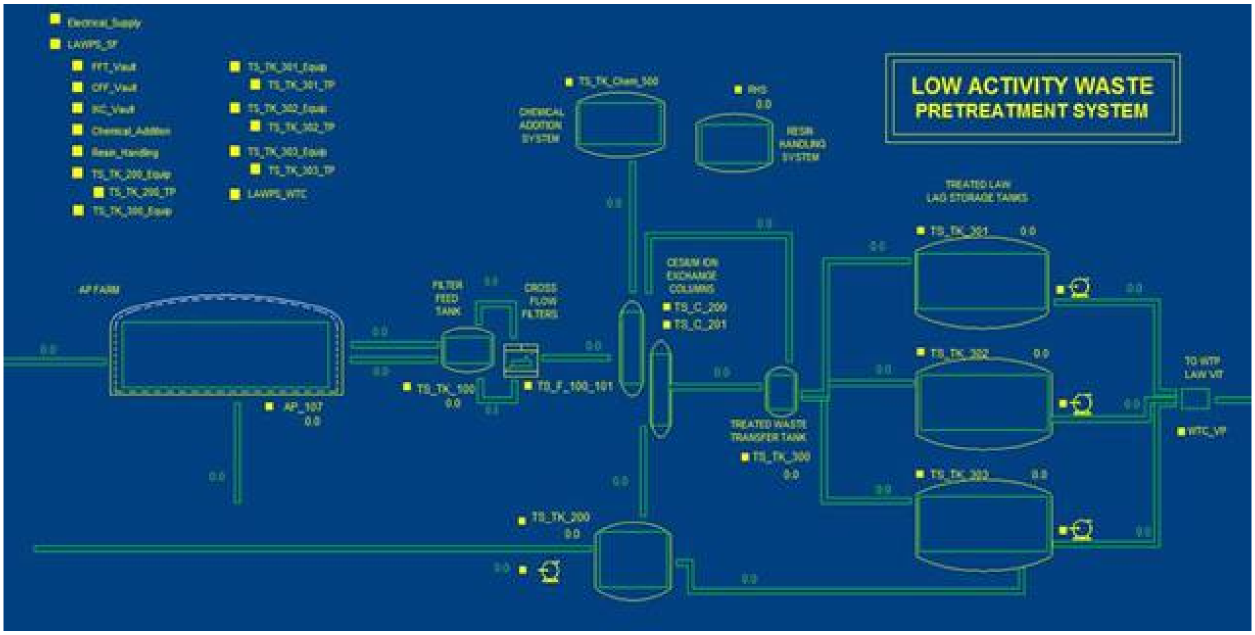

Figure 2. DFLAW (LAWPS) OR Model Screenshot

Expected Results

The DFLAW OR model is designed to assess whether the required throughput and availability targets can be achieved, quantify the impact of equipment failures, and identify any key bottleneck areas. If targets cannot be achieved, the model will be used to identify the necessary improvements in order to minimize operational risks and to ensure more efficient operations. This information will be provided to the project to be incorporated as appropriate into the system design.

Key model results data will include the LAWPS system throughput and overall system availability. LAWPS has a throughput requirement sufficient to support the operation of two LAW melters. In addition LAWPS is required to achieve an overall integrated availability of at least 70%. Multiple OR model runs will be performed to estimate the average system throughput and system availability and to provide confidence levels regarding those estimates.

However, simply estimating the overall throughput and system availability does not provide by itself the information that the project requires to optimize the design to minimize risks. What is required is an investigation into the key bottlenecks and which items of equipment have the greatest impact on overall throughput and system availability. By running multiple simulations, performing sensitivity studies to analyze equipment utilization and downtimes, the items of equipment that are driving the overall system availability are identified. Once they are identified, then mitigation strategies can be developed and tested. A classic question that will be answered in this analysis is whether there is more benefit in decreasing equipment failure rates, i.e. buying more reliable (and presumably more expensive) equipment, or decreasing equipment restoration times, i.e. increasing equipment redundancy, increasing the inventory of ready spares, preplanning work packages, et al. Once the most beneficial strategy is determined, this information is provided to the design agent to be incorporated into the system design.

Planned Enhancements

Planned enhancements include upgrades to the DFLAW model itself and development of additional OR models as tools to analyze other key aspects of the DFLAW program. These are illustrated in Figure 3.

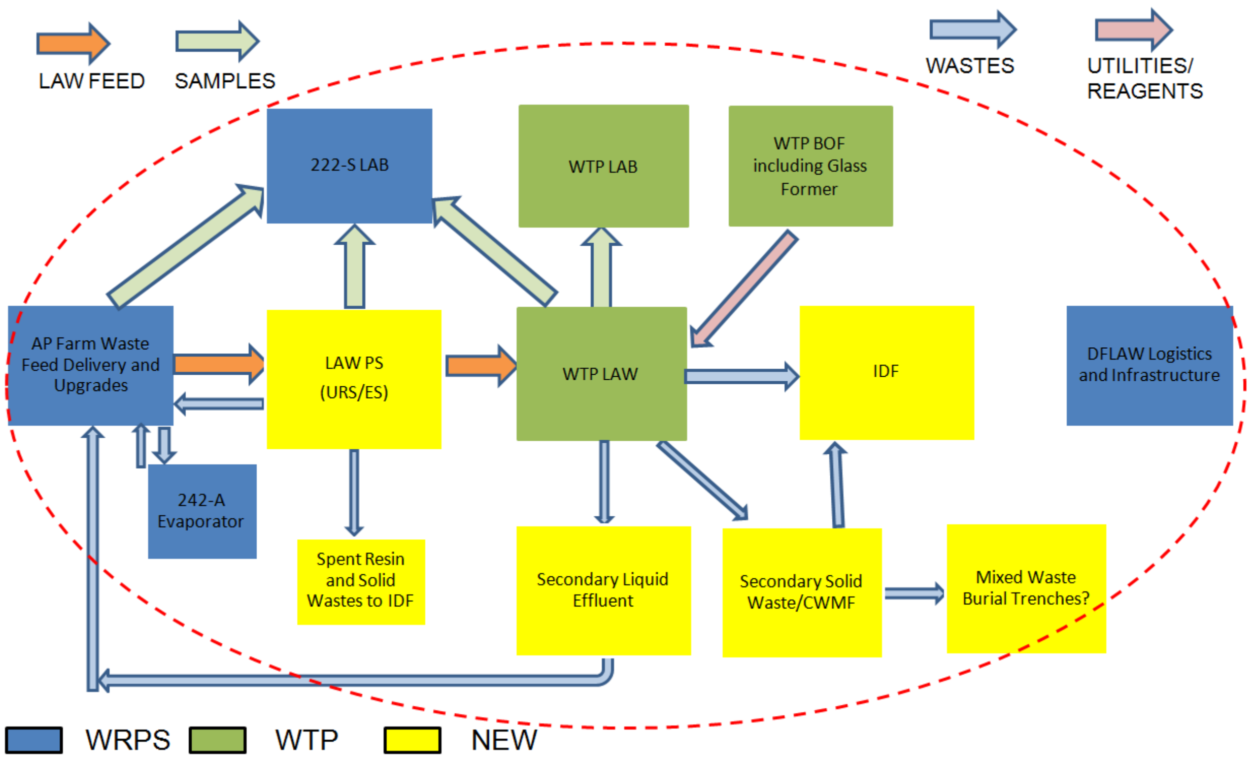

Figure 3. DFLAW OR Model Schematic

Near-term DFLAW model enhancements include increasing the model fidelity as it relates to tank farms operations and LAW vitrification secondary liquid waste handling. One of the major challenges with managing Hanford tank waste is the limited volume of DST space available. DST space must be closely managed to ensure that SST retrievals as well as DFLAW feed staging can be supported. These activities compete for available DST space and require increased 242-A evaporator operations to concentrate dilute waste. The DFLAW OR model will simulate in some detail the DFLAW waste staging in the 241-AP tank farm and the supporting 242-A evaporator campaigns. The model will also simulate the processing and return of WTP vitrification secondary liquid waste to the tank farms. While there are some initiatives being examined that may allow this material to be concentrated at WTP, reducing the volume that must be returned to tank farms, the model will examine the effects of the more severe case of sending higher volumes to tank farms. It is important to note that bottlenecks may shift from LAWPS to the Tank Farms or LAW Vitrification Plant, therefore, the model will be used to identify and prioritize improvements areas.

Additional planned OR modeling activities to support the DFLAW program include LAW vitrification, ILAW container transport to IDF, secondary liquid and solid waste handling, laboratory operations and the DFLAW Program Logistics and Infrastructure. It was determined that rather than trying to construct a single model containing all of these facilities and operations, it would be more efficient to prepare individual models in those cases where there was a clear scope demarcation. Integrating these various models to determine the overall DFLAW program effectiveness will be a challenge and is presently being worked.

CONCLUSIONS

OR models provide critical insights into the expected operational performance of current and planned facilities and help identify operational risks which impact the performance of the plant and equipment. Specifically, OR models quantify the impact of equipment failures and other constraints on mission duration; determine overall system performance; and identify potential bottleneck areas. With this data, mitigation strategies are developed and tested, identifying improvement areas. The usefulness of the model results in influencing design is in direct relation to how early in the process the model is developed. Waiting until the design is essentially fixed to develop a model severely limits the model’s usefulness. Unless the model uncovers a fatal flaw in the design, the cost and schedule impacts of design changes make the resistance to such changes significant.

The DFLAW OR model is being developed early in the DFLAW program. As a result, the DFLAW program will be able to extract the maximum value from the recommendations, incorporating appropriate changes to the design with minimal impacts on cost and schedule. The phased approach to the model development is synched with the needs of the DFLAW program. The initial focus on the LAWPS portion of DFLAW ensures the most time-sensitive analyses are performed first. As the program continues, the DFLAW model will be enhanced to explicitly model the interfacing tank farms systems as well as revising the LAWPS model to incorporate the latest design information. In parallel, additional OR models and analyses will focus on the remaining aspect of the DFLAW program, including the LAW vitrification facility, the ILAW container and secondary solid waste transport and disposal, laboratory interfaces, and secondary liquid waste handling.

This phased strategy will provide the DFLAW program with timely information needed to minimize program risks. This information will be used as input to design and operational planning decisions which will improve the DFLAW program probability of success in the early treatment and immobilization of Hanford tank waste.

REFERENCES

1. Hanford Tank Waste Retrieval, Treatment, and Disposition Framework, U. S. Department of Energy, Washington, D.C., September 24, 2013.

2. J. BRAMELD, "Operations Research Modeling Plan for Direct Feed Low Activity Waste Treatment of Hanford Tank Waste", RPP-PLAN-59946 Rev 0, Washington River Protection Solutions (2014).