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Total System Model Version 6.0 Preprocessor Smoothing Algorithm Validation Report

Prepared for:
U.S. Department of Energy
Office of Civilian Radioactive Waste Management
1000 Independence Avenue, SW
Washington, D.C. 20585

Prepared by:
Bechtel SAIC Company, LLC
1180 Town Center Drive
Las Vegas, Nevada 89144

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Prepared by:	Andrew Blake	10/29/2007 Date
Checked by:	Stephen L. Turner	11-1-2007 Date
Reviewed by:	Scott G. Gillespie	11/02/2007 Date
Approved By:	David Siefken Manager, Waste Management Integration	11/05/07 Date

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CHANGE HISTORY

Revision No.	Date	Description
0	10/2007	Original issue, for use with TSM Version 6, SiMCAD™ 7.1 Build 1235

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CONTENTS

FIGURES

Page

TABLES

Page

ACRONYMS AND ABBREVIATIONS

BSC	Bechtel SAIC Company, LLC
CRWMS	Civilian Radioactive Waste Management System
DOE	U.S. Department of Energy
DOE SNF	U.S. Department of Energy spent nuclear fuel
GROA	Geologic Repository Operations Area
HLW	high-level radioactive waste
INL	Idaho National Laboratory
IS	Initial State
MCO	multi-canister overpack
SRS	Savannah River Site
TSM	Total System Model
TSMPP	Total System Model Preprocessor
UM	User Manual
VB	Visual Basic™
DVCG	DOE Valley Curve Generator
WP	waste package

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1. OBJECTIVE AND BACKGROUND

This validation report supports the issuance of Version 6.0 of the Total System Model (TSM BSC-2007a) that is described in the TSM User's Manual (UM) (BSC-2007b) and the TSM Preprocessor (TSMPP) UM (BSC 2007c). This report assumes the reader has detailed working knowledge of the TSM functions and Civilian Radioactive Waste Management System (CRWMS) operations.

This validation was performed in accordance with AP-ENG-006, *Total System Model (TSM)-Changes to Configuration Items and Base Case.*

Most Department of Energy (DOE) waste streams use codisposal waste packages (WP). The three types of DOE waste streams that use codisposal WPs are the high-level radioactive waste (HLW), U. S. Department of Energy spent nuclear fuel (DOE SNF) and multi-canister over-packs (MCO). The timing of these waste streams can adversely impact the production efficiency of the Geologic Repository Operations Area (GROA) if DOE SNF cask loads are not delivered and maintained in the proper ratios to make codisposal WPs.

This issue has been addressed within the TSMPP via a "smoothing algorithm" designed to adjust the shipment timing of the codisposal waste streams. Two shipping strategies have been developed and are evaluated in this document. The first strategy has the DOE SNF waste streams shipping on schedule with the shipping times of the HLW waste streams adjusted to "follow" to ensure proper codisposal inventory ratios. This strategy is called "SNF Lead". The second strategy has the HLW waste streams ship on schedule with the shipping times of the DOE SNF waste streams adjusted to "follow" to ensure proper codisposal inventory ratios. This strategy is called "HLW Lead".

This objective of this report is to show that the smoothing algorithm behaves as designed.

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2. VALIDATION

2.1 DESIGN OF THE SMOOTHING ALGORITHMS

There are two specific issues that will cause the timing of a waste stream to move when the smoothing algorithms are invoked. First, smoothing will enforce consist sizes of 5 transportation casks of the same type of waste from the same site. Second, smoothing will make major adjustments in the timing of the follower waste stream to ensure the proper codisposal ratio with the lead waste stream. Through out this section, a Test Initial State (IS) file and its Smoothed counterpart are used for illustration. These files are:

Test IS:	IS_CD1_IAS_DefOnly_New Navy_072507.xls
Smoothed IS:	IS_CD1_IAS_DefOnly_New Navy_072507_revised_ISMorph_SNFLeadIgnoreTele.xls

Note: The Smoothed IS file was manually "revised" so that the shipment IDs are numbered from 1 for each waste stream of the same type and origin.

2.1.1 Timing Adjustments due to Consist Size

The SNF Lead strategy will work to minimize changes to the shipping schedule of DOE SNF, with the exception of the enforcement that the creation of consists of 5 shipping casks that originate from the same site and of the same type of waste.

For example, if a DOE SNF shipment is scheduled for the 2nd quarter, smoothing will search for the next 4 DOE SNF shipments from the same facility and reschedule those for the 2nd quarter as well. The sixth DOE SNF cask to ship from the site will ship on its original schedule; however, it will determine the shipment timing for the next 4 DOE SNF shipments that follow it. This impact is shown in Figure 1where the DOE SNF cask loads from the Savannah River Site (SRS) are originally scheduled for calendar quarters 11, 15 and 19 are moved to the 2nd calendar quarter, corresponding with the site's first shipment.

The effects of consist size enforcement are seen both because of a difference in the site of origin and because of the waste type. Figure 2 shows the effect on the DOE SNF short waste stream coming from the Idaho National Laboratory (INL) site.

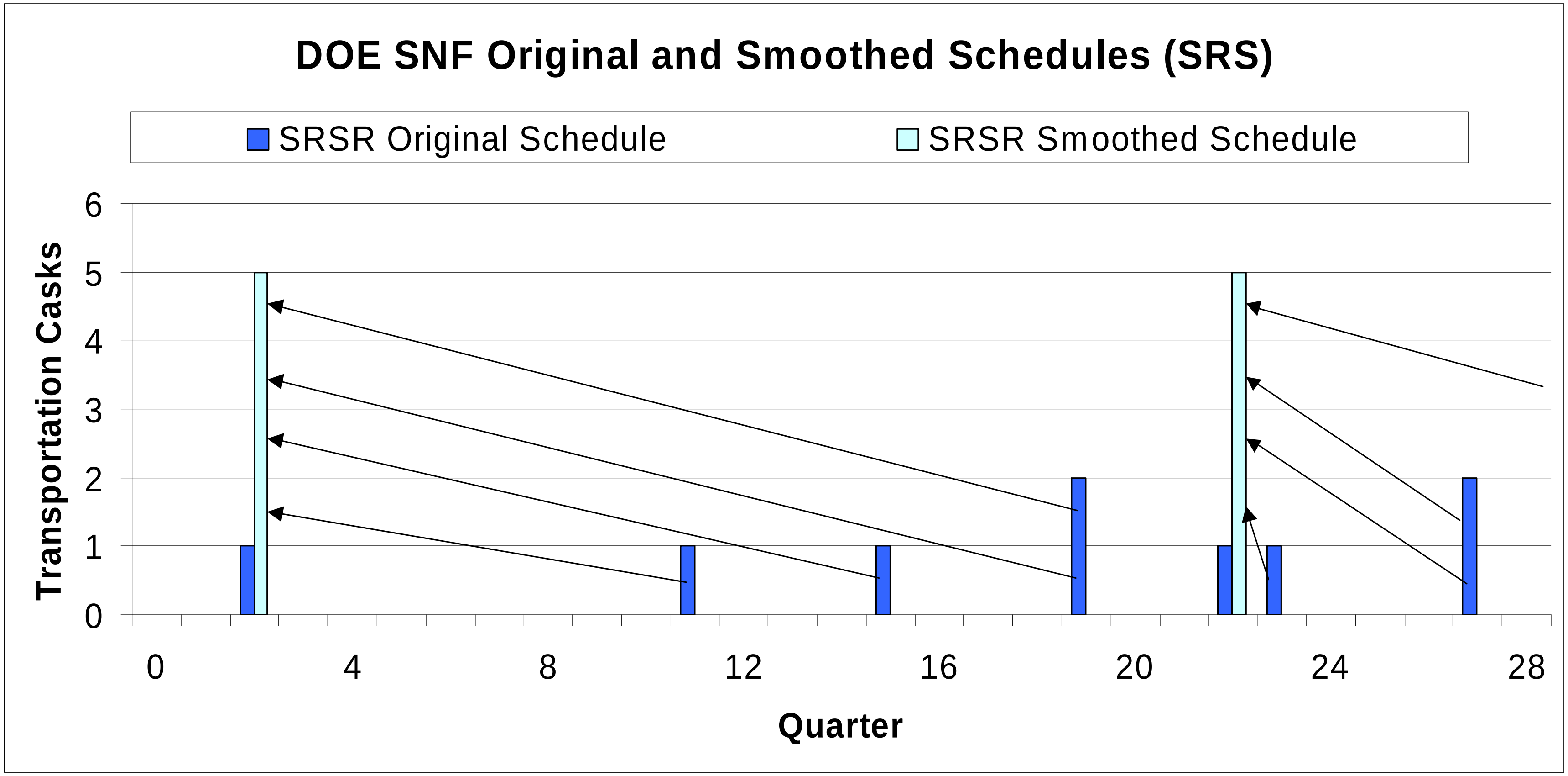

Figure 1. Change in the DOE SNF Schedule from the SRS Facility

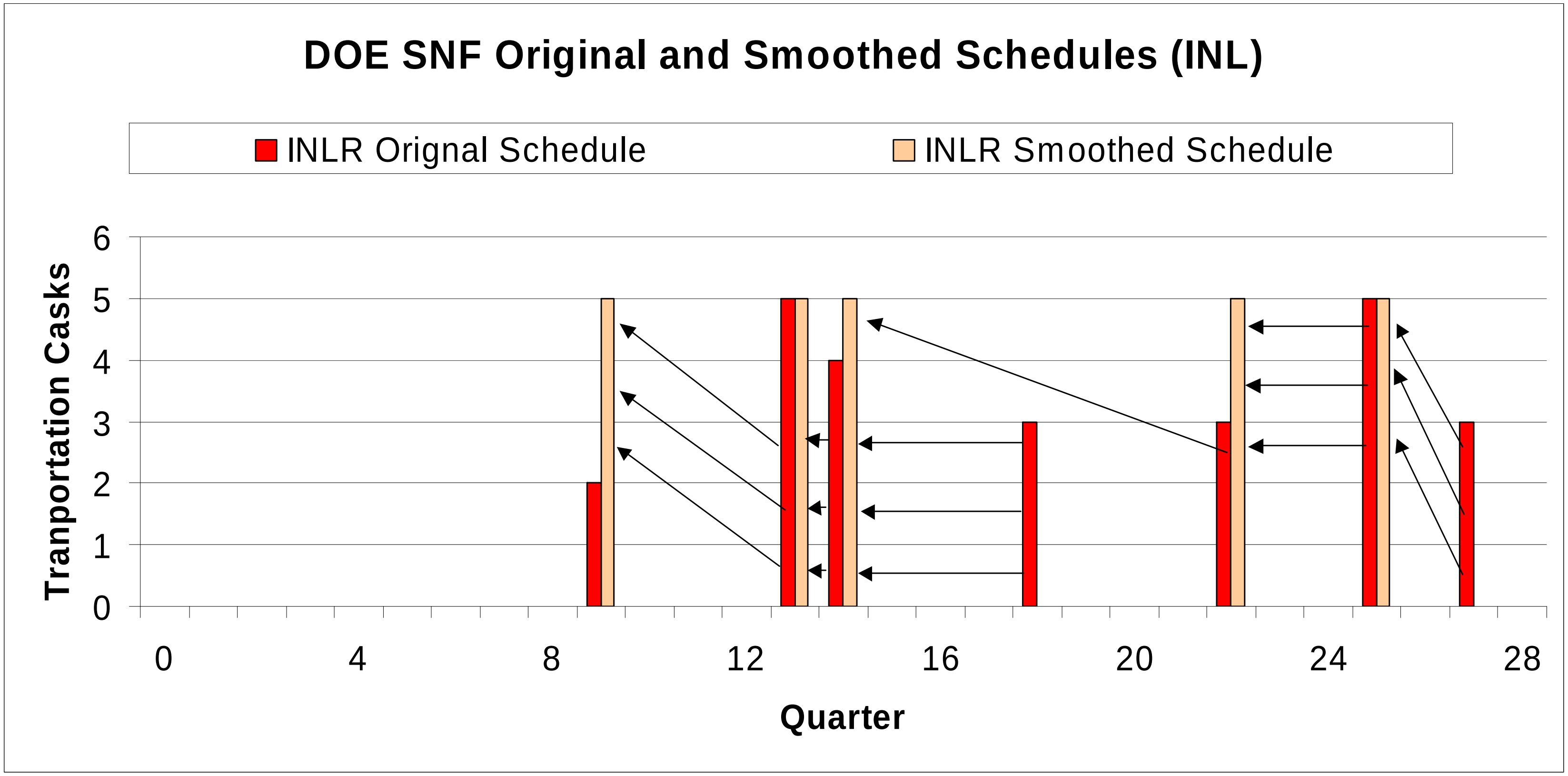

Figure 2. Change in the DOE SNF Schedule from the INL Facility

2.1.2 Timing Adjustments for the Follower Waste Stream

There are several types of codisposal WPs. The smoothing algorithm will maintain the constituent waste stream ratios to make these codisposal WP types. The types are:

1 Short DOE SNF/5 Short HLW
1 Long DOE SNF/5 Long HLW
2 MCO/2 Long HLW
1 Short DOE SNF/ 5 Long HLW

Continuing the example shown in Section 2.1.1 for SRS and INL, 5 short DOE SNF transportation casks are scheduled in the 2nd quarter. The smoothing algorithm will adjust the timing of the short HLW waste stream for matching codisposal.

One DOE SNF transportation cask contains 9 canisters. One HLW transportation cask contains 5 HLW waste canisters. For the WP types above, in order to completely dispose of one transportation cask of DOE SNF, the model will need 9 transportation casks of HLW if the first WP type is used. Therefore, in the 2nd quarter, the model will need 45 transportation cask loads of HLW. In this example, much of the required HLW was already shipping in the 2nd quarter; however, some that was shipped earlier in the 1st quarter was moved to the 2nd quarter (as it was not needed in the 1st quarter for codisposal WP generation in the DOE SNF lead case).

As shown in Figure 2, the next consist of 5 transportation casks of DOE SNF shorts are scheduled for shipping in the 9th quarter (coming from INL instead of SRS). Consequently, Figure 3 shows that the HLW shipments originally scheduled for the 6th, 7th, and 8th quarters are getting pushed later (to the right) into the 9th quarter for codisposal matching.

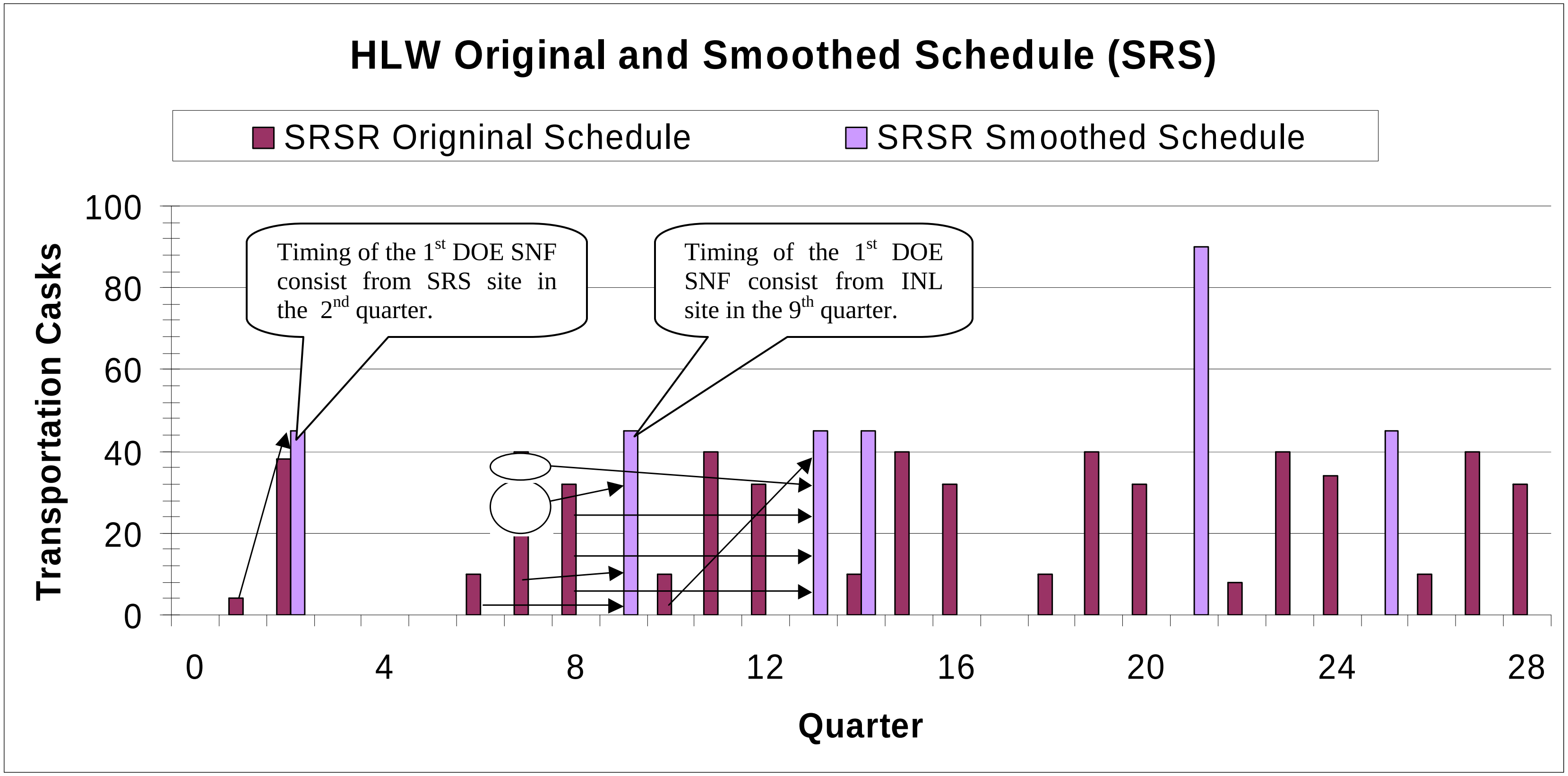

Figure 3. HLW Moved to Follow the DOE SNF

2.2 VALIDATION METHOD

Two case studies are examined. The first study uses the Test IS file and its smoothed counterpart discussed previously. These files are graphically evaluated introducing charts showing the comprehensive impact of SNF Lead smoothing across all the codisposal waste streams. This case will demonstrate the comprehensive adjustment of the timing of the waste streams, showing how HLW short shipments are scheduled to coincide with DOE SNF short shipments, and how HLW long shipments are married with DOE SNF long and MCO shipments. This examination will also demonstrate that the timing of "teleported" HLW will not be changed by the smoothing algorithm. "Teleported" HLW is waste that shows up directly in the GROA waste buffers without being transported from the sites via barges, trains, or trucks.

The second case study examined the impacts to a Reference Case IS file used for the TSM thermal study (BSC 2007d). This study examined both of the SNF Lead and HLW Lead strategies quantitatively and graphically, to include TSM model run data and results. The impact on the arrival of DOE SNF and HLW at the GROA was evaluated using a DOE Valley Curve Generator (DVCG). The DVCG used for this case was an interim version being developed for TSM Version 6.0 that was manually checked by checking formulas and that ensuring all cask loads as part of this validation and it is included in the electronic attachments in Section 6.0. The Reference Case and the TSMPP algorithms used the same input DOE waste stream set by the 2001 Integrated Acceptance Schedule (IAS).

The run used for the Reference Case Scenario is listed in Section 6 in the electronic attachments to this validation. The Reference Case Scenario is a "stressed" case and is a good test of the algorithms since the DOE waste stream includes some manually input cask load items in Years 1-4 and also includes so called "teleported" HLW where the IS sends the cask load directly to the HLW buffer in the GROA and bypasses the transportation elements. As mentioned previously, the timing of the "teleported" HLW will not be impacted (or smoothed).

To support test runs and other comparisons, a software tool (called ISMorph) written in Visual Basic™ (VB) 6 is used to implement the smoothing algorithm by taking an existing IS file as input, then output a "morphed" IS file implementing the desired SNF Lead or HLW Lead scenario as selected. This prepares the IS for a TSM simulation run. ISMorph was validated as part of the Work Order validation (BSC 2007e).

2.3 EVALUATION OF THE TEST AND SMOOTHED IS FILES

The comprehensive codisposal waste stream schedule for the Test IS is shown in Figure 4, and its smoothed counterpart is shown in Figure 5. From comparing these two charts the following observations may be made:

- "Teleported" HLW occurring in years 18 through 30 was not rescheduled. By design, "teleported" HLW is not smoothed.

- As shown in Figures 1 and 2, the first DOE SNF short shipment from SRS occurring in the 2nd quarter (year 1), was increased from 1 cask to 5 casks, and the second DOE SNF short shipment from INL occurring in the 9th quarter (year 3) was increased from 2 casks to 5 casks. As shown in Figure 3, HLW was moved to these quarters (in years 1 and three) to match the DOE SNF shipments. This matching occurs throughout the model life as long as there is HLW available.
- The smoothed result in Figure 5 shows significantly more HLW long shipping within the first year to match with DOE SNF long shipments. This matching occurs throughout the model life as long as there is HLW long available.
- Due to the 5 casks per consist enforcement, there are no DOE SNF long shipments in years 6 though 10 in Figure 5, as those shipments were performed earlier. Since there were no DOE SNF long shipments during this period, there also were no HLW long shipments.
- By year 13, there is no more HLW short available for smoothing. By design, "teleported" HLW is not smoothed.
- For years 21 through 30 of Figure 5, HLW long is evenly paired with MCO, except for the last DOE SNF long shipment in year 21 that begins a period of oversupply of HLW long (in a non-multiple of 5 casks).

2.4 OVERVIEW OF THE REFERENCE CASE SCENARIO

The DOE wastes in the Reference Case Scenario IS file were "manually smoothed" to achieve good processing metrics. The DOE cask loads to be shipped are shown in Figure 6, prior to applying the smoothing algorithms to the IS file.

The cask shipment scheduling in the Reference Case Scenario file using manual smoothing is different from the two IS Files using the TSMPP smoothing algorithm in two ways. First, the Reference Case Scenario ships HLW for about four years before any DOE SNF is shipped. These first few years appear to be the only period where the ratio between HLW and the DOE SNF codisposal constituents are seriously out of balance.

Second, the Reference Case Scenario IS file does not attempt to enforce rail shipment consists of five cask loads. Figure 6 shows that in years 1 – 6 a total of only four casks loads of DOE SNF are shipped. The Reference Case Scenario TSM model will simulate this by shipping a partial consist. The TSMPP smoothing algorithm will attempt to ensure that the consists for the DOE SNF cask loads have five of the same type of cask loads.

2.5 REFERENCE CASE: SNF LEAD RESULTS

The TSMPP SNF Lead algorithm ships the DOE SNF cask loads on schedule and adjusts the shipments of the HLW cask loads for the proper codisposal waste inventory ratio.

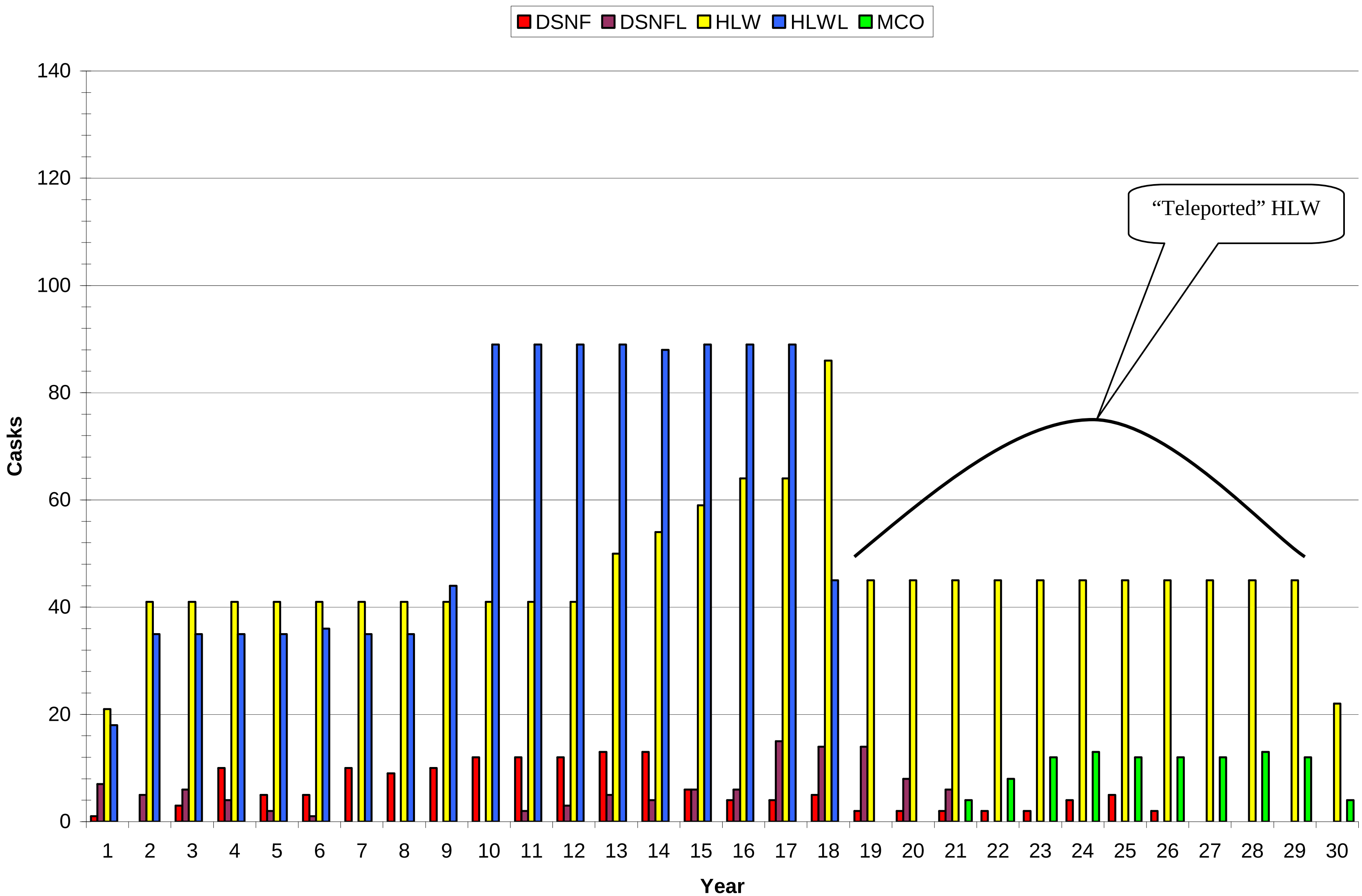

Figure 4. Test IS File

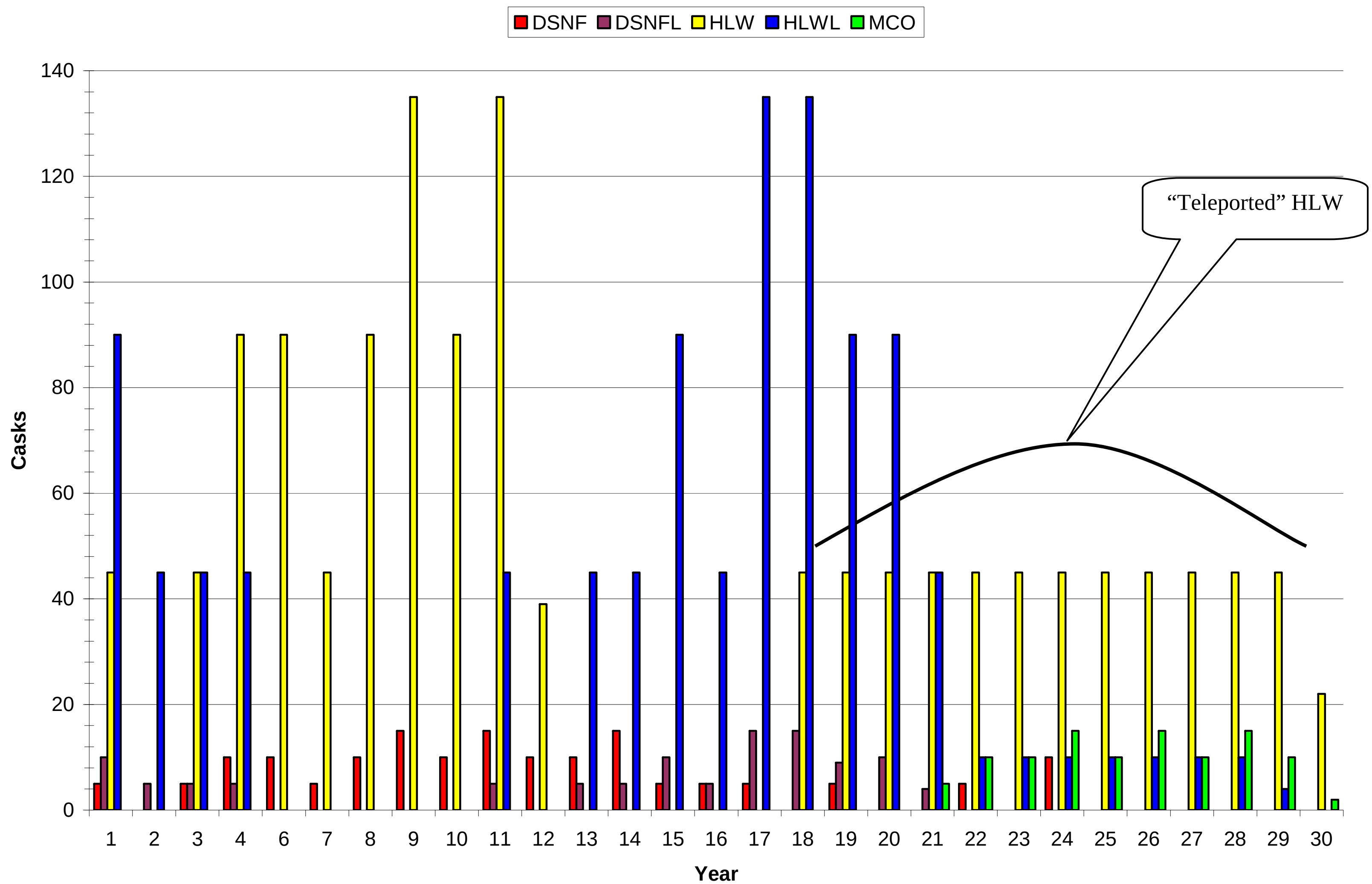

Figure 5. Smoothed IS File

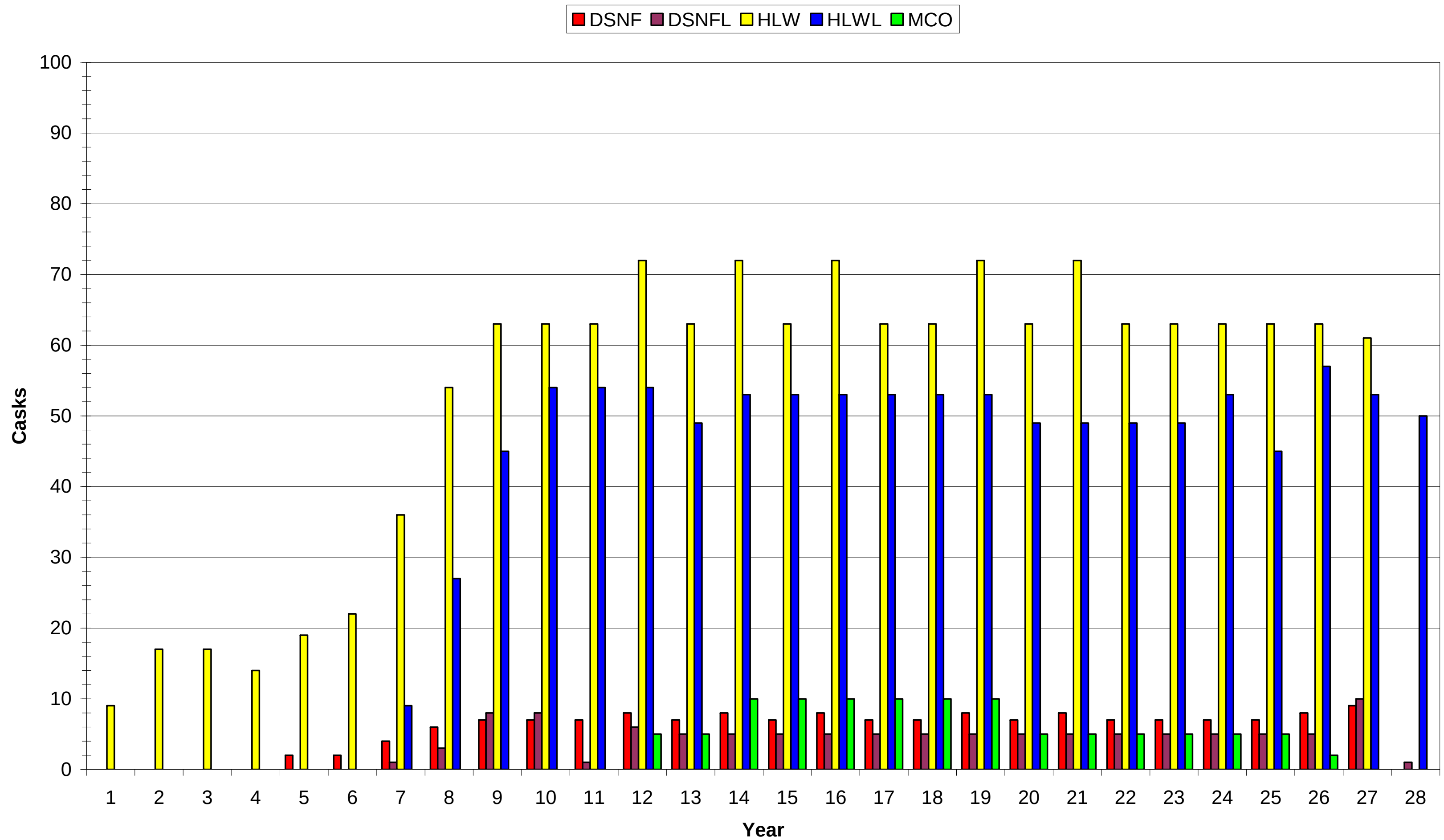

Figure 6. IS Shipments by Year – Reference Case Before Smoothing

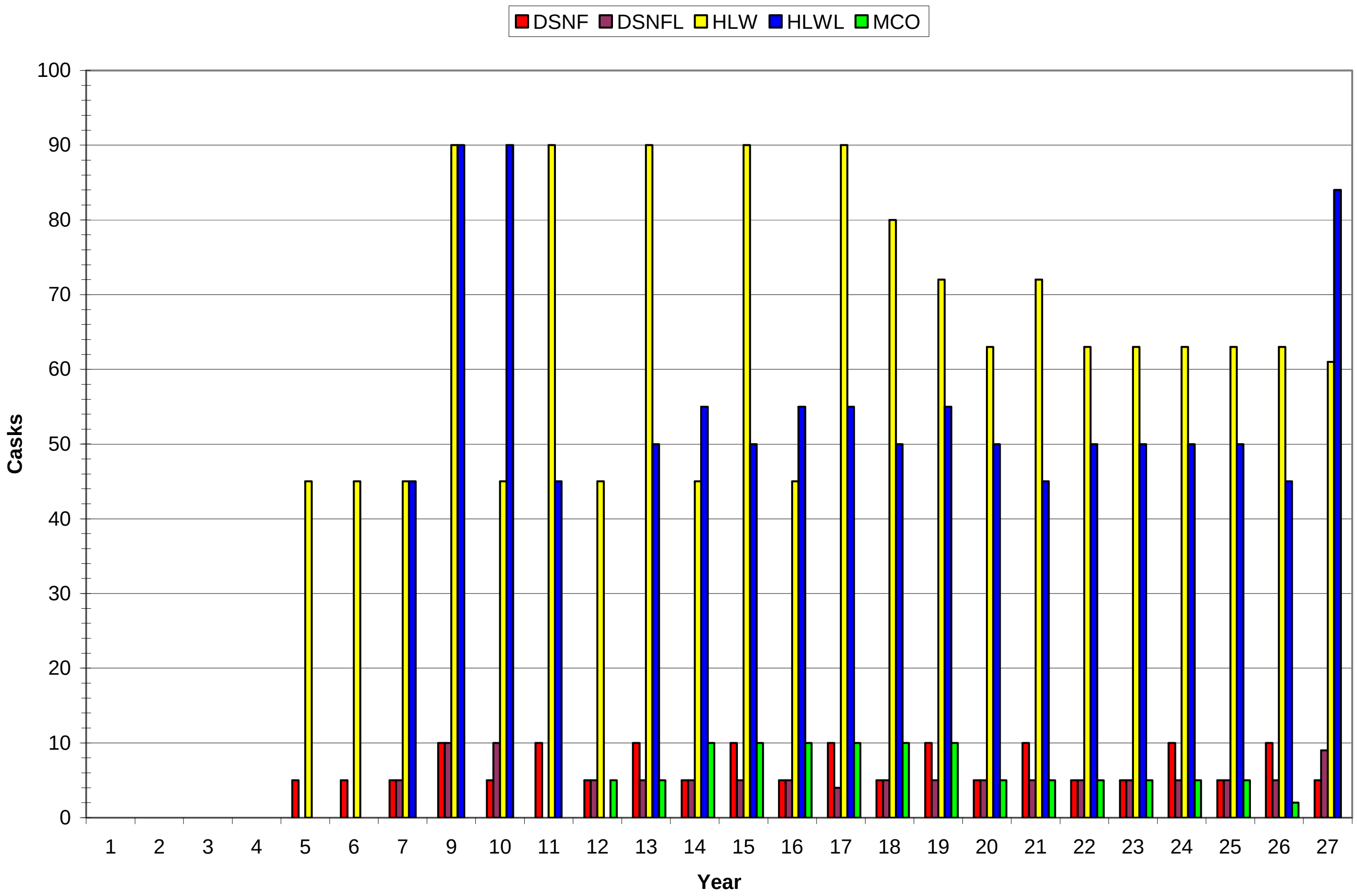

Figure 7. IS Shipments by Year – SNF Lead, Reference Case

Figure 7 shows the results for SNF Lead and that the HLW shipments are delayed until the first DOE SNF shipments begin around year 5.

Figure 8 shows the HLW scheduled (IS file) versus arrival cask loads for the Reference Case Scenario and Figure 9 shows the HLW scheduled versus arrival cask loads for a TSM run using the SNF Lead TSMPP smoothing algorithm. The Reference Case Scenario initiates shipments of HLW from the start where the SNF Lead Scenario initiates HLW shipments at year 5 when the first DOE SNF shipment is scheduled. The initial shipments in the Reference Case Scenario are the cask loads that have been manually added for a thermal analysis run. The SNF Lead algorithm delayed these cask loads as designed.

Also notice that the SNF Lead scenario schedules HLW shipments in increments of 45 casks, the required amount to smooth one consist (5 casks) of DOE SNF. The manual smoothing in the Reference Case Scenario schedules HLW shipments in smaller increments. Therefore, the SNF Lead algorithm has short times of high numbers of shipments indicated by IS scheduling “bubbles” around year 8 and after, when compared with the Reference Case Scenario. This behavior is expected and the bubbles have little impact on the overall simulation results.

2.6 REFERENCE CASE: HLW LEAD

The TSMPP HLW Lead algorithm will ship the HLW cask loads on schedule and then adjust the shipments of the DOE SNF (priority) and MCO (second priority) cask loads for the proper codisposal waste inventory ratio.

Figure 10 (Figure 6 smoothed) shows DOE SNF being rescheduled nearly immediately in the first year in the HLW Lead scenario. The HLW Lead algorithm also enforces 5 cask loads per shipment. Figure 10 also shows how the preference to match the DOE SNF long with the HLWL pushes disposal of the MCOs to after year 25.

As anticipated, comparison between the DVCG results in Figures 11 and 12 shows no distinguishable difference in the arrival of HLW at the GROA between the Reference Case Scenario and the HLW Lead Scenario. However, the figures show that while the rate of DOE SNF acceptance at the GROA remains constant between the two cases, there is a period approximately around years 8 through 18 where the HLW Lead IS file schedules the DOE SNF faster and causes bubbles. These periods of scheduling rapid shipments are due to the 5 cask batching enforced by the smoothing algorithm. This demonstrates that the HLW Lead smoothing algorithm performs as expected.

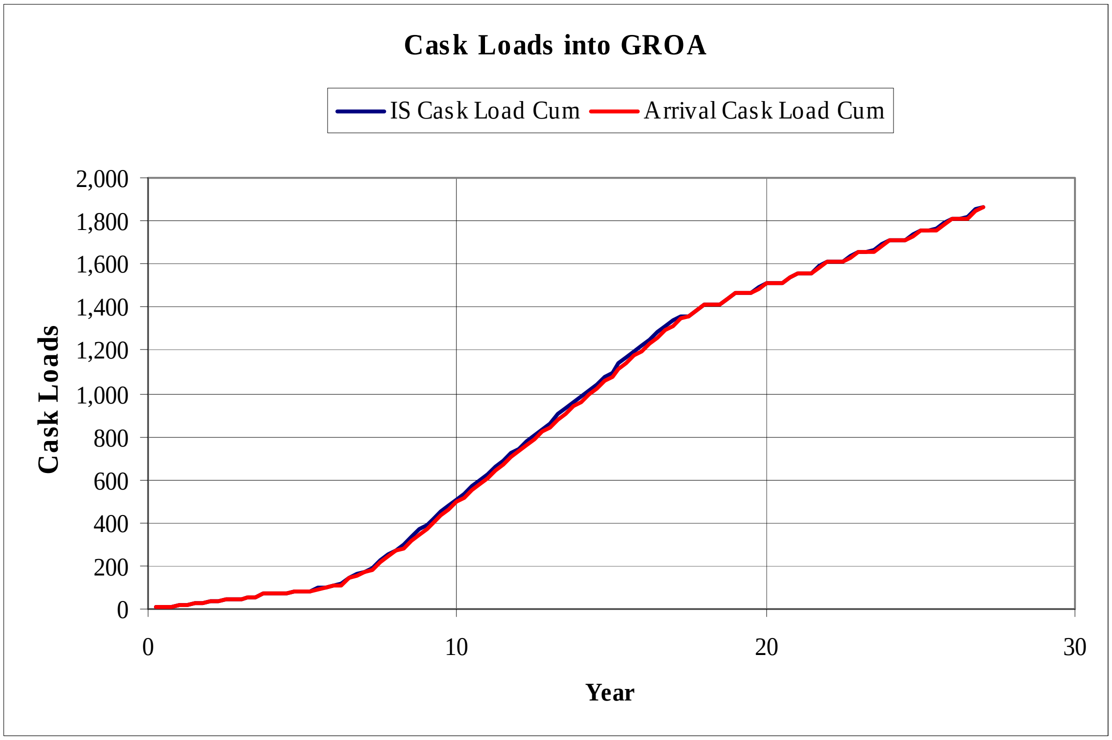

Figure 8. HLW Schedule vs. Arrival, Reference Case

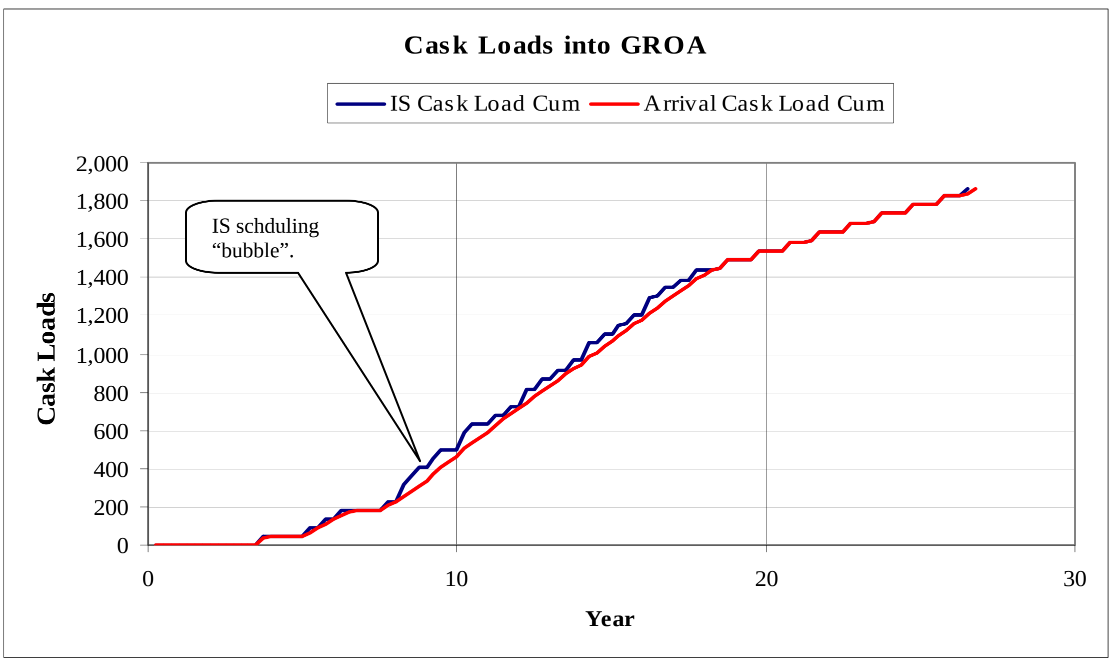

Figure 9. HLW Scheduled vs. Arrival, SNF Lead

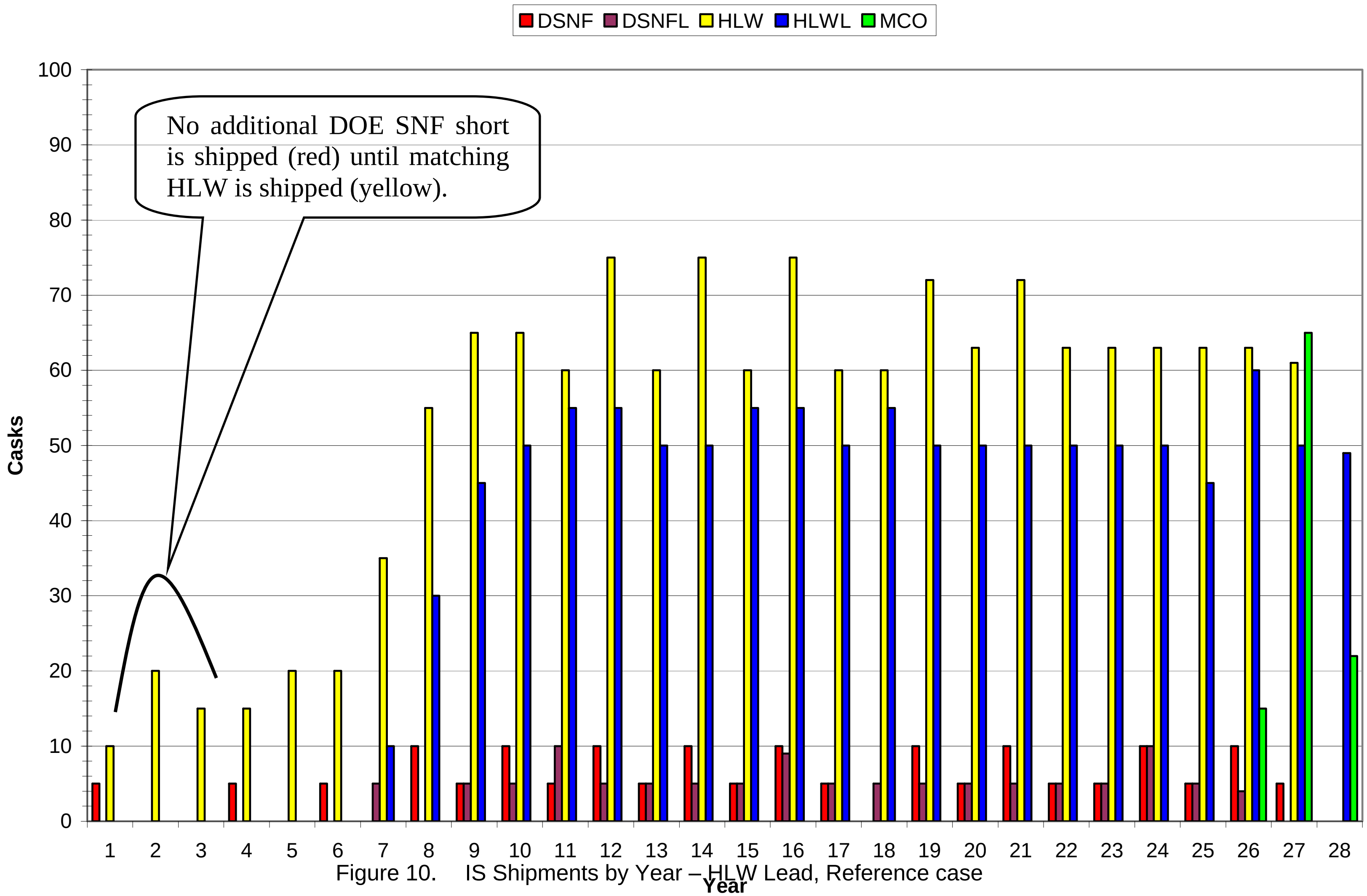

Figure 10. IS Shipments by Year – HLW Lead, Reference case

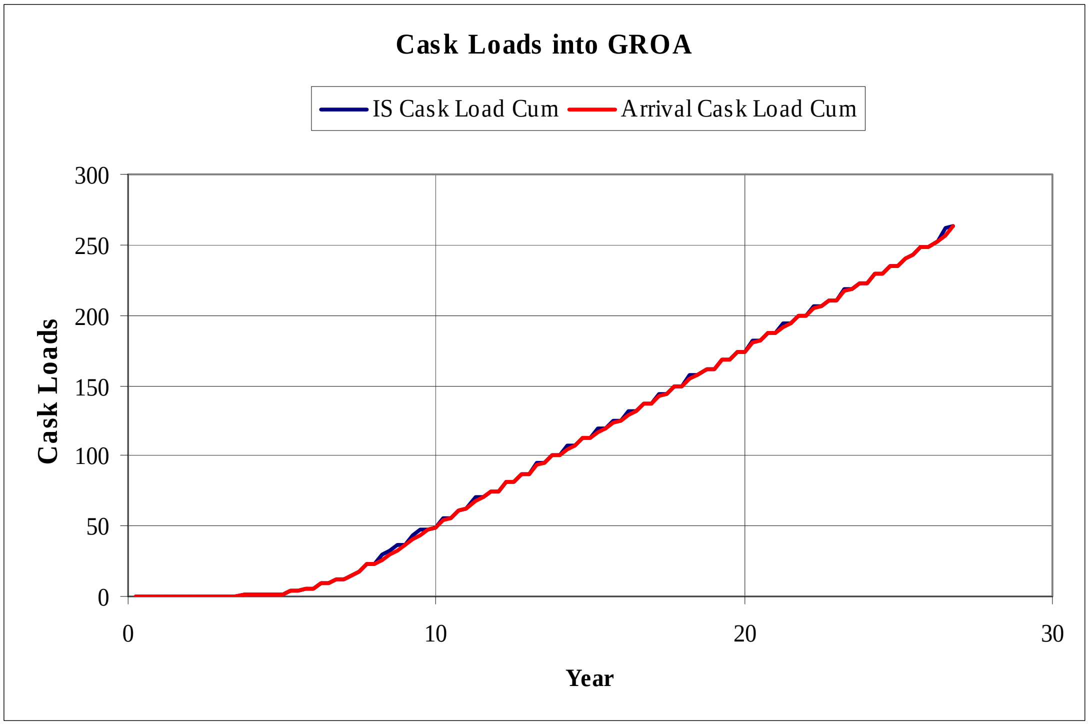

Figure 11. DOE SNF Schedule vs. Arrival, Reference Case

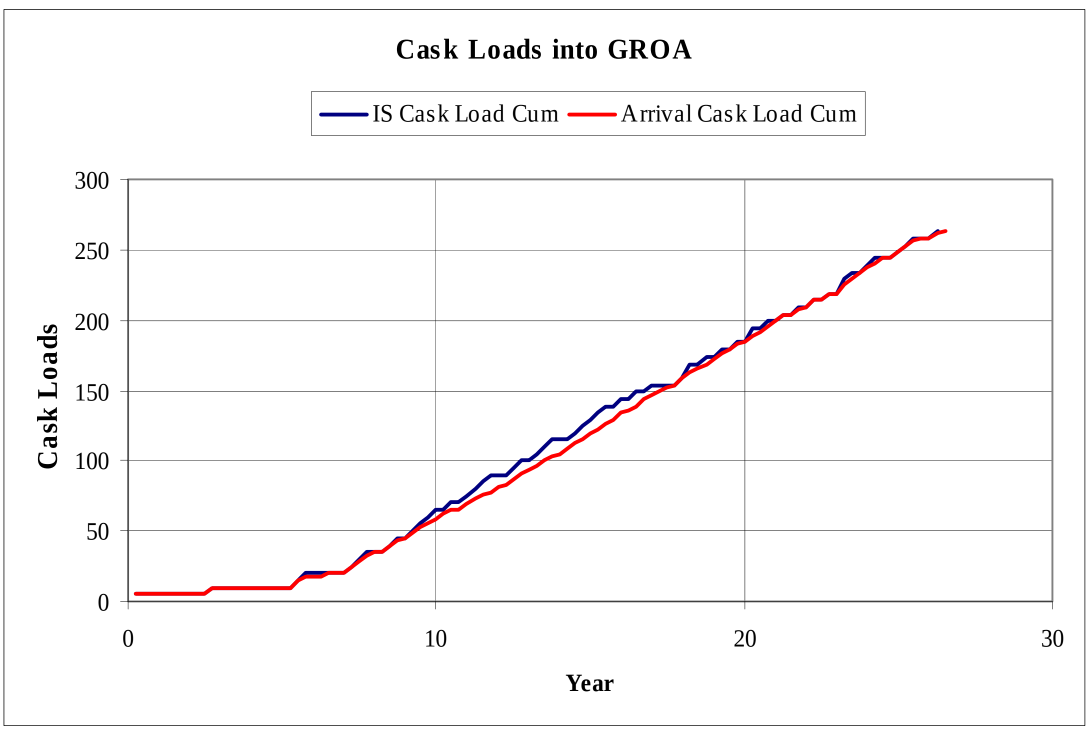

Figure 12. DOE SNF Schedule vs. Arrival, HLW Lead

2.7 HLW_MISMATCH

Another indicator of smoothing performance is in the analysis of the "HLW_Mismatch" variable. This variable allocates a quantity of codisposal WPs that the model may make in cases where WP constituents are not available in the proper ratio. HLW_Mismatch decrements from its initial (entered) value for each WP that is made because there is insufficient DOE SNF to match up with the available HLW; HLW_Mismatch reaches zero when the last "mismatched" WP is made. A comparison of HLW_Mismatch values versus time for the Reference Case, SNF Lead and HLW Lead scenarios is shown in Table 1. In the Reference Case Scenario, HLW_Mismatch (63 WPs) is entirely consumed within 4.5 years of model simulation, due to the manually-added HLW cask loads in Years 1 - 4. The SNF Lead scenario takes 23 years to consume its HLW_Mismatch, consistent with when it starts running out of DOE SNF to match with HLW for codisposal. The HLW Lead scenario takes 14 years to consume HLW_Mismatch. In effect, the TSMPP smoothing algorithm keeps the proper ratios for the codisposal streams far longer than the manually smoothed Reference Case Scenario in Figure 6. However, considering the manually-added HLW cask loads in Years 1 - 4 the Reference Case Scenario IS file, this is an expected result. This does not indicate that the smoothing algorithm is "better" than manual smoothing; it just shows the behavior is understandably different.

Table 1. Case Comparison of HLW_Mismatch Values

Year	Ref. Case	SNF Lead	HLW Lead
1	48	63	63
2	32	63	63
3	15	63	63
4	1	61	63
5	0	61	63
6	0	61	63
7	0	61	60
8	0	61	60
9	0	60	60
10	0	60	59
11	0	60	27
12	0	60	15
13	0	57	15
14	0	57	1
15	0	57	0
16	0	57	0
17	0	50	0
18	0	14	0
19	0	14	0
20	0	14	0
21	0	14	0
22	0	14	0
23	0	0	0

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3. OBSERVATIONS

The TSMPP smoothing algorithms work as expected and provide the user with an effective way to set the timing of DOE SNF and HLW waste streams for proper filling of codisposal WPs. The user may elect to use the DOE SNF waste stream to establish the HLW shipping schedule (SNF Lead), or alternately may use the HLW waste stream to establish the DOE SNF shipping schedule (HLW Lead).

Comparing metrics between the two strategies also demonstrates that the TSM simulation ability to make codisposal WPs using either strategy will be improved when the lead waste stream (either DOE SNF or HLW) is more evenly distributed across time with the following stream scheduled in the proper ratio to fill codisposal WPs.

The biggest difference between the manually smoothed Reference Case Scenario IS file and its automated counterpart is that the TSMPP smoothing algorithm forces 5 transport casks per consist, while the manually smoothed file does not. Therefore, when one consist of DOE SNF (5 casks x 9 canisters/cask = 45 canisters) is dispatched, the algorithm will schedule nine consists of HLW (5 casks x 5 canisters/cask x 9 = 225 canisters) to meet the 5:1 HLW to DOE SNF canister ratio, in order to create 45 codisposal WPs. This causes short periods of high shipment rates (“bubbles”) when using the smoothing algorithm. However; these “bubbles” do not impact overall DOE SNF and HLW arrivals at the GROA.

The algorithms can be integrated into the TSMPP for TSM Version 6.0. This validation was confirmed using runs using TSM Version 5.0. The behavior in TSM Version 6.0 should be identical and is confirmed in the validation of the TSMPP for TSM Version 6.0 (BSC 2007f).

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4. USE OF COMPUTER SOFTWARE AND MODELS

The following computer software and models are used in this calculation:

- TSM Interim Version 3.0L5 (included in run files attached to this report)
- SimCADPro™ 7.1
- MS EXCEL 2003
- MS Access 2003
- DOE Valley Curve Generator interim version dated 7-02-2007 (included in results to this report)
- ISMorph (included in attachments to this report)

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5. REFERENCES

5.1 DOCUMENTS CITED

BSC (Bechtel SAIC Company, LLC) 2005. *TSM System Study: Impact of a Canister-Based System on the CRWMS*. MIS-CRW-SE-000003 REV 00, Bechtel SAIC Company, LLC, Washington, D.C. ACC: DOC.20051213.0001.

BSC 2007a. *Total System Model Version 6.0*. Washington DC: BSC. Software ID: 50040.

BSC 2007b. *User Manual for the Total System Model Version 6.0*, 50040-UM-01-6.0-00, Bechtel SAIC Company, LLC, Washington, D.C. ACC: Submit to RPC.

BSC 2007c. *User Manual for the Total System Model Version 6.0 Preprocessor*, 50040-UM-02-6.0-00, Bechtel SAIC Company, LLC, Washington, D.C. ACC: Submit to RPC.

BSC-2007d. *Engineering Study: Total System Model Analysis for Repository Postclosure Thermal Envelope Study, Phase 1*. 000-00R-G000-00600-000-001. Washington, DC: BSC. ACC: ENG.20070905.0023.

BSC 2007e. *Total System Model Version 6.0 Preprocessor WO Algorithm Validation Report*, 50040-VAL-04-6.0-00, Bechtel SAIC Company, LLC, Washington, D.C. ACC: Submit to RPC.

BSC 2007f. *Total System Model Version 6.0 Preprocessor Validation Report*, 50040-VAL-02-6.0-0, Bechtel SAIC Company, LLC, Washington, D.C. ACC: Submit to RPC.

5.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

AP-ENG-006 REV 1 ICN 0, *Total System Model(TSM) – Changes to Configuration Items and Base Case.* Washington, DC: BSC. ACC: Submit to RPC.

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6. ATTACHMENTS

The files in Table 2 are included electronically.

Table 2. Electronic Attachments

File Names	Description	Size (kB)	Date
IS_CD1_IAS_DefOnly_New Navy_072507_analysis.xls	Test IS file.	3,718	8/10/07
IS_CD1_IAS_DefOnly_New Navy_072507_revised_ISMorph_SNFLeadIgnoreTele.xls	Smoothed variant of Test IS file.	7,961	8/10/07
DOE VCG_Base_07-02-07.xls	DOE Valley Curve Generator for Reference Case Scenario. Includes DOE VCG from 7-2-07.	1,216	7/9/07
CaseCompare.mdb	Access file used in the generation of data for the spreadsheet HowDoesWasteMove.xls	5,792	7/27/07
HowDoesWasteMove.xls	Supporting data and charts for Figures 1 through 3.	4,618	8/10/07
DOE VCG_SNFLead_07-02-07.xls	DOE Valley Curve Generator for SNF Lead Scenario. Includes DOE VCG from 7-2-07.	1,288	7/9/07
DOE VCG_HLWLead_07-02-07.xls	DOE Valley Curve Generator for HLW Lead Scenario. Includes DOE VCG from 7-2-07.	1,217	7/11/07
TSM_V3.0L5_THERMAL-70K_russ_011907.zip Containing:	Reference Case Scenario TSM run files	26,215	8/10/07
TSM.MDB		73,830	1/13/07
BatchInfo_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1.csv		12,72	1/11/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a.xls		3,976	1/12/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_Analysis.xls		14,785	8/10/07
Tsm_v30l5.sim		101,860	1/11/07
TSM_V3.0L5.simdata		84,062	1/13/07
Tsm.xml		3	1/12/07
SNFLead-20070704-Lisa.zip Containing:	SNF Lead Scenario run files .	29,259	8/10/07
ISMorph.mdb		119,069	7/3/07
TSM.mdb		32,444	7/4/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_SNFLead.csv		1,564	7/3/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_SNFLead.xls		8,591	7/3/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_SNFLead_Analysis.xls		14,411	8/10/07
Tsm_v30l5.sim		101,860	1/11/07
TSM_V3.0L5.simdata		94,806	7/4/07
Tsm.xml		3	7/3/07

File Names	Description	Size (kB)	Date
HLWLead-20070711-A2B.zip Containing:	HLW Lead Scenario run files.	29,994	8/10/07
ISMorph.mdb		119,169	7/3/07
TSM.mdb		32,543	7/11/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_HLWLead.csv		1,564	7/3/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_HLWLead.xls		8,591	7/3/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_HLWLead_analysis.xls		14,008	8/10/07
IS_CD-1_70K_nocrit_2011TADs_YFF5_22kW_R1a_ISMorph_HLWLead_Chart.xls		23,660	7/3/07
Tsm_v30l5.sim		101,860	1/11/07
TSM_V3.0L5.simdata		83,866	7/11/07
Tsm.xml		3	7/10/07
HLW_Mismatch.xls	Data compilation for Table 3.	33	7/17/07
SimData-BaseCase.zip Containing:	Reference Case Scenario Simdata file modified with quires in support of Table 3. (See HLW_Mismatch query).	11,930	7/17/07
TSM_V3.0L5.simdata		84,091	7/11/07
SimData-SNFLead.zip Containing:	SNF Lead Scenario Simdata file modified with quires in support of Table 3. (See HLW_Mismatch query).	13,960	7/17/07
TSM_V3.0L5.simdata		94,835	7/17/07
SimData-HLWLead.zip Containing:	HLW Lead Scenario Simdata file modified with quires in support of Table 3. (See HLW_Mismatch query).	11,937	7/17/07
TSM_V3.0L5.simdata		83,866	7/11/07
ISMorph_20070717.zip Containing:	VB 6 Program ISMorph that will take an existing IS file as input and transform it with the select smoothing and/or work order algorithms. Modules are designed for direct interface with TSMPP.	37	7/31/07
ISMorph.mdb		217	7/17/07
ISMorph.vbw		>1	7/13/07
FormMain.frm		8	7/12/07
BasketAndShell.bas		>1	7/4/07
DOESchedule.bas		55	7/8/07
Globals.bas		1	12/19/06
Module1.bas		15	7/4/07
WorkOrders.bas		31	7/12/07
ISMorph.vbp		2	7/4/07