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Description of the Waste Pretreatment and Interfacing Systems Dynamic Simulation Model WHC-SD-WM-DR-013 REVISION 0		ECN No.

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7. Abstract

The Waste Pretreatment and Interfacing Systems Dynamic Simulation Model was created to investigate the required pretreatment facility processing rates for both high level and low level waste so that the vitrification of tank waste can be completed according to the milestones defined in the Tri-Party Agreement (TPA). In order to achieve this objective, the processes upstream and downstream of the pretreatment facilities must also be included. The simulation model starts with retrieval of tank waste and ends with vitrification for both low level and high level wastes.

This report describes the results of three simulation cases: one based on suggested average facility processing rates, one with facility rates determined so that approximately 6 new DSTs are required, and one with facility rates determined so that approximately no new DSTs are required. It appears, based on the simulation results, that reasonable facility processing rates can be selected so that no new DSTs are required by the TWRS program. However, this conclusion must be viewed with respect to the modeling assumptions, described in detail in the report. Also included in the report, in an appendix, are results of two sensitivity cases: one with glass plant water recycle steams recycled versus not recycled, and one employing the TPA SST retrieval schedule versus a more uniform SST retrieval schedule. Both recycling and retrieval schedule appear to have a significant impact on overall tank usage.

The results included in this report are based on the "in-tank, enhanced sludge wash" scenario, as defined by the TWRS Process Flowsheet, WHC-SD-WM-TI-613, Rev. 0.

8. RELEASE STAMP

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Description of Waste Pretreatment and Interfacing Systems Dynamic Simulation Model

May 1995

D.J. Garbrick
B.D. Zimmerman

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Cs IX	cesium ion exchange
D&D	decontamination and decommissioning
DN	dilute non-complexed waste
DSS	double-shell slurry
DST	double-shell tank
HLW	high-level waste
IS	interim stabilization
LLW	low-level waste
Mgal	million gallon
MWTF	Multi Function Waste Tank Facility (Project W236A)
SST	single-shell tank
TCO	terminal cleanout
TOE	total operating efficiency
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TRU	transuranic
TWRS	Tank Waste Remediation System
TX	TX tank farm

METRIC CONVERSION CHART

The following conversion chart is provided to aid in conversion.

Into metric units / Out of metric units

If you know	Multiply by	To get	If you know	Multiply by	To get
Length			**Length**		
inches	25.40	millimeters	millimeters	0.0393	inches
inches	2.54	centimeters	centimeters	0.393	inches
feet	0.3048	meters	meters	3.2808	feet
yards	0.914	meters	meters	1.09	yards
miles	1.609	kilometers	kilometers	0.62	miles
Area			**Area**		
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092	square meters	square meters	10.7639	square feet
square yards	0.836	square meters	square meters	1.20	square yards
square miles	2.59	square kilometers	square kilometers	0.39	square miles
acres	0.404	hectares	hectares	2.471	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.0352	ounces
pounds	0.453	kilograms	kilograms	2.2046	pounds
short ton	0.907	metric ton	metric ton	1.10	short ton
Volume			**Volume**		
fluid ounces	29.57	milliliters	milliliters	0.03	fluid ounces
quarts	0.95	liters	liters	1.057	quarts
gallons	3.7850	liters	liters	0.2642	gallons
gallons	0.0037854	cubic meters	cubic meters	264.17287	gallons
cubic yards	0.76	cubic meters	cubic meters	1.308	cubic yards
Temperature			**Temperature**		
Fahrenheit	subtract 32 then multiply by 5/9ths	Celsius	Celsius	multiply by 9/5ths, then add 32	Fahrenheit

Source: *Engineering Unit Conversions*, M. R. Lindeburg, PE., Second Ed., 1990, Professional Publications, Inc., Belmont, California.

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EXECUTIVE SUMMARY

INTRODUCTION

The Waste Tank Pretreatment Dynamic Simulation Model was created to represent the standard sludge wash pretreatment option (Chiao et al. 1994). This initial version of the dynamic simulation was used to estimate the high-level and low-level pretreatment facility processing rates needed to support tank waste remediation activities per the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology et al. 1994). It also provided additional design and operation information related to the entire tank waste retrieval and processing system, since the model was built to represent the entire processing train from retrieval of the tank waste to waste vitrification. This standard sludge wash model has now been modified to represent the in-tank enhanced sludge washing process currently part of the Tank Waste Remediation System (TWRS) baseline. These modification are consistent with the aggregrate material flows of the current TWRS baseline flowsheet (Orme 1994).

The main objective of the current work is to estimate required minimum LLW and HLW pretreatment and glass plant facility processing rates, based on an explicit model of the time-varying nature of the material flows through the processing system. The processing rates are to be matched to minimize system bottlenecks, to reduce the need for lag waste storage, and to complete the processing program in accordance with Tri-Party Agreement milestones.

The analysis described in this report determined required facility process rates in the following manner. First, an "exploratory" case (Operating Case 1) was created based on facility process rates that were expected to be lower than required to support satisfactory system performance. The results of the exploratory case were then analyzed in detail to determine where the bottlenecks occurred, why they occurred, and whether all the exploratory facility processing rates should be increased to obtain adequate system preformance (a "balanced" system), or whether only some facility process rates needed to be adjusted (an "unbalanced" system). Once the analysis of the exploratory case was complete, the results were used to select increased facility process rates until cases were found that produced adequate system performance with aproximately 6 additional DSTs estimated as being required (Operating Case 2), and with no new DSTs estimated as being required (Operating Case 3). The significantly decreased bottlenecks that remain in Operating Cases 2 and 3 were briefly considered.

It should be noted that none of the Operating Cases discussed above is intended to represent a performance assessment of any particular set of currently recommended design capacities. The purpose of this study was to provide a basis for independently estimating required design capacities, based on a simulation model of the dynamics of the TWRS at the systems level.

The conclusions presented in this report are subject to the model assumptions (section 2.0) and caveats (Section 3.0) discussed in the body of this report.

SUMMARY OF RESULTS

Based on the results discussed below, it appears that reasonable TWRS facility processing rates can be selected so as to allow completion of the TWRS program per the Tri-Party Agreement milestones and without requiring that new DSTs be made available for storage. Based on Operating Case 1, it appears that the rates of the LLW processing facilities are fairly well balanced; though evaporator capacity is a bottleneck in the system because of the large amount of liquids recycled.

The first section below summarizes required facility processing rates as determined for the three operating cases. The second section presents an informal comparison with other recently published rates, and the final section briefly discusses the bottleneck analysis.

Required Facility Process Rates

The required facility process rates are summarized in Table E-1.

Table E-1. Summary of Tank Space Usage at Differing Facility Process Rates

Parameter	Operating Case 1 (Exploratory)	Operating Case 2 (6 New DSTs needed)	Operating Case 3 (No New DSTs needed)
Estimated Peak Tank Storage Space Used (m^3)	179,100 (47.3 Mgal)	135,500 (35.8 Mgal)	109,000 (28.8 Mgal)
Estimated Tank Space Surplus/Deficit (m^3)*	Deficit 69,300 (18.3 Mgal)	Deficit 25,700 (6.8 Mgal)	Surplus 757 (0.2 Mgal)
LLW Pretreatment Feed Evaporator Boil-off Rate (liters/min)	63.6 (106.0)**	71.2 (118.7)**	76.8 (128.0)**
LLW Pretreatment Facility (Cs IX) Feed Rate (l/min)	65.9 (109.7)**	73.8 (123.0)**	77.6 (129.3)**
LLW Vitrification Feed Concentrate Evaporator Boil-off Rate (l/min)	138.9 (231.5)**	157.5 (262.5)**	179.8 (299.7)**
LLW Vitrification Plant Daily Glass Production Rate (MT/day)♣	80.7 (134.5)**	89.4 (149.0)**	108.0 (180.0)**
HLW Pretreatment/ Evap. Facility Feed Rate (l/min)	34.8 (58.0)**	34.8 (58.0)**	34.8 (58.0)**
HLW Glass Plant Daily Glass Production Rate (MT/day)♣♣	8.0 (13.3)**	8.0 (13.3)**	8.0 (13.3)**

* - Tank space surplus or deficit values refer to extra or needed tank storage space relative to a maximum storage space available of existing 26 DSTs (28 DSTs minus 2 DSTs in reserve), totaling 109,800 m^3 (29 Mgal).
** - Values given in these parentheses are values inflated assuming a 60% TOE to give a rough estimate of the necessary processing rates to overcome downtime inefficiency. Values not in parenthesis are the values used in the simulation model which does not explicitly model facility downtime with the exception of downtime caused by feed unavailability.
♣ - LLW glass production rates assume 25 wt% sodium (Na) oxide loading.
♣♣ - HLW glass production rates assume 45 wt% waste oxide loading.

The facility process rates given in Table E-1 are the maximum average rates a facility needs to maintain for an extended period of time (typically 3 to 5 years) during the mission, as calculated by the simulation model. For the LLW processing facilities, it was found that these average rates are nearly equal to the maximum instantaneous (maximum allowable) rates used in the model. For the HLW processing facilities, these maximum average rates are somewhat lower than the maximum instantaneous rates used in the model.

Operating Case 1 (Exploratory) represents the use of suggested mission average facility processing rates from the *TWRS Process Flowsheet* (Orme 1994) as instantaneous maximum rates in the simulation (since no suggested processing rate was found for HLW pretreatment/evaporator, a reasonable instantaneous rate was selected in order to assume adequate capacity at this point). It was not expected that mission average processing rates would represent adequate instantaneous processing rates for the system. However, as discussed above, the purpose of Operating Case 1 is to provide a starting point for analyzing the balance and bottlenecks of the system, to initially probe the overall system dynamics, and to suggest what changes should be made in the system processing rates to obtain adequate system performance.

As expected, the maximum instantaneous process rates used for Operating Case 1 were not adequate to process the waste without extra lag storage. The large requirement for lag storage results substantially from an inadequate processing rate for the LLW pretreatment feed evaporator, downstream of the sludge wash process. The peak tank utilization occurs during the year 2018, shortly after Tri-Party Agreement single-shell tank (SST) retrieval milestone M-45-05-T13 (see Figure 2-2).

Operating Cases 2 and 3 represent increasing the LLW facility processing rates to estimate the maximum average and maximum instantaneous processing rates sufficient to reduce the estimated number of required new tanks to six and zero, respectively.

<u>Comparison with Previously Published Process Rates</u>

Mission average facility process rates were recently established in a Raytheon/BNFL trade study (BNFL 1995) based upon a water and material balance analysis. Table E-2 shown below presents for information, a comparison of the above rates with these recently published rates, and with the program average rates given in the *TWRS Process Flowsheet*. It may be noted that the maximum 3 to 5 year average Interfacing Systems Dynamic Simulation rates are somewhat higher, because the BNFL and TWRS Process Flowsheet rates are program average rates.

Table E-2. Comparison of Pretreatment and Interfacing Systems Model Process Rates with Raytheon/BNFL Published Process Rates

Parameter	Interfacing Systems Dynamic Simulation Estimated Maximum 3-5 Year Average Rates (gpm) Operating Case 3	Interfacing Systems Dynamic Simulation Mission Average Rates (gpm) Operating Case 3	TWRS Flowsheet (Orme, 1994) 14 Year Estimated Mission Average Rates (gpm)	BNFL Evaporation and Water Reuse Trade Study 14 Year Estimated Mission Average Rates (gpm)
LLW Pretreatment Feed Evaporator (Supernatant Evaporator) Feed Rate	78.3	51.2	56.8	55.0
LLW Pretreatment Feed Evaporator Boil-off (Condensate) Rate	33.8	22.9	28.0	25.0
Cs IX Feed Rate	35.5	26.7	29.0	23.4 (Water only)
LLW Glass Plant Feed Concentrate Evaporator Feed Rate	87.56	80.6	85.4	65.0*
LLW Glass Plant Feed Concentrate Evaporator Boil-off (Condensate) Rate	79.2	60.5	66.0	45.0*

All Rates in Gallons/minute with 60% TOE included
* - These rates are not comparable as it has been determined the Raytheon/BNFL case has a lower amount of recycle liquid fed to the LLW glass plant feed evaporator than the pretreatment and systems interfacing model.

Major Bottlenecks (Facility Processing Rate Mismatching)

Bottlenecks in the system cannot be completely eliminated from 2010 to 2019 unless instantaneous LLW facility processing rates significantly higher than those of Operating Cases 1, 2, or 3 are used. However, the bottlenecks that did exist in Operating Case 1 were decreased significantly to manageable levels in Operating Cases 2 and 3. Furthermore, some bottlenecks are not processing rate dependent. The individual bottlenecks in the system for the

Operating Cases are briefly described below:

- The main bottleneck found in the system was the LLW pretreatment feed (supernatant) evaporator. It was found unable to keep up with the large amount of decanted wash solution. The severity (amount of accumulation) and duration of the bottleneck varied with evaporator boil-off rate, generally lasting from 2016 to 2020, with a 20 to 30 million gallon (Mgal) backlog (Operating Case 1) at the LLW pretreatment feed evaporator feed tanks (includes liquid from caustic and dilute wash decants, primary and secondary settle tank decants, and HLW melter offgas scrubbing recycle flow). This backlog was reduced to 10 to 15 million gallons (Mgal) in Operating Case 3.

- A milder bottleneck was caused by the Tri-Party Agreement LLW pretreatment (Cs IX) startup date. Specifically, the main waste stream (LLW from early DST and TX farm retrieval) reaches pretreatment about a year (February 2004) before the pretreatment facility begins operation (January 2005). This causes an accumulation in the lag storage tanks immediately upstream of the LLW pretreatment facility.

- A third bottleneck is caused by the LLW glass plant processing at half capacity (one stream) from July 2005 to July 2008. This rate (Operating Case 1 rate of 42.5 MT LLW glass/day, up to 60 MT/LLW glass/day for Operating Case 3) is inadequate to process the incoming LLW feed. The six tanks allocated by the model to LLW melter staging become full, causing a close-coupled shutdown of feed to the facilities upstream. This bottleneck is reduced significantly by allowing the LLW glass plant to process at full capacity (two streams) by the July 2005 startup date.

- A final bottleneck was caused by an inadequacy of LLW glass plant processing capacity (85 MT LLW glass/day) in Operating Case 1. This bottleneck was eliminated in Operating Cases 2 and 3.

- No significant bottlenecks were detected in the HLW processing system.

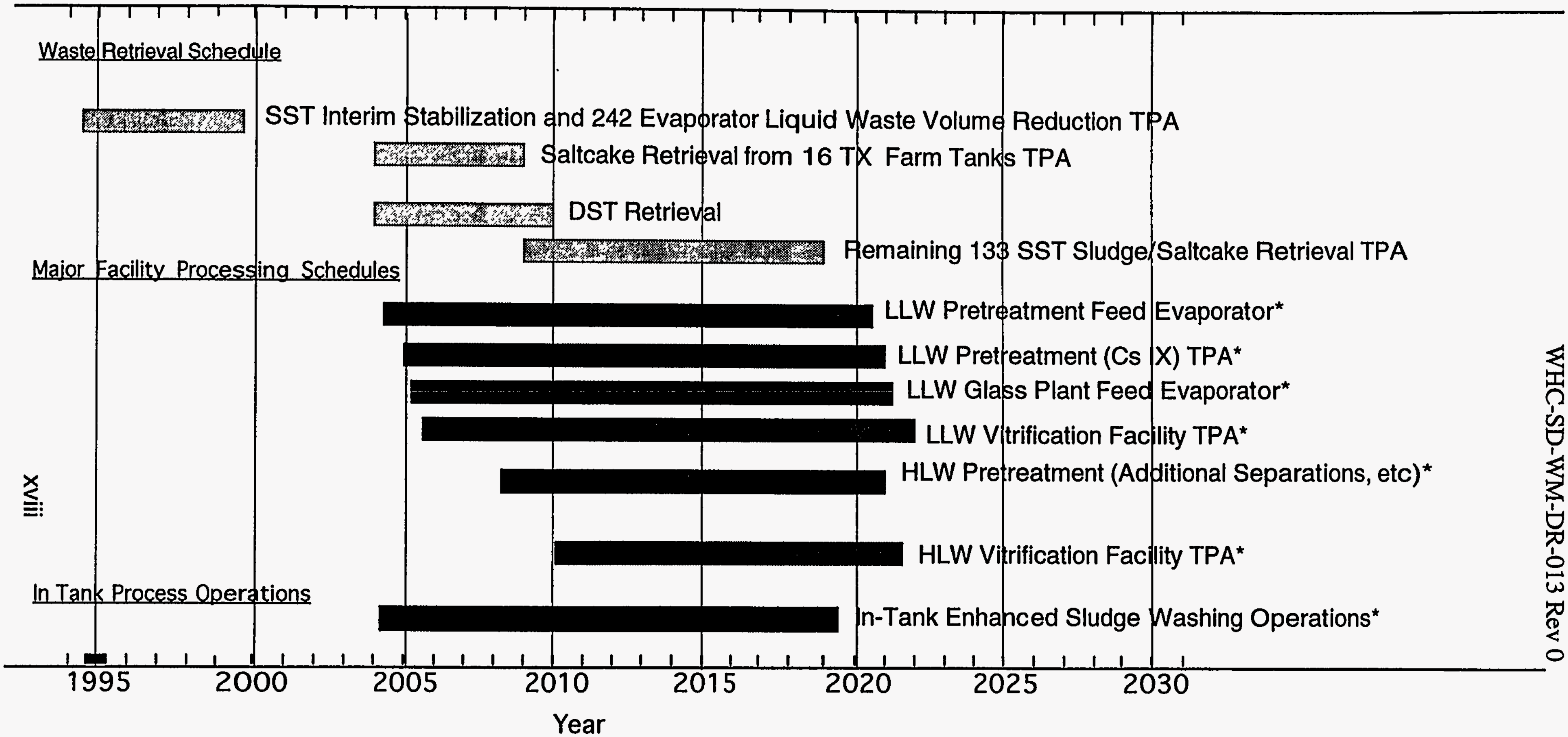
ASSUMPTIONS

It is important to consider the model conclusions in the context of the assumptions employed in building the model. Figure E-1 illustrates the major times assumed for retrieval of the waste groups and for the HOT startup of the processing facilities. It also gives facility processing end times as estimated by the simulation model. Other major assumptions used in implementing the model are as follows:

- The simulation divides all tank wastes into four separate and distinct inventory groups requiring different processing. The four inventory groups are 16 SST tanks in the TX farm containing salt cake wastes with little sludge, Interim Stabilization (IS) liquor pumped to the DSTs from the SSTs before retrieval, the remaining 133 SST tanks containing primarily sludge and salt cake with interstitial liquor, and the DSTs containing primarily supernatant liquids and double-shell slurries.

- The primary elements modeled are bulk volume contributors, specifically sodium (Na) by weight and the total liquid and solid volumes. It may be noted that, if model parameters are set to the values given in the flowsheet (Orme 1994), the aggregate flowsheet flows are closely reproduced by the model. The solid volumes were estimated using a nominal solids density of 3.5 kg/l (MacLean 1995).

- Each of the four waste inventory groups in the model assumes a homogeneous distribution of sodium and sludge throughout the group's respective processing. As estimates of sodium and sludge distributions in the retrieved waste vs time (from specific retrieval sequences) become available, a more rigorous analysis



*-The end times shown are not preestablished milestones or objectives but rather are the end times as measured from the simulation runs. These end times represent operating case 3 in the report and may vary greatly with the choice of processing options and parameters.

Figure E-1 Overall Time Schedule of Events will be possible.

- The model assumes a limited waste storage capacity at or immediately associated with the specific LLW processing facilities (2,839 m^3 [750 Kgal] for both LLW evaporators, and about 680 m^3 [180 Kgal] at the LLW pretreatment). There are three locations inthe process stream that are modeled as having unlimited storage capacity: one before the LLW pretreatment feed evaporator after wash decant, one immediately before LLW pretreatment and after the LLW pretreatment feed evaporator, and one immediately before HLW pretreatment. This enables the model to analyze the severity of bottlenecks. A limited amount of staging tank storage (6 DSTs, 22,700 m^3) is assumed available for the LLW and HLW glass plants.

- If a processing facility accumulates more than its storage capacity, the system responds by shutting down the feed to that particular facility. This may cause a propagation upstream of "close-coupled" facility input feed stoppages.

These and many other important assumptions regarding model issues are presented in more detail in Section 2.0.

It may be noted that the simulation model allows sensitivity studies to be performed with respect to a variety of system timing and processing parameters. A full program of sensitivity studies has not been performed at this time. However, preliminary results of two sensitivity studies are included in appendix A. The first analyzes the system dynamics when the melter offgas recycle flows are recycled into the processing system versus not recycled into the processing system. The second represents an analysis of the use of a "flatter" or more time constant SST retrieval schedule versus the time increasing TPA SST retrieval schedule.

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DESCRIPTION OF THE WASTE PRETREATMENT AND INTERFACING SYSTEMS DYNAMIC SIMULATION MODEL

1.0 INTRODUCTION

The Tank Waste Pretreatment Dynamic Simulation Model was created to estimate the high-level waste (HLW) and low-level waste (LLW) pretreatment processing rates required to support the current Tank Waste Remediation System (TWRS) in-tank enhanced sludge wash baseline flowsheet and the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology et al. 1994) milestones. As a part of this analysis, it can be determined whether the LLW and HLW pretreatment, evaporator, and vitrification facility processing rates are matched to avoid unnecessary system bottlenecking. In order to achieve these objectives, the TWRS processes both up stream and down stream of the pretreatment facilities were included. This simulation model starts from the retrieval of tank waste and ends at the completion of glass vitrification for both LLW and HLW. Because the simulation includes the entire TWRS processing system, it also allows the investigation of other issues related to tank waste retrieval and processing, such as completion dates for glass vitrification, sodium molarities, tank space requirements, water recycle issues, etc.

The primary source of information used to design and implement this model is the *TWRS Process Flowsheet* (Orme 1994), the current TWRS baseline flowsheet based on the enhanced sludge wash pretreatment process. Total flowsheet process stream flows, as well as other flowsheet data, were used extensively to define operating points for the simulation model. The simulation model then was used to determine processing rate values that are matched to avoid system bottlenecking and excessive waste storage needs.

For nearly all simulation cases, it was assumed that the retrieval would be accomplished as specified in the Tri-Party Agreement, and that various processing facilities would become available per Tri-Party Agreement milestone dates. It is assumed there is no shutdown of retrieval once retrieval begins (i.e., retrieval milestones must be met).

The remainder of this report discusses the assumptions employed in the simulation model, briefly describes model verification and model caveats, then presents model results obtained to date.

The simulation model was implemented with the Ithink™[1] simulation code (Version 2.2) for a Macintosh™[2] computer. Waste composition and inventory data was prepared for use by the simulation model using Quattropro[3] and Excel[4] Spreadsheet programs.

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[1]Ithink is a trademark of High Performance Systems, Inc.

[2]Macintosh is a trademark of Apple Computer, Inc.

[3]Quattropro is a trademark of Borland International, Inc.

[4]Excel is a trademark of Microsoft, Inc.

2.0 ASSUMPTIONS FOR THE SIMULATION MODEL

The current simulation model was built according to some known operating scenarios and a number of assumptions. This simulation model starts with single-shell tank (SST) interim stabilization, waste retrieval, an enhanced caustic sludge wash, followed by pretreatment of both LLW and HLW, and ends with vitrification. A number of assumptions were made at each processing stage. Many of the same assumptions used in the "standard" water wash simulation model (Chiao 1994) still apply. However, many new assumptions given by the *TWRS Process Flowsheet* were used to create the enhanced sludge wash model. Other more detailed assumptions were validated directly by process engineers working in a particular area. The simulation model itself has been internally reviewed for accuracy periodically in the course of its development (see Section 3.2).

2.1 WASTE AND WASTE RETRIEVAL

2.1.1 Tanks and Their Contents

All double-shell tanks (DST) and single-shell tanks (SST) and their contents are considered separated into the following four groups, based primarily on similarity of pretreatment processing requirements:

- The first group consists of liquid pumped from SSTs for interim stabilization.

- The second group is 16 TX farm tanks, which contain only salt cake.

- The third group is the DSTs containing mostly supernatants.

- The fourth group is the remaining 133 SSTs, which contain mostly sludge and salt cake.

2.1.2 Tri-Party Agreement Milestones

Tri-Party Agreement milestones define facility availability dates and the waste retrieval schedule except for the DST waste retrieval schedule. The DST retrieval schedule was defined in this model as being from January 1, 2004, to January 1, 2010. The waste retrieval schedule and facility availability schedule are shown in Figure 2-1.

2.1.2.1 Interim Stabilization Liquids. Of the 149 SSTs, 106 are assumed to have been stabilized at the time the model begins (all but about 38.0 m^3 of the pumpable liquid in each tank has been pumped to DSTs). The first inventory group the model will process consists of an homogenized mixture of 20,680 m^3 (5.5 Mgal) (Hanlon 1993) of SST liquid from the 43 SSTs that remain to be stabilized. It is assumed that 38.0 m^3 (10 kgal) of liquid will remain in each tank following this stabilization. The retrieval of the 20,680 m^3 of

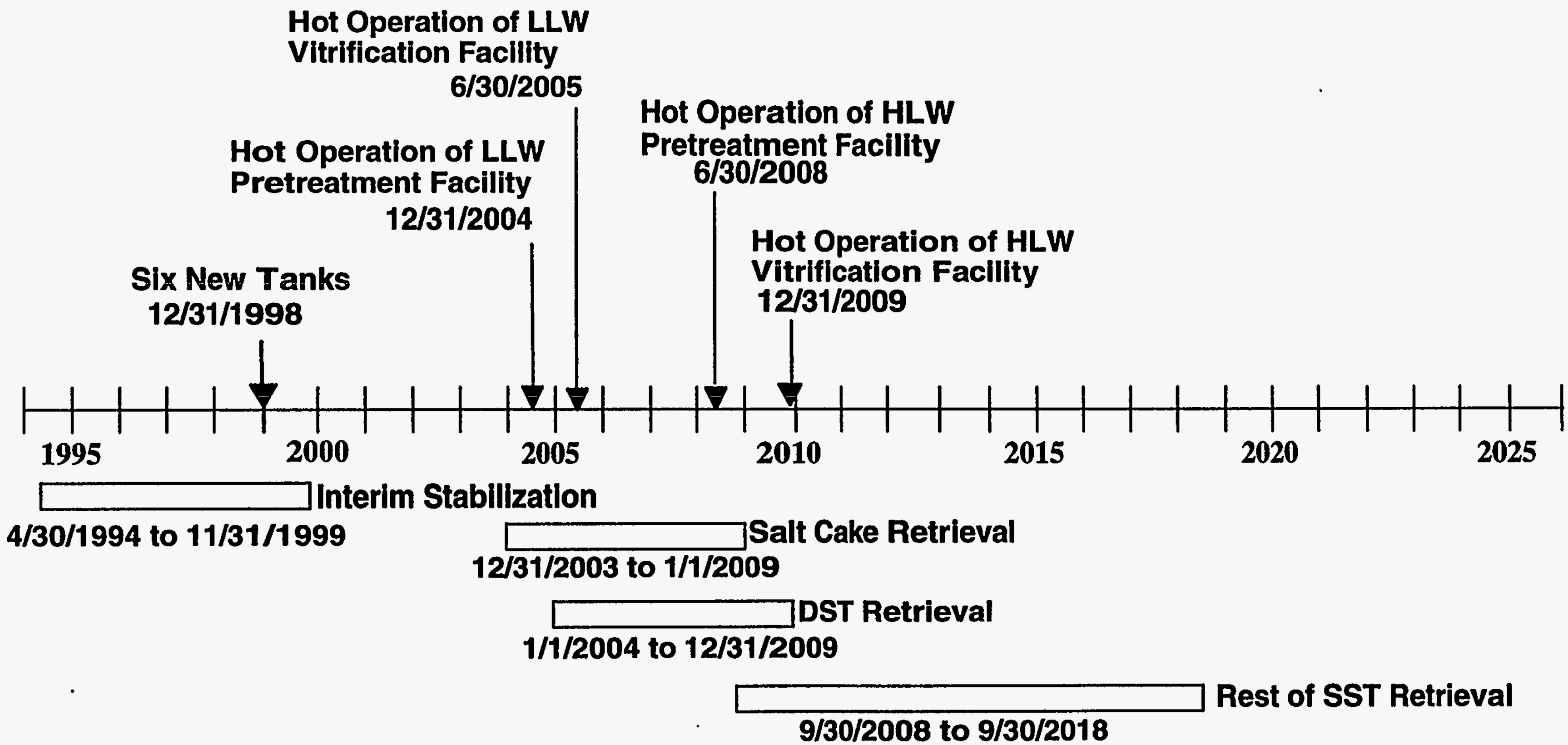

Figure 2-1 Waste Retrieval and Facility Availability Schedule

liquid will be modeled as occurring per the Tri-Party Agreement schedule, to begin on April 30, 1994, (M-41-01-T03), and to be completed by November 30, 1999 (M-41-14-T01). A fraction of the interim stabilization liquid is assumed to be evaporated during retrieval, to leave a 10 molar sodium solution for pumping into the DSTs (Orme 1994).

The *TWRS Process Flowsheet* specifies some additional supernatant and sludge from the decontamination and decommissioning (D&D) of N Reactor and the terminal closeout (TCO) of B-Plant, PUREX, PFP, and T-Plant that was not accounted for in the previous standard water wash model. The totals are 21,955 m^3 of supernatant and 2,695 m^3 of sludge (Orme 1994). This material is not represented by a separate inventory group in the model, but is included implicitly in the retrieval streams. The sludge is explicitly added to the DSTs for subsequent washing.

2.1.2.2 Salt Cake Retrieval From 16 Tanks. The Tri-Party Agreement specifies that the salt cake, solids, and interstitial liquid will be retrieved from the SSTs beginning on December 31, 2003, (M-45-05-T01) and completing on September 30, 2018 (M-45-05). However, Retrieval Engineering states that only salt cake will be retrieved before 2009 because the HLW vitrification plant is not scheduled to be online until December 31, 2009, (M-51-03). The first tanks retrieved will be in the TX farm (Williams 1994). According to the Tri-Party Agreement schedule, this time period (December 31, 2003, to January 1, 2009) corresponds to retrieval from approximately 16 SSTs. Since there are 16 SSTs in TX farm that contain little sludge, they are assumed to be retrieved in this time period. The material in these tanks is homogenized to form an inventory group containing 25,200 m^3 of salt cake, and the retrieval is assumed to occur per the Tri-Party Agreement milestones, (M-45-05-T01, M-45-05-T02, M-45-05-T03, etc.). The retrieval schedule and required monthly retrieval rates for the 16 TX farm tanks as used in the simulation are shown in Figure 2-2.

2.1.2.3 Salt Cake and Sludge Retrieval. The remaining 133 SSTs are retrieved following the 16 SSTs above, and before September 30, 2018, at the rate specified by the Tri-Party Agreement milestones (M-45-05-T07, etc.). This gives a gradually increasing retrieval rate with time. Since no tank-by-tank retrieval schedules are given and blending studies are currently underway, the contents of these 133 tanks are assumed to be homogenized with a total 62,500 m^3 of salt cake, 47,180 m^3 sludge (Hanlon 1993) before retrieval. The SST retrieval schedule and necessary monthly retrieval rates as used in the simulation are shown in Figure 2-2.

2.1.2.4 DST Retrieval. The total amount of waste in all DSTs (28 tanks) is 98,050 m^3, which includes 80,050 m^3 of supernatant, 7,400 m^3 of sludge and 10,600 m^3 of the combination of salt cake and DSS (Hanlon, 1993). Eleven DSTs with DN contain only supernatant. Since this liquid is likely to be removed from the DSTs and evaporated before DST retrieval, a total of 32,590 m^3 (Orme 1994) has been removed from the DST inventory group for simulation purposes. Also, the supernatants from interim stabilization from 2.1.2.1 above (following evaporation) has been added to the DST group. Because no detailed

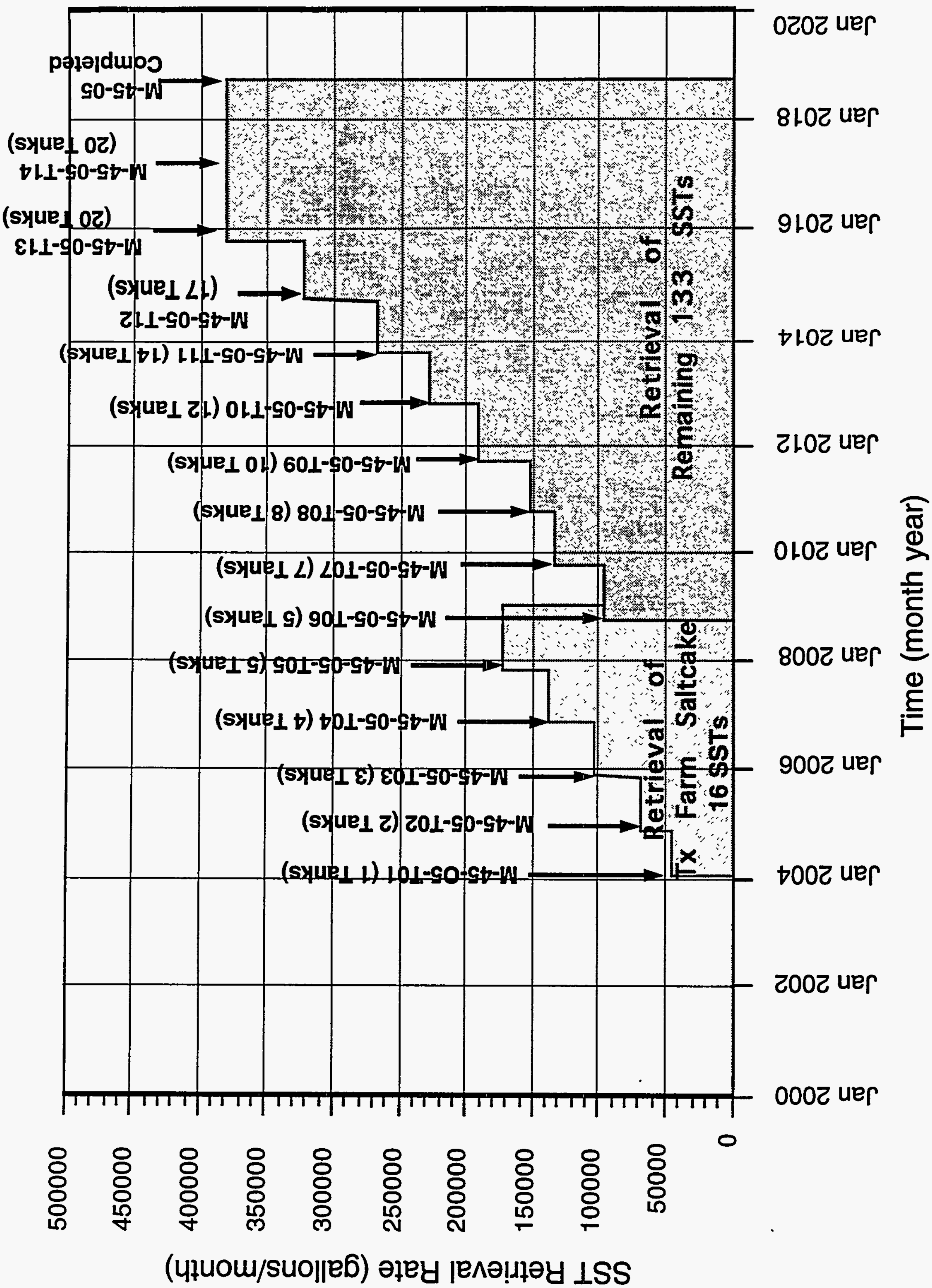

Figure 2-2 Simulation Input - SST Retrieval Schedule

retrieval schedule is yet available for the DSTs, the net contents of these tanks are assumed to be homogenized, and retrieval is assumed to occur uniformly beginning January 1, 2004, (Chiao et al., 1994) and completing on December 31, 2009. Also, DSS waste is treated as salt cake, and the supernate is assumed used as part of the liquid needed for retrieval. The DST retrieval schedule and necessary monthly retrieval rates are shown in Figure 2-3.

2.1.3 Tank Inventory Data

Tank inventory data were taken from the *Tank Farm Surveillance and Waste Status Summary Report*, (Hanlon, 1993), and the *Tank Waste Technical Options Report*, Appendix D, "Tank Waste Radionuclide and Chemical Compositions" (Boomer et.al., 1993). The inventory data were recorded in two Symphony™[5] files, SST-08.WR1 and DST-08.WR1, provided by Betty H. Hanlon of Tank Farms Plant Engineering. Quattropro (Version 3.0) read the data from the two Symphony™ files and performed the computation for homogenized input for the simulation model. Cross checks for consistency between these sources and the *TWRS Process Flowsheet* were done recently from data by Shelton 1994.

A discrepancy was found between the total waste volume given after retrieval at the interface of sheet 0 (retrieval) and sheet 1 of the *TWRS Process Flowsheet*, with sheet 0 giving a lower value of total waste volume. A decision was made to have the simulation model match the evaporation volumes given on sheet 0 for the initial simulation retrieval processes (DN and IS evaporation), and to scale the simulation model's initial sodium inventory data to force a match with the beginning of sheet 1 (stream 1). In this manner, consistency is maintained with the flowsheet flows for the remaining wash, pretreat, and vitrification processes. Checks were made to verify that the starting total inventories are consistent with those assumed in the *TWRS Process Flowsheet*.

2.1.4 Dilution

The dilution of the salt cake and solids for pumping in the enhanced sludge wash simulation model is implicitly given by the *TWRS Process Flowsheet* within the total liquid and solid mass flows throughout the process. The amount of water included in particular streams in the flowsheet is assumed to be adequate for proper mobilization and transfer of the waste.

All miscellaneous pipe transfers (slurry transfer, tank decants, etc.) are assumed to flow at a nominal 379 l/min (100 gal/min) (Hendrickson 1994). At this flowrate, sufficient inner pipe turbulence is sustained in most cases to avoid flow stoppages at the assumed dilutions.

2.1.5 Entrained Solids

The model allows for separation of entrained solids from both the

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[5]Symphony is a trademark of Lotus Development Corporation

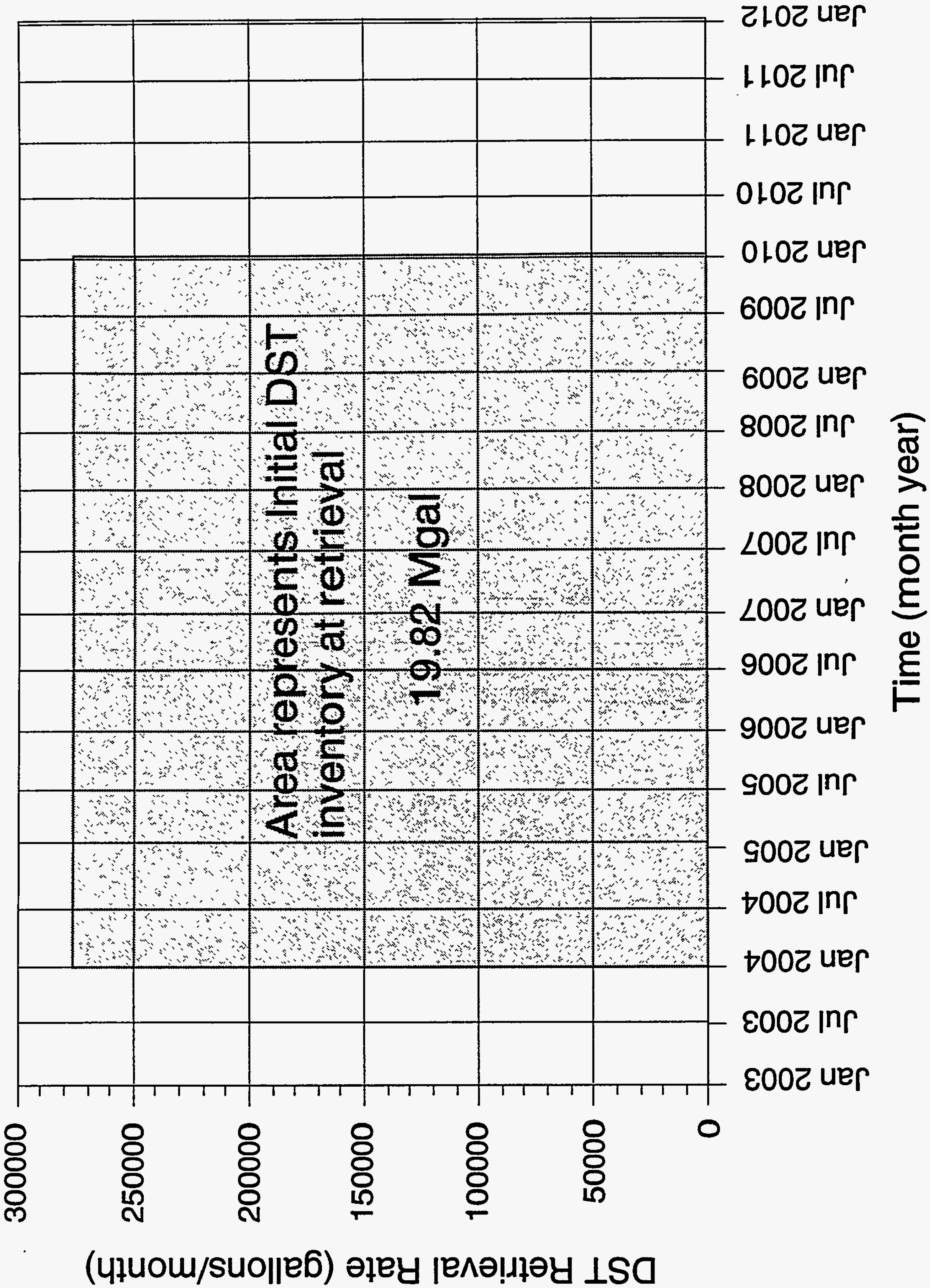

Figure 2-3 Simulation Input - DST Retrieval Schedule

interim stabilization liquid and the salt cake. Currently, there are assumed to be no entrained solids in the retrieved interim stabilization liquid volume, and two percent entrained solids in the retrieved "salt cake" volume. These entrained solids are assumed not to require washing.

2.2 THE IN-TANK ENHANCED SLUDGE WASH PRETREATMENT

The enhanced sludge wash pretreatment consists of an initial wash occurring along with retrieval, followed by at least one leach with a concentrated caustic solution, and three washes with dilute caustic solution to minimize the amount of soluble metals that get carried in the interstitial liquid (Orme 1994). At this time, no additional caustic washes are given to any batches of retrieved sludge.

2.2.1 Tanks for Retrieved Waste

For SSTs, it is assumed that waste must be retrieved into one or more DSTs for the wash activities. For DSTs, these activities may take place in the original tank. However, the simulation shows separate washing blocks for both DSTs and SSTs. The retrieval in the simulation is never shutdown (retrieval milestones must be met), therefore, the shutdown of any facility for a significant length of time in the system will cause waste accumulation. There are three places in the simulation that are given an unlimited storage capacity, (wash storage, and the LLW and HLW lag storage tanks after the wash) that is, they are allowed to hold the resulting accumulation with no limit. This needed storage is added to the overall tank space volume usage calculation. Figure 2-4 illustrates the location of these unlimited tanks within the system and gives the order and nomenclature of each of the processing facilities as modeled within the simulation model.

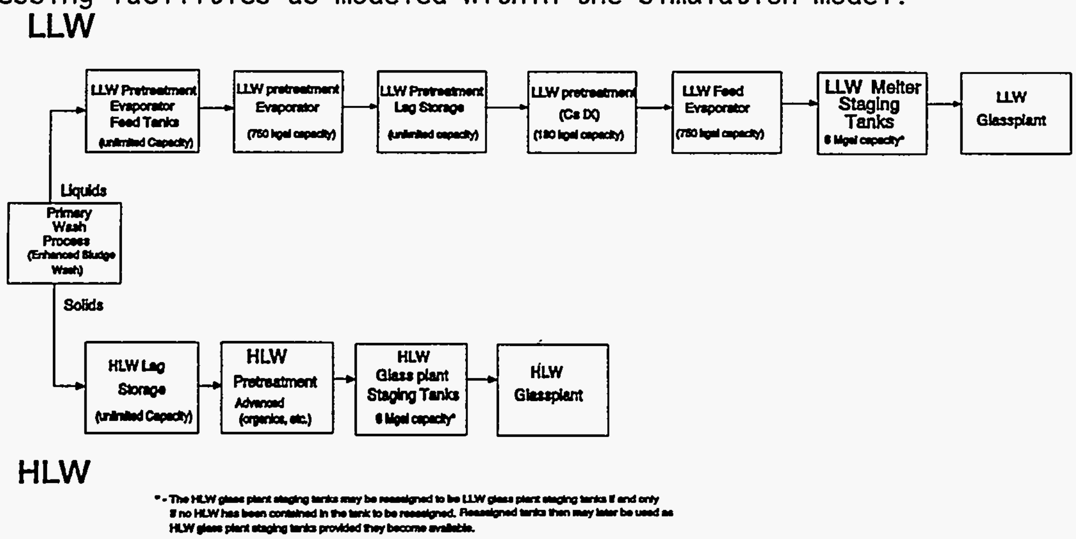

Figure 2-4 Illustration of the TWRS Waste Processing Facilities as Modeled

The volume expansion of the sludge upon retrieval is assumed to be accounted for by the *TWRS Process Flowsheet* in the volume of stream 5. This amount comes out to be a total of 55,500 m^3 interstitial liquid + 4,880 m^3 solids (using 3.5 kg/lit, MacLean 1995) = 60,380 m^3 (16.0 Mgal) total sludge to wash. This total amount of sludge is divided proportionally from the SSTs and DSTs using the proportions of the total sludge volumes mentioned in Sections 2.1.2.3 and 2.1.2.4.

2.2.2 Initial Wash

The mixing of retrieval water with the waste during retrieval and transfer constitutes the initial wash. The *TWRS Process Flowsheet* gives a 4.9 molar average sodium solution after retrieval water is added to the waste. The model is set up for a variable retrieval molarity by calculating the necessary amount of retrieval water to be added based on the initial sodium contributed by the retrieved waste. The desired molarity of the resulting retrieved slurry is maintained on a nearly instantaneous basis. Figure 2-5 illustrates the retrieval and initial washing process as done in the simulation model. The following in-tank initial wash strategy per the *TWRS Process Flowsheet* (Orme 1994) is used in the simulation:

- The mixed retrieved waste and retrieval water are pumped into a primary initial wash tank. The tank is completely filled.
- The contents are allowed to settle for the required amount of time. The simulation is setup to allow a variable settle time from 0 to 6 months. The standard assumption is 1 month.
- While filled tanks are simultaneously settling, retrieval continues into other DST wash tanks. The number of tanks needed is determined by the retrieval rate, settling time, and the tank capacity. 1.14 Mgal tanks are assumed. This results in a staggered fill, settle, decant cycle for each tank used.
- After settling, the supernatant is decanted and the solids remain. The decanted tank then is filled again with retrieved waste and retrieval water and allowed to settle for the appropriate length of time.
- This process is repeated until the tank contains a settled layer with about 20 weight% solids or approximately 1,300 m^3 (about 3 m) of sludge (*TWRS Process Flowsheet*). There will be a wide variation of solids loading during retrieval, however it is assumed that this occurs in 5 fill, settle, and decant cycles for the DST's (approximately 10% sludge by volume) and 3 fill, settle, and decant cycles for the SST's (35 to 40% by volume) sludge. The sludge also is assumed to be homogeneously mixed. The fill, settle, and decant cycles with the exception of the main caustic wash are assumed to be on average 45 days, not including time for retrieval.

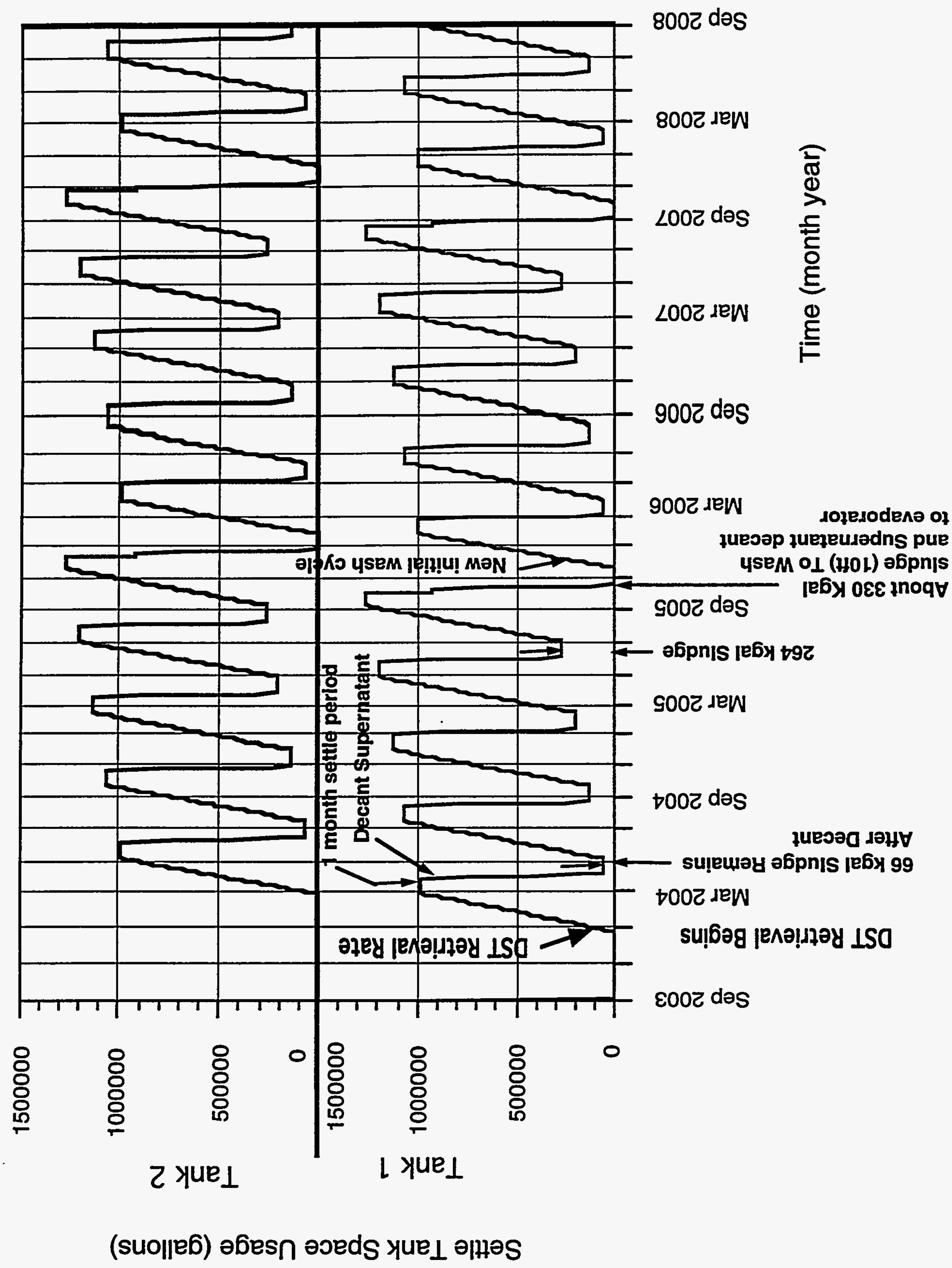

Figure 2-5 DST Retrieval into Initial Wash Settle Tanks.
2 Tanks Support DST Retrieval Simultaneously.

- After 20 wt% solids is reached in the sludge, the tank supernatants are decanted, and the sludge is mobilized into a slurry by adding caustic NaOH wash solution (3 Molar at completion) and then is ready for the primary wash process.

2.2.3 Primary Wash Process

The primary wash process is modeled as follows from the wash schedule given by the In-Tank Pretreatment Description and Diagrams (MacLean 1994) and the *TWRS Process Flowsheet*. Figure 2-6 illustrates the primary washing process as modeled.

- The caustic solution is blended, and then allowed to settle for a 1 month settling period. The entire process, including transfers, is assumed to take 2 months.

- The supernatant is decanted and the sludge is remobilized by a dilute NaOH wash solution. Upon completion of the remobilization, the solids are allowed to settle for 1 month. The entire process again is assumed to take 2 months.

- This dilute mobilization, settle, and decant cycle is repeated two more times assuming more caustic washing is found to be unnecessary.

- After the final dilute wash, the solids are mobilized and transferred to the HLW lag storage. All wash decants are transferred to the LLW pretreatment feed evaporator for concentration.

- The simulation assumes an unlimited number of wash tanks are available. That is, the model uses whatever space is required, and then tracks the total required wash tank demand versus time. This assumption is made in order to estimate wash tank capacity required to support the Tri-Party Agreement retrieval.

The wash process described above approximates that specified in Table 2-1 below (MacLean, 1994).

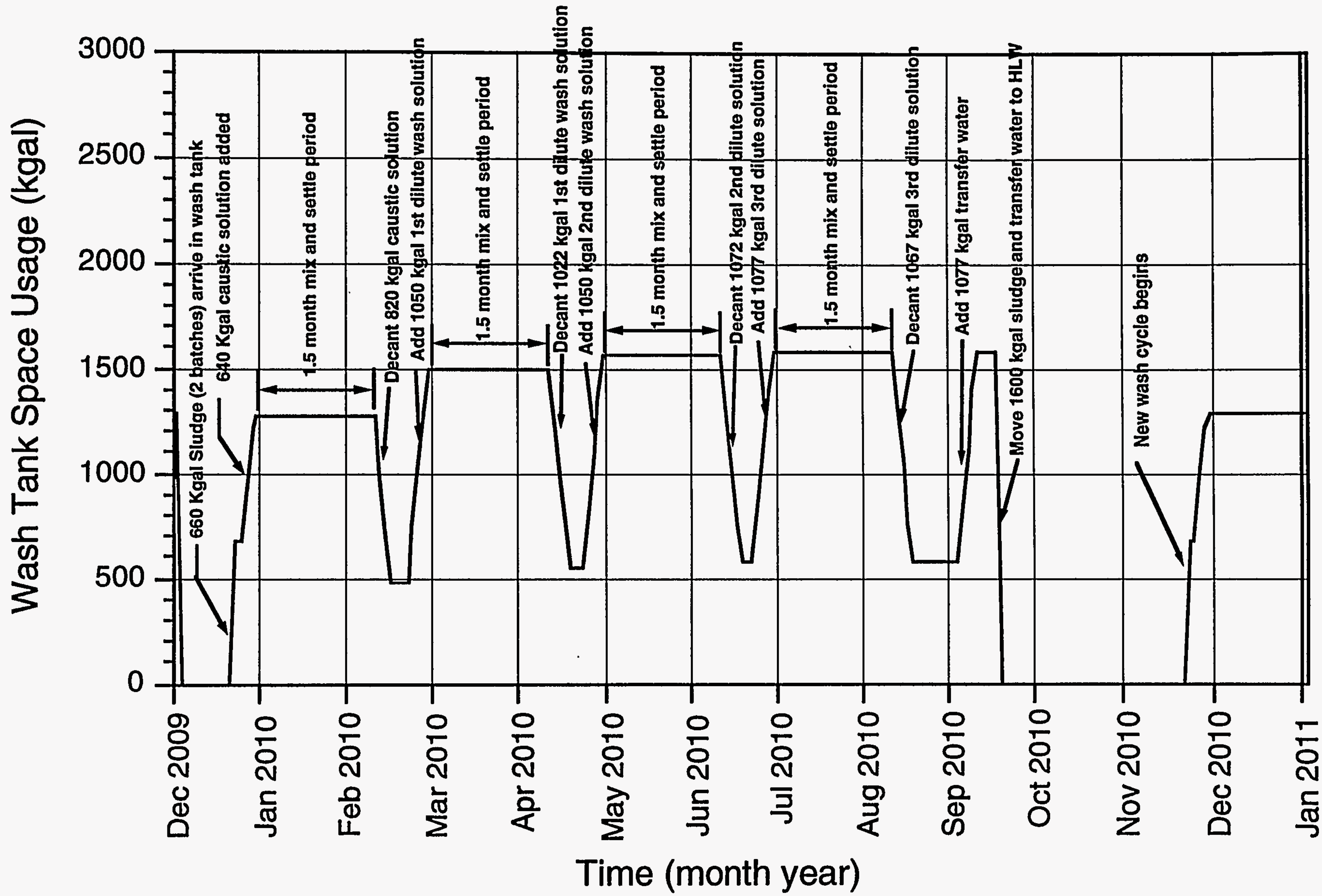

Figure 2-6 Two Sludge Batches (330 kgal each) Undergoing Caustic and Dilute Washes.

Table 2-1. In-tank Enhanced Sludge Wash Process Steps

Processing Steps	Time Duration
Retrieval and Initial Wash	
1. Transfer waste to processing tank	10 days
2. Allow suspended solids to settle	30 days*
3. Decant supernatant liquid	7 days
4. Steps 1-3 are repeated 3-5 times on avg. to accumulate about 1300 m^3 sludge	approx. 180 days**
Leaching Sludge	
5. Add 50% NaOH Caustic Solution	3 days
6. Mobilize sludge and leach	30 days
7. Allow suspended solids to settle	30 days*
8. Decant supernatant liquid	7 days
Dilute Sludge Washes	
9. Fill tank with dilute wash water	7 days
10. Mix waste with mixer pumps	7 days
11. Allow suspended solids to settle	30 days*
12. Decant supernatant liquid	7 days
13. Repeat steps 9-12 twice	102 days
Add Water for Transfer	
15. Add water for transfer	5 days
16. Transfer to High-Level Waste Accumulation	10 days
TOTAL	418 days (13.9 mos)

* - Baseline is assumed 30 days settle time, however the simulation is setup for a user variable settle time (0-6 mos).
** - This will be somewhat longer as modeled by the simulation. This total is assuming the sludge needing wash has previously been retrieved and is immediately ready to pump into the initial wash tanks. The simulation model fills the initial wash tanks directly from the retrieval flow rate.

2.2.4 HLW and LLW Lag Storage Tanks

The liquids (including dissolved salt cake) and solids resulting from solid/liquid separation and washing are sent to lag storage tanks. These LLW and HLW lag storage tanks are assumed to have an unlimited capacity as demanded by the simulation. The specific location of these unlimited tanks for LLW is immediately after the wash decant before the LLW pretreatment feed evaporator and immediately after the LLW pretreatment feed evaporator before Cs IX. For HLW, the unlimited tank is immediately downstream of where washed sludge is transferred out of the washing tanks. The first LLW tank is used to hold the backlog of waste feed caused by an inadequate LLW pretreatment feed evaporator boil-off rate. The second LLW tank serves as a point for waste accumulation if a LLW processing facility downstream of Cs IX is shutdown because of overfilling. The tank space required for the tanks then is tracked versus time and used to assess the severity of the bottlenecks caused by facility process rate mismatches.

After LLW pretreatment and HLW pretreatment, the liquids and solids (with entrained liquids) respectively are sent to different lag storage tanks, which essentially serve as glass plant staging tanks. There are currently 6 tanks in the model for both LLW and HLW. Each of these tanks is assumed to have a capacity of 3,785 m^3 (1 Mgal). However, if any of these 6 HLW lag storage tanks are not used, they can be reassigned for use as LLW staging tanks. These tanks may only be reassigned if no HLW has been contained in them before reassignment.

2.3 LLW PRETREATMENT FEED EVAPORATOR

2.3.1 LLW Pretreatment Feed Evaporator

Because of the large volume of liquids that are present in the system after solids washing, the solids wash water is subjected to concentration (evaporation) before entering the staging tanks for cesium ion exchange (Cs IX). The *TWRS Process Flowsheet* gives a sodium concentration of 7 molar after the first evaporator. However, the model is setup to evaporate the correct amount of water for a variable (user defined) sodium molarity going into the Cs IX. This molarity is sustained on an instantaneous basis. In other words, the model keeps the unevaporated output stream at the desired molarity in every simulation time step. This ensures a constant molarity stream to the Cs IX. This is done by calculating the instantaneous molarity in the LLW pretreatment evaporator feed tanks for each time step. This is dependant on the accumulation of sodium in the tanks on an instantaneous basis. If necessary, the evaporator, limited by its boil-off rate, then evaporates the correct portion of water in one time step. The calculated feed tank molarity then is used to determine the unevaporated amount of waste and sodium (bottoms) that exit the evaporator.

No wash water is assumed to be generated from interim stabilization liquid retrieval or salt cake only retrieval since most of these wastes bypass the caustic washing process.

The *TWRS Process Flowsheet* shows a recycle stream merging into the waste stream upstream of the wash water evaporator. It originates from the HLW melter offgas scrubbing. In the simulation, this stream is fed into the pretreatment feed evaporator and the amount that is instantaneously fed in is determined by the instantaneous amount of HLW that is fed into the melter. The total amount of this stream fed back into the system is thus assumed to be determined by the total waste (not including water) entering the melter. The simulation also is set up such that the user may allow this stream to not be recycled.

2.3.2 LLW Pretreatment Feed Evaporator Capacity

The flowsheet gives a total throughput of 950,000 m^3 (250.7 Mgal) of liquid, with a total evaporation of 476,200 m^3 (125.8 Mgal) of water to give an output stream of about 7 molar sodium. These throughput values may change significantly with changes in the user defined variables affecting the process and total flow amounts upstream of this evaporator. Therefore, the model is setup for a user variable instantaneous evaporator boil-off rate. The mission average boil-off rate for the LLW pretreatment evaporator is 63.6 l/min (16.8 gpm).

The 63.6 l/min (16.8 gpm) mission average boil-off rate was estimated in the TWRS flowsheet by using a constant waste feed (constant retrieval rate) to the evaporator to calculate an average boil-off rate of 63.6 l/min (16.8 gpm), based on 476,200 m^3 (125.8 Mgal) evaporated in an assumed 14 years.

The total operating efficiency (TOE) is not explicitly modeled in the simulation model by including randomly generated downtimes based on a mean time between failure and mean downtime period. Facility process rates used in the model are the processing flowrates assuming the facility never has any downtime. There will be downtime of course, so to estimate the flowrates needed to overcome this downtime, the no-downtime flowrate was divided by a conservative TOE of 60% to obtain a more realistic process rate.

If the LLW pretreatment feed evaporator is not processing at an adequate rate to avoid accumulation, the accumulation is assumed to occur in the evaporator feed tanks. This evaporator is never assumed to shutdown with the unlimited tanks on both sides of it.

2.4 LLW MELTER FEED EVAPORATOR

2.4.1 Evaporation after LLW pretreatment

To further reduce the volume of the LLW liquid stream, a second evaporation is done after the Cs IX (LLW pretreatment). The *TWRS Process Flowsheet* specifies a concentration of the stream to 10 molar sodium. In addition to the main waste stream entering this evaporator, the flowsheet shows large recycle streams (521,600 m^3 (137.8 Mgal), streams 692, 419, and 916 from *TWRS Process Flowsheet*) coming from the LLW melter offgas scrubbing and filter washing, as well as Cs IX regeneration liquids, entering the LLW feed evaporator's feed tank. This gives a total waste throughput of 1.430 Mm^3 (377.8 Mgal) and a total evaporation of 1.1 Mm^3 (290.6 Mgal) (evaporator EV-402) of water. The user also has the capability to not allow the simulation recycle streams to be fed back into the system. Since these total amounts change significantly with changes in other system parameters, the evaporator instantaneous boil-off rate also was set up as a variable parameter. The average boil-off rate for the feed evaporator given by the *TWRS Process Flowsheet* is 150.0 l/min (39.6 gpm) without the 60% TOE applied, giving a necessary rate of 250 l/min (66 gpm) with the 60% TOE applied.

Waste feed to the LLW melter feed evaporator is shutdown when the waste storage demand at the evaporator exceeds 2,840 m^3 (750 kgal). If the LLW feed evaporator is not processing waste at an adequate rate, an accumulation eventually will occur at the unlimited lag storage tank after the LLW pretreatment evaporator (discussed in Section 2.2.5). This is caused by a close-coupled shutdown of the LLW pretreatment plant if its capacity is exceeded.

2.5 ADVANCED HLW PRETREATMENT/EVAPORATION

2.5.1 HLW Pretreatment Block in Simulation Model

This block will account for organic destruction or other advanced sludge treatment processes, if they turn out to be necessary. Currently, it performs no waste processing function in the model.

2.5.2 HLW Evaporation

Immediately after the HLW pretreatment, the HLW stream is concentrated to decrease the volume of liquid used to transfer the HLW solids. The simulation model does not explicitly model the dynamics of centrifuging the solids before evaporation as shown by the *TWRS Process Flowsheet* but the waste is flow-limited by a flow rate set at HLW pretreatment in the model. The concentration decreases the total entrained liquid volume by 50%, thus reducing the total need for HLW lag storage before the HLW glass plant.

2.5.3 Date Available and Processing Capacity

The HLW pretreatment facility is assumed to be available on June 30, 2008, (Tri-Party Agreement, M-50-04), and its processing capacity is variable as defined by the user. For Operating Case 1, the maximum instantaneous processing rate was set to 189.3 l/min (50 gpm) maximum. This setting was high enough to be unconstraining to allow the actual capacity demanded by the system to be determined. For Operating Cases 2 and 3, 56.8 l/min (15 gpm) was used. This setting was found sufficient to satisfy system demand.

2.6 LLW PRETREATMENT

2.6.1 Cesium Ion Exchange (Cs IX)

This block is assumed to include the Cs IX, and other separation processes as needed. Water that has been used during the Cs regeneration process is assumed to be added to the LLW waste stream at this point per the *TWRS Process Flowsheet*. The simulation provides a nominal instantaneous 7 Molar sodium waste stream to this block as the standard setting.

2.6.2 Date Available and Processing Capacity

The LLW Pretreatment facility is assumed available on December 31, 2004, (M-50-02), and the instantaneous processing capacity is set up to be a variable defined by the user. The average process rate given by the *TWRS Process Flowsheet* is 66.0 l/min (17.4 gpm) waste feed rate without the 60% TOE applied giving an instantaneous rate of 110 l/min (29 gpm) with the 60% TOE applied.

Waste feed to the LLW pretreatment facility is stopped when the waste storage demand exceeds 681 m^3 (180 kgal) at the facility. If the LLW pretreatment processing rate is inadequate, the accumulation will occur in the unlimited LLW lag storage tank after the LLW pretreatment feed evaporator described in Section 2.2.5. This tank is assumed to hold any accumulation from shutdowns caused anywhere downstream of its location.

2.7 HLW GLASS PLANT STAGING TANKS

2.7.1 Mixing of HLW

HLW from different batches can be freely mixed in the HLW lag storage tanks that serve as HLW glass plant staging tanks. In the current model, the transuranic (TRU) waste is not treated separately from the rest of the HLW.

2.7.2 HLW Staging Tank Filling Strategy

HLW glass plant staging tanks will employ the following filling strategy (Certa et al. 1993):

- A HLW glass plant staging tanks contents are completely pumped to the glass plant.
- New batch(es) of waste are pumped into the empty tank.
- The tank remains "open" for three-months after receiving the most recent batch. During this time it can receive another batch, until the tank is full. If another batch is received, the 3-month counter starts over.
- Once three months goes by without receiving any more waste, or the tank is filled, the tank is "closed" and the 18-month "frit timer" begins counting; additional waste may be pumped into another HLW staging tank. There are six staging tanks available in the model.
- This 18-month delay is assumed to be the time delay for sampling and certification of the HLW composition and to account for procurement of the required glass formers.
- When the 18-month period has passed, the entire contents of the tank is pumped to the glass plant.

This sequence of events occurs simultaneously at several staging tanks during the simulation.

2.8 LLW GLASS PLANT STAGING TANKS

2.8.1 LLW Batches

LLW "batches" can always be freely mixed in lag storage tanks.

2.8.2 Frit Delays

The six LLW glass plant staging tanks will employ a filling strategy similar to HLW lag storage tanks, except that the frit and certification delay will be 1.5 months (Hendrickson 1994).

2.9 LLW VITRIFICATION PLANT

2.9.1 Waste Oxide Weight Percent

The limit for waste oxide in the glass is assumed to be 30 weight percent or about 25 wt% sodium oxides. It should be noted that other values, such as 20 weight percent (Tauscher 1993) have been proposed. Currently, the amount of waste oxides produced is assumed equal to 50.5 percent of the amount of dry (water removed) waste entering the glass plant (*TWRS Process Flowsheet*) based on the given LLW oxide weight percentage of 30 (approximately 25 wt% Na) and a ratio of the total waste and waste oxide weights in the glass given in the flowsheet. The ratio of .505 units of waste oxide produced per unit of dry waste feed from the flowsheet is considered an unchanging constant in the simulation. This ratio along with the desired glass plant daily capacity are used to back calculate the corresponding waste feed rate to the LLW glass plant. A constant waste oxide content and glass plant waste feed rate is assumed since no specific blending and retrieval sequences are modeled.

2.9.2 Date Available and Processing Capacity

The LLW vitrification facility is assumed available on June 30, 2005, (one processing line, M-60-05), with an instantaneous processing capacity defined by the user. A second processing line becomes available June 30, 2008, (Johnson 1994 and Tauscher 1993). The mission average LLW glass production rate necessary given in the flowsheet (Orme 1994) is 85 MT/day (two line operation).

2.10 HLW GLASS PLANT

2.10.1 Waste Oxide Weight Percent

The limit for waste oxide is assumed as 45 weight percent in the final glass. This parameter is variable in the model. Currently, the amount of waste oxides produced is assumed equal to 67 percent of the amount of dry (weight of waste with weight of water subtracted) waste entering the glass plant as calculated from the total weight of waste entering and the weight of waste oxide exiting the melter in the glass. The appropriate waste feed rate is back calculated based on this ratio, similar to the method used to calculate the LLW glass plant feed rate.

2.10.2 Date Available and Processing Capacity

The High-Level Glass Plant is assumed to be available on December 31, 2009, M-51-03, with a capacity of 12.05 MT/day (20 MT/day necessary for a 60% TOE).

2.11 WATER RECYCLE

Assumptions regarding the water recycle system are as follows:

- All condensate water from evaporation is sent to a recycle tank.
- Wash water is sent to LLW storage after the evaporation process.
- All excess retrieval decant water is sent to LLW storage after the evaporation process.
- Excess water and offgas evaporated at the HLW glass plant is sent to the LLW pretreatment feed evaporator.
- Excess water evaporated and offgas evaporated at the LLW glass plant is recycled into the LLW melter feed evaporator.
- Fresh water will be used only if the recycle tank is emptied.
- A liquid effluent retention facility is provided in the model to receive overflow recycle water if the 75,700 m^3 (20 Mgal) recycle water tank is overfilled.

3.0 THE MODEL

3.1 MODEL STRUCTURE

Figure 3-1 shows a block diagram of the main processing functions performed in the simulation model.

3.2 MODEL VERIFICATION

As mentioned above, model assumptions have been gathered from and reviewed with pretreatment engineers. References have been kept for the various model assumptions.

The programming of the model was checked frequently during development using a three step process. First, individual sections of the model, such as the LLW staging tank section, were checked in detail by the use of Ithink tables. Ithink tables allow the value of any model variable to be checked at every time step during a simulation run. When various model sections were originally programmed, or later modified, a table of important variables was created and the values of the variables were verified either by inspection or by hand calculation. Where applicable, stream values from the *TWRS Process Flowsheet* (Orme 1994) were used for comparison. Many of these tables have been permanently built into the model.

The second verification step is global in nature. Periodically during development, an overall "material balance" was made on the entire model. A material balance verifies that no material is gained or lost by the model. It provides a sensitive check for incorrectly connected flow paths between various sections of the model. Material balances also are performed using Ithink tables.

Finally, in the later stages of model development some key calculated process parameters were verified against values for these parameters available elsewhere. For the current model, total production of HLW and LLW glass has been verified against glass production estimates available from the TWRS flowsheet. Also, a small number of calculated timing results from the model have been informally compared with results available from the SIMAN/Arena simulation model being prepared by the TWRS Integration Analysis and Simulation group (Wittman et. al. 1995). All such verifications that have been made to date appear satisfactory.

An important model parameter is the discrete time-step interval employed by the model. Initially, this was set to be 3.75 days, a number seeming to give reasonable results with tolerable errors and reasonable computer run times. As the system was redesigned meeting the enhanced sludge wash, the total system throughput increased significantly. This brought about increasing errors because of the discreetness of the simulation. Resolution

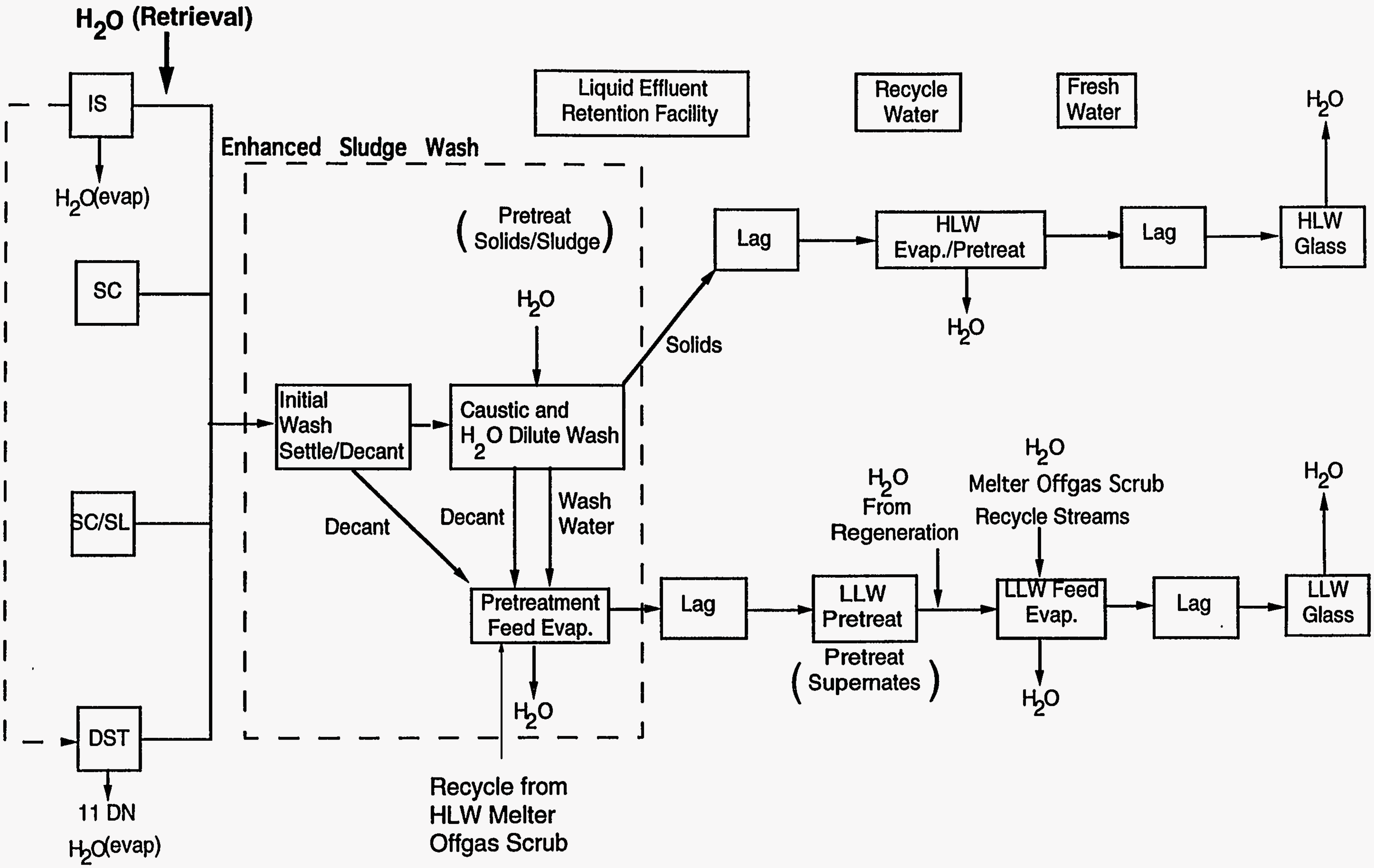

Figure 3-1 Block Diagram of Waste Pretreatment and Interfacing Systems Dynamic Simulation Model

was lowered to about 1 day and the errors decreased, however this gave a computer run time of nearly a workday, limiting the total number of system sensitivities that could be performed. It was found that a resolution of about 2 days gave tolerable errors and reasonable run times.

3.3 MODEL CAVEATS

Various simplifying assumptions were made during model construction. While these assumptions were not expected to introduce serious errors in the results, they should be kept in mind when evaluating model conclusions. These assumptions include the following:

1. The TRU wastes are not kept separate from other waste during storage and processing. There are no processes programmed in the simulation model specifically for waste that contains transuranics.

2. The model treats tank waste as homogenized into four inventory groups for processing.

3. The model assumes that 2.28 Mgal of DST storage space must be kept in reserve, and therefore is not available for normal processing and storage use. The model assumes that other DSTs not already in use at any given time for waste storage, waste processing, or as facility feed tanks, are available for these activities.

4. The model assumes that HLW and LLW glass each contain a fixed weight percent of waste oxide. These fixed weight percents are values commonly assumed by the TWRS program. In reality, the waste loading is expected to depend on the concentrations of several different components in the feed, though it has not yet been firmly established what these various concentration limits will be. Use of these concentrations, when they are available, may change the effective processing rates for the glass plant and the volume of immobilized waste produced.

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4.0 CASES STUDIED

Standard case assumptions were defined for analysis of the system operating under design options described in the *TWRS Process Flowsheet*. The Tri-Party Agreement SST retrieval schedule was assumed as standard. The overall analysis strategy was first to use the flowsheet's suggested mission average rates to get a preliminary idea of the dynamics involved at these processing rates and to assess rate matching between processing facilities. Information from these runs was then used to establish processing rates to give a successful mission. A successful mission means achieving minimal bottleneck accumulations (needed storage) between the various LLW processing facilities (i.e., improved rate matching), accomplishing the mission using a maximum of the existing 28 DSTs plus a predetermined maximum number of assumed new tanks (and minus the 2.28 Mgal of space kept in reserve), and completing the entire program by the Tri-Party Agreement milestone dates.

Three main cases are defined: Operating Case 1 utilizes the suggested mission average LLW facility processing rates from the flowsheet, Operating Case 2 has rates adequate to complete the mission assuming 6 new 4,160 m^3 (1.14 Mgal) DSTs are constructed, and Operating Case 3 has higher rates to complete the mission assuming no new DSTs are constructed. Detailed simulation results for these three cases are given in Section 5.0.

4.1 PARAMETERS OF VARIANCE (SIMULATION INPUTS)

The purpose of this section is to introduce all the parameters in the simulation that are variable and may be set to the desired value for purposes of sensitivity analysis.

The model is currently set up so that 14 significant TWRS process system parameters may be varied and their effects on the overall system evaluated. Every attempt was made to ensure that the variance of these parameters within a reasonable range produces a viable and accurate result matching that of the actual system as closely as possible. Some of the parameters are facility processing rates, physically induced wait times, option switches, stream sodium molarities, etc. Before the presentation of the simulation run results, sections describing the model parameters of variance (input parameters) and the calculated parameters (output parameters) used to estimate system performance are given. The limits given for the parameters are not limits in the simulation model, they give suggested values only.

1. **SST Retrieval Schedule**: Tri-Party Agreement-driven or variable. Tri-Party Agreement-driven specifies an increasing SST retrieval rate with time, matching that of the appropriate Tri-Party Agreement SST retrieval milestones. The variable rate option gives the user the capability of designing a custom SST retrieval schedule. Use of a constant rate SST retrieval schedule is evaluated in appendix A.

2. **HLW and LLW Glass Plant Offgas Scrubber Feedbacks**: Fed back into main system or sent to the recycle tank. It was found that the scrub feedback recycle streams comprise a significant portion of the evaporator volume and thus create potentially significant demand for tank space. It is assumed desirable to look at the system without these recycle streams directly fed in. The flowsheet streams affected by this option are *TWRS Process Flowsheet* streams 916, 419, and 692, the HLW and LLW melter offgas scrubbing and cooling recycle streams. A preliminary sensitivity study of this case is also shown in appendix A.

3. **DST Completion Date**: 2010 to 2020. The date by which the DST retrieval is completed.

4. **Recycle Water Tank Capacity Limit**: 0 to unlimited. Models a limited capacity for the recycle water tank. If no recycle water is available, fresh water makeup must be added to the system.

5. **LLW Pretreatment Evaporator Exit Molarity**: 2 to 5. Sets the sodium molarity of the unevaporated bottom stream of the pretreatment feed evaporator immediately after wash decant. It is controlled by calculating the amount of unevaporated stream from the preceding water boil-off amount. Variance of this parameter results in significant changes in the total volumes of the waste stream.

6. **LLW Feed Evaporator Exit Molarity**: 5 to 12. Sets the sodium molarity of the unevaporated bottom stream of the LLW feed evaporator immediately after LLW pretreatment.

7. **Retrieval Sodium Molarity**: 3 to 7. Sets the molarity of the retrieval stream by controlling the amount of water used for retrieval.

8. **HLW Glass Waste Oxide Percentage**: 25 to 55 wt%. Percentage of waste oxide in final glass product. Total volume of glass produced estimate is a function of this value.

9. **LLW Glass Waste Oxide Percentage**: 20 to 30 wt%. Percentage of waste oxide (Na and other waste elements) in final glass product.

10. **LLW Sampling Delay**: 0.5 to 3 months. Assumed wait period for LLW approval before vitrification. The "LLW frit-delay."

11. **HLW Sampling Delay**: 3 to 24 months. Assumed wait period for HLW approval before vitrification. The "HLW frit-delay."

12. **Evaporator Processing Rates**: 10 to 100 gal/min. Instantaneous maximum evaporator water boil-off rate. Variable rate evaporators include all LLW stream evaporators. This rate is then divided by the total operating efficiency (TOE) to estimate a maximum instantaneous boil-off rate to overcome downtime since explicit downtime modeling (except for no feed) is not currently performed.

13. **LLW and HLW Pretreatment Rates**: 10 to 50 gal/min. Instantaneous maximum LLW and HLW pretreatment waste feed rates. This rate then is divided by TOE to estimate nominal design maximum instantaneous rates needed.

14. **LLW and HLW Glass Plant Capacities**: 30/60 to 180/360 MT/day (one process line/two process lines LLW); 4 to 20 MT/day (HLW). Instantaneous LLW and HLW waste vitrification processing rates. This rate also is divided by TOE to estimate a nominal design maximum instantaneous rate.

Table 4-1 summarizes the specific values of the parameters listed above that were considered the standard values for all three Operating Cases. The only parameters varied between Operating Cases 1, 2, and 3 are the process rates for: the LLW pretreatment evaporator, the LLW and HLW pretreatment facilities, the LLW glass plant feed evaporator, and the LLW and HLW glass plants glass production rates.

Table 4-1. Simulation Input Parameters For Operating Cases* (3 Sheets)

Waste in SST (m^3)	
Total liquid in SST for IS	20,680
Salt cake in 16 TX tank	25,200
Salt cake and sludge in remaining 133 SSTs	109,700
Total SST	155,580
Waste in DST (m^3)	
DSS	7,720
Sludge	7,400
Salt cake	2,880
Supernatant	80,050
Total DST	98,050
Total Waste Stream after Retrieval (m^3) (5 Molar)	595,060
Total Sludge after Retrieval for Wash (m^3)	60,570 (8.56e4 MT)
LLW Sampling Delay (months)	1.50
HLW Sampling Delay (months)	18.00
Maximum Instantaneous LLW Pretreatment Feed Evaporator Boil-off (1st LLW Evap.) l/min model value (Maximum instantaneous value with 60% TOE factor in parenthesis) Operating Case 1 (top), Operating Case 2, and Operating Case 3 (bottom)	63.6 (106.0) 71.2 (118.6) 77.2 (128.7)
Maximum Instantaneous LLW Melter Feed Evaporator Boil-off (2nd LLW Evap.) l/min model value (Maximum instantaneous value assuming 60% TOE factor in parenthesis) Operating Case 1 (top), Operating Case 2, and Operating Case 3 (bottom)	150.0 (250.0) 168.4 (280.7) 189.3 (315.4)
HLW Pretreatment Capacity l/min model value (A maximum instantaneous value of 189.3 lit/min (50 gpm) was used in Operating Case 1 to be unconstraining. Maximum average (over 3 to 5 years) processing rate measured on cumulative throughput graph shown in parenthesis.	189.3 (36.4) 56.8 (36.4) 56.8 (36.4)

Table 4-1. Simulation Input Parameters For Operating Cases* (3 Sheets)

Maximum Instantaneous LLW Pretreatment Waste Feed l/min model value (Maximum instantaneous value assuming 60% TOE factor in parenthesis) Operating Case 1 (top), Operating Case 2, and Operating Case Three (bottom)	65.9 (109.7) 73.8 (123.0) 80.6 (134.4)
Generic Flow Rate (l/min) - The flowrate at which all miscellaneous transfers (tank decant, cross-site transfers, etc.)	379.00
Solids Settle Time during Wash Cycles (months)	1.00
LLW Pretreatment Facility Ready (year)	1/2005
HLW Pretreatment Facility Ready (year)	7/2008
LLW Glass Plant Ready (year) (1 Processing Stream) (2 Processing Streams)	7/2005 7/2008
HLW Glass Plant Ready (year)	1/2010
Time for 16 TX Salt Cake Retrieval (year)	1/2004 to 12/2008
Time for Remaining 133 SST Retrieval (year)	10/2008 to 10/2018
Time for DST Retrieval (year)	1/2004 to 1/2010
Instantaneous HLW Glass Plant Processing Rate (MT/day) model value (Maximum instantaneous rate assuming 60% TOE in parenthesis)	12.05 (20.00)
LLW Glass Plant Processing Rate (MT/day) model value (Maximum instantaneous rate assuming 60% TOE in parenthesis) Operating Case 1 (top), Operating Case 2, and Operating Case 3 (bottom)	85.0 (142.0) 95.5 (159.2) 120.0 (200.0)
HLW Glass Specification (assuming constant waste oxide since blending data is currently being composed)	45.0 wt% Waste Oxide
LLW Glass Specification (assuming constant waste oxide since blending data is currently being composed)	30 wt% Waste Oxide
Retrieval Sodium Molarity (Instantaneous Basis)	4.9 Molar
Supernatant Evaporator Molarity (Instantaneous Basis)	7.0 Molar

Table 4-1. Simulation Input Parameters For Operating Cases* (3 Sheets)

LLW Glass Plant Feed Evaporator Molarity	10.0 Molar
Recycle Water Holding Tank Capacity	20 Mgal
Melter Scrubber Recycle Flows	Fed back in

4.2 MEASURES OF PERFORMANCE (SIMULATION OUTPUTS)

The measures of performance are parameters calculated by the model to assess the effects on the overall system resulting from changes in the parameters described in Section 4.1.1. This section gives a detailed description of each of the performance measures used in the results section of the report. It also gives a description of the way each parameter is defined and calculated from the model.

1. **LLW Glass Completion Date**. This date refers to the month and year when approximately 4.32e8 kg (estimated by *TWRS Process Flowsheet*) of glass from LLW vitrification is completed.

2. **HLW Glass Completion Date**. This date refers to the month and year when approximately 2.28e7 kg (estimated by *TWRS Process Flowsheet*) of glass from HLW vitrification is completed.

3. **Tank Space Usage**. This value refers to the estimated storage volume in cubic meters (millions or thousands of gallons [Mgal or kgal]) that particular functions in the remediation process use. It must be pointed out that the actual number of tanks used is not represented by this value at all times during the simulation runs. Specifically, during the sludge washing phases some tanks are not completely full at times creating "artificial" dips or valleys in the estimate. These dips are relatively small when compared to the magnitudes of the total tank usage estimate. Because of various model assumptions and "real life" factors, the value of these estimates contain some degree of uncertainty (estimated to be in the order of 1 to 2 Mgal for overall system tank usage estimates). The uncertainty value estimate of 1 to 2 Mgal is based on the average change in overall tank usage estimates before and after more detailed process events were inserted into the model.

4. **Tank Space Usage Deficit/Surplus**. This is an estimate of the tank storage volume deficit/surplus obtained by subtracting a continuous estimate of tank volume usage from a continuous estimate of DST tank volume that becomes available during the simulation run. Only retrieval and evaporation from DST inventories changes the availability of DST space. The peak tank space available is 109,900 m^3 (31.3 Mgal for 28 DSTs [Hanlon, 1994], minus 2.28 Mgal kept in reserve). The tank space available is only used to calculate the deficit/surplus number, it does

not act as a limit on tank space that may be used by the simulation. The estimated space available time series plot is shown in Figure 5-9..

5. **Cumulative Facility Throughput**. This is a sum of the total cumulative waste feed input to the LLW and HLW pretreatment plants as a function of time. For evaporators, this parameter refers to the cumulative amount of water that is evaporated with time.

6. **Facility Usage Factor**. This calculation is an indication of the fraction of time the plant is operating since the facility startup date. This is a cumulative parameter. It does not give a cumulative indication of how fast a facility is processing relative to its maximum instantaneous processing rate. It is an indication of whether it is "busy."

4.2.1 Facility Throughput Rate Parameters

This section gives an exact definition of each of the facility waste throughput or processing rates as used in the results section. This is necessary to avoid confusion between how rate parameter values are specified.

The instantaneous maximum throughput rate is the absolute maximum instantaneous rate a facility is allowed to process with feed continuously available. When referring to LLW or HLW pretreatment (Cs IX, or other separations), the rate refers to the waste feed rate. When referring to the evaporator rates, the rate refers to the boil-off rate.

The TOE is not explicitly modeled in the simulation model. It is assumed that a facility is always available once it has come on line. There will be times when the facility is unavailable (maintenance, failures, etc.). To estimate the design flowrate needed to compensate for this downtime, the no-downtime flowrate may be divided by an appropriate TOE. A TOE of 60% is commonly used.

The maximum average throughput (flow) rate as given in Tables E-1 and 5-1 for each processing facility is a measure of the maximum average processing rate needed over a period of several years. It is estimated by fitting a line to the cumulative throughput curve at the location where the slope is visually maximum. The duration of this "visually maximum" slope must be at least 3 to 5 years and is generally longer depending on the facility. The slope then is considered the maximum average rate that the facility must process over a extended period during the mission.

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5.0 RESULTS AND DISCUSSIONS

The results of the simulation model runs are presented on the following pages in tables and graphs. For each run case, a discussion is also given describing quantitative and qualitative conclusions drawn from the data given. All conclusions are drawn directly from the raw data out of the simulation model. A detailed analysis is performed on Operating Case 1, however the main report conclusions will generally be drawn from Operating Cases 2 and 3 as the dynamics are similar and the bottlenecks are reduced.

5.1 OPERATING CASE 1 RESULTS AND BOTTLENECK ANALYSIS

The Operating Case 1 was designed by setting the parameters in the simulation equal to the mission average facility and process design values given in the *TWRS Process Flowsheet*. The average LLW facility processing rates given by the *TWRS Process Flowsheet* (deflated values before the 60% TOE) were used in the simulation as maximum instantaneous rates to get an idea of the dynamics occurring between the various facilities and to investigate the matching of the relative facility suggested processing rates. The following discussion represents just one example of the dynamic analysis that may be done with the simulation model.

5.1.1 Retrieval and Wash Model Results

Figures 2-2, 2-3, 2-5, 2-6, 5-1, and 5-2 present the retrieval schedules utilized (Tri-Party Agreement) by the simulation, and show the specific dynamics of the initial (retrieval) wash and the caustic and dilute washes. These figures may be used to get an idea of how the simulation implements the basic retrieval and wash steps and to visually see many of the assumptions as implemented in the simulation. These figures also show the basic processing steps leading up to the waste pretreatment sections. The retrieval and wash sections play an important role in determining the dynamic relationships between the various pretreatment facilities and within the system as a whole.

The facility process rate matching of the facilities relative to one another is assessed below by analyzing where the bottlenecks in the system occur, which facilities caused the bottlenecks, and the severity of the bottlenecks.

5.1.2 Bottleneck Analysis Downstream of Washing

<u>Bottleneck at LLW Pretreatment Feed Evaporator</u>

The most severe bottleneck was caused by an inadequate boil-off rate of the LLW pretreatment feed evaporator immediately downstream of where the wash and retrieval solution is decanted. This lag storage location also receives the HLW melter offgas recycle, flowsheet stream 336, Orme 1994. This forced the beginning of an accumulation in the evaporator feed tanks beginning around 2012. Figure 5-3 illustrates this accumulation in the tanks as a function of time. The DST waste retrieval occurred from January 2004 to January 2010 and

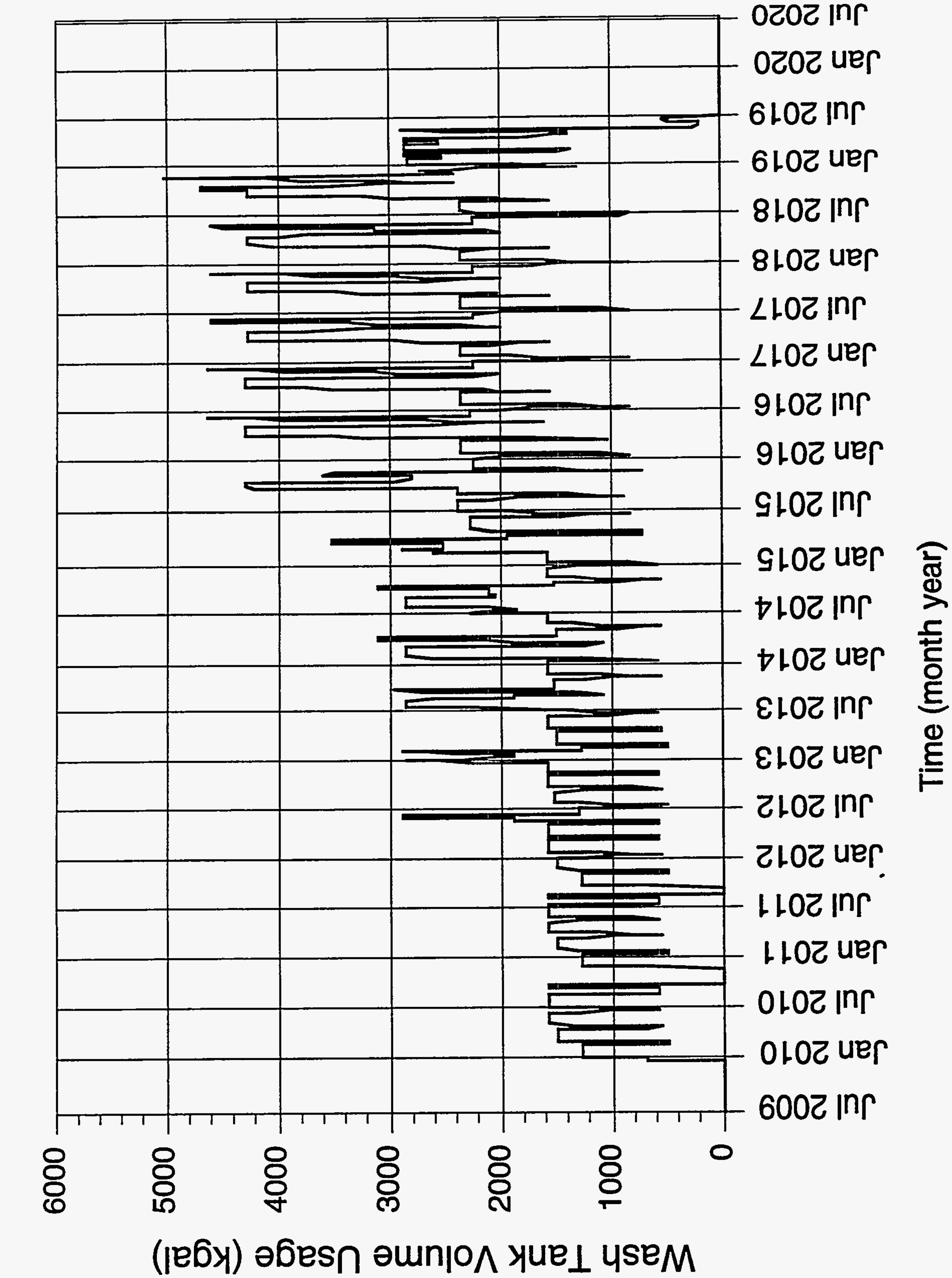

Figure 5-1 Wash Tank Space Usage during Entire Washing Period. Waste from Retrieval of Remaining 133 SSTs.

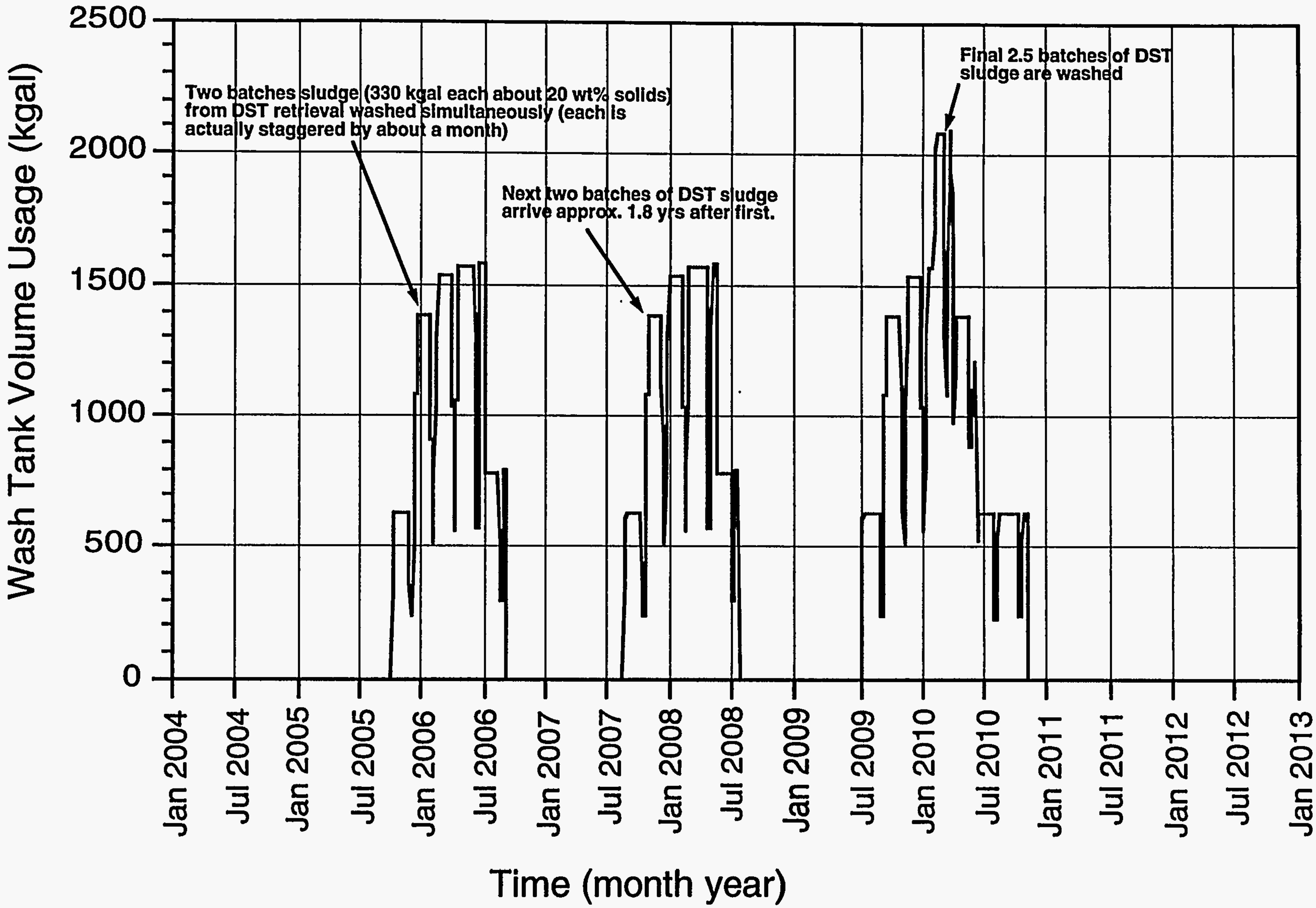

Figure 5-2 Wash tank space usage during entire washing period. Sludge is from DST waste retrieval. Spaces between washes represent time for retrieval/initial wash (shown in figure 2-5).

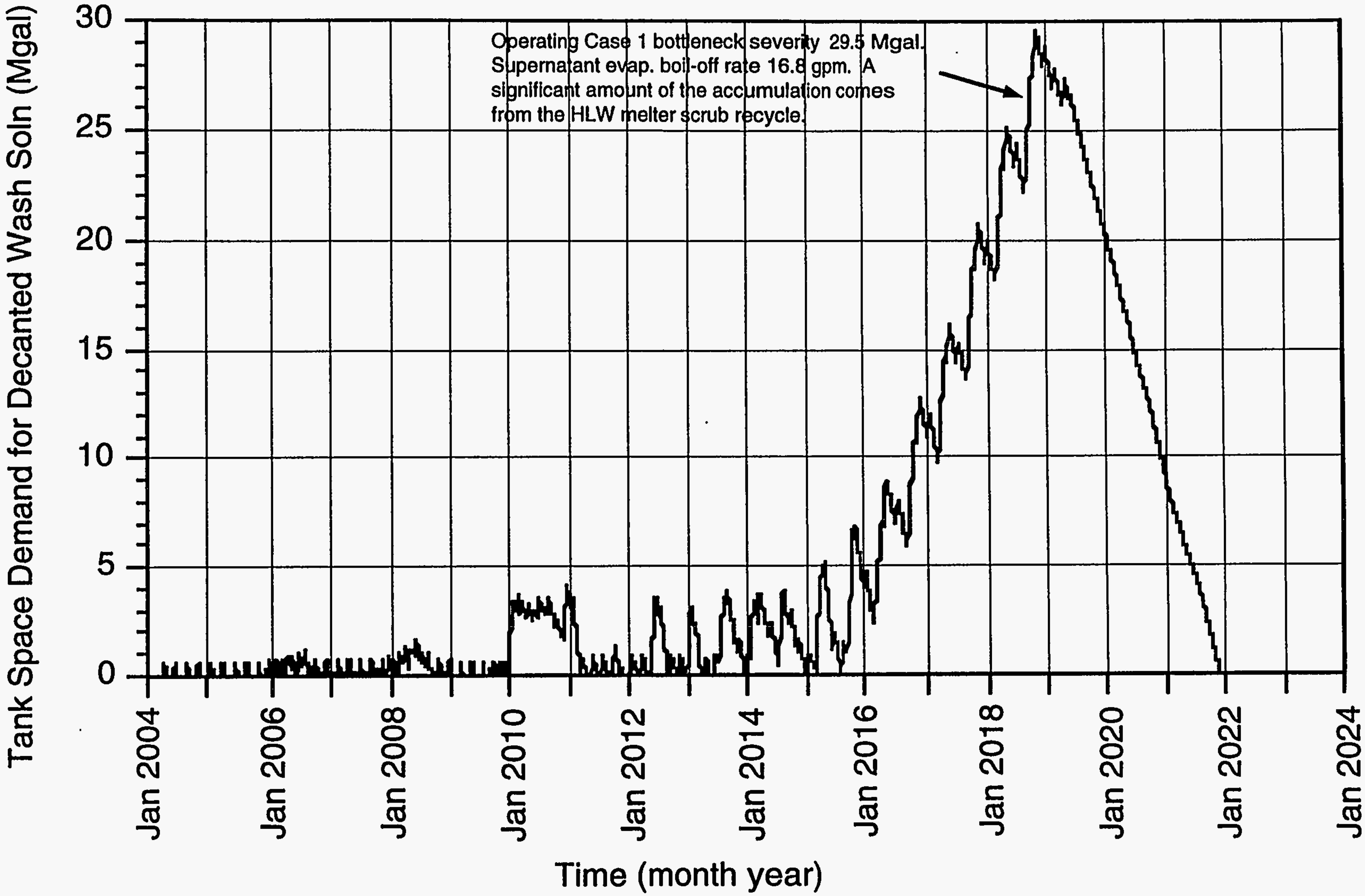

Figure 5-3 Accumulation of wash decant solution directly downstream of wash tanks for operating case 1. This illustrates the accumulation resulting from the bottleneck. The LLW pretreatment feed evaporator does not have the processing capacity to "keep up" with the wash decants, secondary settle/decant solution decants, and the HLW melter offgas recycle that accumulates.

it is evident the LLW pretreatment feed evaporator is able to process this decanted wash solution adequately with little accumulation during this early period. The accumulation begins when the remaining 133 SSTs (excluding 16 TX farm SSTs already retrieved) are retrieved.

The severity of this bottleneck may be assessed by the maximum amount of accumulation that occurs in the evaporator feed tanks. The maximum accumulation using the Operating Case 1 LLW pretreatment feed evaporator maximum boil-off rate of 16.8 gpm (29 gpm with 60% TOE) was found to be about 29.7 Mgal in the last half of 2018. It was determined that an evaporator maximum instantaneous boil-off rate of 40 to 42 gpm (66 to 70 gpm with 60% TOE) was needed to substantially eliminate this accumulation, however this just relocates the accumulation immediately upstream of the Cs IX and reestablishes this bottleneck after the evaporator.

Bottleneck at LLW Pretreatment Facility

A second bottleneck occurs in the lag storage tanks upstream of the Cs IX because of the delay between the arrival of the waste stream (from early DST retrieval) and the January 2005 startup date of the pretreatment facility (Cs IX) (See Figure 5-4). Approximately 5,000 kgal of concentrated wash supernatants (7 molar) accumulate in this year before the LLW pretreatment facility (Cs IX) goes online. When the LLW pretreatment facility goes online, the accumulation (backlog) is worked off. This bottleneck is primarily a result of beginning DST retrieval in January of 2004, a year prior to LLW pretreatment facility start of operation.

Bottleneck at LLW Glass Plant Staging Tanks - Single Melter Line Operation

A third bottleneck occurs in the staging tanks feeding the LLW vitrification facility. The events leading up to this accumulation are described in the following paragraphs using Figure 5-5 Waste storage demand at the LLW pretreatment facility, Figure 5-6 Storage demand at the LLW glass plant feed evaporator, and Figure 5-7 Space demand at LLW melter staging tanks.

An examination of the storage demand at the LLW glass plant feed evaporator reveals that its rate seems to be matched to the LLW pretreatment facility rate from January 2005 to about July 2008, since no accumulations greater than feed shutdown capacity (750 kgal) occur. Beginning July 2008, however, an accumulation occurs in the evaporator exceeding its maximum holding capacity, and its feed is therefore shutdown. Since the waste feed rate to the LLW glass plant evaporator from the LLW pretreatment plant is not sufficient to force an evaporator shutdown (i.e., the pretreatment facility rate and the evaporator rate are matched), the evaporator must be shutting down because of an accumulation downstream.

Figure 5-7 shows that the 8 LLW melter staging tanks (6 previously allocated to LLW staging, plus 2 unused HLW staging tanks reallocated to LLW

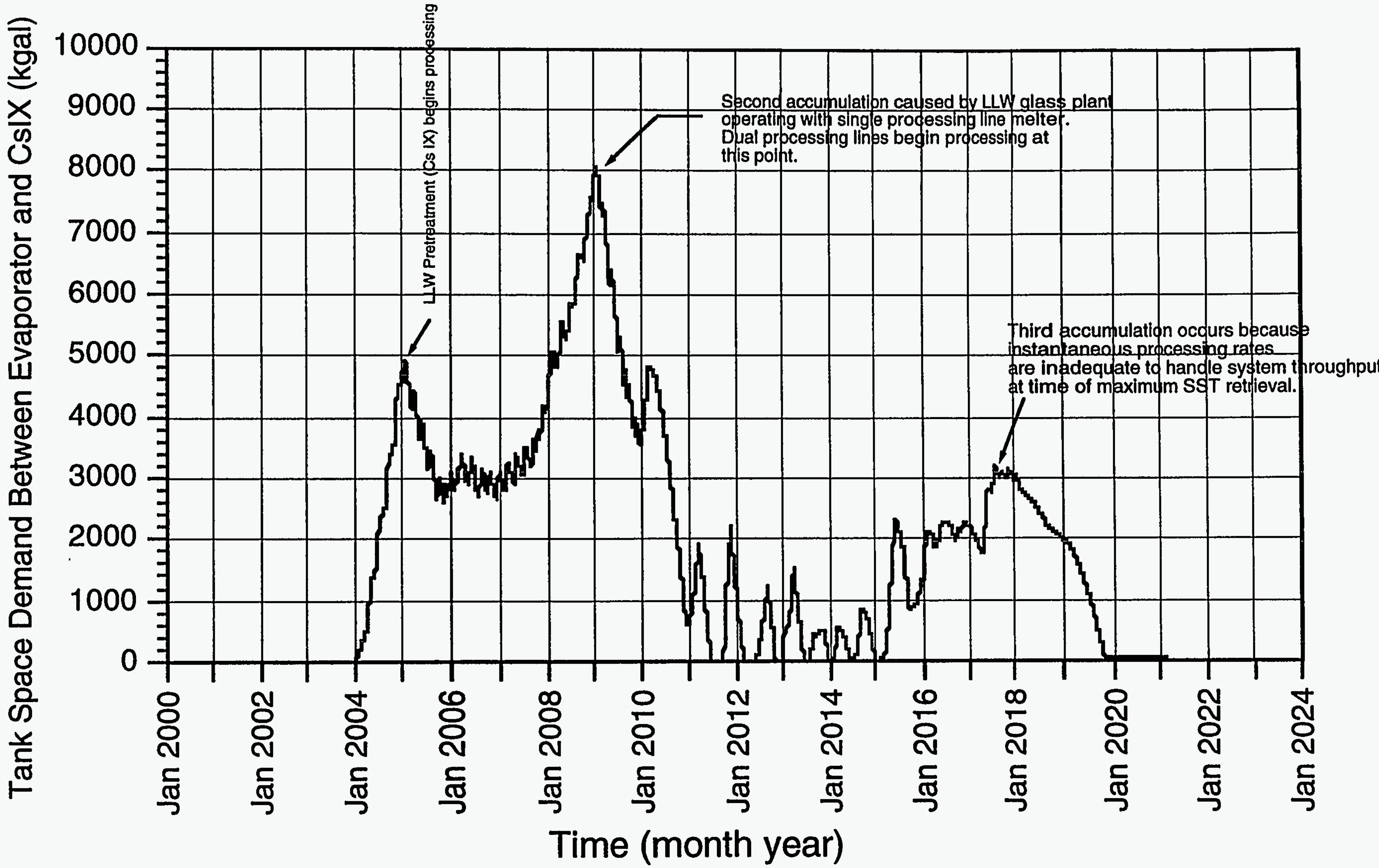

Figure 5-4 Cumulative tank space demand between LLW pretreatment feed evaporator (nominal 7 M Na output) and pretreatment (CsIX) for Operating Case 1. The first accumulation is caused by the delay between the waste stream reaching pretreatment and the startup of LLW pretreatment. The second accumulation is caused by the LLW glass plant operating with one melter stream. The final accumulation is caused by general inadequacy of flowsheet average rates used as instantaneous maximum rates in the model.

glass plant staging) are filled completely by July 2008. This stops the flow into the staging tanks making it necessary for the LLW glass plant feed evaporator to shutdown. This shutdown results in the accumulation in the LLW glass plant feed evaporator described above (Figure 5-6), and results in the LLW pretreatment facility (Cs IX) shutting down (Figure 5-5), producing the "second" accumulation in the unlimited lag storage tank upstream of the LLW pretreatment facility. This second accumulation is seen in Figure 5-4.

The root cause of this chain of accumulations and shutdowns is the LLW glass plant's initial single line operation. Recall that the glass plant comes online in July 2005 at a single vitrification line processing rate of 42.5 MT/day, half the two line processing capacity of 85 MT/day. The bottleneck at the glass plant staging tanks is illustrated in Figure 5-7. Note the net filling rate of the staging tanks decreases (slope decreases) in July 2005. This is the single line startup of the vitrification plant. However since the staging tank demand continues to rise, this single line vitrification capacity is shown to be inadequate. In July 2008, when two line vitrification processing begins, the rapid increase in tank demand stops (however, it takes a few years to "catch up" to the incoming waste stream as shown by the progressively decreasing need for LLW staging tanks past 2011).

<u>Bottleneck at LLW Glass Plant Staging Tanks - Peak Glass Plant Capacity</u>

A final system bottleneck occurs from about 2016 to 2018, with the accumulation originating at the LLW glass plant (melter) staging tanks. This accumulation is caused by the inadequacy of the LLW glass plant processing rate of 85 MT LLW glass/day during the peak of the Tri-Party Agreement SST retrieval schedule. This accumulation fills the six allocated LLW glass plant staging tanks causing a shutdown of feed into those tanks. As a result, the LLW glass plant feed evaporator is forced to shutdown. Subsequently, the LLW pretreatment plant stops processing, forcing a final accumulation to occur in the unlimited capacity LLW pretreatment feed tanks. The resulting close coupled shutdown waste accumulations are illustrated in figures 5-7, 5-6, 5-5, and 5-4.

From the above discussion, it is evident that the main bottlenecks in the overall system are caused by the Cs IX feed evaporator, the early (June 2005 to June 2008) one vitrification line processing capacity of the LLW glass plant, and the inadequacy of the LLW vitrification processing rate late in the mission when retrieval rates are high.

5.1.3 Overall Tank Space Usage and LLW Vitrification Completion Time

The simulation estimates the total overall demand for tank space as a function of time by summing the estimated storage space demands from single facilities and designated lag storage locations throughout the process. For Operating Case 1 with the suggested average processing rates from the *TWRS Process Flowsheet* as described above, a peak overall tank space usage of

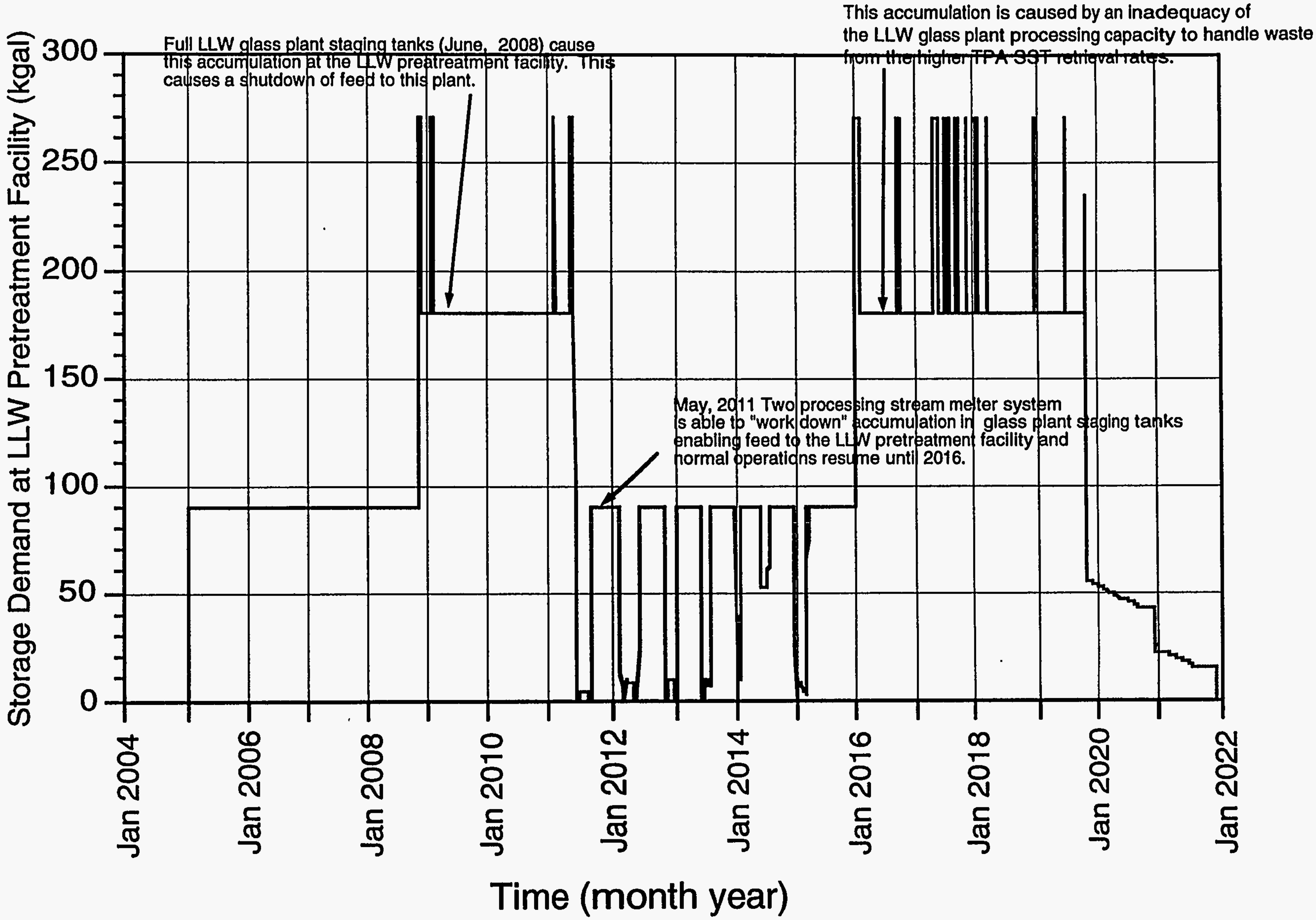

Figure 5-5 Waste storage demand at the LLW pretreatment facility for the Operating Case 1. The model assumes a maximum storage capacity of 180 kgal at the facility. When this level is reached, feed to the plant is shutdown.

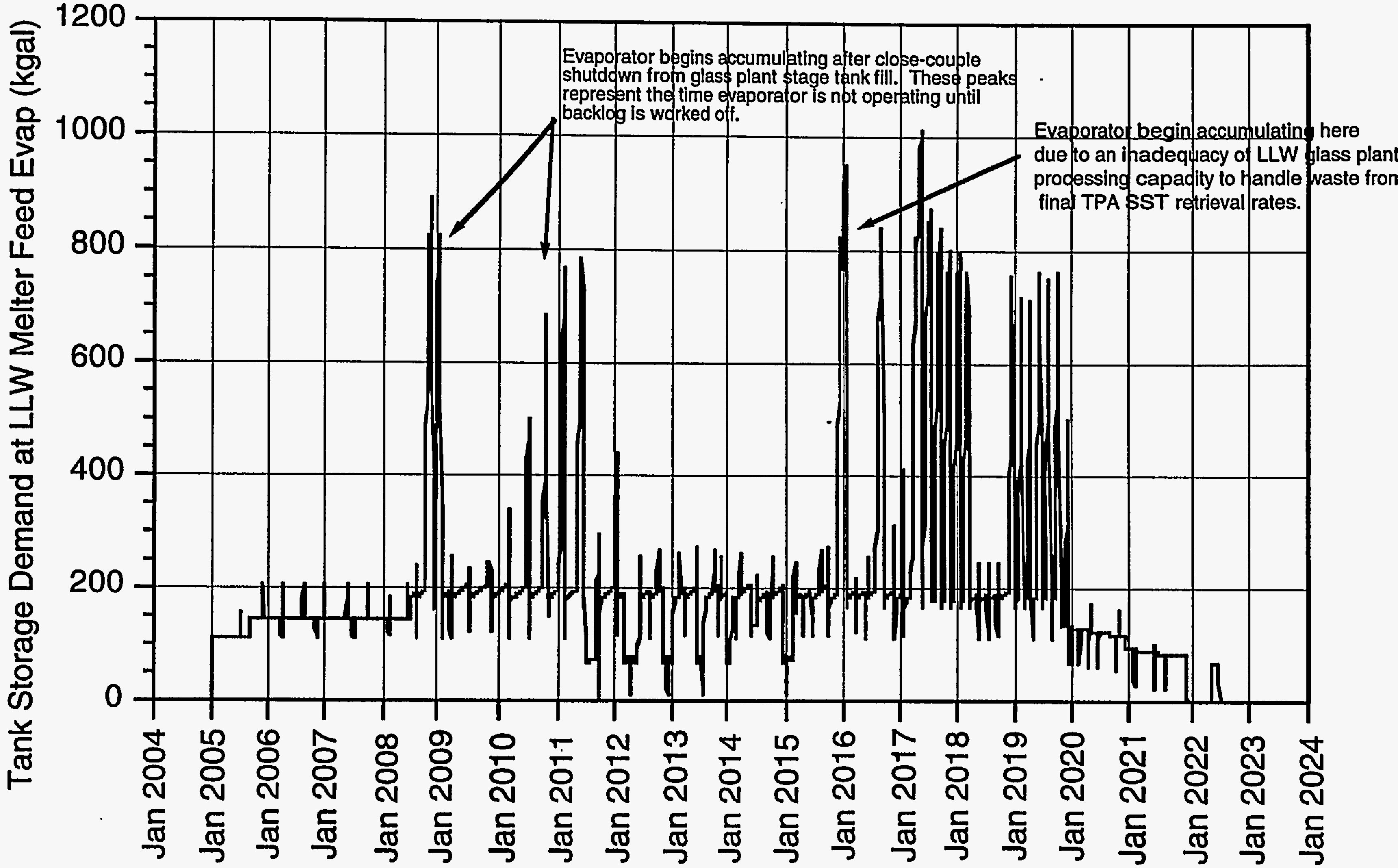

Figure 5-6 Storage demand at the LLW melter feed evaporator for the operating case 1. The maximum instantaneous boil-off rate is 39.6 gpm. The maximum storage capacity is 750 kgal for the facility evaporator lag storage tanks.

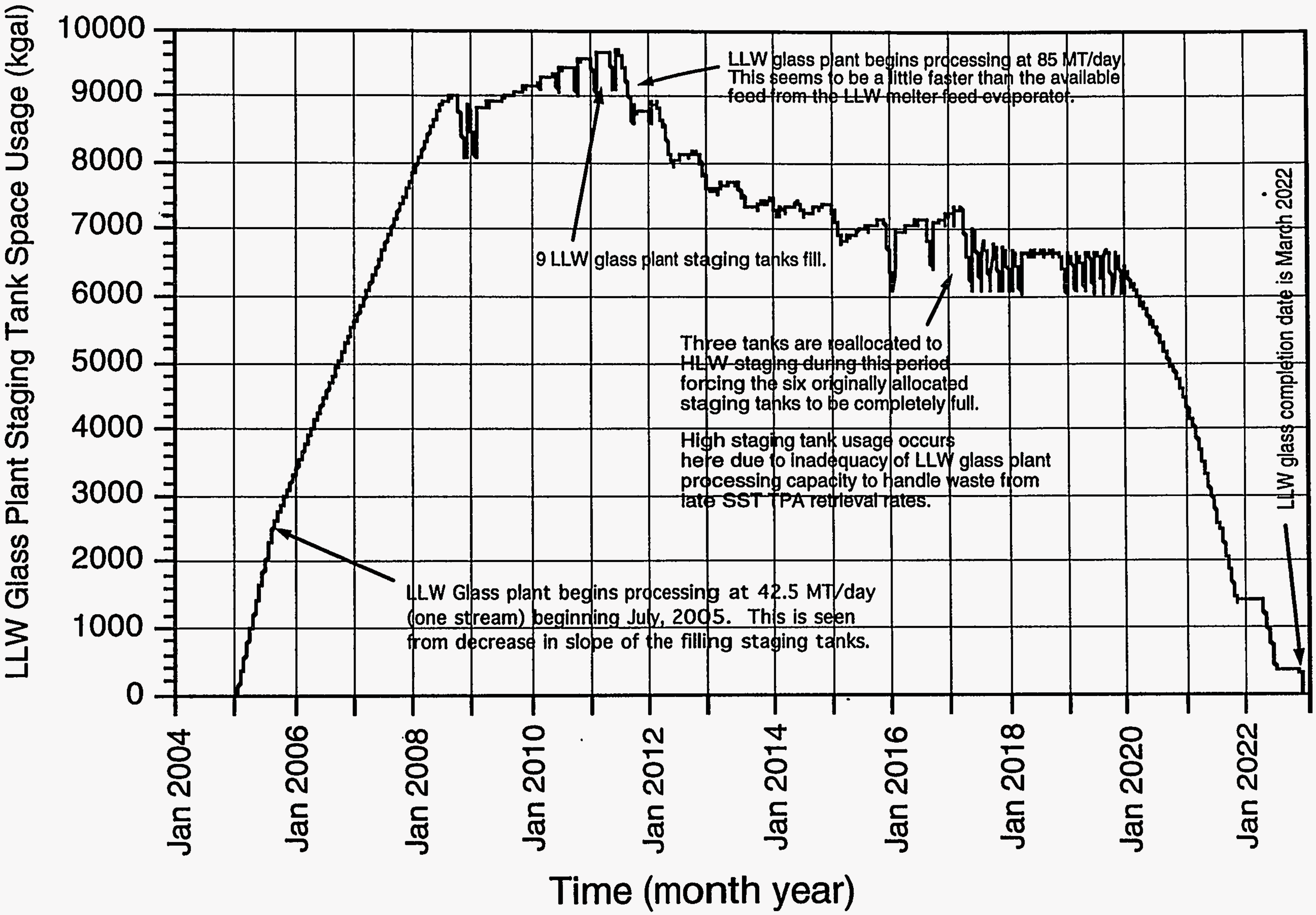

Figure 5-7 Space demand at LLW melter staging tanks. 6 tanks are originally allocated to this purpose and 3 unused HLW staging tanks are reallocated to LLW giving a total of 9.

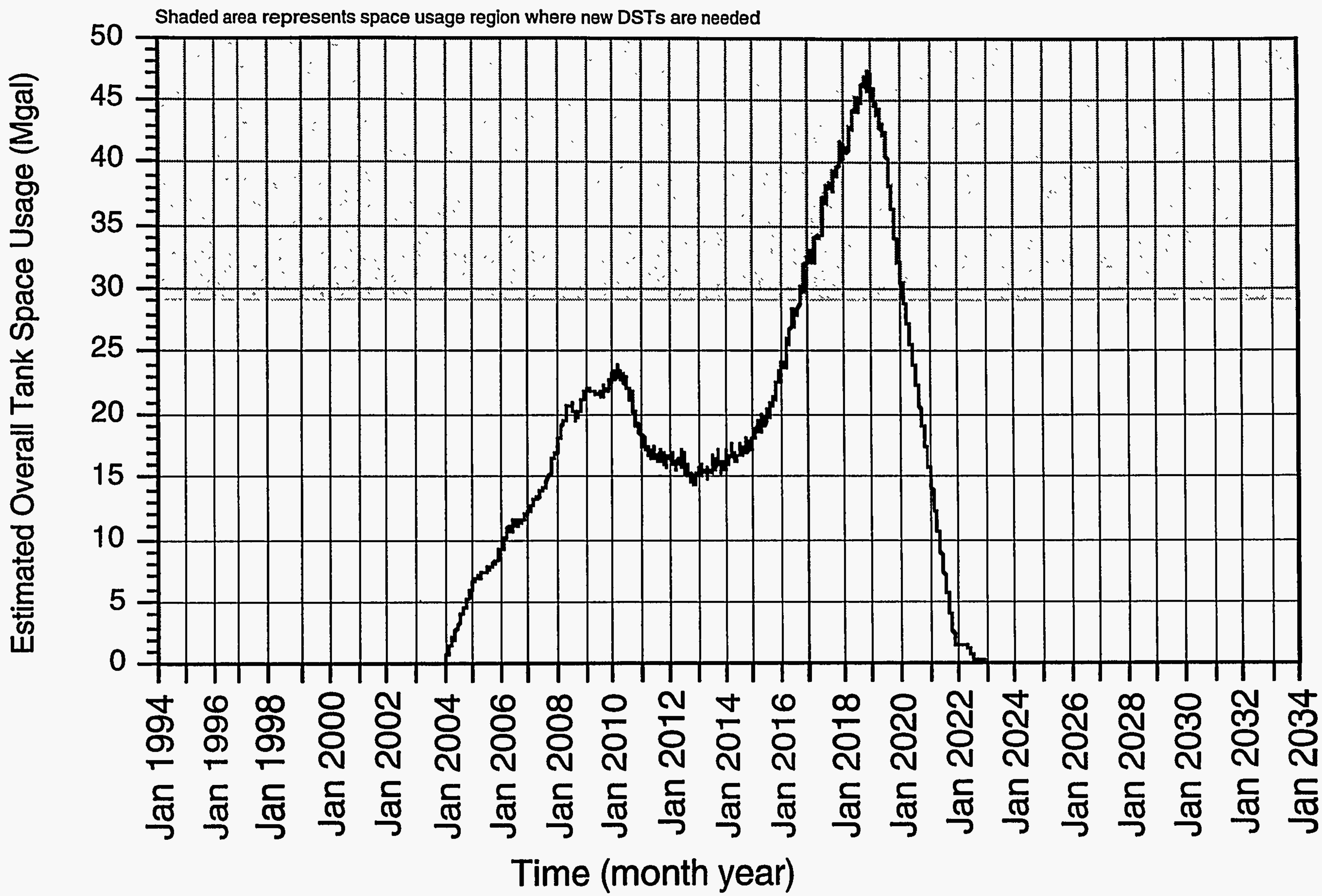

Figure 5-8 Estimate of overall tank utilization for operating case 1. Maximum estimated utilization of 47.3 millions gallons occurs in September of 2018. Note the high peak from 2016 to 2021 in lag storage need from the final Tri-Party Agreement SST retrieval rates.

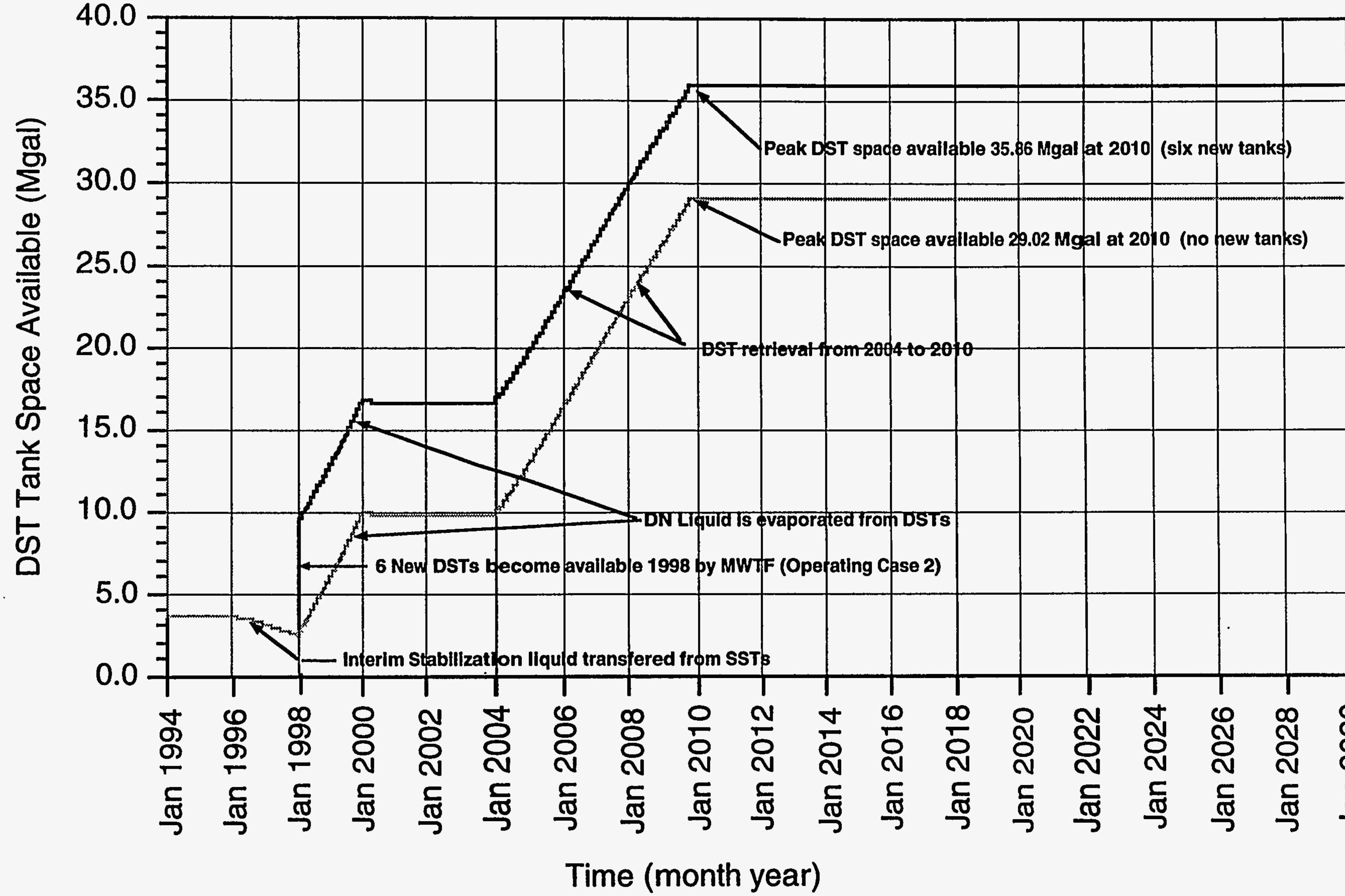

Figure 5-9 Estimate of total available DST space. The solid black curve represents the availability assuming 6 new 1.14 Mgal DSTs become available in 1998 and the shaded curve assumes no new DSTs.

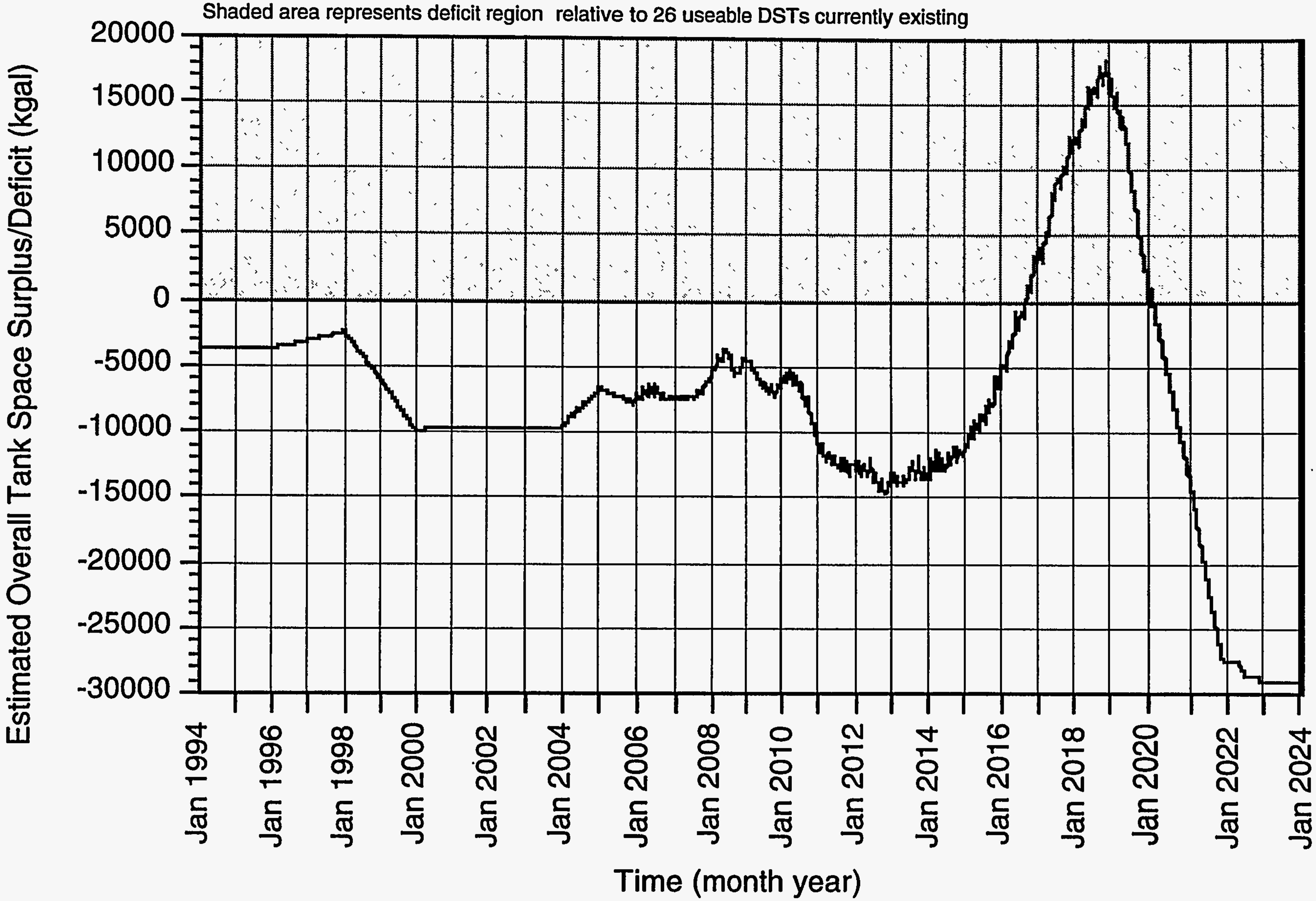

Figure 5-10 Total estimated space surplus/deficit based on curves in figures 5-8 and 5-9 for operating case 1. Negative values denote surplus, positive denote deficit. A peak space deficit of about 18.3 Mgal occurs around October 2018. This curve is plotted relative to a peak availability of the existing 26 useable DSTs (28 - 2 spare DSTs; 29.0 Mgal total space).

approximately 47.3 Mgal occurs around September 2018. Figure 5-8 shows the overall tank space usage estimate versus time. Assuming 26 DSTs (29 Mgal) available for use (28 DSTs minus 2 DSTs in reserve), this gives a peak tank space deficit of about 18.3 Mgal. The overall tank space deficit/surplus estimate versus time is shown in Figure 5-10, where this surplus/deficit is estimated by subtracting the DST tank space available estimate (Figure 5-9 no new DST curve) from the DST tank space used estimate (Figure 5-8). Negative values on the surplus/deficit plot are therefore surplus values, positive values are deficit.

The completion of LLW vitrification is estimated to have occurred in November 2022 for Operating Case 1.

5.1.4 Water Usage and Recycle

Water usage and recycle issues also are analyzed in the simulation. Specifically, a recycle water holding capacity of 20 Mgal is allocated for the return of all evaporator condensate water. Any demand for water during the processing (including retrieval, wash, transfer, etc.) is taken from this recycle holding capacity. The recycle water holding capacity versus time is shown in Figure 5-11. For Operating Case 1, this figure shows the holding capacity supplies the demand for water most of the time with the exception of the period from May 2017 to January 2019. The emptying of the holding capacity during this time period most likely is caused by the high demand for water during washing of the sludge retrieved during the peak SST retrieval period. Figure 5-12 gives an estimate of the cumulative amount of fresh water needed during processing. The total cumulative fresh water estimated for Operating Case 1 is about 6300 kgal. Total cumulative water that is brought into the recycle tank is approximately 527 Mgal (much of this water is counted multiple times). Figure 5-13 gives an illustration of the cumulative water brought into the recycle tank and the rate at which it enters.

5.1.5 Cumulative Facility Throughputs

Additional information regarding the dynamics of the system is shown in Figures 5-14 through 5-19 which give the cumulative throughputs for each LLW facility and the HLW pretreatment and glass facilities. For each plot, the slope representing the maximum instantaneous allowable rate is plotted at the start times of each facility to represent the theoretically optimal facility performance potential. Using this, a particular facility's actual processing rate over time may be compared to the maximum potential processing rate for that facility. This comparison gives an indication of how well the system is providing feed to the respective facilities.

Table 5-1 gives the maximum average rates (minimum of 3 to 5 years duration) necessary for the processing facilities as measured from the cumulative throughput graphs.

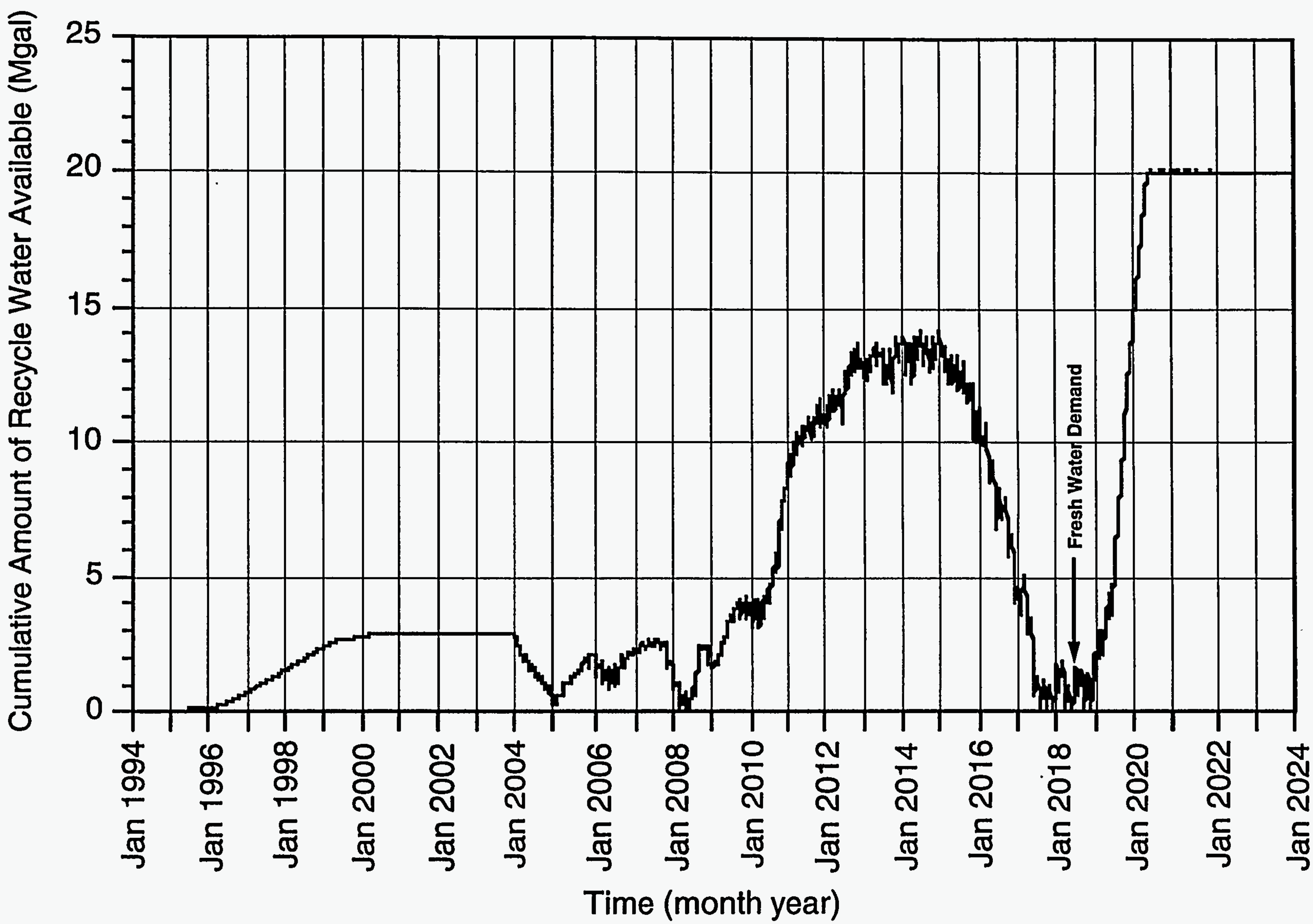

Figure 5-11 This figure represents the amount of recycle water in the recycle water tank versus time for operating case 1. Operations that are included are retrieval, wash, and transfer water taken out, and evaporator condensate and melter condensate water brought in. A 20 Mgal holding capacity is assumed.

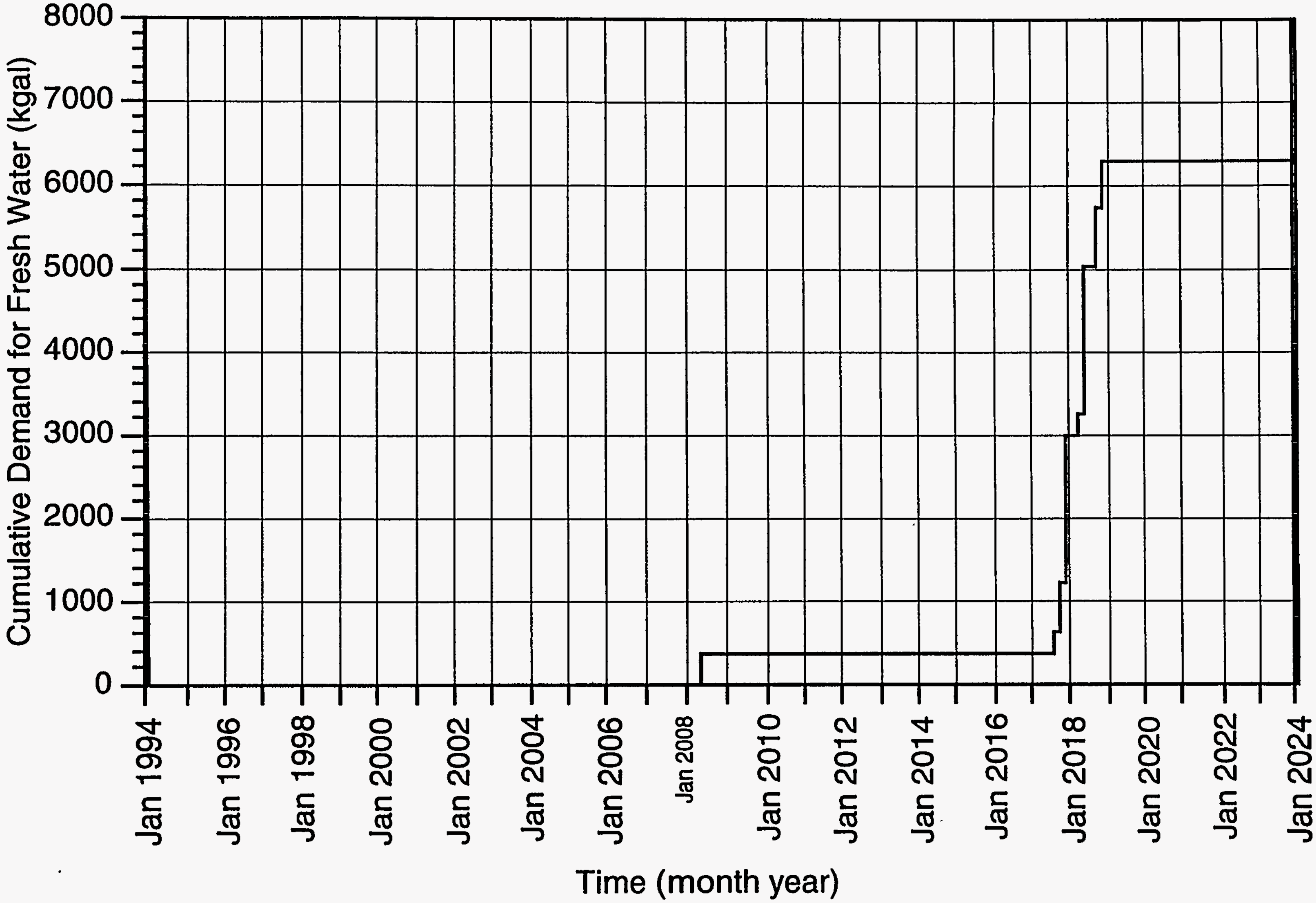

Figure 5-12 Cumulative demand for fresh water vs. time. A total of 6.3 Mgal of fresh water is required throughout processing from 2008 to 2018. Most of the fresh water is needed during the peak retrieval and washing period from Jan. 2017 to Jan. 2019.

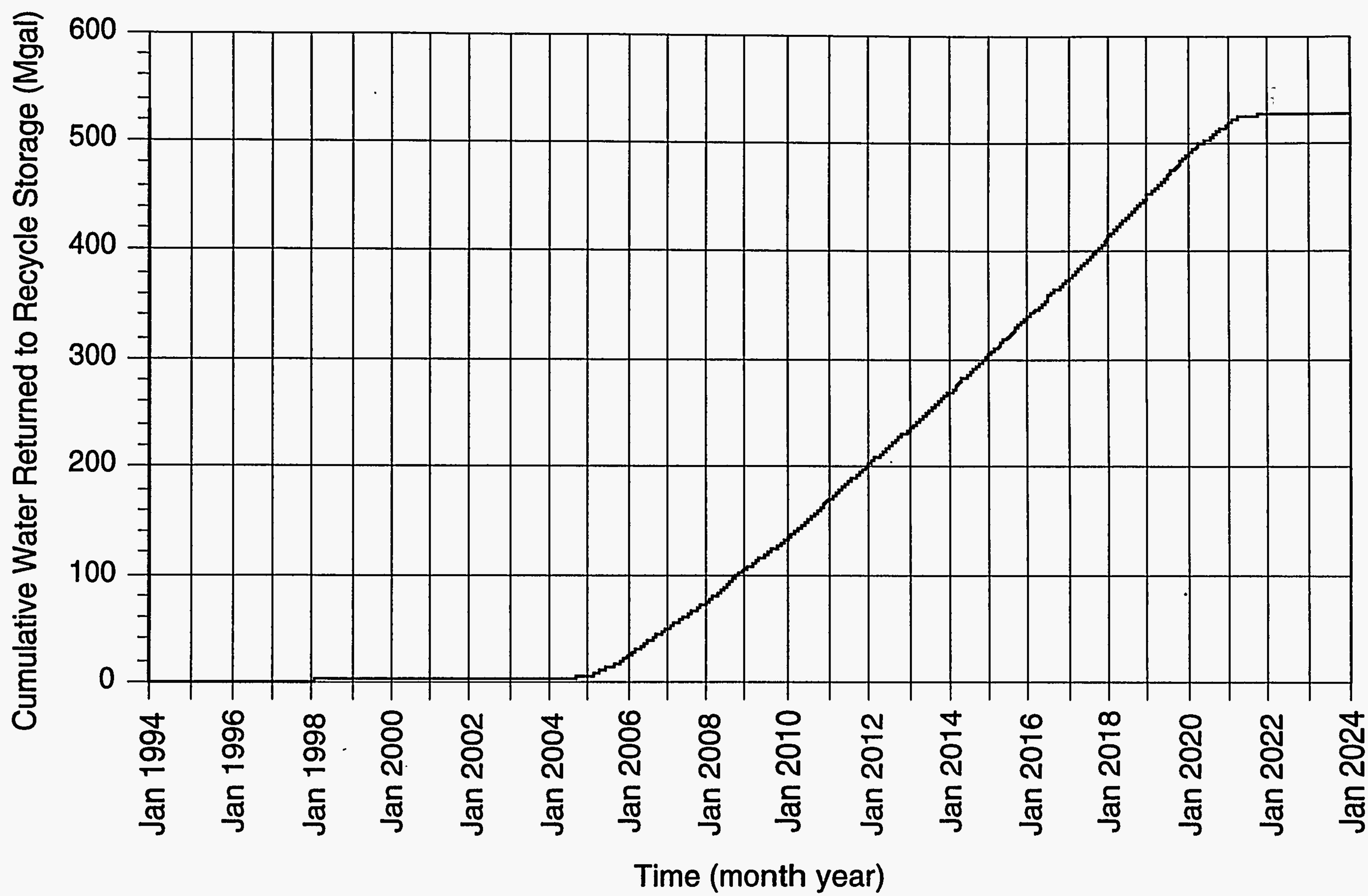

Figure 5-13 Cumulative amount of recycle water returned to the recycle tank vs. time. Some of the same water may be counted multiple times as a result of reuse.

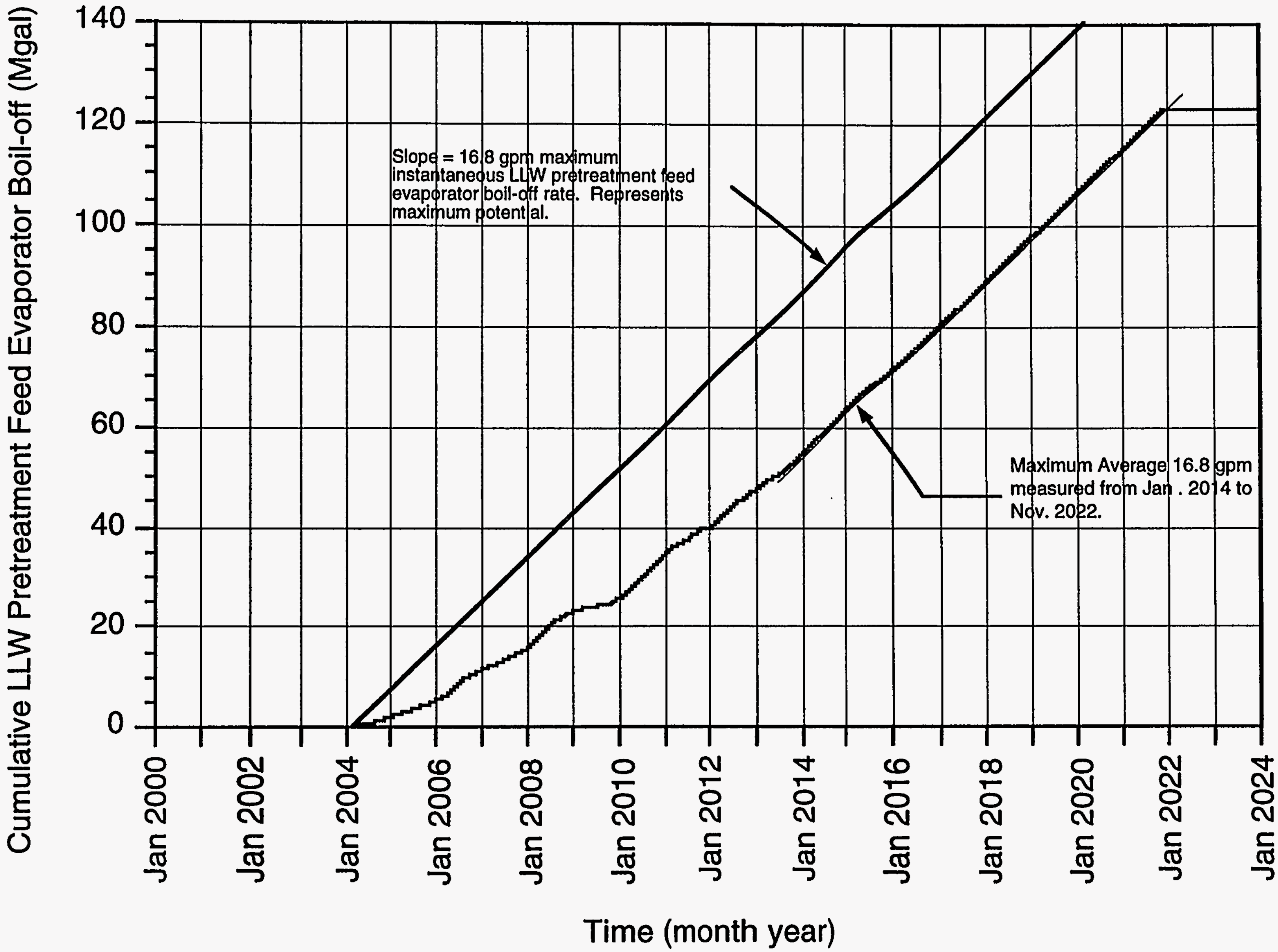

Figure 5-14 Cumulative boil-off of LLW pretreatment feed evaporator for operating case 1. The total amount of condensate matches flowsheet, stream 103 (125.8 Mgal), Orme, 1994.

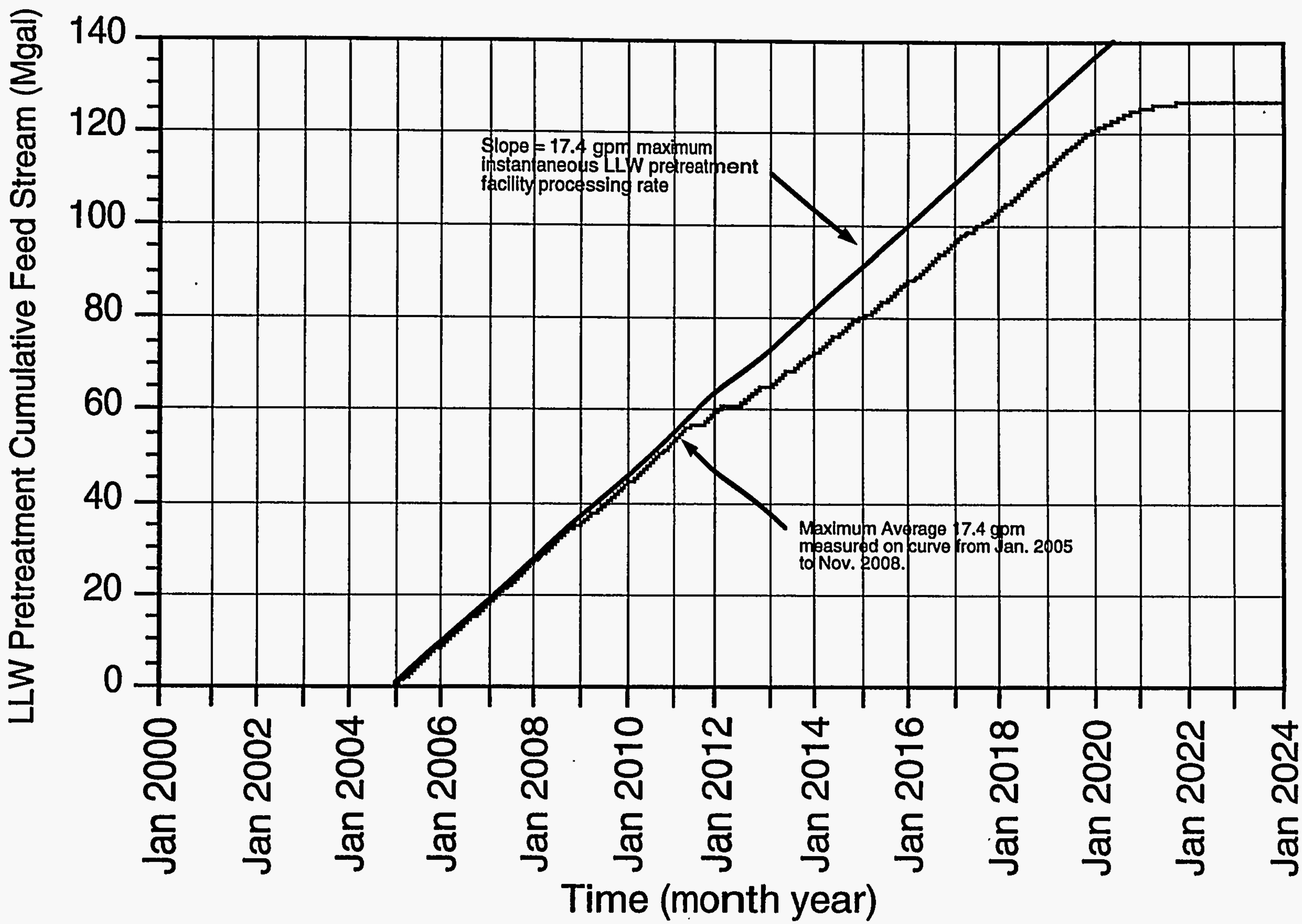

Figure 5-15 Cumulative feed into LLW pretreatment facility. Close-couple shutdowns cause maximum operating potential curve and actual curve to diverge. The total supernatant treated (125.0 Mgal) matches TWRS flowsheet stream 205 (Orme, 1994).

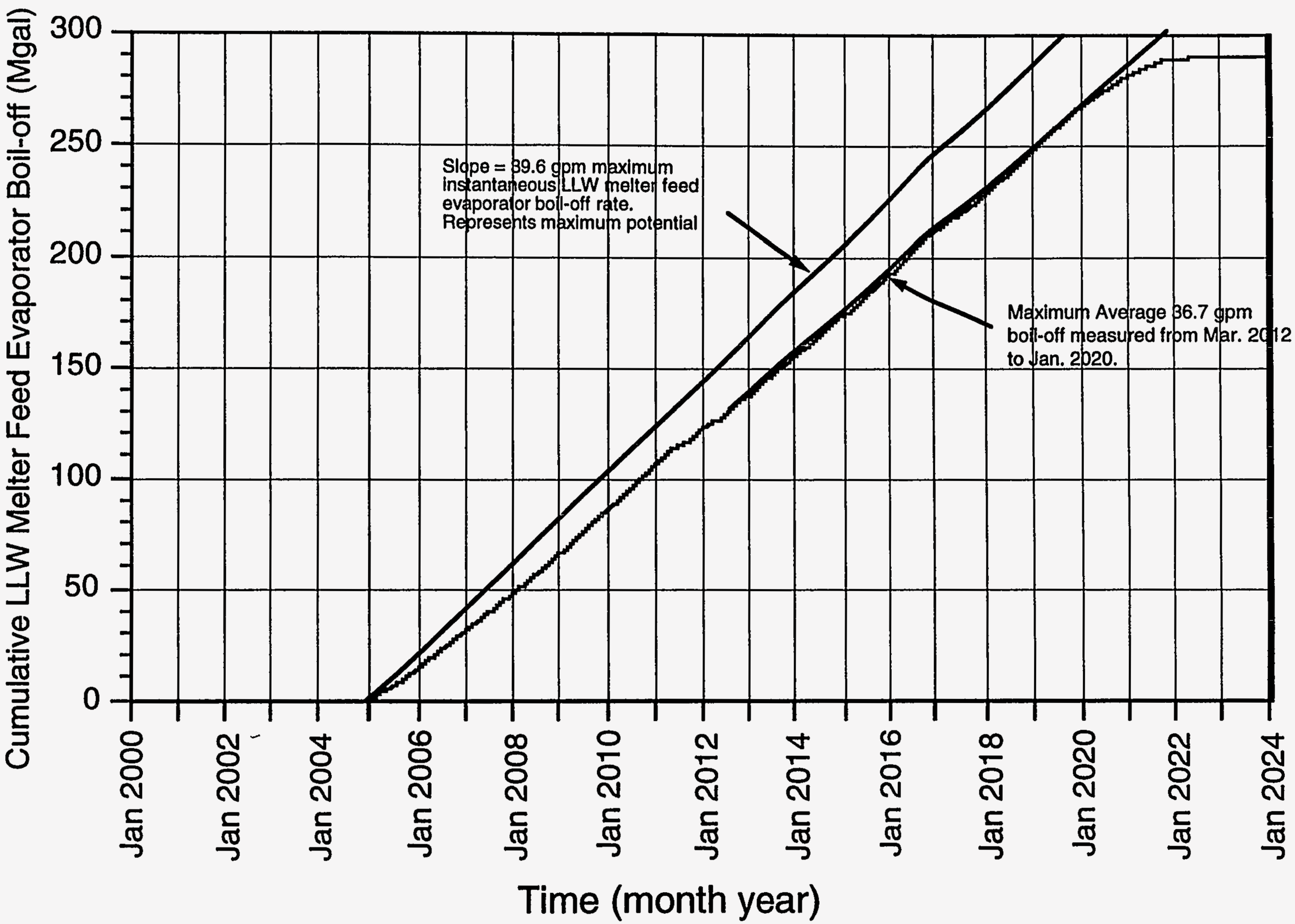

Figure 5-16 Cumulative water evaporated by LLW glass plant feed evaporator. The total condensate (290.6 Mgal) matches the TWRS process flowsheet (Orme, 1994) stream 401.

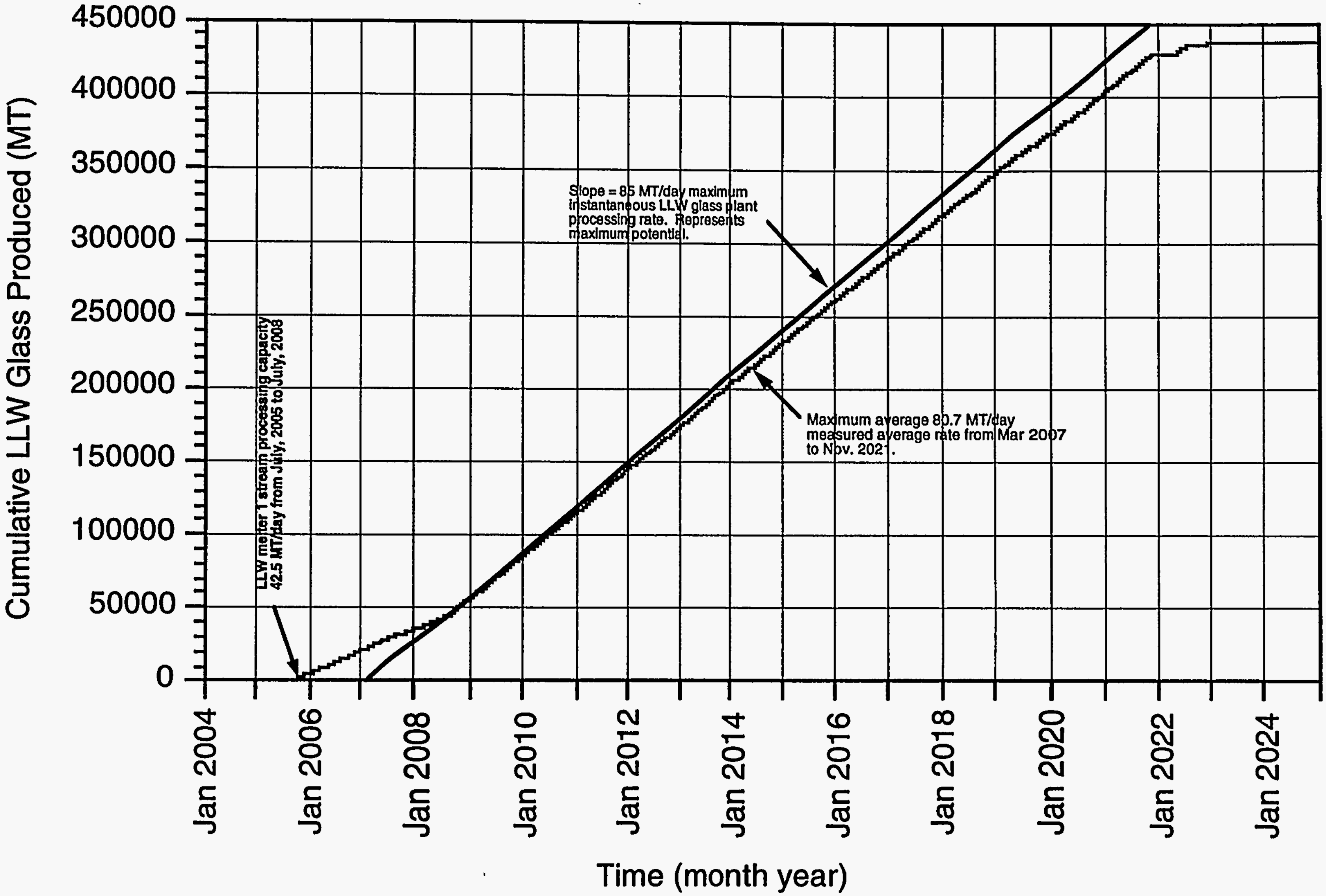

Figure 5-17 Cumulative Production of LLW glass for operating case 1. Completion date approximately Nov., 2022. The model assumes a constant sodium oxide loading of 25 wt% in LLW glass (Orme, 1994).

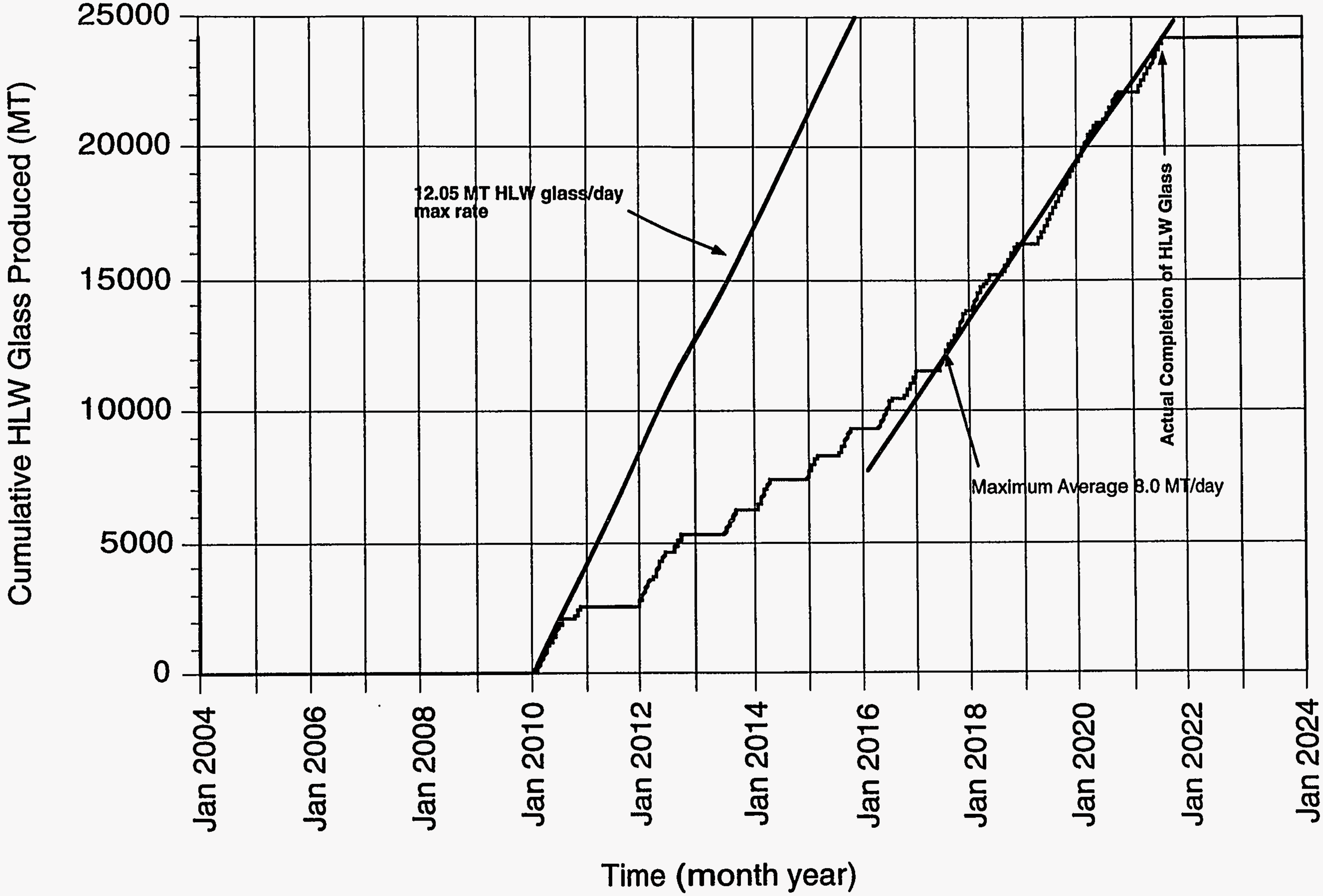

Figure 5-18 Cumulative HLW glass production vs. time. HLW glass completion is estimated by the simulation to occur in June, 2021. A constant 45 wt% waste oxide HLW glass loading is assumed (Orme, 1994).

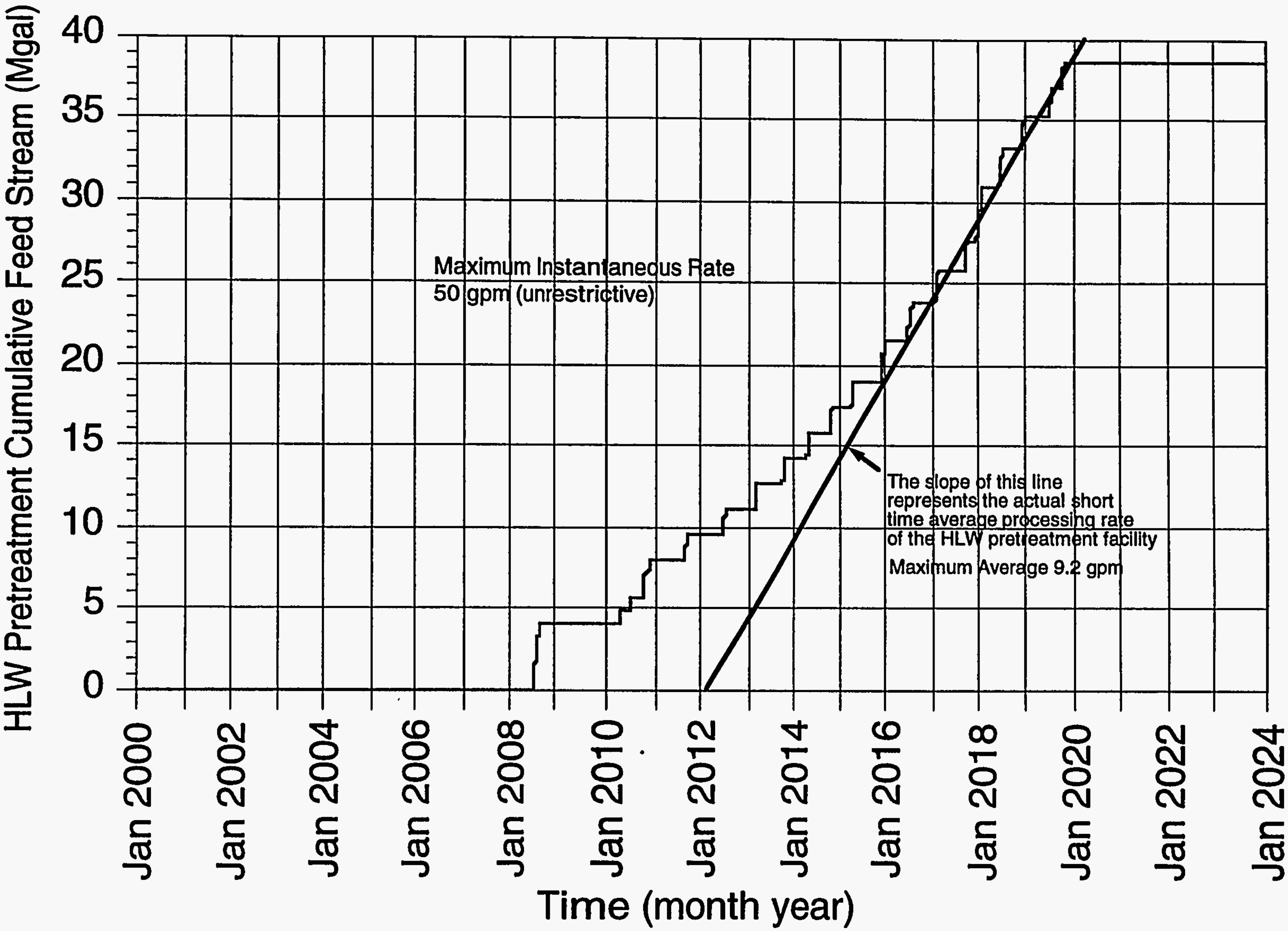

Figure 5-19 Cumulative throughput of feed into HLW pretreatment. The intent here was to set the instantaneous process rate high enough to be unrestrictive to the feed. In this way, the actual necessary instantaneous process rate may be estimated from the model result. The rate is measured to be about 9.2 gpm of HLW sludge/slurry treatment.

5.1.6 HLW Glass Plant Staging Tanks

Figure 5-20 illustrates the waste accumulated in staging tanks feeding into the HLW vitrification facility. The plot has an upward trend to a total of 5 tanks, primarily because of the increasing retrieval rate dictated by the Tri-Party Agreement SST retrieval schedule.

An examination of this plot and the cumulative HLW pretreatment plot reveals that there is no indication of bottlenecks in the HLW processing system, however this conclusion may be dependant upon the final decision on what type of HLW pretreatment is needed after sludge washing.

5.1.7 LLW Facility Percentage of Time Usage

Figures 5-21 through 5-24 give the facility usage fractions or the cumulative fraction of possible operating time the particular facilities are actually operating. The percentage of time that a particular facility is operating during the mission can be estimated from the plots by reading the percent usage value where a sudden decrease occurs toward the end of the mission. This decrease represents the instantaneous usage factor going to zero after the facility is finished processing.

It can be seen from these plots that the model estimates that the LLW processing facilities are busy greater than 90% of the possible processing time after processing begins. The downtimes are because of feed stoppage to the plant resulting from the close-coupled shutdowns.

5.2 OPERATING CASES 2 AND 3

The results of Operating Case 1 were used to initially analyze the dynamics of the system to aid in the design of additional Operating Cases that would provide a successful mission. A successful mission is defined here as one that has minimal bottlenecks resulting in minimal accumulations between facilities and that requires no more tank space than a specified amount (either 6 new tanks or no new tanks). The successful mission should have a minimal number of close couple plant feed shutdowns. Operating Case 2 provides a successful mission assuming the addition of 6 new DSTs and Operating Case 3 provides a successful mission with 0 new DSTs.

The design of a successful mission in this analysis primarily involved increasing particular LLW facility maximum instantaneous waste processing rates above the values used in Operating Case 1. This was expected since Operating Case 1 used the flowsheet mission average rates as the instantaneous maximum process rates. The rate proportions relative to one another also were changed slightly.

It was evident from analysis of Operating Case 1 that some of the bottlenecks were unavoidable because of the Tri-Party Agreement specified facility startup dates. Specifically, LLW pretreatment begins its processing

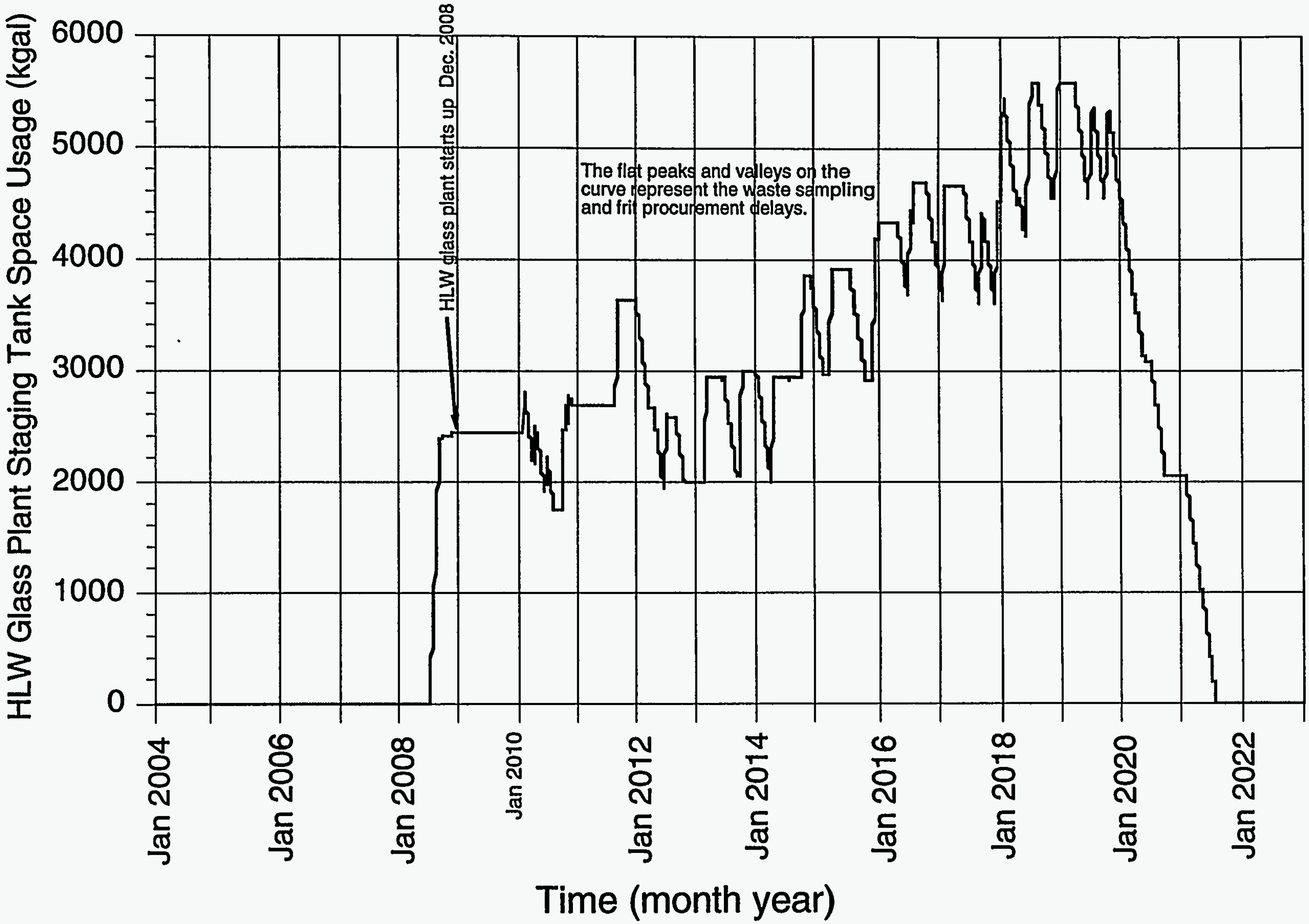

Figure 5-20 Tank Space demand between the HLW pretreatment facility and the HLW glass plant. Note that all HL solid batches entering the staging tanks undergo an 18 month waste sampling and frit procurement delay before vitrification.

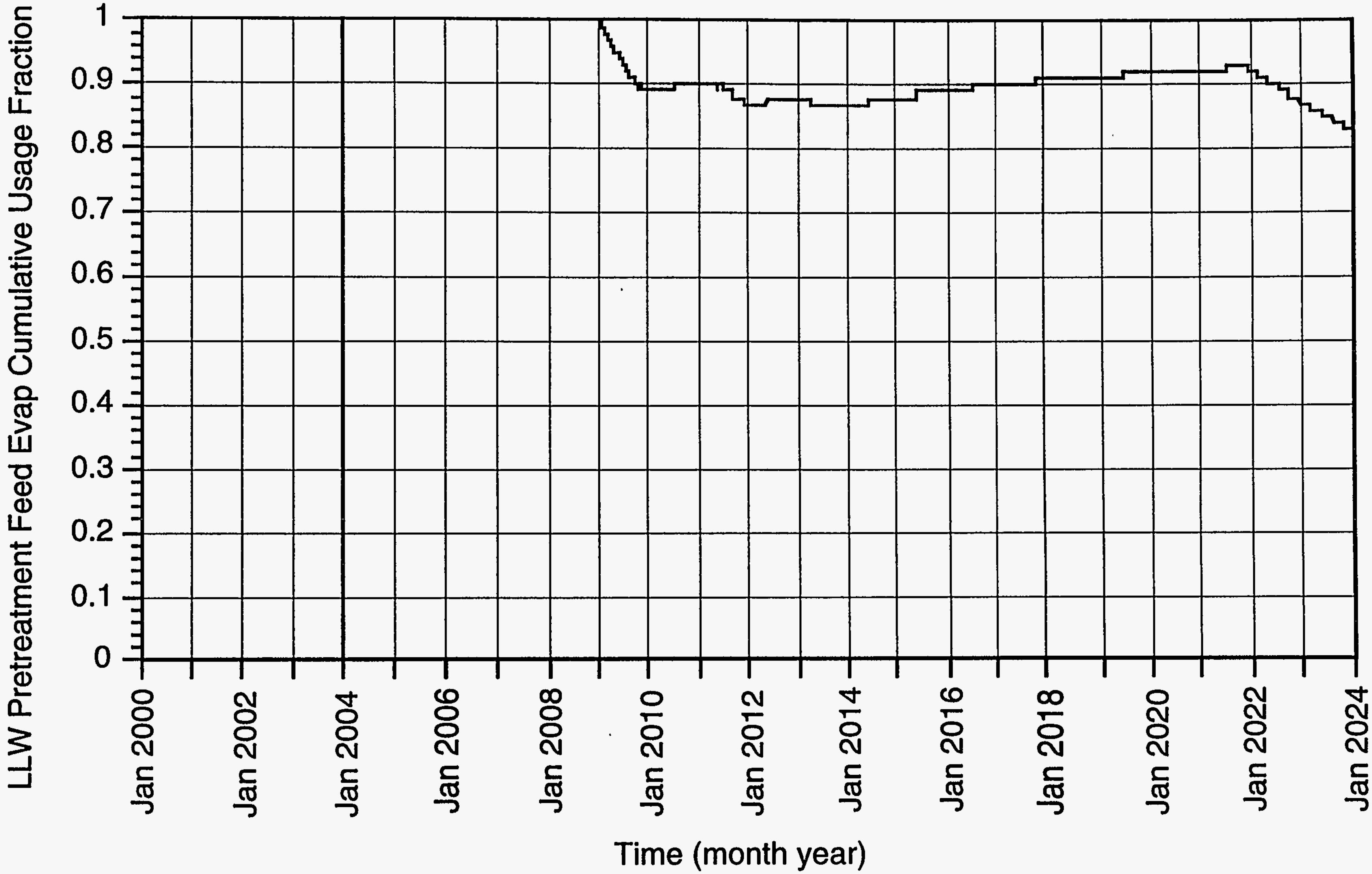

Figure 5-21 Cumulative LLW pretreatment feed evaporator usage fraction vs. time for operating case 1. This curve is representative of the fraction of time the evaporator has been operating relative to the total operation time possible after startup. It does not indicate the fraction of capacity utilized. Value when evaporator has completed processing (before sudden dip) indicates fraction of operating time during the entire processing.period.

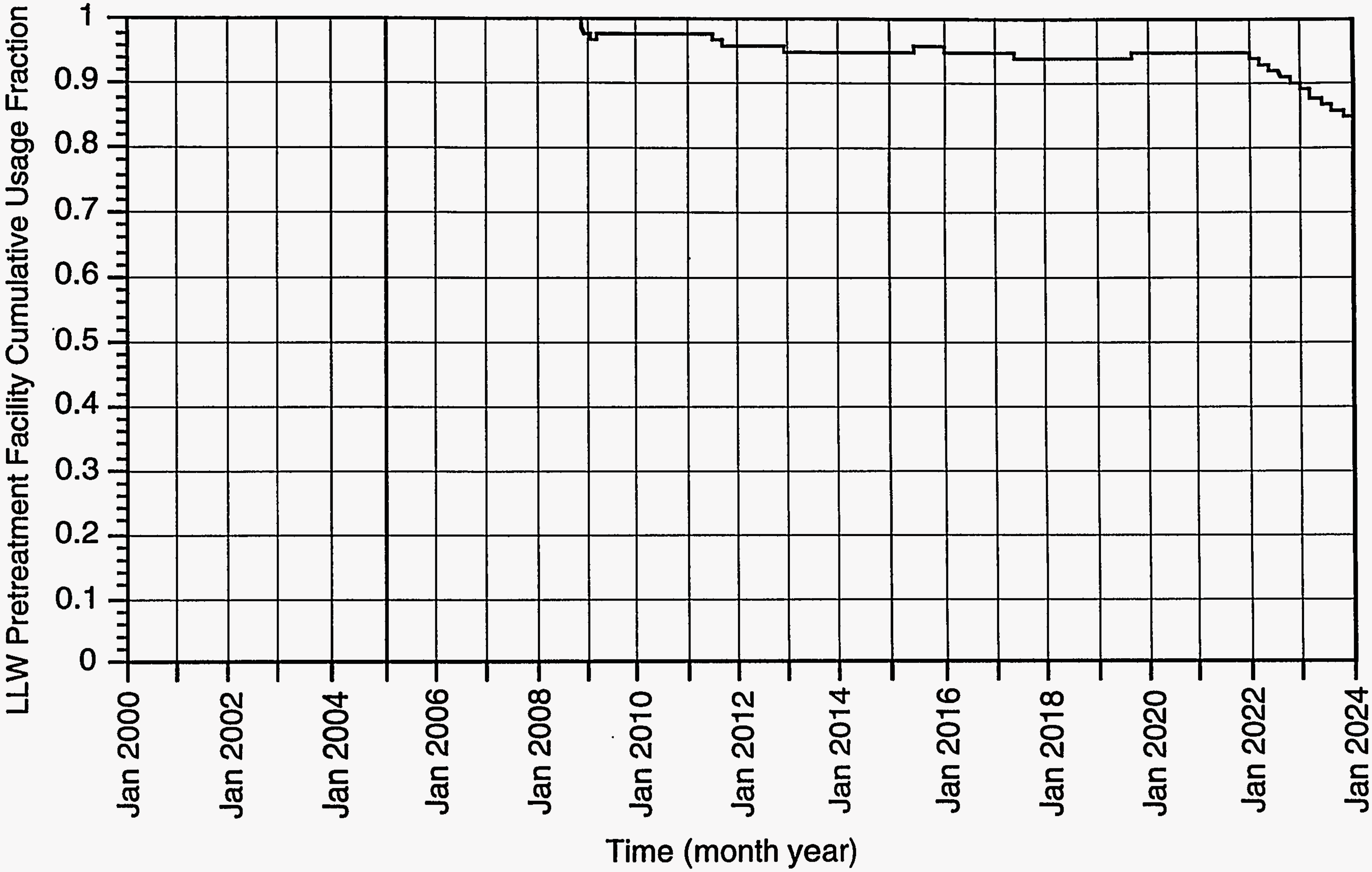

Figure 5-22 Cumulative LLW pretreatment facility usage fraction vs. time for operating case 1. This curve is representative of the fraction of time the facility has been operating relative to the total time possible after startup. It does not indicate the fraction of the total capacity utilized. Value when facility has completed processing (before sudden dip) indicates fraction of operating time during entire processing period.

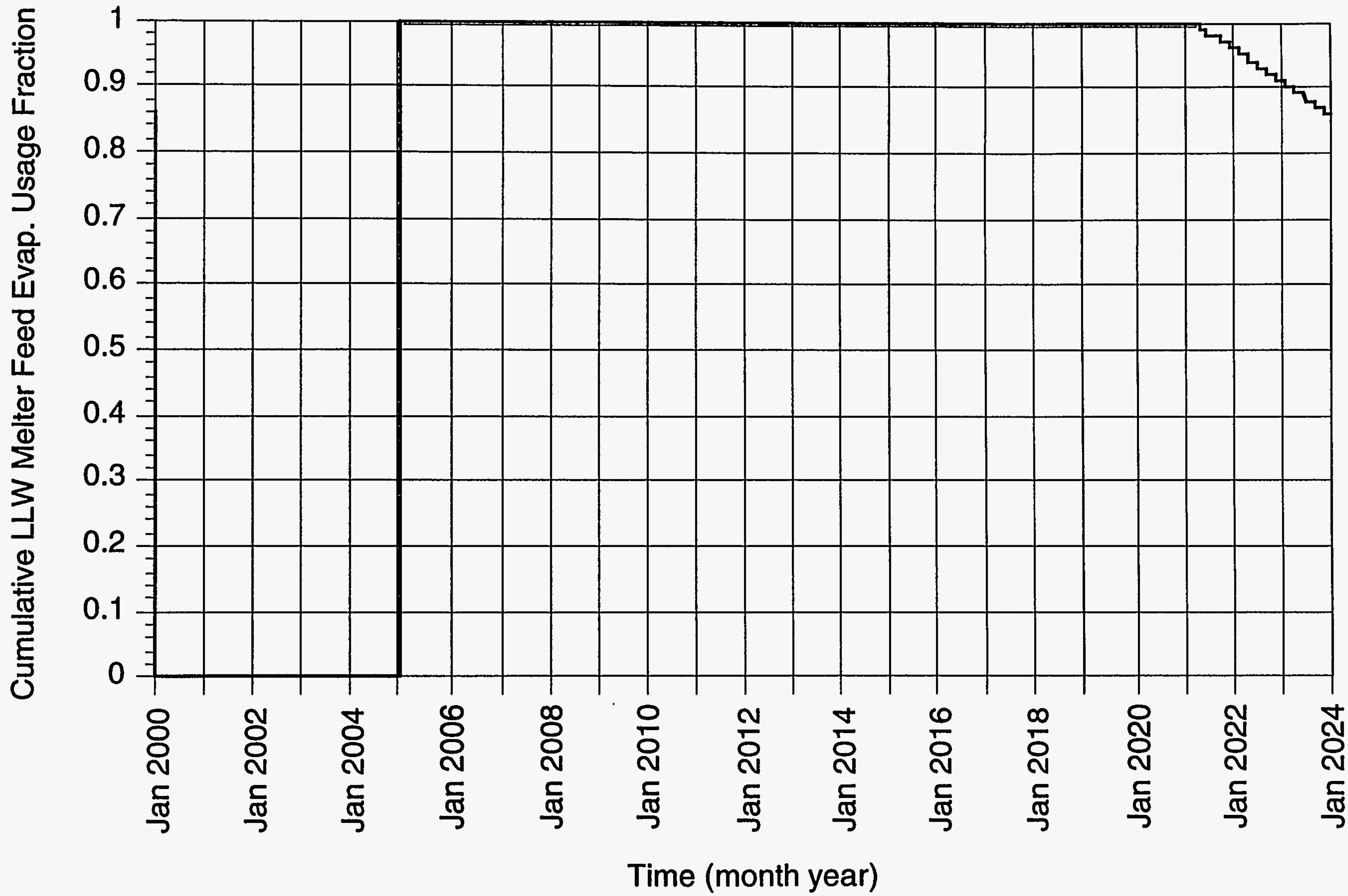

Figure 5-23 Cumulative LLW glass plant feed evaporator usage fraction vs. time for operating case 1. This curve is representative of the fraction of time the evaporator has been operating relative to the total operating time possible after startup. It does not indicate the fraction of total capacity utilized. Graph shows evaporator is busy 99% of the operating period.

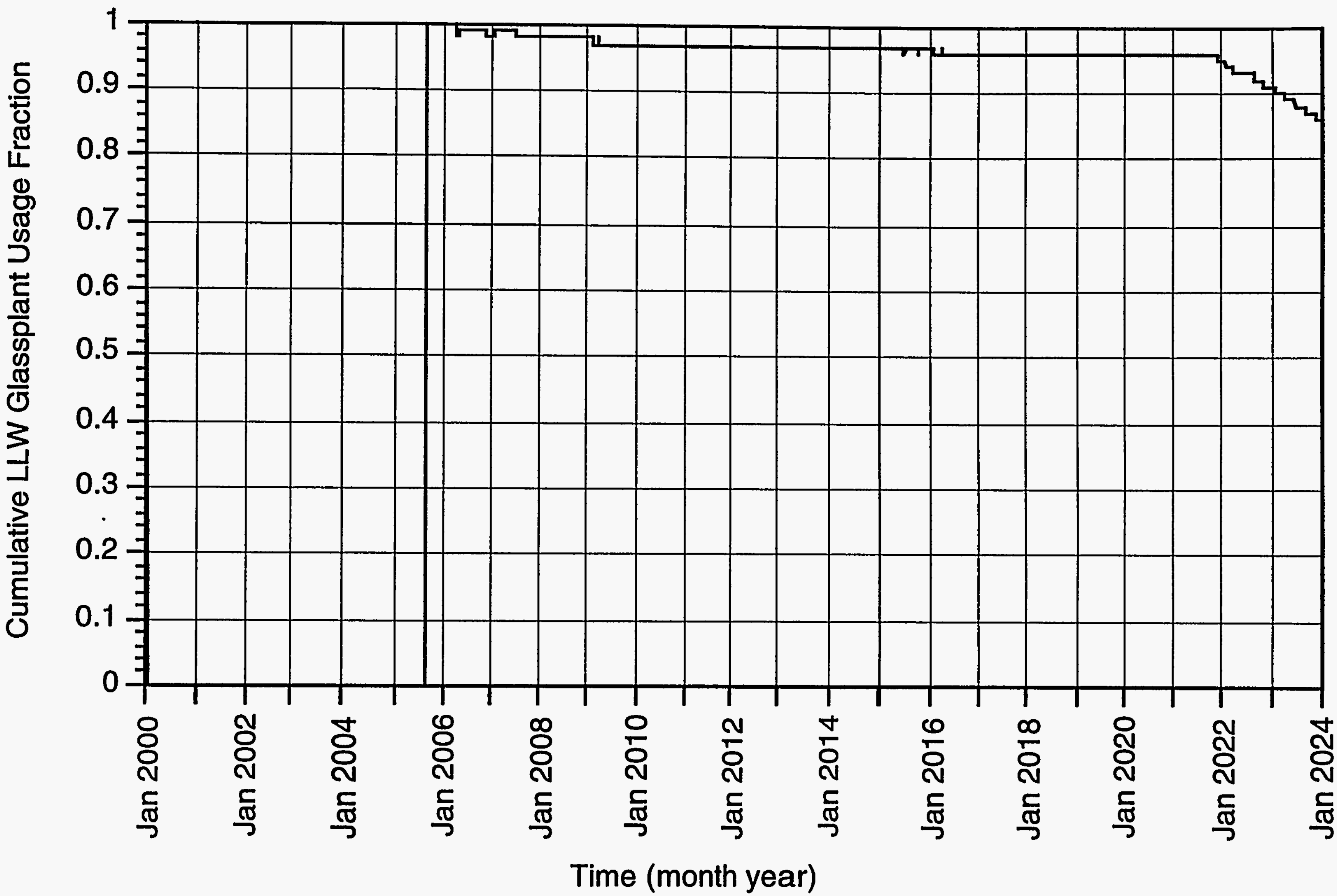

Figure 5-24 Cumulative LLW glass plant usage fraction vs. time for operating case 1. This curve is representative of the fraction of time glass plant has been operating relative to the total time possible after startup.

slightly delayed from when the waste stream initially reaches the facility. Also, the glass plant begins processing at half its full two-line vitrification capacity of 85 MT/day in June of 2005. The glass plant delay causes accumulation in the LLW melter feed tanks until the glass plant begins processing with two vitrification lines in 2008.

Another bottleneck in the system is caused by the LLW pretreatment (Cs IX) feed concentrate evaporator. It has been found to process at an inadequate rate later in the remediation process. The result is a very large accumulation upstream of the evaporator, immediately after the wash solution decant. This bottleneck cannot be worked down completely unless greatly increased facility processing rates are used to reduce this accumulation of waste by moving it through the system at a rapid rate. This is not a desirable solution. However, smaller accumulations that occur as a consequence of the larger bottleneck accumulations may be eliminated by fine adjustment of the relative processing rates.

5.2.1 The Design of Operating Cases 2 and 3

After the dynamics of the system were thoroughly analyzed at the average LLW facility processing rates given by the flowsheet, rates were designed to provide successful missions by minimizing bottlenecks and the resulting accumulations.

Designing for 6 new DSTs (Operating Case 2), the LLW Cs IX feed evaporator maximum instantaneous boil-off rate was increased from 16.8 to 18.8 gpm (28 gpm to 31.3 gpm inflated for 60% TOE), a 12% increase relative to Operating Case 1. This reduced the peak accumulation in the Cs IX feed evaporator feed tanks from 29.7 Mgal to 22.6 Mgal. This reduction is illustrated in Figure 5-25. From Operating Case 1, it was evident the pretreatment facility rate was fairly well matched to the pretreatment feed evaporator output rate. Therefore, the instantaneous maximum pretreatment rate was increased by the same proportion as the LLW pretreatment feed evaporator from 17.4 to 19.5 gpm (29 gpm to 32.5 gpm inflated for 60% TOE), a 12% increase. Finally, the LLW melter feed evaporator maximum instantaneous rate was increased to 44.5 gpm from 39.6 gpm (74.2 gpm from 66 gpm inflated for 60% TOE), and the LLW glass plant maximum capacity was increased from 85 MT/day to 95.5 MT/day (142 MT/day to 159 MT/day inflated for 60% TOE). Both have about a 12% increase from Operating Case 1 values. These rate increases reduced the duration of the feed stoppage (decreased lag storage accumulation immediately upstream of pretreatment) caused by the one stream processing of the LLW glass plant. Additionally, they reduced the accumulation caused by the peak SST retrieval rates lasting from 2016 to 2018. This is illustrated in Figures 5-25 through 5-29.

Operating Case 2 resulted in a peak overall tank space usage (not counting reserve tanks) of 35.8 Mgal. Six new 1.14 Mgal DSTs can provide the required space. This is illustrated in Figures 5-30 and 5-31. This

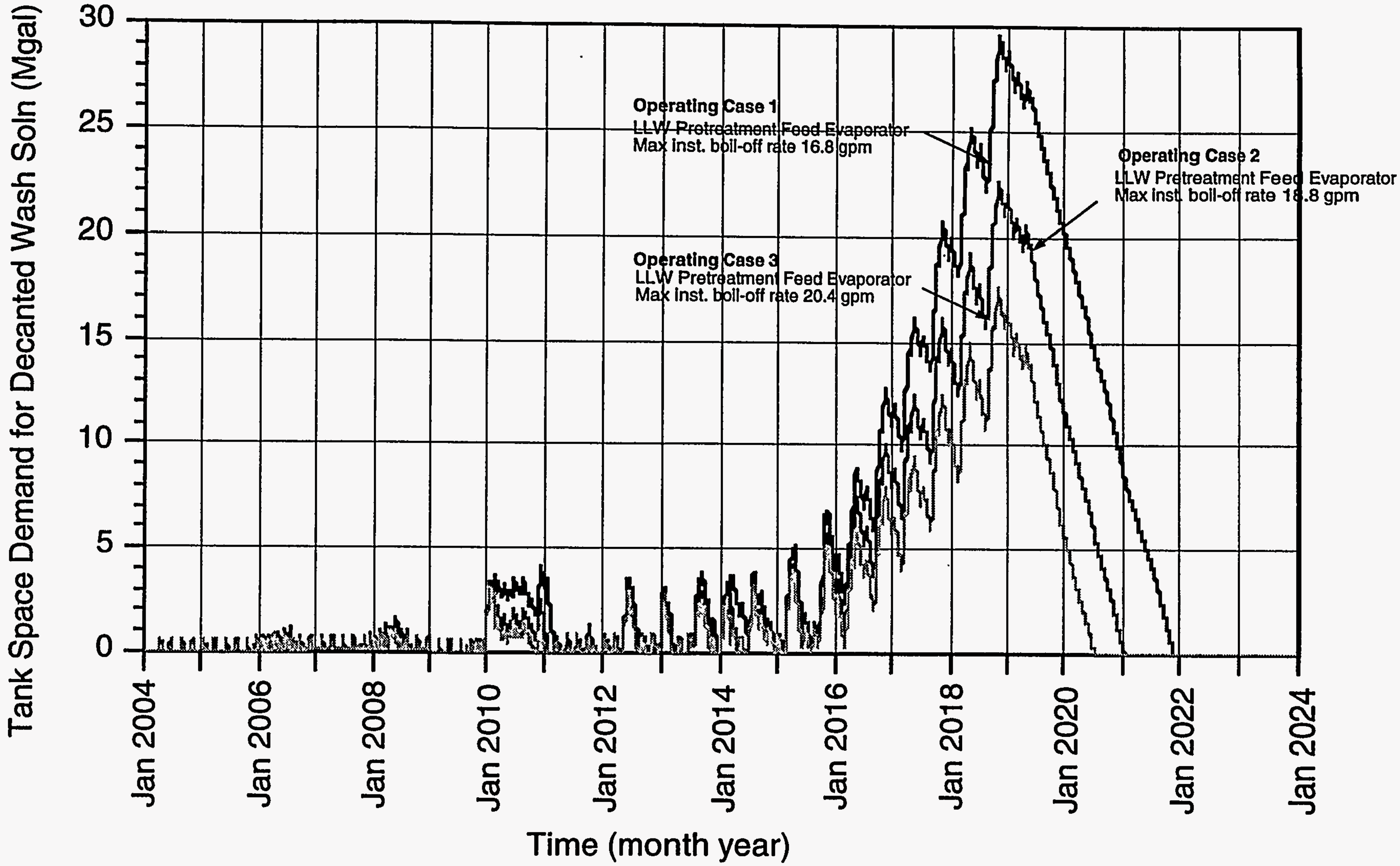

Figure 5-25 Accumulation of wash decant solution directly downstream of wash for operating case 3 (lowest curve), operating case 2 (middle) and operating case 1 (highest curve). Note the sensitivity of the bottleneck severity to the evaporator boil-off rate. This plot represents the aggregate accumulation of caustic and water wash decants, retrieval and settling water decants, and recycle from the HLW melter to subsequently feed into the LLW pretreatment feed evaporator.

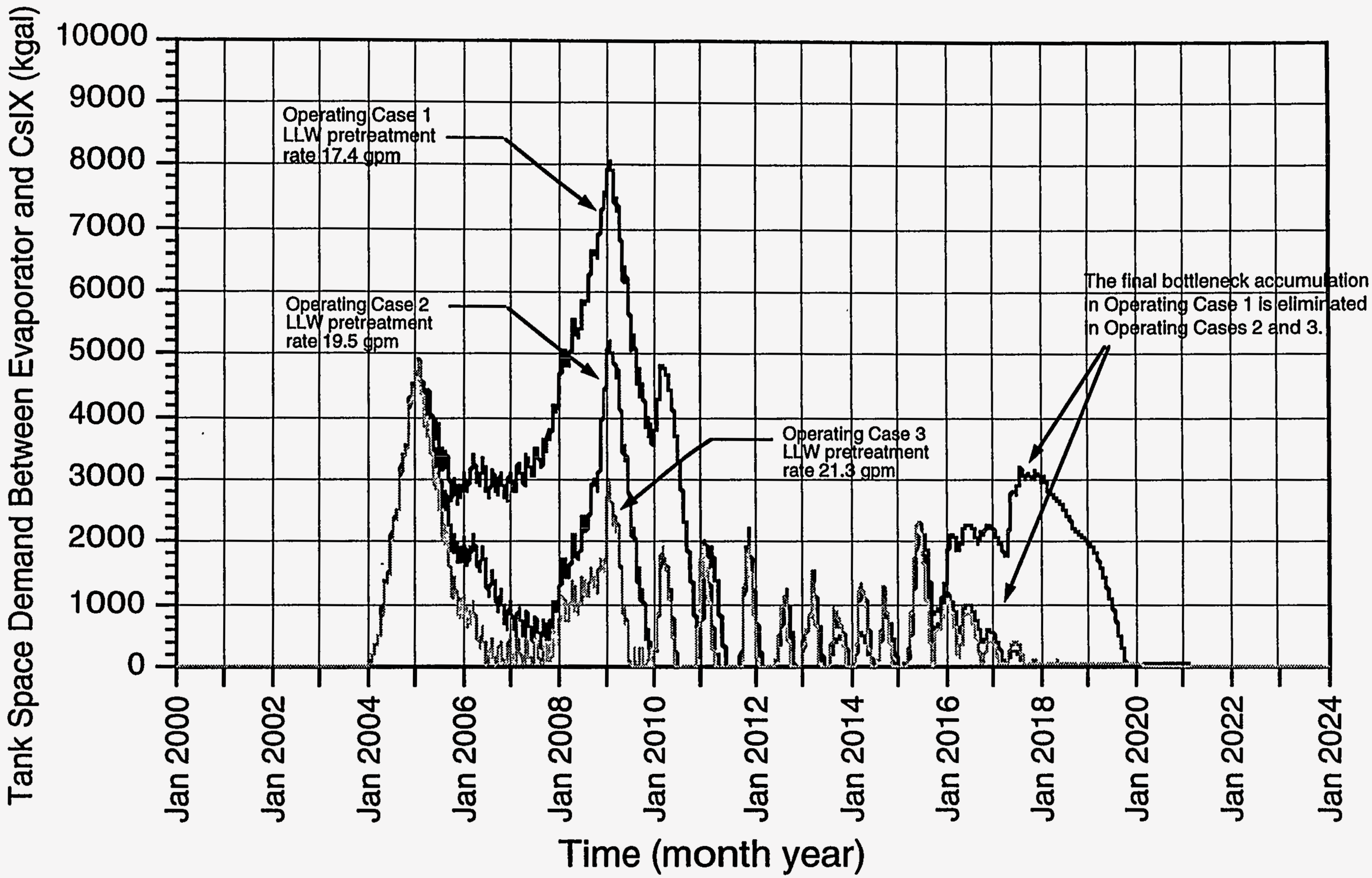

Figure 5-26 Tank space demand between LLW pretreatment feed evaporator (7 M Na output) and the CsIX for the operating case 3 (lowest curve), operating case 2, and operating case 1 (upper curve). The second accumulation was reduced by the increased LLW pretreatment and LLW glass plant rates.

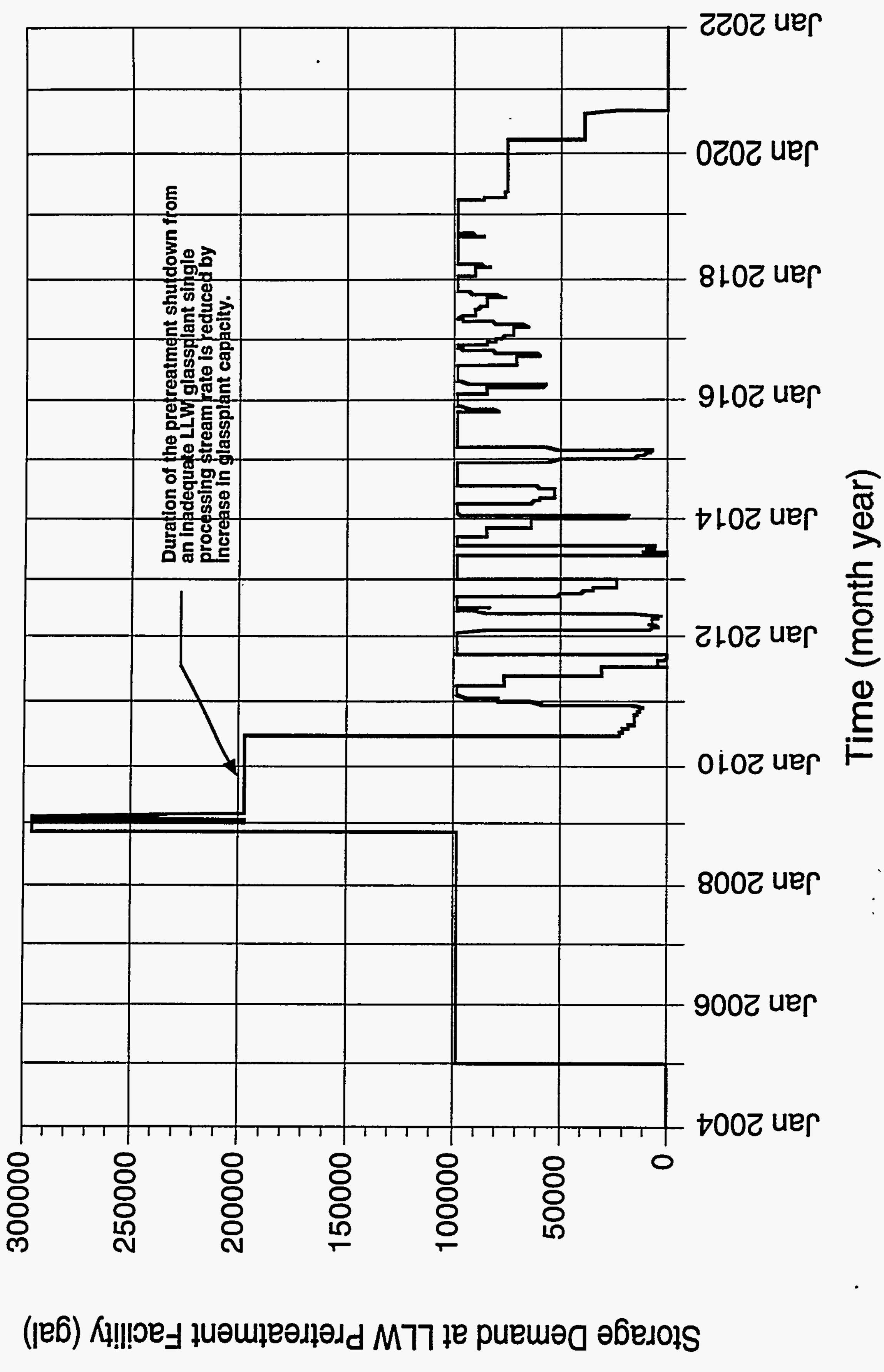

Figure 5-27 Storage demand at the LLW pretreatment facility for operating case 3. Compare to figure 5-5 representing operating case 1.

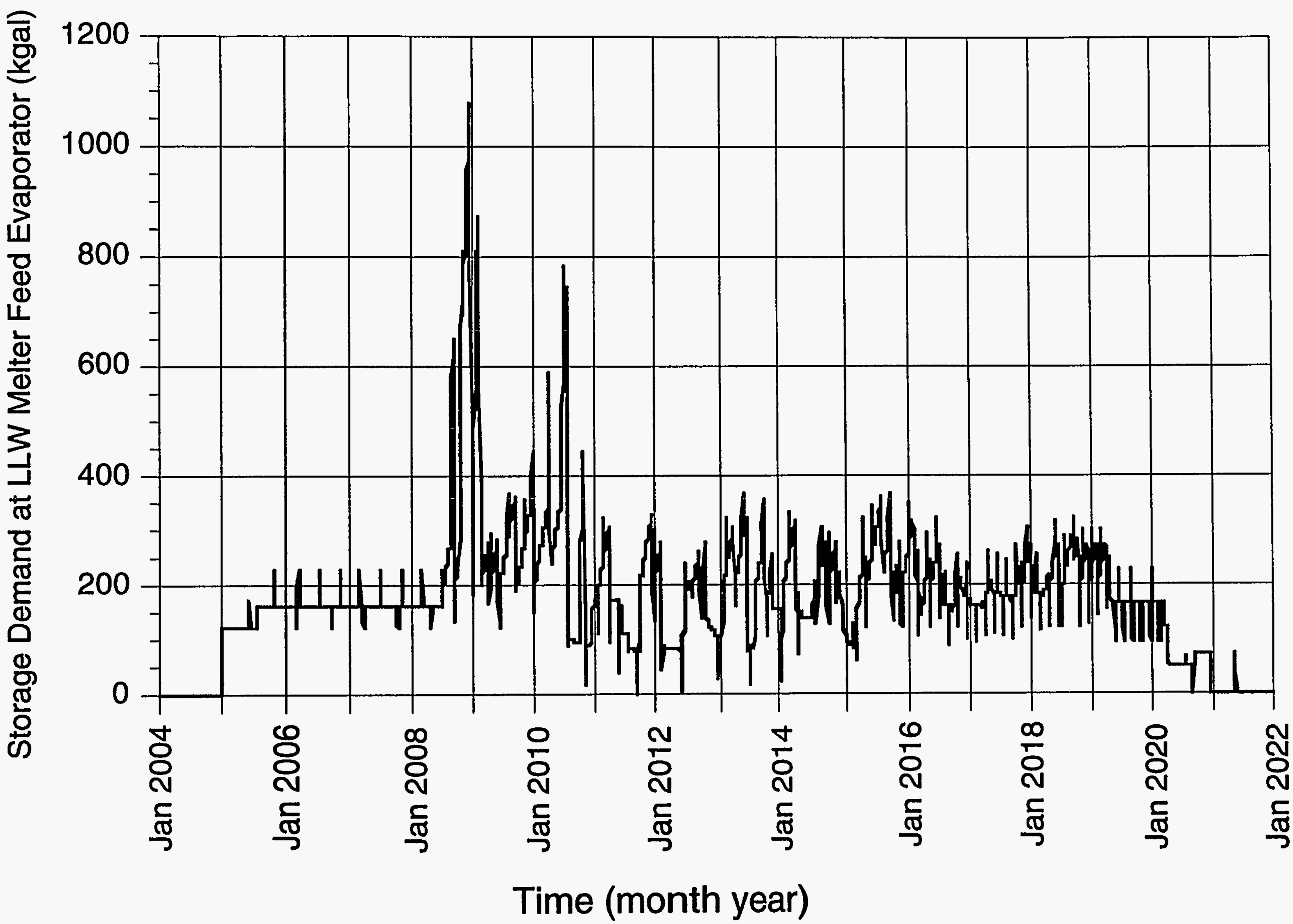

Figure 5-28 Storage demand at the LLW glass plant feed evaporator for operating case 3. A comparison with figure 5-6 shows a significant decrease in the number of close-couple shutdowns after 2012.

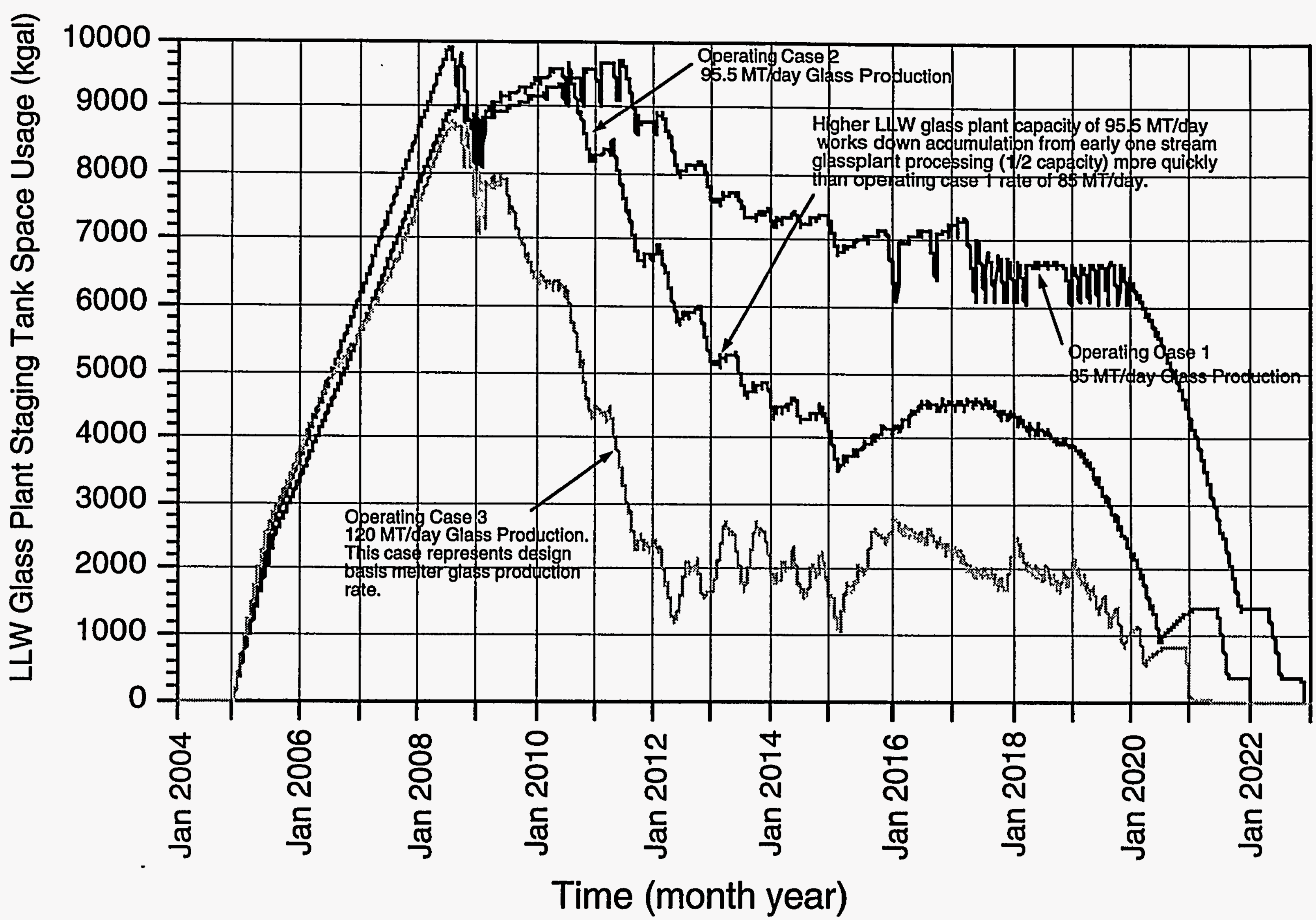

Figure 5-29 LLW melter staging tanks for Operating Case 1,2, and 3 . Note that Operating Case 2 uses 9 instead of 8 staging tanks, however the backlog is worked off much sooner in Operating Cases 2 and 3 than Operating Case 1.

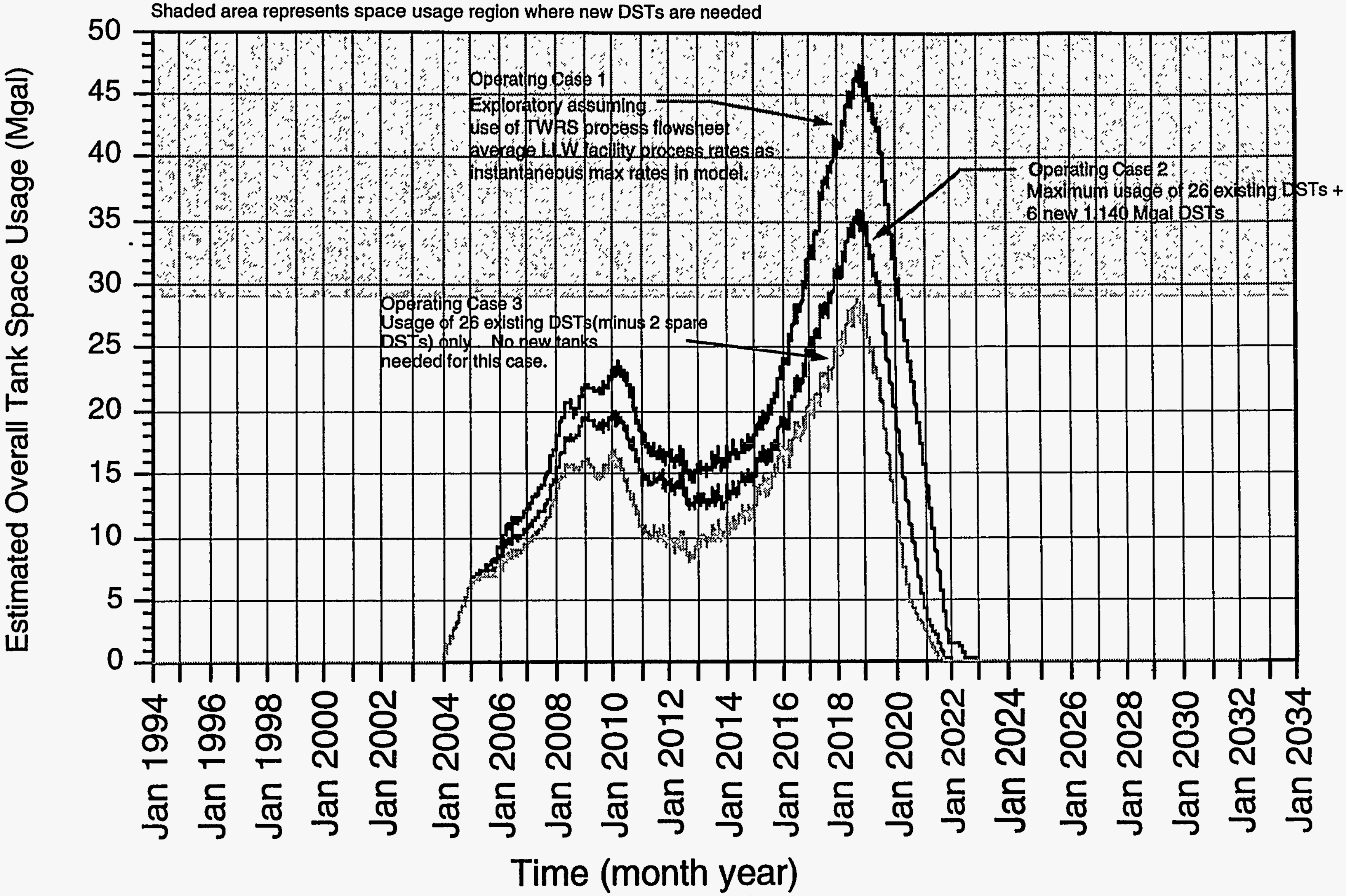

Figure 5-30 Estimate of overall tank space utilization for operating case 3 (lowest curve), operating case 2, and operating case 1(upper curve). Maximum estimated utilization of 28.8 and 35.8 million gallons occur in 2018 for operating case 3 and operating case 2 respectively.

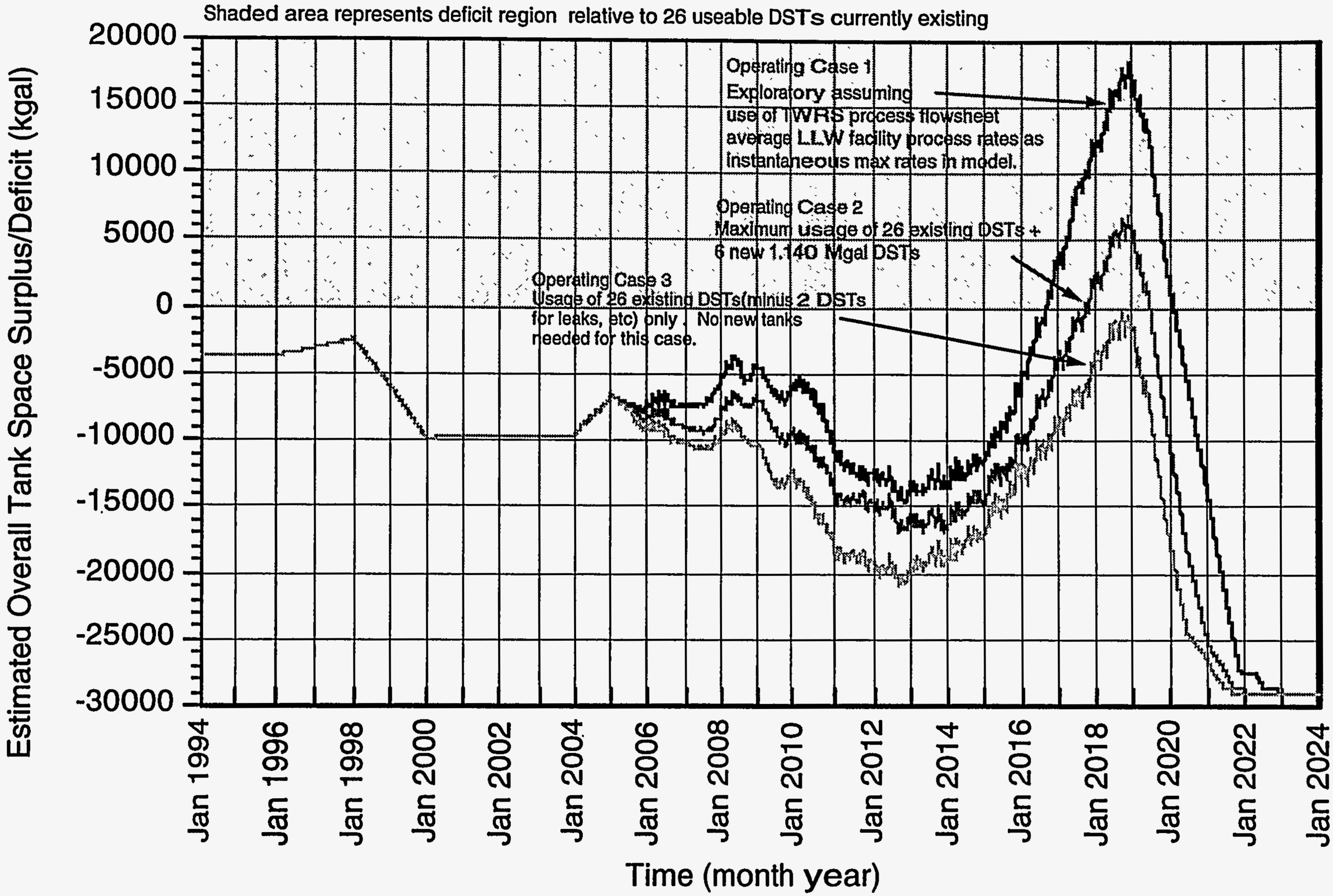

Figure 5-31 Total estimated tank space deficit using curves in figures 5-30 and 5-9 for operating case 3 (lowest curve),operating case 2, and operating case 1 (upper curve). Negative values denote surplus, positive denote deficit. Operating case 3 and operating case 2 had peak space surplus/deficits of 200 kgal surplus and 6800 kgal deficit respectively assuming 26 DSTs for available storage space (28 minus 2 spare DSTs; 29 Mgal total). All curves on this plot are adjusted to be relative to 26 DSTs maximum available tank space.

significant decrease in overall tank usage is a direct consequence of reducing the severity of each specific bottleneck.

Operating Case 3 was designed by increasing the Operating Case 1 maximum instantaneous processing rates enough to reduce the peak total tank usage estimate by about 7 Mgal over Operating Case 2. This was accomplished by raising the maximum instantaneous LLW pretreatment feed evaporator boil-off rate to 20.4 gpm (34.0 gpm for 60% TOE, a 21.4% increase over the Operating Case 1 rate and a 8.5% increase over Operating Case 2). The maximum instantaneous pretreatment (Cs IX) processing rate was increased to 21.3 gpm (35.5 gpm for 60% TOE), a 22.4% increase over Operating Case 1, and a 9.2% increase over Operating Case 2. The maximum instantaneous LLW melter feed evaporator boil-off rate was increased to 50 gpm (83.3 gpm for 60% TOE), a 26.3% increase over Operating Case 1, and a 12.4% increase over Operating Case 2. The maximum LLW glass plant capacity (two stream) was increased to 120 MT/day (200 MT/day for 60% TOE), a 41.2% increase over Operating Case 1, and a 25.7% increase over Operating Case 2. Numerical results from Operating Cases 1, 2 and 3 are summarized in Table 5-1.

Table 5-1. Calculational Results from Operating Cases 1, 2 and 3. (2 Sheets)

Parameter Estimated	Operating Case 1	Operating Case 2	Operating Case 3
Completion for LLW Glass Vitrification (year)	Nov 2022	Jan 2022♠	Jan 2022♠
Completion for HLW Glass Vitrification (year)	Jun 2021	Sept 2021	Sept 2021
LLW Pretreatment Facility Maximum Average Rate (Measured by slope of line fitted at the visual maximum slope of the cumulative waste throughput, see section 4.2.1) Mlit/year, (lit/min in parenthesis), percentage of maximum instantaneous	34.6 (65.9) 100%	38.8 (73.8) 100%	40.8 (77.6) 96%
LLW Pretreatment Feed Evaporator Maximum Average Boil-off Rate Mlit/year, (lit/min), percentage of maximum instantaneous	33.4 (63.6) 100%	37.4 (71.2) 100%	40.4 (76.8) 100%
LLW Glass Plant Feed Evaporator Maximum Average Boil-off Rate Mlit/year, (lit/min), percentage of maximum instantaneous	73.0 (138.9) 93%	82.8 (157.5) 93%	94.5 (179.8) 95%

Table 5-1. Calculational Results from Operating Cases 1, 2 and 3. (2 Sheets)

Parameter Estimated	Operating Case 1	Operating Case 2	Operating Case 3
LLW Glass Plant Maximum Average Glass Production Rate MT/year, (MT/day), percentage of maximum instantaneous	29500 (80.7) 95%	47000 (89.4) 94%	39400 (108.0) 90%
HLW Pretreatment Facility Maximum Average Feed Rate Mlit/year, (lit/min), percentage of maximum instantaneous	18.3 (34.8) 18.4%	18.3 (34.8) 61%	18.3 (34.8) 61%
HLW Glass Plant Maximum Average Glass Production Rate MT/year, (MT/day), percentage of maximum instantaneous	2920 8.0 66.7%	2920 8.0 66.7%	2920 8.0 66.7%
Peak Overall Tank Space Required Estimate (Mgal)@time	47.3 Oct 2018	35.8 Oct 2018	28.8 Aug 2018
Tank Space Deficit/Surplus Estimate* (Mgal)@time	18.3 Oct 2018	6.8 Oct 2018	-0.2 Aug 2018
Peak Wash Tank Usage (from DST retrieval) (Mgal)@time***	2.1 Mar 2010	2.1 Mar 2010	2.1 Mar 2010
Peak Wash Tank Usage (from SST retrieval) (Mgal)@time***	5.0 Nov 2018	5.0 Nov 2018	5.0 Nov 2018
Peak Lag Storage Tank Usage (after wash directly before LLW pretreatment feed evap.) (Mgal)@time	29.7 Oct 2018	22.7 Oct 2018	17.5 Oct 2018
Peak Lag Storage Tank Usage (after pretreatment feed evaporator before pretreatment) (Mgal)@time	8.1 Feb 2009	5.2 Feb 2009	4.9 Jul 2005
Total Consumed Fresh Water (Mgal)	6.3	0	0
Total Recycle Water (Mgal)**	527	527	527
HLW Pretreatment Usage Factor (% of time operating)♣	16	44	44
HLW Glass Plant Usage Factor (% of time operating)♣	49	49	49
LLW Glass Plant Usage Factor (% of time operating)♣	96	93	82
LLW Pretreatment Plant Usage Factor (% of time operating)♣	95	93	91
LLW Pretreatment Feed Evaporator Usage Factor (% of time operating)♣	93	89	86

Table 5-1. Calculational Results from Operating Cases 1, 2 and 3. (2 Sheets)

Parameter Estimated	Operating Case 1	Operating Case 2	Operating Case 3
LLW Melter Feed Evaporator Usage Factor (% of time operating)♣	99.7	99.5	99.1

* - Deficit positive, surplus negative. Deficit/surplus calculation made with respect to 26 existing DSTs (28 DSTs minus 2 reserve DSTs; 29 Mgal) available maximum.
** - Total cumulative recycle water entering recycle tank. Some of it is counted multiple times.
*** - does not include initial wash (storage from retrieval)
♣ - This number does not include facility downtime except for no-feed available downtime.
♠ - End times for LLW vitrification in Operating Cases 2 and 3 are representative of when the vitrification of the HLW offgas recycle streams is completed. The actual end time for vitrification of the main LLW waste stream is somewhat earlier for Operating Cases 2 and 3. (ie. the LLW glass plant remains operating after the main waste stream to exclusively vitrify the HLW melter offgas recycle stream)

6.0 CONCLUSIONS

The main objective of this analysis was to determine LLW and HLW pretreatment and glass plant facility processing rates that are matched to avoid degraded process system performance, excessive system bottlenecks, and to minimize the need for additional waste storage at TWRS processing facilities. The main source of data used when implementing the model was the *TWRS Process Flowsheet* (Orme 1994). Also, an SST retrieval rate schedule based on the Tri-Party Agreement was assumed, with no stoppage of retrieval activities, beginning January 2004 and completing September 2018. Facility start dates were assumed as given by the Tri-Party Agreement.

It may be noted that the simulation does not explicitly model facility downtimes because of maintenance, inspections, etc. It is assumed that, if desired, an appropriate factor (typically 60%) can be applied to the simulation's flowrates to account for these activities. The simulation does, however, explicitly model facility downtime caused by no-feed-available conditions, thus providing a means to estimate no-feed efficiency values.

The main conclusions of the analysis are as follows:

<u>Operating Cases</u>

- **Operating Case 1 (Exploratory Analysis)** - For Operating Case 1, the simulation used instantaneous maximum facility waste processing rate values equal to the average facility processing rates suggested by the *TWRS Process Flowsheet* (Orme 1994). These rates were: 16.8 gal/min (28 gal/min necessary with 60% TOE applied) for the LLW pretreatment evaporator immediately after the wash; 17.4 gal/min (29 gal/min with 60% TOE applied) for the Cs IX; 39.6 gal/min (66 gal/min with 60% TOE applied) for the LLW feed concentrate evaporator after pretreatment; 85 MT/day (142 MT/day with 60% TOE applied) of LLW glass production, and 12 MT/day (20 MT/day with 60% TOE applied) for the HLW glass plant. A maximum instantaneous rate of 50 gal/min was selected for the HLW pretreatment/evaporator (83.3 gal/min with 60% TOE applied) because no suggested rate was found for this facility (the 50 gal/min rate was selected simply to be nonconstraining).

  The assumed facility instantaneous processing rates specified above resulted in an excessive need for waste storage (approximately 18 Mgal above the peak 29 Mgal storage space available [28 DSTs minus 2 DSTs in reserve]). This deficit occurs during the period of maximum SST retrieval and subsequent wash operations in the year 2018 to 2019. The deficit occurs because of the large volume of wash supernatant sent to the LLW pretreatment evaporator, resulting in a large requirement for feed tank storage immediately upstream of the evaporator. The average LLW facility processing rates were originally calculated assuming a constant waste feed to the respective facilities over a period of 14 years. The Tri-Party Agreement retrieval schedule and overall system dynamics result in nonconstant feed and processing demand. Consequently, it was not expected that these rates would represent adequate instantaneous maximum processing rates necessary to complete the mission without bottlenecks and subsequent increases in storage need. These rates were used only as a starting point to gain insight into the dynamics of the system and to analyze rates relatively.

- **Operating Case 2 (6 new DSTs needed)** - The simulation was used next to estimate maximum instantaneous LLW facility processing rates necessary to complete the TWRS mission per the Tri-Party Agreement milestones, with approximately 6 new DSTs required in addition to the existing 28 DSTs (35.8 Mgal total storage potentially available). Again, all simulation parameters were set at documented baseline values (i.e., the simulation's resulting total processing stream volumes match closely with those of the *TWRS Process Flowsheet*, sodium molarities are equal, etc.), and the simulation used the Tri-Party Agreement SST retrieval schedule and facility start dates.

  A successful mission was achieved using LLW facility maximum instantaneous processing rates with a 12% average increase over the *TWRS Process Flowsheet* average processing rates. These increased rates were: 18.8 gpm boil-off (31.3 gpm necessary with 60% TOE applied) for the LLW pretreatment feed (supernatant) evaporator immediately downstream of the wash; 19.5 gpm (32.5 gal/min necessary with 60% TOE applied) for the LLW pretreatment (Cs IX); 44.5 gpm (74.2 gpm necessary with 60% TOE applied) boil-off for the LLW melter feed evaporator; and 95.5 MT/day (159 MT/day necessary with 60% TOE applied) for the LLW glass plant two stream capacity. The HLW pretreatment facility maximum instantaneous processing rate was reduced to 15 gpm.

- **Operating Case 3 (No new DSTs needed)** - Finally, the simulation was used to estimate maximum instantaneous LLW facility processing rates necessary to complete the TWRS mission per the Tri-Party Agreement milestones, with no new DSTs required (29 Mgal of storage space potentially available). Simulation parameters were set at documented baseline values, and the Tri-Party Agreement SST retrieval schedule and facility start dates were used, as in Operating Cases 1 and 2.

  A successful mission was achieved using LLW facility maximum instantaneous processing rates with a 21% to 26% increase over the *TWRS Process Flowsheet* average processing rates (41% for LLW glass plant). These rates were: 20.4 gal/min (34.0 gal/min @ 60% TOE) for the LLW pretreatment feed evaporator; 21.3 gal/min (35.5

gal/min @ 60% TOE) for Cs IX; 50 gal/min (83.3 gal/min @ 60% TOE)for the melter feed evaporator; and 120 MT/day LLW glass (200.0 MT/day @60% TOE). The HLW facility processing rates were unchanged from Operating Case 2.

Instantaneous Processing Rates Versus Maximum Average Rates

The maximum average processing rates required over an extended period (at least 3 - 5 years) were estimated from the cumulative waste throughput plots for particular facilities. It was found that the required maximum 3 to 5 year average rates are generally close to the maximum instantaneous (maximum allowable) rates for all the LLW waste processing facilities. Thus, for the absolute and relative processing rates investigated in this analysis, it appears the LLW processing facilities are working at maximum processing capacity for a significant percentage of the entire mission duration.

The HLW facility required maximum average rates over an extended time period (at least 3 to 5 years) are 9.2 gpm for the HLW pretreatment facility and about 8.0 MT/day for HLW glass production.

Bottlenecks

It was found by examining the dynamic relationships among the various LLW processing facilities that several bottlenecks are occurring. The main bottleneck is caused by the LLW pretreatment feed evaporator resulting in a large accumulation (Operating Case 1 about 30 Mgal with a 16.8 gpm boiloff rate) upstream of the LLW pretreatment feed evaporator immediately after wash decant. Three other milder bottlenecks (Operating Case 1 about 5 to 8 Mgal accumulation) are caused by the startup date of the LLW pretreatment plant, by the LLW melter processing at half capacity (one processing line rather than two) from 2005.5 to 2008.5, and by the LLW glass plant processing rate inadequacy between 2016 and 2018. In particular, the waste stream from early DST retrieval and 16 TX farm retrieval reaches the LLW pretreatment plant before its startup date.

Based on the above results, it appears that TWRS facility instantaneous processing rates can be selected to allow completion of the TWRS program per the Tri-Party Agreement milestones and without requiring that new DSTs be made available for storage. The relative rates used in Operating Case 1 seemed to be well matched implying a fairly well balanced system provided these rate proportions are preserved. It was not expected that the absolute Operating Case 1 rates would achieve a successful mission relative to overall waste lag storage. However, increasing the Operating Case 1 rates with the same proportions (Operating Cases 2 and 3), a successful mission was achieved relative to lag storage needs.

These conclusions are reached based on the assumptions (Section 2.0) and caveats (Section 3.3) of the model. It is suggested that the facility instantaneous and maximum average processing rates determined in this study be used as a reference point when actual design basis facility specifications are selected.

Facility Usage Time

The simulation model calculates the fraction of time each waste processing facility in the model is utilized during the mission. For the maximum instantaneous facility processing rates utilized in Operating Cases 1, 2, and 3, the LLW facilities were operating 90 to 100% of their total possible processing duration. This indicates that all LLW facilities are kept operating almost the entire operating duration of the mission at these processing rates.

Sensitivity Analysis Potential

It may be noted that the simulation model allows sensitivity studies to be performed with respect to a variety of system timing and processing parameters. Preliminary results to two such studies are included in appendix A. The first analyzes the effects of recycling the HLW and LLW melter offgas scrubbing and cooling streams into the processing system versus not recycling these streams. The second analyzes the use of a "flatter" time constant SST retrieval versus the Tri-Party Agreement SST retrieval schedule.

7.0 FUTURE WORK

The following are suggestions for a continuation of work and analysis with the simulation model:

1. The simulation has been designed to allow sensitivity analysis to be performed with respect to numerous process parameters. A selection of these sensitivity studies could be performed.

2. Cost and/or risk data might be included in the simulation model.

3. The simulation was built on the assumption that all bulk volume materials are homogeneously distributed in the four inventory batches of tank waste. Individual tank distributions and proposed retrieval sequences may be obtained to develop a more rigorous model. This is now a topic of study by Wittman et al. (1995) in the SIMAN/ARENA dynamic simulation model.

4. The simulation does not explicitly model facility downtimes, etc. Explicit modeling of this may change some of the dynamics within the simulation.

5. More resolution (detail) can be modeled in the particular processing facilities. In addition, physical location considerations also may be taken into account in future models.

6. The simulation allows changes of the retrieval schedule. Different retrieval schedules could be modeled and analyzed.

7. The glass plant melter requires a specific distribution of radionuclides and other elements to optimize glass formulation. This changes the waste loading in the glass. The model could be modified to assume a time varying waste or sodium loading.

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8.0 REFERENCES

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APPENDIX A SELECTED SENSITIVITY ANALYSIS RUNS

This section presents selected sensitivity studies as relevant to the detailed bottleneck analysis done in Section 5.0 of the main report. Specifically, two main sensitivities are analyzed. The first represents the recycling versus not recycling of the HLW and LLW melter offgas scrubbing recycle streams (flowsheet stream 336 added in upstream of the LLW pretreatment feed evaporator from HLW offgas scrubbing; and streams 916, 419, and 692 added in upstream of the LLW glass plant feed evaporator from LLW offgas cooling and scrubbing). The second sensitivity represents an analysis of the use of a "flattened" (not time increasing) rate of SST retrieval versus the TPA "ramping upward" SST retrieval rate. These sensitivities are performed using Operating Case 3 (no new DSTs necessary) as the sensitivity base or control case. Only the parameter of interest is changed (in Operating Case 3) for the test case.

A.1 MELTER OFFGAS COOLING AND SCRUB RECYCLE STREAMS

This case is a sensitivity comparing the system dynamic behaviors when the offgas cooling and scrubbing recycle flows are either introduced into the main waste stream or not introduced into the main waste processing stream. The specific flowsheet flows affected by the sensitivity are streams 336 from the HLW melter offgas treatment added in directly upstream of the LLW pretreatment feed evaporator and streams 916, 419, and 692 from LLW melter offgas treatment and filtering added in directly upstream of the LLW glass plant feed evaporator. The intention of this sensitivity study is to analyze the effects of these recycle streams on system dynamics and system processing capacity loading.

The sodium molarities of the exit streams from both the LLW pretreatment feed and the LLW glass plant evaporators remain at 7 and 10 molar respectively for both cases. The exclusion of the melter offgas recycle greatly reduces the amount of water that must be evaporated.

RESULTS

The main results are summarized as follows:

- The peak overall tank space usage estimate has decreased dramatically from 28.8 Mgal for inclusion of the recycling streams (Operating Case 3) to 22.1 Mgal peak for the exclusion of the melter offgas recycle streams. This is shown in Figure A-1.

- The accumulation found to occur in the tanks feeding the LLW pretreatment feed evaporator in Operating Case 3 was dramatically decreased from a peak accumulation of 17.5 Mgal to 7.6 Mgal. This is illustrated in Figure A-2. In Operating Case 3 (recycle streams included), this accumulation includes decant from caustic and dilute sludge washing, secondary settle/decant tank decants, and HLW offgas recycle flowsheet stream 336, (Orme, 1994). In the no recycle sensitivity case, the HLW offgas recycle stream is not included, thus the underlying reason for this decreased accumulation is the decreased load imposed on the LLW pretreatment evaporator.

- In contrast, a larger accumulation occurs in the lag storage tanks between the LLW pretreatment evaporator and the pretreatment facility (Cs IX) and at the LLW glass plant staging tanks with the recycling streams excluded. This is caused by an inherent increase in both LLW evaporator's waste throughput rates because of an increase in sodium concentration of the waste fed to the evaporators. This increase in sodium concentration results from the lack of the HLW and LLW offgas recycle streams, which would dilute the waste stream. The evaporator processing rates used in Operating Case 3 are mismatched relative to the CsIX processing rate if the melter offgas recycle streams are excluded. The higher accumulations from the recycle streams excluded case are shown in Figures A-3 and A-4.

A.2 CONSTANT SST RETRIEVAL RATE

This sensitivity case examines the changes in system dynamics when a "flatter" or more constant rate of SST retrieval is used versus the "ramping upward" time increasing Tri-Party Agreement SST retrieval schedule. The "flat" retrieval schedule also meets the Tri-Party Agreement deadline with the difference being the instantaneous retrieval rate remains constant and is adequate to remove all wastes from the 149 SSTs by the Tri-Party Agreement deadline of September 30, 2018. It is not expected that this "flat" schedule can be met practically, but results of these two extreme cases may be used to get an idea of the sensitivity of the system to accelerated, more constant SST retrieval rates.

For this case, only the retrieval of the remaining 133 SSTs, excluding the 16 tanks in the TX farm containing mostly saltcake, is made constant. DST retrieval will remain constant as it is in the Operating Cases 1, 2, and 3, and the 16 saltcake tanks remain retrieved by the schedule shown in Figure 2-1. In addition, it continues to be assumed that retrieval does not stop at any time after it begins (retrieval milestones must be met) and feed to a processing plant is shutdown if the allocated lag storage limit for that plant is reached (close-coupling).

RESULTS

The main results are summarized as follows:

- The overall peak tank usage has dropped somewhat from 28.8 Mgal (Operating Case 3) to 26.6 Mgal by use of a "flat" or constant rate SST retrieval in place of the time increasing TPA retrieval. The peak is shifted in time to about 2010. This is due to the slight overlap of the end of DST retrieval and the beginning of the "flat" SST retrieval. This is illustrated in Figure A-5.

- An evaluation of the individual lag storage locations within the system shows a decreased accumulation in the LLW pretreatment evaporator feed tanks immediately downstream of the caustic wash decant and secondary settle/decant tank decant. The storage needed for caustic and dilute washing for the "flat" SST retrieval is shown in Figure A-6. The accumulations in each of the simulation's unlimited capacity lag storage tanks and the LLW glass plant staging tanks are shown in Figures A-7 to A-9.

- Neither the original TPA ramped retrieval schedule nor the flattened SST retrieval schedule appear to be optimized from a peak tank use point of view.

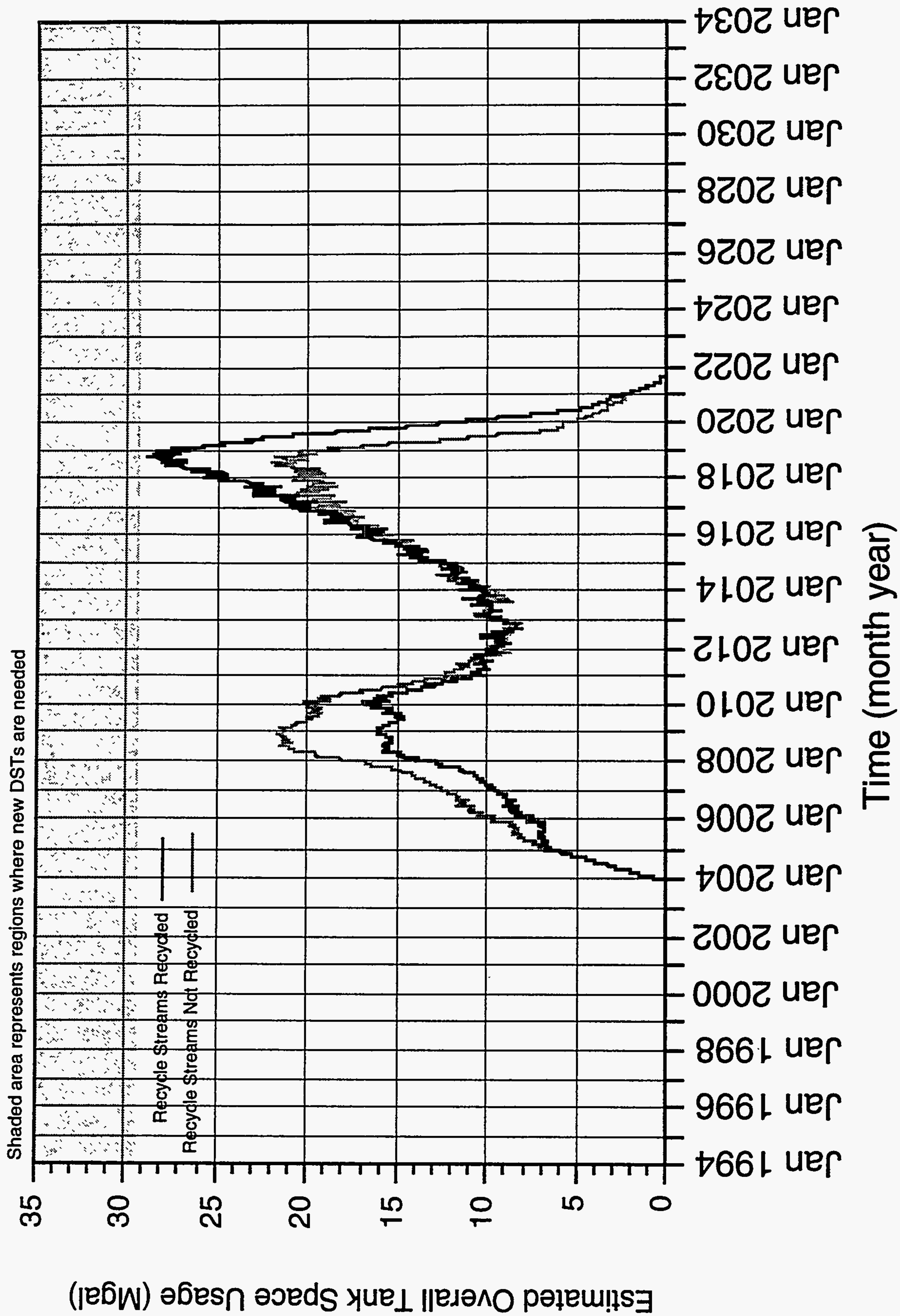

Figure A-1 Estimate of overall tank utilization for melter offgas recycle streams recycled (solid curve) and not recycled (gray shaded curve) into processing system. Note reduction of approximately 6.5 million gallons in peak storage capacity needed (around Sep 2018) for the recycle streams not recycled case.

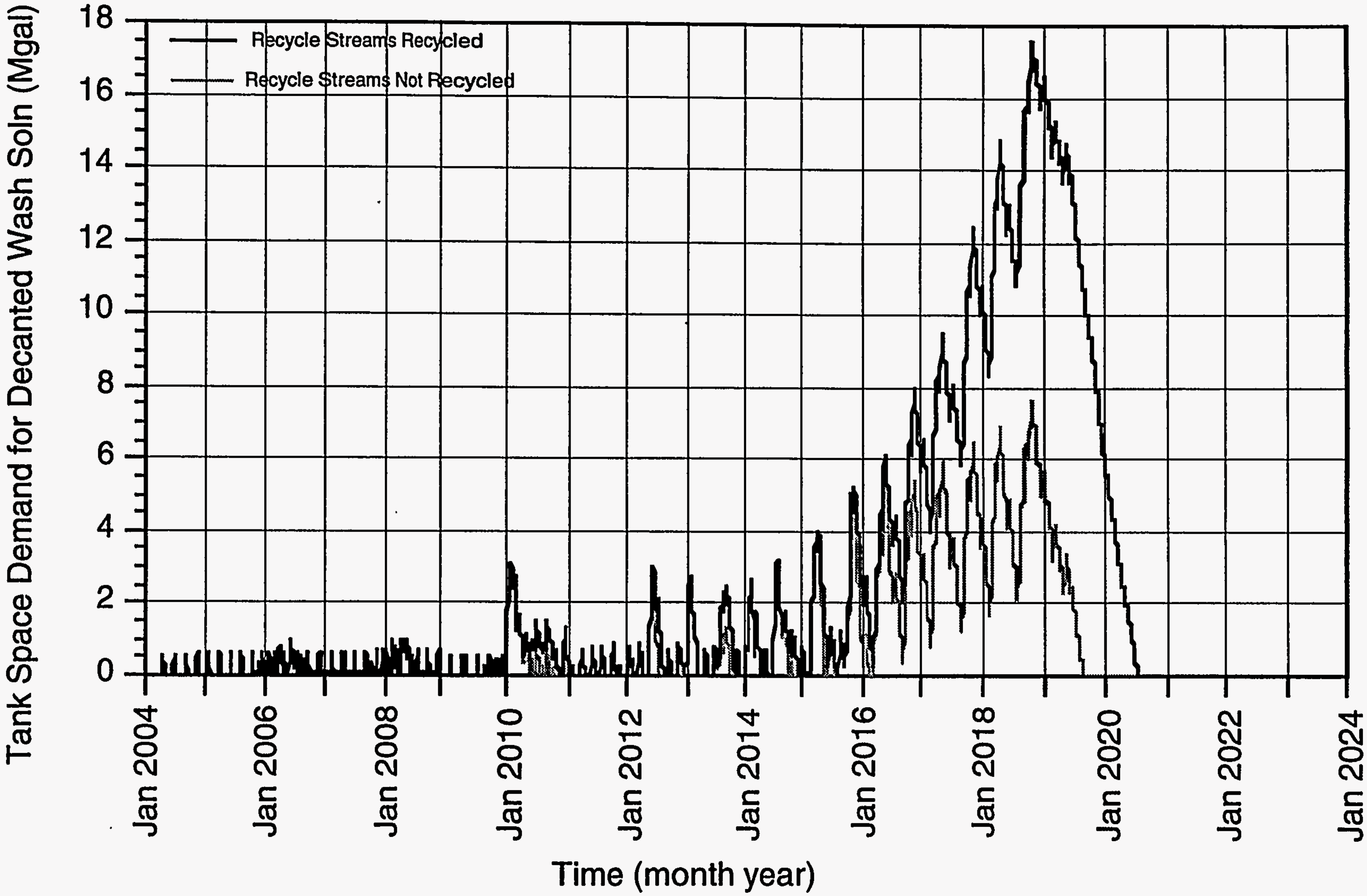

Figure A-2 Accumulation of wash decant solution directly downstream of wash for melter offgas recycle streams recycled (solid curve) and offgas recycle streams not recycled (gray shaded curve). Operating case 3 (no new DSTs needed) represents the case with the recycle streams recycled. The major decrease seen in this plot is primarily caused from the absence of flowsheet recycle stream 336 (Orme, 1994), from the HLW melter offgas scrub system.

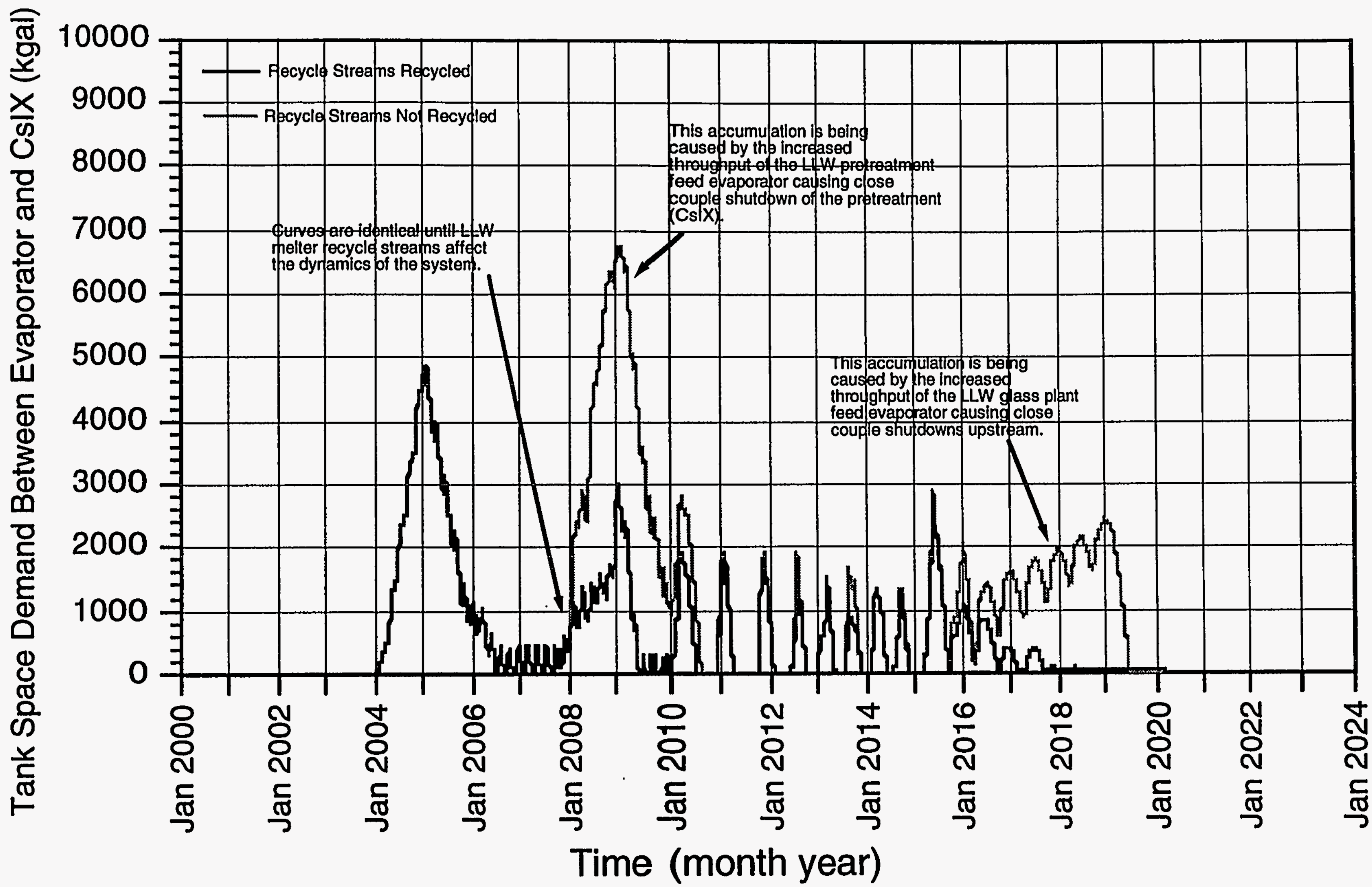

Figure A-3 Tank space demand between supernatant evaporator (7 M Na output) and the CsIX for melter offgas recycle streams recycled (solid curve) and not recycled into processing system. Note that the case without the recycle streams recycled requires more lag storage than the case with the streams recycled between 2008 and 2010. This is caused by an increase in the LLW preatreatment feed evaporator throughput rate due to the higher concentration of Na (higher Na concentration = less amt . to evaporate) entering the evaporator feed tanks.

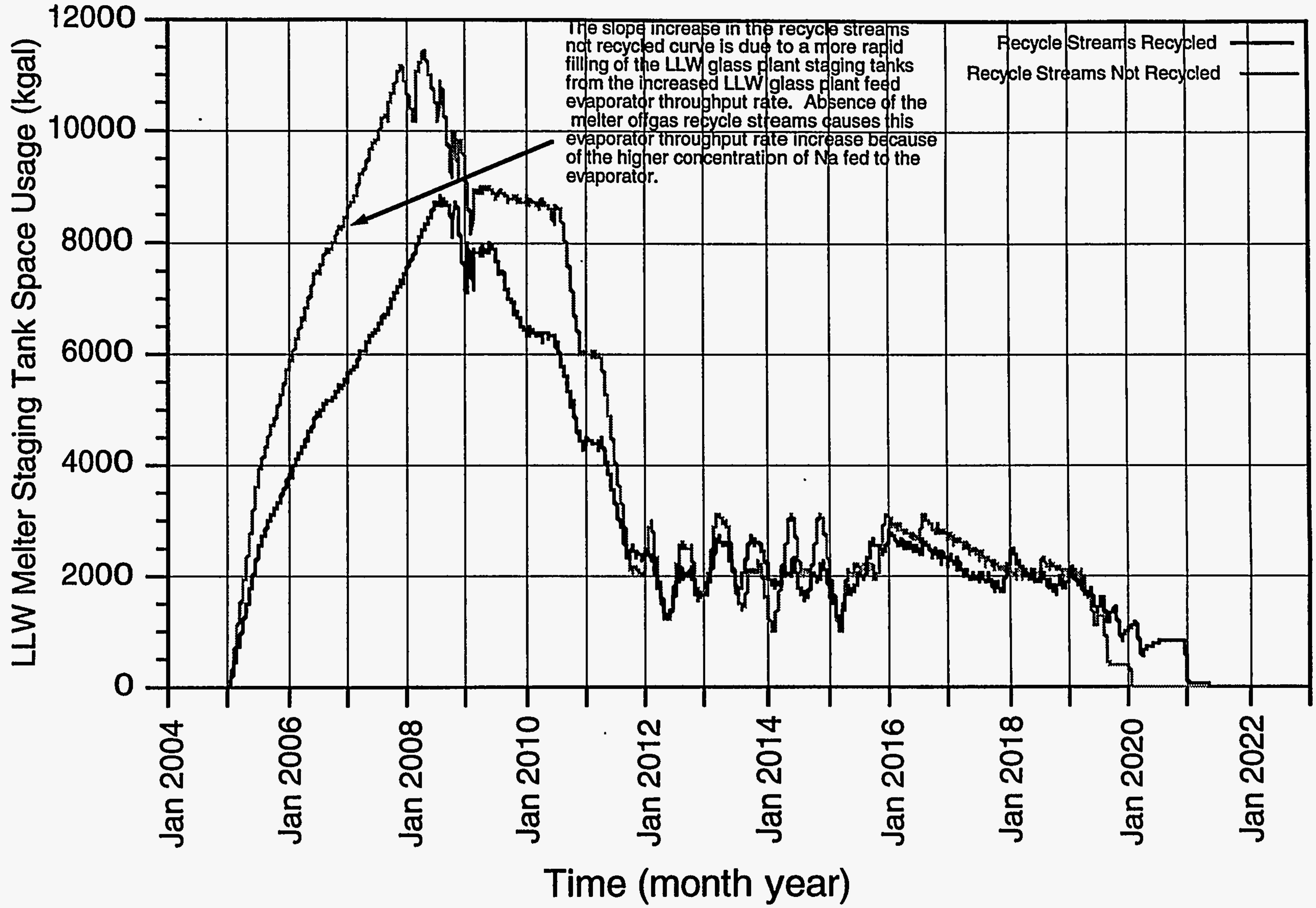

Figure A-4 Space demand at LLW glass plant staging tanks between LLW pretreatment and LLW glass plant. The solid curve represents the melter offgas recycle streams recycled in and the gray shaded curve represents the recycle streams not recycled. The non recycled case shows a higher tank demand because of the higher glass plant feed evaporator throughput rate due to the higher Na concentration.

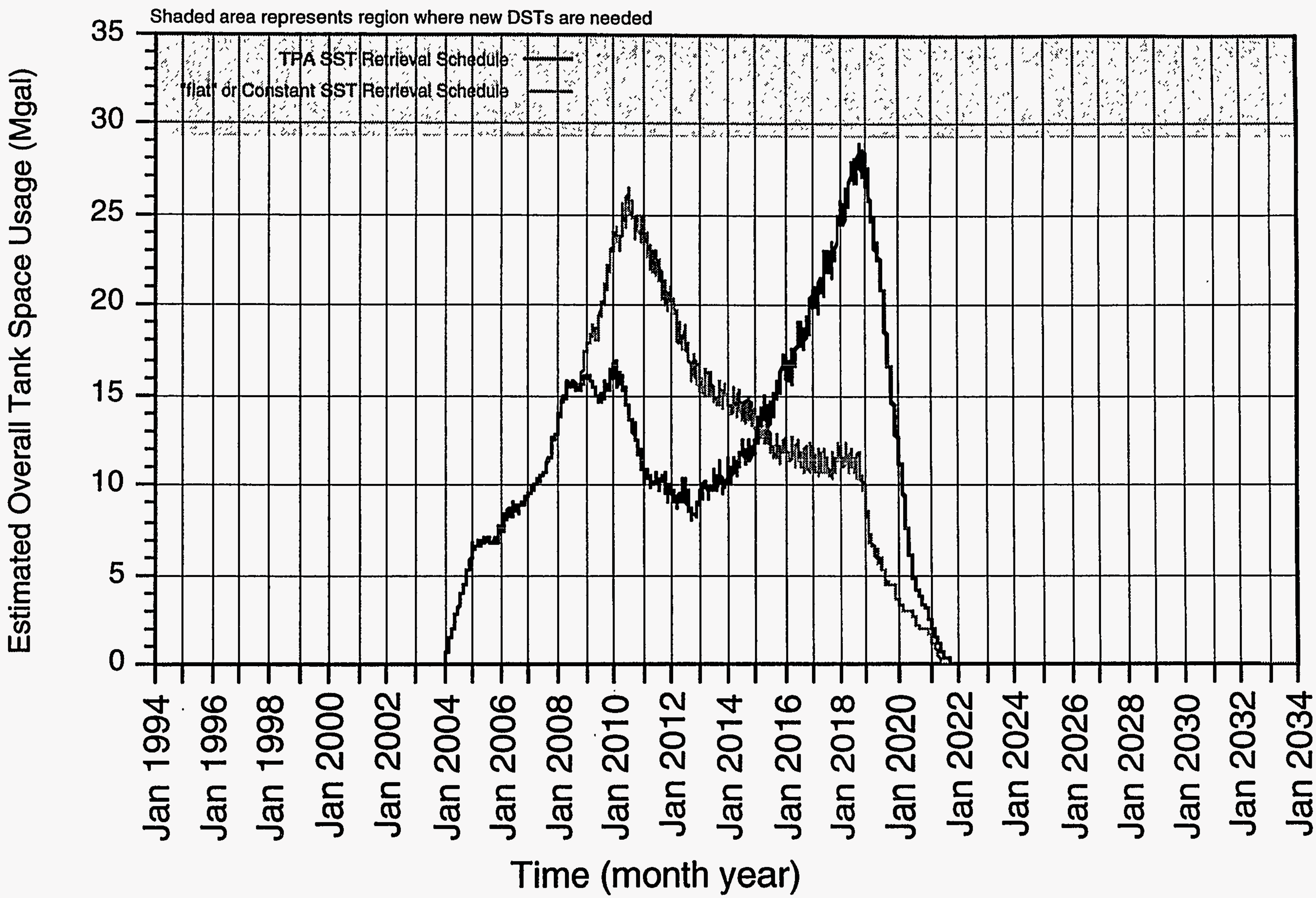

Figure A-5 Estimate of overall tank utilization resulting from use of TPA SST retrieval schedule (solid curve) and a "flat" constant rate SST retrieval schedule (gray shaded curve). Note the shift in time of the peak and the difference in value of the peak estimated tank space usage.

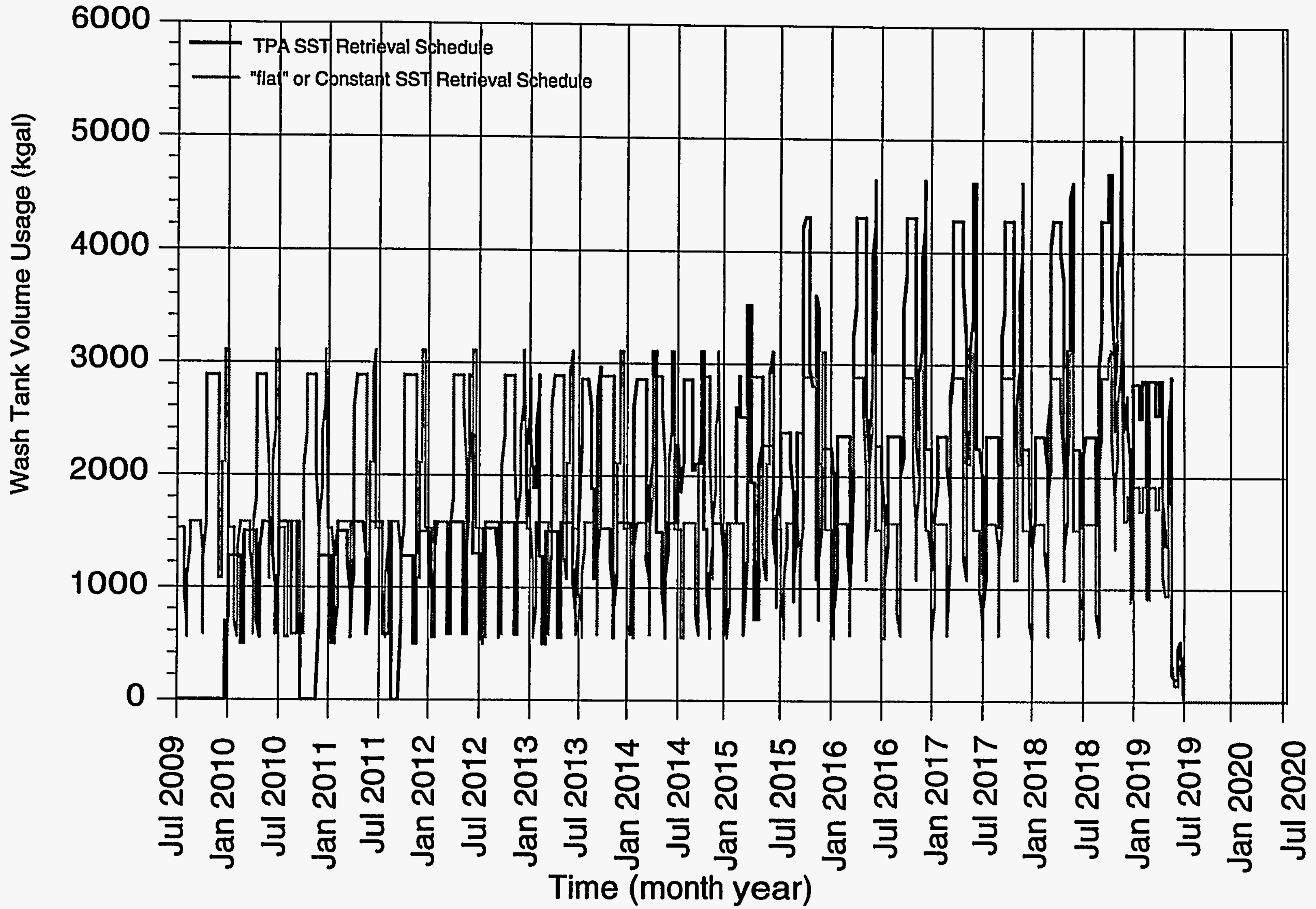

Figure A-6 Wash Tank Space Usage during Washing Period assuming TPA SST retrieval schedule (solid curve) and assuming "flat" or constant SST retrieval schedule (gray shaded). Washing from retrieval of 133 remaining SSTs (excl. 16 TX farm SC tanks that mostly bypass caustic washing) is shown.

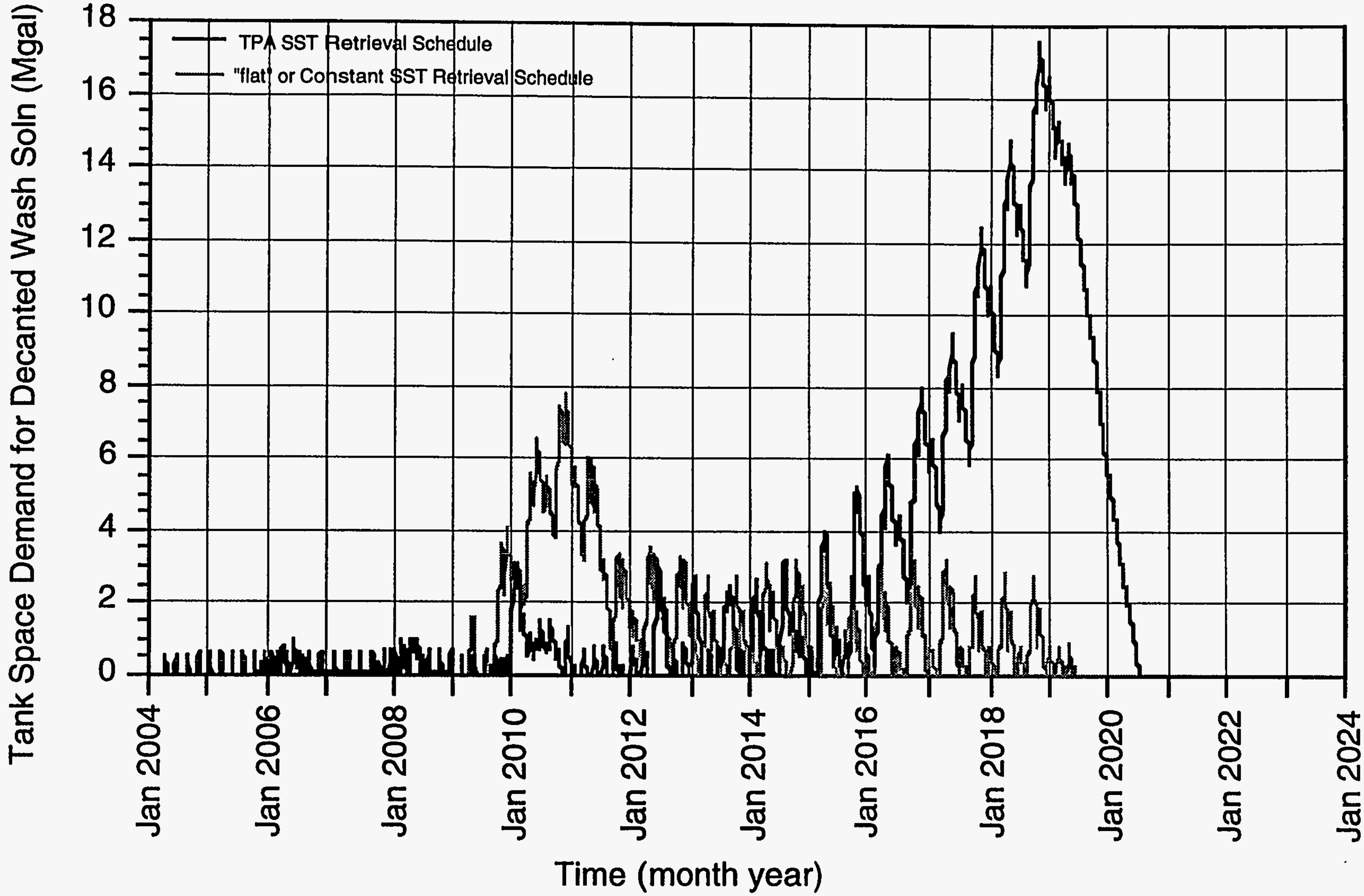

Figure A-7 Accumulation of wash decant solution directly downstream of wash. Solid curve represents result from use of the TPA SST retrieval schedule and shaded gray curve represents use of a "flat" or constant rate SST retrieval schedule over time. The accumulation in the "flat" SST retrieval is being caused by a slight time overlap of the end of DST retrieval, 16 TX retrieval, and the remaining 133 SST retrieval. The peak of the accumulation is much lower than with the use of the TPA ramping retrieval.

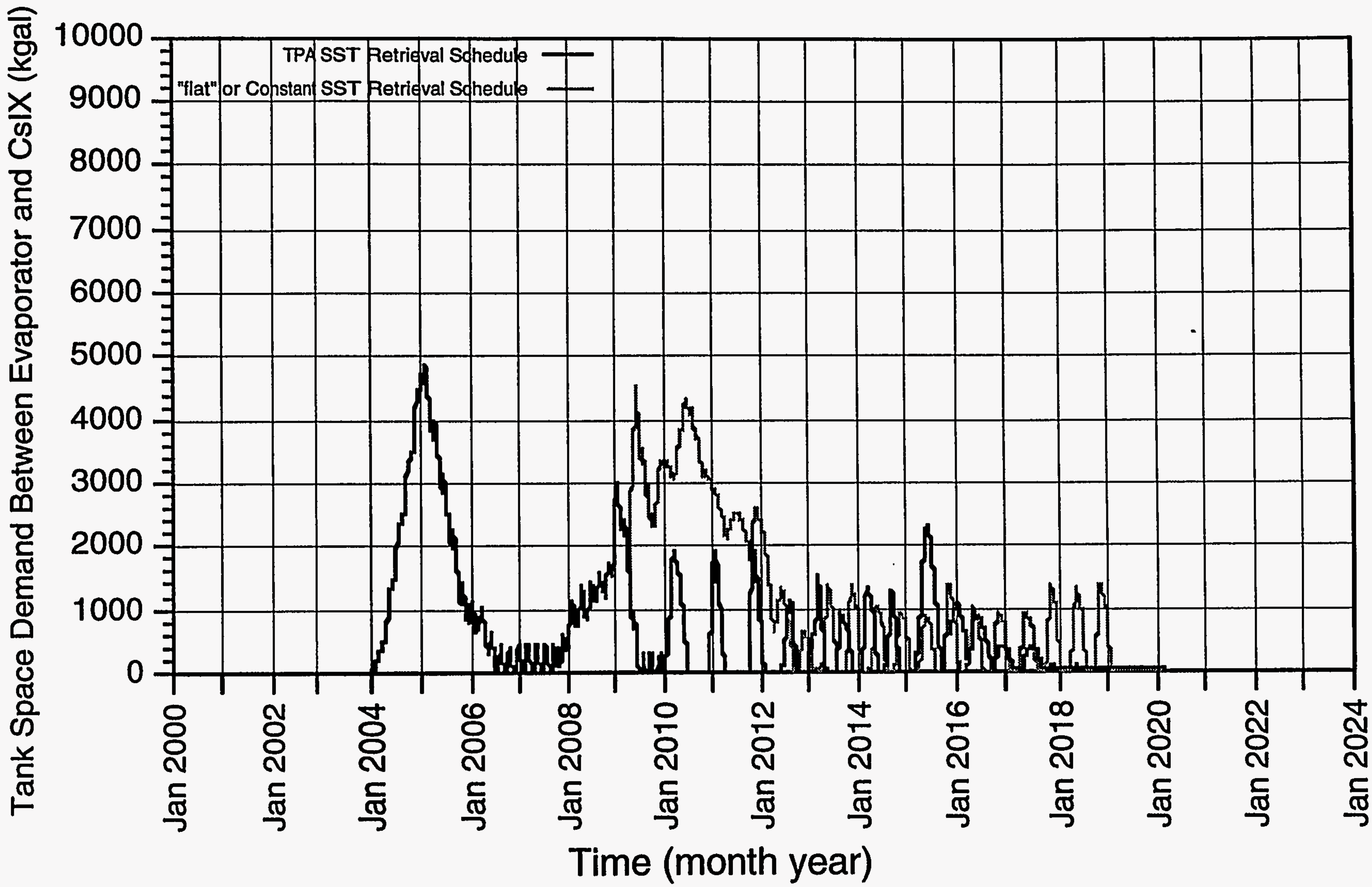

Figure A-8 Tank space demand between LLW pretreatment feed evaporator (7 M Na output) and LLW pretreatment (CsIX). The solid curve represents the result from use of the TPA SST retrieval schedule and the gray shaded curve represents the result from use of a "flat" or constant rate SST retrieval schedule.

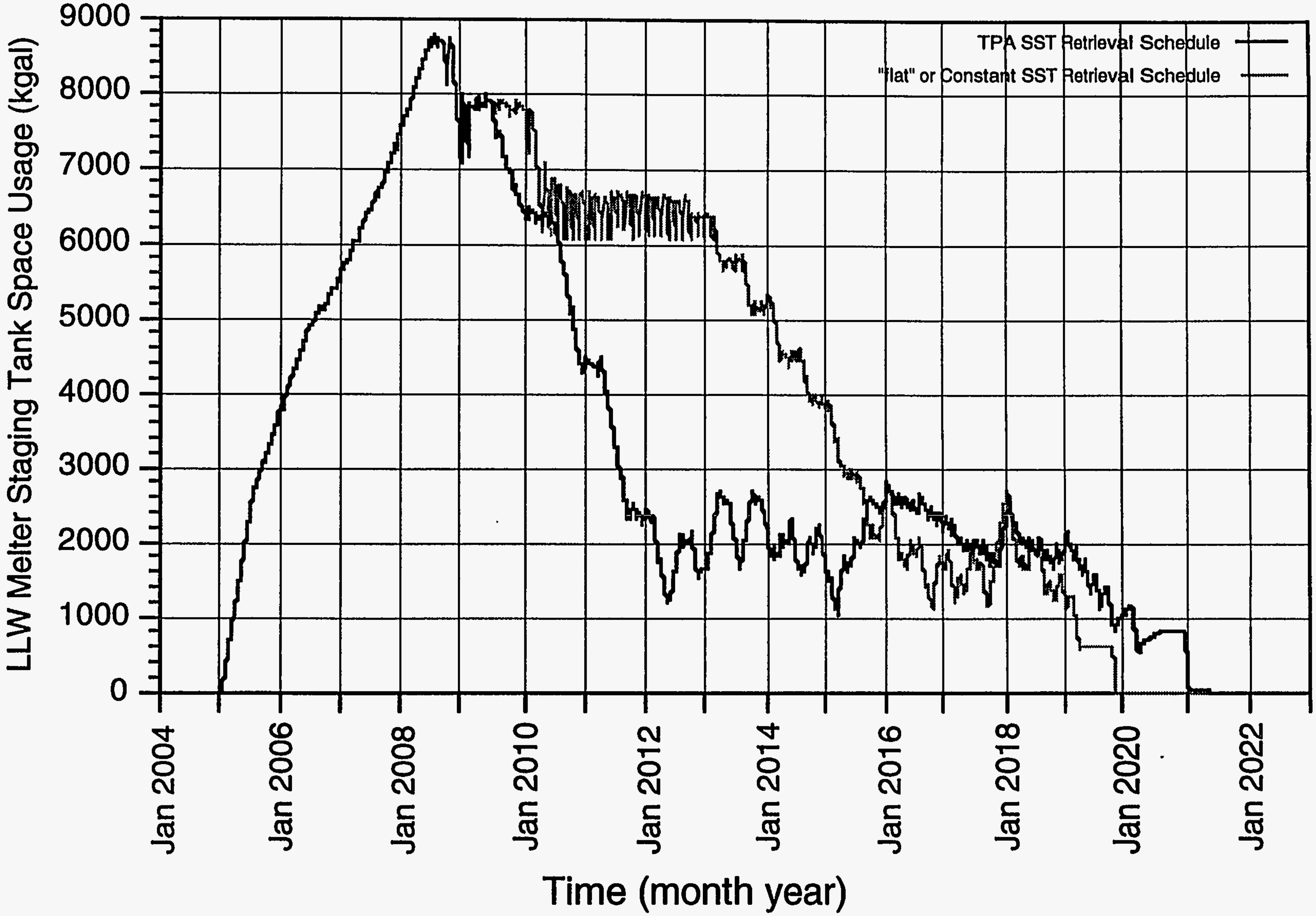

Figure A-9 Lag storage used at LLW glass plant staging tanks between LLW glass plant feed evaporator and the LLW glass plant. Solid curve represents the result from the use of the TPA SST retrieval schedule and gray shaded curve represents the result from using a "flat" or constant rate SST retrieval schedule. The LLW melter processing with one stream for the first three years is also a bottleneck in the flat retrieval case.