Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Design Hazard Analysis Supplement 1

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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G. R. Franz
R. H. Meichle
XRON

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P.O. Box 1600
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Nancy A Fouad 7/18/2011
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TERMS

DOE-RL	U.S. Department of Energy Richland Operations Office
ECRTS	Engineered Container Retrieval and Transfer System
HAZOP	Hazard and Operability Study
LOEP	Loss of Electric Power
NPH	Natural Phenomena Hazards
NS	Nuclear Safety
PDR	Preliminary Design Review
PC	Performance Category
SDC	Seismic Design Criteria
SDS	Safety Design Strategy
STS	Sludge Transport System
STSC	Sludge Transport and Storage Container

1.0 INTRODUCTION

1.1 PURPOSE

This “What/If” Hazards Analysis addresses hazards affecting the Sludge Treatment Project Engineered Container Retrieval and Transfer System (ECRTS) NPH and external events at the preliminary design stage. In addition, the hazards of the operation sequence steps for the mechanical handling operations in preparation of Sludge Transport and Storage Container (STSC), disconnect STSC and prepare STSC and Sludge Transport System (STS) for shipping are addressed.

This analysis provides a supplement to PRC-STP-00467, “*Sludge Treatment Project Engineered Container Retrieval And Transfer System Preliminary Design Hazard And Operability Study*”.

1.2 BACKGROUND

The Engineered Container Retrieval and Transfer System (ECRTS) is being designed to retrieve sludge from six containers in the KW Basin for transfer to STSCs in the KW Basin Modified Annex. The ECRTS is summarized in PRC-STP-00467 and additional descriptions can be found in HNF-41051. PRC-STP-00467 provides the follow-up to the “What/If” Hazard Analysis for the Conceptual Design, PRC-STP-00124 “*Sludge Treatment Project Engineered Container Retrieval And Transfer System Conceptual Design Hazards Analysis*” and HAZOP for the draft preliminary design, PRC-STP-00346, “*Sludge Treatment Project Engineered Container Retrieval And Transfer System Draft Preliminary Design Hazard And Operability Study*”.

The HAZOP methodology does not lend itself well to NPH and external events hazards analysis or consideration of the operation sequences steps involving personnel access to the modified annex and interaction with the installed equipment. The latter was referred to the Gap Analysis in the hazard analysis meetings. The NPH and External Event and Operation Sequence hazard analysis for the draft preliminary design status was captured in an initial Hazard Analyses on September 10, October 19, and October 22 and is documented in PRC-STP-00382, “*Sludge Treatment Project Engineered Container Retrieval And Transfer System Draft Preliminary Design Hazard Analysis Supplement 1*”.

PRC-STP-00409, 2011, “*Sludge Treatment Project Engineered Container Retrieval and Transfer System Draft Preliminary Design Control Decision*” documented the control decision for the draft preliminary design.

1.3 SCOPE

This document provides the “What/If” hazards analysis of NPH, external events and selected operation sequences for the ECRTS preliminary design to supplement the HAZOP provided PRC-STP-00467. The process conditions covered were:

- Retrieving sludge from an Engineered Container
- Transferring the slurry to an STSC

- Decanting the STSC
- Backwashing the Sand Filter into the STSC
- Purging the STSC with nitrogen
- Purging the STS cask with nitrogen
- Pressurizing the STS cask with nitrogen
- Adding flocculant to the slurry during transfer
- Adding flocculant to the supernate
- Automatically flushing the transfer line
- Recovering excess sludge from an over-filled STSC

2.0 FACILITY AND PROCESS DESCRIPTION

2.1 FACILITY DESCRIPTION

The facility description is provided in PRC-STP-00467 which includes ECRTS systems in 105 KW Basin, Shielded Hose Chase, and Modified KW Basin Annex including Process Flow Diagrams (PFDs) and P&IDs.

2.2 PROCESS

2.2.1 Retrieval and Transfer Processes

Sludge transfer to STSC, Flush sequence, Settle/Flocculate, Decant, Filter Backwash and Overfill Recovery processes are described in PRC-STP-00467 including Process Flow Diagrams (PFDs) and P&IDs.

2.2.2 Operation Sequences (Gap Analysis)

In addition to the retrieval and transfer processes of section 2.2.1 above the Operation Modes from PRC-STP-00358, "*Operating Sequence and Interlock Definition Document for the Engineered Container Retrieval and Transfer System (ECRTS)*" which were analyzed are described as follows.

Mode 1: Prepare STSC. The process begins with receipt of an empty STSC in the STS Cask on the STS transport trailer. The trailer is positioned on the truck scale in the annex and disconnected from the tractor, which then exits the annex. The as-received weight is recorded, the cask is vented, the lid is removed and a radiological survey is performed. Exposed surfaces are covered with contamination control measures (plastic wrap, glove bags, etc.) as needed and the slurry transfer, decant, and ventilation hoses and instrument cables are attached to their respective STSC nozzles and instrument connections. Weight and level instrument readings are recorded continuously on a data logger.

Mode 8: Disconnect STSC. When the weight and level measurements in the decanted STSC indicate that the transferred sludge quantity is within the established process control limits, the final flush sequence is performed. The operators enter the annex building and align the valves to flush the sludge transfer and decant connector hoses with IXM water from the valve box to the STSC to reduce contamination levels and adjust the liquid level in the STSC to the specified final fill height. After flushing, the fill hose and decant hose are drained by opening the vent valves in the valve boxes. The hose connectors are unbolted and raised about one inch to open the vent port inside the connector. This allows air to flow from the vent valve through the inner hose to the connector and into the STSC, blowing out any residual liquid to prevent drips. If desired, the system can be left in this configuration for an extended time to dry the interior of the hoses. The hose connectors are then disconnected, the hose nozzle caps and STSC nozzle blind flanges are installed, and the hose connectors are placed in the storage position on the annex mezzanine. The ventilation hose is disconnected and capped. The inert gas system valve is opened, the inlet breather filter is valved off, and the STSC head space is purged. The purge hoses are disconnected and capped, and replaced with Nucfil^{®1} vent filters, and the final level reading is obtained before the instrument cables are disconnected from the STSC. Contamination control measures are removed and an exit radiological survey is conducted. Decontamination is performed if needed and the STS cask lid is installed.

Mode 9: Prepare for Shipping. After the STS cask lid is secured, the final shipping weight is measured and the shipping manifest is prepared. The vent port tools are installed on the cask and the cask is vented, purged with inert gas, and leak tested in preparation for transport. The annex door is opened, the tractor is connected, and the trailer removed from the annex. Shipping papers are verified and the STS is transported to T Plant.

3.0 METHODOLOGY

The purpose of this document is to provide input on the hazards and their consequences resulting from NPH, external events, and operation sequences to the control decisions for determination of necessary prevention and/or mitigation SSCs or administrative controls for ECRTS preliminary design. This document contains the NPH and External Events What-If/Checklist portion of the hazards analysis as well as the what-if operating sequences evaluations for modes 1, 8, and 9. These are the modes when the K Basin Modified Annex will be occupied, and the focus has been on the potential to initiate radiological control events as well as to review for significant process fault initiators.

The results of the What-if meetings are documented in tabular form in Appendices C and D. The table column headings are as follows:

Identifier: Unique identifier assigned to each What-if question. For NPH and external events, the identifier is the first character or series of characters of the event designation from the list in Table 1, followed by a hyphen and the number of the what-if within the event. For the gap

¹ NucFil[®] is a registered trademark of Nuclear Filter Technology

analysis based on the operating nodes, the first character is the mode, then a hyphen followed by the second character which is the activity within the mode, followed by the unique event number. The first and second numbers come from Appendix A and are described in the table.

“What-If”: A description of the event that is postulated by the review team.

Causes: This column in the NPH and External Event lists the specific phenomenon. In the gap analysis for modes 1, 8, and 9, this column identifies the mechanism that may have allowed the What-if to occur.

Hazardous Condition: This column identifies the hazardous condition that was identified as a result of the What-if (if any). If no hazardous condition results, then the word None is indicated. For this hazards analysis, conditions that may result in a future uncontrolled release event are identified with the initiating What-if as well as the subsequent operating activity that actually results in the release. As an example, a valve postulated to be left closed resulting in an overpressure and spray or splash and splatter when a transfer is initiated, would show as a hazardous condition both at the valve mis-positioning and at the pump starting.

Consequences: This column describes the consequence associated with the hazardous condition. If there is not a hazardous condition, then operational upset is indicated with corresponding cost and schedule impacts.

Candidate Controls: Candidate engineered and administrative controls are listed for those hazardous conditions that may result in consequences to onsite workers or off site public.

Remarks/Actions: The remarks column is used to relate events, identify design considerations that have come up in the hazards review, and to carry actions for future work. These would be revised as the final design hazards analysis is completed.

3.1 NPH AND EXTERNAL EVENTS

The NPH and External events addressed by the hazard analysis for the ECRTS processes are provided in Table 1.

Table 1 - List of ECRTS NPH and External Events Considered in Hazards Analysis

Seismic	Ash fall	Extreme Cold	Explosion – vehicle fuel or propane or welding gas
Wind	Rain	Loss of Electrical Power	Aircraft crash – below extremely unlikely
Flood	Lightning	Range Fire	Adjacent facility Fire
Snow	Extreme heat	Vehicle Crash	Facility fire

The results of the NPH “What/If” hazards analysis are documented in Appendix C.

3.2 OPERATION SEQUENCES (GAP ANALYSIS)

The operation sequence steps for Modes 1, 8 & 9 evaluated by the “What/If” hazard analysis are provided in Appendix A. Included is the evaluation of differences resulting from the design progression from draft preliminary design operation sequence steps addressed in PRC-STP-00382 versus the operation sequence steps addressed in this analysis.

The results of the Operation Sequences (Gap Analysis) “What/If” hazards analysis are documented in Appendix D.

3.3 HAZARD ASSESSMENT TEAM

The participants in Hazard Assessments for the draft preliminary design hazards analysis are shown in Appendix B. Following the release of the preliminary design information, (e.g. PFDs, P&IDs, revised project documents) reviews were made to determine if changes to the results of the draft preliminary design hazard analysis results are necessary. It was determined that changes to the design affecting NPH and external event results were not significant enough to require additional meetings. The changes to the operation sequence steps were reviewed by representatives from Process Engineering and Nuclear Safety and were judged to not require additional meetings. The identified changes were distributed for project review prior to incorporation in this document.

3.4 UNMITIGATED FREQUENCY AND CONSEQUENCE ESTIMATES

Unmitigated radiological consequence and frequency levels were assigned to hazardous conditions identified by the “What/If” Hazard Analysis. The onsite and offsite radiological consequence levels are shown in Tables 2 and 3, respectively.

Table 2 - Collocated Worker and Offsite Public Consequence Levels*

Consequence Level	Collocated Worker (100 m)	Offsite Public
High	> 100 rem	> 25 rem
Moderate	≥ 25 rem	≥ 5 rem
Low	< 25 rem	< 5 rem

*Modified from PRC-STD-NS-8736, Table 2-1. Specifically, the moderate and low consequence level for the offsite public is set at 5 rem (versus 1 rem) based on guidance in DOE-STD-1189-2008.

Table 3 - Frequency Levels*

Frequency Level	Frequency
Anticipated	Above 1E-2/yr
Unlikely	1E-4 to 1E-2/yr
Extremely Unlikely	1E-6 to 1E-4/yr
Beyond Extremely Unlikely	Below 1E-6/yr

*Derived from PRC-STD-NS-8736, Table 2-2

In addition the Seismic Design Criteria and other NPH design criteria to be applied as required by DOE STD 1189-2008, and the Owendoff letter are shown in Table 4.

Table 4 - Guidance for SDC & Other NPH Criteria Based on Unmitigated NPH Induced SSC Failures

Seismic Category	Other NPH Category (1)	Collocated Worker	Public
SDC-1	PC-1	Dose < 5 rem	Not applicable (2)
SDC-2	PC-2	5 rem < dose < 100 rem	5 rem < Dose < 25 rem
SDC-3	PC-3	<100 rem < dose	25 rem < dose
(1) DOE Memorandum, April 15, 2009, Implementation of DOE-STD-1189, <i>Integration of Safety into the Design Process</i> for Environmental Management Activities, J. M. Owendoff to Distribution, U.S. Department of Energy, Washington, D.C.. (2) A Hazard Category 1, 2, or 3 nuclear facility with consequences to a collocated worker from failure of an SSC in a seismic event will require that SSC to be classified as SDC-1 at a minimum. Therefore, a public criterion for SDC-1 is not needed.			

4.0 RESULTS

4.1 IDENTIFIED ACCIDENT INITIATORS

The Identified hazardous conditions for which prevention and/or mitigative SSCs or Administrative Controls may be required are identified in Appendix D. The specific hazardous conditions for the NPH or external events are provided in Table 5.

Table 5 - NPH and External Event Accident Initiators

Event	Spray Leak	Splash and splatter	Hydrogen Deflagration	Overpressure	STSC Overturn
Seismic	X	X	X	X	X
Wind	X	X	X	X	

Table 5 - NPH and External Event Accident Initiators

Event	Spray Leak	Splash and splatter	Hydrogen Deflagration	Overpressure	STSC Overturn
Flood			X	X	
Snow	X	X	X	X	
Ashfall	X	X	X	X	
Rain			X	X	
Lightning	X	X	X	X	
Extreme heat (113° F)				X	
Low Ambient Temperature Extreme Cold (-23° F)	X	X	X	X	
Loss of Electrical Power LOEP	X	X	X	X	
Range Fire	X	X	X	X	X
Vehicle Impact	X	X	X	X	X
Explosion – vehicle fuel or propane or welding gas	X	X	X	X	X
Aircraft crash – <i>beyond extremely unlikely</i>	X	X	X	X	X
Adjacent facility Fire	X	X	X	X	X
Facility fire - combustibles	X	X	X	X	X

4.2 IDENTIFIED UNMITIGATED HAZARDOUS CONDITIONS

The hazards analysis results shown in Appendices C and D identified the following hazardous conditions as providing significant uncontrolled releases.

- Spray leak

- Splash and splatter
- Deflagration
- Overpressure STS
- Overturn STSC, spill.

It is noted that the splash and splatter event includes a pool release component. The hazardous condition identified as “spread of contamination” encompasses a range of radiological conditions including fixed or low level airborne radioactivity that is a serious radiological concern but does not lead to a facility worker getting greater than 100 rem and would not likely be measurable for the collocated worker.

4.3 FREQUENCY AND CONSEQUENCE LEVELS

The frequency and consequence levels assigned to each hazardous condition are shown in Appendix E and are based on Table 6. The NPH initiated uncontrolled release is unlikely due to the initiating phenomena frequency. The unmitigated consequences are considered the same as events analyzed for the ECRTS conceptual safety design report. Similar consequences would result from the uncontrolled releases postulated as part of the gap analysis, but the frequency of those events is considered to be anticipated.

Table 6 - Basis for Appendix E Frequency and Consequence Levels

Hazardous Condition	Source Material ¹	Unmitigated Frequency	Unmitigated Consequence		
			Facility Worker	Onsite	Offsite
Seismic induced Spray Leak	Slurry (retrieval and transfer)	U	H	H	L
	Slurry (overflow recovery)	U	H	H	L
	Sand filter backwash	U	L	L	L
	Slurry (overflow recovery line failure)	U	H	H	L
	Slurry (overflow recovery diaphragm pump failure)	U	L	L	L
Splash and Splatter/Pool	Slurry (retrieval and transfer)	U	L	L*	L
	STSC supernate	U	L	L	L
	Sand filter backwash	U	L	L	L
	Slurry (overflow recovery line failure)	U	L	L	L
	Slurry (overflow recovery diaphragm pump failure)	U	L	L	L

Table 6 - Basis for Appendix E Frequency and Consequence Levels

Hazardous Condition	Source Material ¹	Unmitigated Frequency	Unmitigated Consequence		
			Facility Worker	Onsite	Offsite
Hydrogen Deflagration	STSC	U	H ²	L	L
	Transfer Line Service Box	U	H ²	L	L
	Decant Pump Box ³	U	H ²	L	L
	Sand Filter ³	U	H ²	L	L
	Sand Filter Enclosure ³	U	H ²	L	L
Overpressurization	Sludge slurry	U	L	L	L
¹ Consequences based on settler tank sludge which has a higher radionuclide inventory than KE or KW Basin sludge. For a given hazardous condition (e.g., spray release) the consequences vary as a function of the estimated volume percent solids. ² A high consequence is assigned to the facility worker for hydrogen deflagrations based on the potential for prompt death or serious injury. ³ PRC-STP-CN-N-00401 does not analyze hydrogen deflagrations in the Decant Pump Box, sand filter, or Sand Filter Enclosure. The low consequences are qualitatively assigned based on the low consequences calculated for deflagrations in the STSC and Transfer Line Service Box. A = Anticipated H = High M = Moderate L = Low L* = Low, but requires SDC-2 and Other NPH PC-2 design criteria see Table 4(5 rem < dose < 100 rem)					

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APPENDIX A

OPERATION SEQUENCE STEPS

MODE 1 - RECEIVE STS TRAILER & CONNECT STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
1	1	Enter Annex and open loading bay door	N	N		1	Enter Annex and open loading bay door
1	2	Position and align STS trailer on weigh scales	N	N		2	Position and align STS trailer on weigh scales
1	3	Secure STS trailer	N	N		3	Secure STS trailer
1	4	Disconnect STS tractor and exit loading bay ramp	N	N		4	Disconnect STS tractor and exit loading bay ramp
1	5	Close Annex loading bay door	N	N		5	Close Annex loading bay door
1	6	Record trailer weight (WIT-740-401) and verify shipping manifest.	N	N		6	Weigh trailer with cask and record weight.
1	7	Remove IP-2 bag from Drain Port	NA	New	Content changed because of STS Cask purge through drain port rather than vent port and adding a new hose (H-603) from drain port to new drain tank.		
1	8	Remove Cask drain port cap and install drain port tool	NA	New			
1	9	Attach Purge Line H-602 to drain port tool. Align V-609 to "Cask" position. Verify V-607 and V-608 are closed.	NA	New			
1	10	Attach drain line H-603 to drain port tool	NA	New			
1	11	Open drain port	NA	New			
1	12	Verify STS cask pressure is 0 psig (PI-760-606)	NA	New			
1	13	Unzip/remove Outer IP-2 bag	Y	No - was 7		7	Unzip/remove Outer IP-2 bag.
1	14	Unzip/remove Inner IP-2 bag	Y	No - was 8		8	Unzip/remove Inner IP-2 bag
1	15	Install Lid Lift Fixture on STS cask lid (3 bolts)	Y	No - was 16		16	Install Lid Lift Fixture on STS cask lid
1	16	Remove the STS Lid bolts (24 bolts)	Y	No - was 17		17	Remove the STS Lid bolts
1	17	Remove the STS Lid and install onto the Lid Inspection Station.	Y	No - was 18		18	Remove the STS Lid and install onto the Lid Inspection Station.
1	18	Verify V-103 and V-109 are OPEN. Verify V-101, AOV-104, and AOV-105 are CLOSED.	Y	Y - was 19	AOV-104 changed to closed and AOV-105 verified closed (corrections to current configuration)	19	Verify V-103, V-109 and AOV-104 are OPEN. Verify V-101 is CLOSED
1	19	Remove and store the 3-bolt blind flange from STSC Nozzle A.	Y	No - was 20		20	Remove and store the 3-bolt blind flange from STSC Nozzle A.
1	20	Remove contamination controls and end cap from Sludge line connector. Air flows from the room into the TLSB through H-107 and H-107 annulus. IL-125 turns ON.	Y	Y - was 21	Added IL-125 status	21	Remove contamination controls and end cap from Sludge line connector. Air flows from the room into the TLSB through H-107 and H-107 annulus

MODE 1 - RECEIVE STS TRAILER & CONNECT STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
1	21	Connect the Sludge Inlet Riverbend connector (Hose H-107) to the 3 bolt PUP connector on Nozzle A and torque the acorn nuts. Verify IL-118 is ON.	Y	No - was 22		22	Connect the Sludge Inlet Riverbend connector (Hose H-107) to the 3 bolt PUP connector on Nozzle A and torque the acorn nuts. Verify IL-118 is ON
1	22	Verify V-205 and V-201 are OPEN. Verify V-202 and V-206 is CLOSED.	Y	Y - was 23	Added closed verification for V-206 (verifies IXM Water shutoff).	23	Verify V-205 and V-201 are OPEN. Verify V-202 is CLOSED
1	23	Remove and store the 4-bolt blind flange from STSC Nozzle B.	Y	No - was 24		24	Remove and store the 4-bolt blind flange from STSC Nozzle B.
1	24	Remove contamination controls and end cap from Decant line connector. Air flows from the room into the decant box through H-203 and H-203 annulus. IL-223 turns ON.	Y	Y - was 25	Added IL-223 status (FE 720-202 added)	25	Remove contamination controls and end cap from Decant/backwash line connector. Air flows from the room into the decant box through H-203 and H-203 annulus
1	25	Connect the Decant Outlet/Backflush Inlet Riverbend connector (Hose H-203) to the 4 bolt PUP connector on Nozzle B and torque the acorn nuts. Verify IL-218 is ON.	Y	No - was 26		26	Connect the Decant Outlet/Backflush Inlet Riverbend connector (Hose H-203) to the 4 bolt PUP connector on Nozzle B and torque the acorn nuts. Verify IL-218 is ON
1	26	Remove and store the 2 inch Camlok cap from Nozzle F2 and connect the IXM Water Inlet onto the 2 inch Camlok connection (Hose H-752).	Y	No - was 27		27	Remove and store the 2 inch Camlok cap from Nozzle F2 and connect the IXM Water Inlet onto the 2 inch Camlok connection (Hose H-752)
1	27	Remove and store the 4 inch Camlok cap from Nozzle F1 and connect the 4 inch STSC Vent Camlok connection (Hose H-501).	Y	No - was 28		28	Remove and store the 4 inch Camlok cap from Nozzle F1 and connect the 4 inch STSC Vent Camlok connection (Hose H-501)
1	28	Connect the Purge Inlet 1 inch Quick Connect (Hose H-604) to Nozzle S2.	Y	Y - was 29	Identified Nozzle designator (S2)	29	Connect the Purge Inlet 1 inch Quick Connect (Hose H-604)
1	29	Connect I&C connector to LDE-710-103 (Leak Detector) and LE-740-401 (Level Detector) Safety Significant instruments	Y	No - was 30		30	Connect I&C connector to LDE-710-103 (Leak Detector) and LE-740-401 (Level Detector) Safety Significant instruments Connect STSC instruments
1	30	Connect I&C connector to LDE-720-204 (Leak Detector) and LSH-740-402 (Level Switch) General Service instruments	Y	Y - was 31	Corrected LDE-720-410 to LDE-720-204	31	Connect I&C connector to LDE-720-410 (Leak Detector) and LSH-740-402 (Level Switch) General Service instruments
1	31	Turn on STSC Instrument disconnect switch. Verify instrument Health is OK (IL-408 and IL-412 are ON)	NA	New			
1	32	Weigh and record initial filling condition weight (WIT-740-401).	N	Y	Identified instrument	32	Weigh and record initial filling condition weight
1	33	Select/Verify sludge type on PNL-401 (ECRT-KS-401 to 'K-East', 'K-West', or 'Settler' position) and reset PNL-401: Press HS-402 'SIP RESET' pushbutton.	N	N		33	Select Sludge Type on PNL-401 (ECRT-KS-401 to 'K-East', 'KWest', or 'Settler' position) and reset PNL-401: Press HS-402 'reset' pushbutton

MODE 1 - RECEIVE STS TRAILER & CONNECT STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
1	34	Initiate operability test of LSH-740-402: Verify ECRT-HS-113 in 'DISABLE' position.	N	Y	Corrected LSH-740-313 to LDE-740-402, added verification for disabling of flush, deleted HS-701	34	Initiate verifying operability of LSH-740-313: Place ECRT-HS-701 in 'test' position.
1	35	Record starting value of water meter FQI-770-701	N	N		35	Record starting value of water meter FQI-770-701
1	36	Open Valve STP-V-731 and begin initial fill of STSC with IXM water.	N	N		36	Open Valve STP-V-731 and begin initial fill of STSC with IXM water
1	37	Close V-109 and V-205	NA	New	Shut off TLSB and DPB air vents.		
1	38	Level reaches LSH-740-402 level. IL-13 and IL-402 turn ON. Interlock I-3 trips and shuts off IXM water supply valve AOV-701, Bladder flush valve AOV-102 opens. HS-113 'DISABLE' mode prevents bladder flush from occurring (AOV-113 held closed).	Y	No - was 37	Corrected LSH-740-713 to LSH-740-402, changed AOV-102 from closed to open, added HS-113 DISABLE mode to hold new valve AOV-113 closed.	37	Level reaches LSH-740-713 level. IL-13 and IL-402 turn ON. Interlock I-3 trips and shuts off IXM water supply valve AOV-701. HS-701 'test' mode prevents bladder flush from occurring (AOV-102 held closed).
1	39	Close valve STP-V-731 when indicator reflects full STSC.	Y	No - was 38		38	Secure Valve STP-V-731 when indicator reflects full STSC
1	40	Record ending value of water meter FQI-770-701	Y	No - was 39		39	Record ending value of water meter FQI-770-701
1	41	Drain (V-736) and disconnect IXM water hose H-752 from Nozzle F2	Y	Y - was 40	Added drain (new valve V-736)	40	Disconnect the IXM Water (H-752) from Nozzle F2
1	42	Connect the Purge Outlet 1 inch Quick Connect (Hose H-659) to Nozzle F2.	Y	Y - was 41	Change 2 inch to 1 inch	41	Connect the Purge Outlet 2 inch Quick Connect (Hose H-659) to Nozzle F2
1	43	Verify pressure gauge PI-760-652 is reading at least 1 inch of water vacuum.	Y	No - was 42		42	Verify pressure gauge PI-760-652 is reading at least 1 inch of water vacuum
1	44	Record first STSC tare weight and level W1 and L1 (WIT-740-401 and LIT-740-401). Initialize PNL-401 by pressing 'high tare' pushbutton HS-403. (Safety Significant Measurement)	Y	Y - was 43	Added Instrument designation and safety significant measurement designation.	43	Record first STSC tare weight and level W1 and L1. Initialize PNL-401 by pressing 'high tare' pushbutton HS-403.
1	45	Verify AOV-201 is in 'filter' position (HS-201 'filter') Verify IL-215 indicates 'filter.' Open V-202	Y	Y - was 44	Corrected IL-201 to IL-215, Added open V-202	44	Verify AOV-201 is in 'filter' position (HS-201 'filter') Verify IL-201 indicates 'filter'
1	46	Start decant pump P-201 by opening AOV-760 (HS-760 'start') Verify IL-760 indicates 'running'	Y	No - was 45	HS-701 deleted.	45	Start decant pump P-201 by opening AOV-760 (HS-760 'start') Verify IL-761 indicates 'running'
1	47	STSC level drops, resetting interlock I-3. Verify IL-13 and IL-402 turn OFF.	Y	No - was 46		46	STSC level drops, resetting interlock I-3. Verify IL-13 and IL-402 turn OFF

MODE 1 - RECEIVE STS TRAILER & CONNECT STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
1	48	Pump until loss of suction. Turbidity meter AI-720-202 trips Interlock I-2 (ASH-720-202) and shuts off P-201 (AOV-760 closes) Verify IL-761 indicates 'stopped'	Y	Y - was 47	Change to reflect new Turbidity meter AI-720-202 trips and Interlock I-2 and deletion of ASH-720-20.	47	Pump until loss of suction. Turbidity meter AI-720-201 trips Interlock I-2 (ASH-720-201) and shuts off P-201 (AOV-760 closes) Verify IL-760 indicates 'stopped'
1	49	Record second STSC tare weight and level W2 and L2 (WIT-740-401 and LIT-740-401). Initialize PNL-401 by pressing 'low tare' pushbutton HS-406. Calculate and verify STSC geometry factor. (Safety Significant Measurement)	Y	Y - was 48	Added Instrument designation and safety significant measurement designation.	48	Record second STSC tare weight and level W2 and L2. Initialize PNL-401 by pressing 'low tare' pushbutton HS-406. Calculate and verify STSC geometry factor.
1	50	Secure from test mode:	Y	Y - was 49	Deleted HS -701 in test mode.	49	Secure from 'test' mode (HS-701 to 'auto' position)
1	51	Close V-109. Open V-101 and visually verify alignment of all manual valves in TLSB (V-101, V-103 OPEN, V-102 in 'transfer' position, all others closed). Verify IL-125 is OFF.	N	Y - was 50	Deleted close AOV-104 (closed in Step 18). Added IL-125 status.	50	Close V-109 and AOV-104. Open V-101 and visually verify alignment of all manual valves in TLSB (V-101, V-102, V-103 open, all others closed)
1	52	Close V-205. Open V-202, and visually verify alignment of all manual valves in decant box (V-201, V-202, V-204, V-210, V-227 OPEN, all others closed). IL-223 is OFF.	Y	Y - was 51	Added IL-223 status.	51	Close V-205. Open V-202, and visually verify alignment of all manual valves in decant box (V-201, V-202, V-204, V-210, V-227 OPEN, all others closed)
1	53	Exit and secure Annex loading bay.	Y	No - was 52		52	Exit and secure Annex loading bay

MODE 8 - DISCONNECT & PURGE STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
8	1	Enter Annex loading bay	N	N		1	Enter Annex loading bay
8	2	Perform final IXM flush of sludge line: Close V-101, open AOV-104	N	Y	Deleted V-712	2	Perform final IXM flush of sludge line: Close V-101, open V-712 and AOV-104
8	3	Secure from final sludge line flush: Close AOV-104	N	Y	Deleted V-712	3	Secure from final sludge line flush: Close AOV-104 and V-712
8	4	Drain sludge line: Open V-109	N	Y	Deleted open AOV-104 (valve line up changed).	4	Drain sludge line: Open V-109 and AOV-104
8	5	Perform final Decant line flush: Close V-202, Open V-206	N	N		5	Perform final Decant/backwash line flush: Close V-202, Open V-206
8	6	Top off STSC with IXM water to final level for shipping using V-206	Y	No - was 7	Corrected sequence	7	Top off STSC with IXM water to final level for shipping using V-206
8	7	Secure from final Decant line flush: Close V-206	Y	No - was 6	Corrected sequence	6	Secure from final Decant/backwash line flush: Close V-206
8	8	Drain decant line: Open V-205	N	N		8	Drain decant/backwash line: Open V-205
8	9	Record STSC Weight and level (WIT-740-401 and LIT-740-401). Calculate and verify final buoyant weight of sludge transferred (DWI-740-401). Begin preparation of shipping manifest. (Safety Significant Measurement)	N	Y	Added Instrument designation	9	Record STSC Weight and level. Calculate and verify final buoyant weight of sludge transferred (DWI-740-401). Begin preparation of shipping manifest
8	10	Unbolt the Sludge Inlet Connection from Nozzle A. Raise flange 2" to open the connector internal vent port. Verify IL-118 turns OFF.	N	N		10	Unbolt the Sludge Inlet Connection. Raise flange 2" to open the connector internal vent port. Verify IL-118 turns OFF.
8	11	Verify positive airflow through TLSB high point vent (IL-125 turns ON)	N	N		11	Verify positive airflow through TLSB high point vent (IL-125 turns ON)
8	12	Unbolt the Decant line Connection from Nozzle B. Raise flange 2" to open the connector internal vent port. Verify IL-218 turns OFF.	N	N		12	Unbolt the Decant/backwash line Connection. Raise flange 2" to open the connector internal vent port. Verify IL-218 turns OFF
8	13	Verify positive airflow through Decant box high point vent (IL-223 turns ON)	N	N		13	Verify positive airflow through Decant box high point vent (IL-223 turns ON)

MODE 8 - DISCONNECT & PURGE STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
8	14	Note: At this point, air is flowing from the room into the decant box and the TLSB through the HIH annulus, and from the air breaks in the decant box and TLSB through the inner hose of HIH hoses H-107 and H-203 into the STSC. Leave nozzles in this configuration until the inner hoses are drip-free.	N	Y	Changed dry to drip-free.	14	Note: At this point, air is flowing from the room into the decant box and the TLSB through the HIH annulus, and from the air breaks in the decant box and TLSB through the inner hose of HIH hoses H-107 and H-203 into the STSC. Leave nozzles in this configuration until the inner hoses are dry.
8	15	Disconnect the Sludge line connector from Nozzle A. Install 3-bolt blind flange on Nozzle A.	N	N		15	Disconnect the Sludge line connector from Nozzle A. Install 3-bolt blind flange on Nozzle A
8	16	Disconnect the Decant line connector from Nozzle B. Install 4-bolt blind flange on Nozzle B.	N	N		16	Disconnect the Decant/backwash line connector from Nozzle B. Install 4-bolt blind flange on Nozzle B
8	17	Note: At this point, air is flowing from the room up through both the inner hose and the annulus of H-107 and H-203 into the TLSB and the decant box .	N	N		17	Note: At this point, air is flowing from the room up through both the inner hose and the annulus of H-107 and H-203 into the TLSB and the decant box
8	18	Install the end caps and contamination controls on the sludge and decant line connectors. IL-125 and IL-223 turn OFF. Place the connectors in the storage position.	N	N		18	Install the end caps and contamination controls on the sludge and decant/backwash line connectors. Place the connectors in the storage position
8	19	Secure from Sludge line draining/venting: Close V-109	N	N		19	Secure from Sludge line draining/venting: Close V-109
8	20	Secure from Decant line draining/venting: Close V-205	N	N		20	Secure from Decant/backwash line draining/venting: Close V-205
8	21	Disconnect the 4 inch STSC Vent connection and install the Camlok cap on Nozzle F1	N	N		21	Disconnect the 4 inch STSC Vent connection and install the Camlok cap on Nozzle F1
8	22	Initiate STSC Inert Gas Purge:	N	N		22	Initiate STSC Inert Gas Purge:
8	23	Align inert gas 3-way valve V-609 to 'STSC' position	N	N		23	Align inert gas 3-way valve V-609 to 'STSC' position
8	24	Open V-608. Inert gas flows into the STSC.	N	Y	V-610 deleted by design progression	24	Open V-610 and V-608. Inert gas flows into the STSC
8	25	Verify/adjust inert gas flow rate with rotameter FI-760-601	N	N		25	Verify/adjust inert gas flow rate with rotameter FI-760-601
8	26	Close V-732. Air purge flow stops. Verify IL-651 is ON.	N	N		26	Close V-732. Air purge flow stops. Verify IL-651 is OFF.

MODE 8 - DISCONNECT & PURGE STSC

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
8	27	Prior to securing from STSC Inerting, insure shipping window availability.	N	N		27	Prior to securing from STSC Inerting, insure shipping window availability.
8	28	Secure from STSC Inert Gas Purge upon O ₂ Sensor AI-760-601 reading less than 1 vol%: Close V-608. Start the Cask Purge Clock.	N	N		28	Secure from STSC Inert Gas Purge upon O ₂ Sensor AI-760-601 reading less than 1 vol%: Close V-608 and V-610. Start the Cask Purge Clock
8	29	Disconnect the Purge Outlet and install shipping Filter onto the 2 inch Quick Connect Nozzle F2	N	N		29	Disconnect the Purge Outlet and install shipping Filter onto the 2 inch Quick Connect Nozzle F2
8	30	Disconnect the STSC Purge Gas inlet hose and install the shipping filter onto the 1 inch Quick Connect Nozzle S2	N	Y	Change 2 inch to 1 inch	30	Disconnect the STSC Purge Gas inlet hose and install the shipping filter onto the 2 inch Quick Connect Nozzle S2
8	31	Disconnect I&C connector to LDE-710-103 (Leak Detector) and LE-740-401 (Level Detector) Safety Significant instruments	N	N		31	Disconnect I&C connector to LDE-710-103 (Leak Detector) and LE-740-401 (Level Detector) Safety Significant instruments
8	32	Disconnect I&C connector to LDE-720-204 (Leak Detector) and LSH-740-402 (High Level Switch) General Service instruments	N	N		32	Disconnect I&C connector to LDE-720-204 (Leak Detector) and LSH-740-402 (High Level Switch) General Service instruments
8	33	Concurrent with Purging operations, Inspect the STS Lid o-ring and replace Helicoflex seal.	N	N		33	Concurrent with Purging operations, Inspect the STS Lid o-ring and replace Helicoflex seal
8	34	Install the STS Lid and torque Lid Bolts (24 bolts).	N	N		34	Install the STS Lid and torque Lid Bolts
8	35	Remove Lid Lift Fixture from STS cask lid	N	N		35	Remove Lid Lift Fixture from STS cask lid
8	36	Perform leak test on STS Lid:	N	N		36	Perform leak test on STS Lid:
8	37	Remove leak test plug	N	N		37	Remove leak test plug
8	38	Install leak test tool in test port	N	N		38	Install leak test tool in test port
8	39	Pressurize the lid seal annulus and monitor for specified time	N	N		39	Pressurize the lid seal annulus and monitor for specified time

MODE 9 - PURGE & SHIP STS CASK

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
9	1	Remove STS Cask vent port cap and install vent port tool	Y	No - was 4	Steps changed because initial venting of STS Cask was via the drain port rather than vent port for Mode 1. Steps 1 thru 3 not needed.	4	Remove STS Cask vent port cap and install vent port tool
9	2	Attach vent line (H-659) to vent port tool	Y	No - was 5		5	Attach vent line (H-659) to vent port tool
9	3	Open STS drain port and STS vent port	Y	No - was 6		6	Open STS drain port and STS vent port & Align inert gas 3-way valve V-609 to 'STS Cask' position
9	4	Align inert gas 3-way valve, V-609, to 'STS' position	Y	No - was included in 6			
9	5	Open V-608 to Purge STS cask with inert gas. Stop the Cask Purge Clock.	Y	No - was 7		7	Open V-608 to Purge STS cask with inert gas. Stop the Cask Purge Clock
9	6	Secure from STS Cask Inert Gas Purge upon O ₂ Sensor AI-760-601 reading less than 1 vol%: Close V-608. Start the Shipping Window Clock	Y	No - was 8		8	Secure from STS Cask Inert Gas Purge upon O ₂ Sensor AI-760-601 reading less than 1 vol%: Close V-608. Start the Shipping Window Clock
9	7	Close STS vent port	Y	No - was 9		9	Close STS vent port
9	8	Open needle valve V-607 to pressurize the STS with Inert Gas to approximately 3 psi (PI-760-606). Close V-607.	Y	Y - was 10	Added Instrument designation	10	Open needle valve V-607 to pressurize the STS with Inert Gas to approximately 3 psi. Close V-607
9	9	Disconnect vent line from vent port tool	Y	No - was 11		11	Disconnect vent line from vent port tool
9	10	Close STS drain port	Y	No - was 12		12	Close STS drain port
9	11	Relieve inert gas line pressure and disconnect inert gas supply line from drain port tool	Y	No - was 13		13	Relieve inert gas line pressure and disconnect inert gas supply line from drain port tool
9	12	Remove vent port tool and install vent port cap	Y	No - was 14		14	Remove vent port tool and install vent port cap
9	13	Install/zip up Inner IP-2 STS lid bag	Y	No - was 15		15	Install/zip up Inner IP-2 STS lid bag

MODE 9 - PURGE & SHIP STS CASK

Mode	Step	Current Operations Sequence Description (from PRC-STP-00358 Rev 1)	Step Change	Content Change	Discussion (basis for change)	Previous Step & Description (PRC-STP-00382)	
9	14	Install/zip up Outer IP-2 STS lid bag	Y	No - was 16		16	Install/zip up Outer IP-2 STS lid bag
9	15	Remove drain port tool and install drain port cap	Y	No - was 17		17	Remove drain port tool and install drain port cap
9	16	Close/install IP-2 closure on STS drain port	Y	No - was 18		18	Close/install IP-2 closure on STS drain port
9	17	Weigh and record final STS loaded weight (WIT-740-401).	Y	Y - was 19	Added Instrument designation	19	Weigh and record final STS loaded weight
9	18	Complete preparation of shipping manifest	Y	No - was 20		20	Complete preparation of shipping manifest
9	19	Open loading bay door	Y	No - was 21		21	Open loading bay door
9	20	Position tractor and connect to STS trailer	Y	No - was 22		22	Position tractor and connect to STS trailer
9	21	Receive and verify shipping manifest	Y	No - was 23		23	Receive and verify shipping manifest
9	22	Remove loaded STS trailer from annex loading bay	Y	No - was 24		24	Remove loaded STS trailer from annex loading bay
9	23	Close loading bay door	Y	No - was 25		25	Close loading bay door
9	24	Exit Annex loading bay	Y	No - was 26		26	Exit Annex loading bay

1	Initiate STS Inert Gas Purge: Open/remove IP-2 closure on STS drain port
2	Remove STS Cask drain port cap and install drain port tool.
3	Attach inert gas line to drain port tool

APPENDIX B

“WHAT/IF” HAZARD ANALYSIS MEETING PARTICIPANTS

ECRTS What/If Hazard Analysis NPH, External Events, and Fire September 10, 2010	
Hazards Analysis Team	
Name	Organization
Robert Meichle	Facilitator, STP NS
Gary Franz	Facilitator/Scribe, STP NS
Dewey Burbank	STP/ECRTS Eng
Ralph Crowe	STP NS
Gail Chaffee	100K NS
Lindsay Nelsen	STP Rad Control
Jeff Broussard	100K Ops
James Mathews	STP Ops
Darren Schwartz	100K OS/IH
Brett Kujath/Susan Omberg Carro	STP Fire Protection
David Watson	STP Environmental
Raymond Puigh	Crit Safety
William Edwards	Transportation
Additional Attendees	
Dennis Hamilton	STP/ECRTS Manager
Craig Carro	STP NS
Richard Raymond	STP Chief Engineer
Al Bridges	CHPRC Transportation Safety
John Dearing	STP Sampling & Characterization Eng
Jim Criddle	STP/ECRTS Eng
Hall, Mark A	STP/ECRTS Eng
Geoff Barnes	STP/ECRTS Eng
Dennis Markman	STP/ECRTS Eng

ECRTS What/If Hazard Gap Analysis October 19, 2010 Meeting Participants	
Hazards Analysis Team	
Name	Organization
Robert Meichle	Facilitator, STP NS
Gary Franz	Facilitator/Scribe, STP NS
Dewey Burbank	STP/ECRTS Eng
Craig Carro	STP NS
Lindsay Nelsen	STP Rad Control
James Mathews	STP Ops
Darren Schwartz	100K OS/IH
Brett Kujath/Susan Omberg Carro	STP Fire Protection
Additional Attendees	
Dennis Hamilton	STP/ECRTS Manager

ECRTS What/If Hazard Gap Analysis Reconvene October 22, 2010 Meeting Participants	
Hazards Analysis Team	
Name	Organization
Robert Meichle	Facilitator, STP NS
Gary Franz	Facilitator/Scribe, STP NS
Dewey Burbank	STP/ECRTS Eng
Ralph Crowe	STP NS
Lindsay Nelsen	STP Rad Control
Gary Hastings	100K Rad Control
James Mathews	STP Ops
Darren Schwartz	100K OS/IH
Brett Kujath/Susan Omberg Carro	STP Fire Protection
Additional Attendees	
Dennis Hamilton	STP/ECRTS Manager
Craig Carro	STP NS
Dan McHugh	STP NS
Dennis Clapp (part time)	DOE-RL
Greg Morgan (part time)	DOE-RL

APPENDIX C

**“WHAT/IF” HAZARD ANALYSIS RESULTS
NPH AND EXTERNAL EVENTS**

TABLE C-1 "WHAT/IF" HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
SEISMIC							
S-1	Modified Annex structure or crane collapses due to basin structure failure prior to sludge retrieval and loading	NPH Seismic	Industrial hazard	Personnel hazard, programmatic impact from structural collapse or equipment damage	Structure and equipment designed to International Building Code or better.	None	
S-2	Modified Annex structure or crane collapses due to basin structure failure during sludge retrieval and loading or overfill recovery	NPH Seismic	Spray leak Splash and splatter	Impact on transfer line in annex leads to Uncontrolled release, worker and public dose.	Seismic separation between Annex Structure and Basin structure to prevent interaction, even if basin structure fails. Seismic switch, Dead man operating switch, Pump operating timer.	None	Annex structure damage includes potential failure of any of the walls or internal walls and upper levels or roof or valve boxes, and where applicable, ventilation stack or ducting/equipment. Secondary confinement, hose barn, leak detection, interlocks, ventilation confinement, fire protection are assumed to fail to function during unmitigated seismic event.
S-3	KW Basin super-structure failure during sludge retrieval and loading or overfill recovery	NPH Seismic	Spray leak Splash and splatter	Impact on transfer line outside basin and outside annex leads to Uncontrolled release of sludge, worker and public dose.	Hose barn design prevents impact, Seismic switch, Dead man operating switch, Pump operating timer,	None	
S-4	Modified Annex Structure or crane collapses during transfer or overfill recovery	NPH Seismic	Spray leak Splash and splatter	Impact on transfer line in annex leads to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure or hose pathway so as to protect from structure, Seismic switch, Dead man operating switch, Pump operating timer.	None	
S-5	Hoses disconnected at transfer box during transfer or overfill recovery	NPH Seismic	Spray leak Splash and splatter	Transfer line failure leading to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure and transfer box, Seismic switch, Dead man operating switch, Pump operating timer.	None	
S-6	Modified Annex structure collapses due to basin structure failure during decant	NPH Seismic	Spray leak Splash and splatter	Impact on decant/backwash line in annex leads to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure and decant box, Seismic switch, Dead man operating switch, pump operating timer.	None	
S-7	Basin super-structure collapses during decant	NPH Seismic	Spray leak Splash and splatter	After decant filtration , impact on decant/backwash line above basin water or outside annex leads to Uncontrolled release of sludge	Hose barn design prevents impact, Seismic switch, Dead man operating switch, Pump operating timer.	None	
S-8	Hoses disconnected at decant box or sand filter or STSC during decant or circulation to inject floc	NPH Seismic	Spray leak Splash and splatter	Decant/backwash line failure leading to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure and decant box and STSC and sand filter and hoses, Seismic switch, Dead man operating switch, Pump operating timer.	None	

Identifier	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
S-9	Modified Annex structure collapses due to KW basin super-structure failure during backwash	NPH Seismic	Spray leak Splash and splatter	Impact on decant/backwash line in annex leads to Uncontrolled release of sludge, worker and public dose.	Seismic separation between Annex Structure and Basin structure to prevent interaction, even if basin structure fails. Seismic switch, Dead man operating switch, Pump operating timer.	None	
S-10	Modified Annex structure collapses during backwash	NPH Seismic	Spray leak Splash and splatter	Impact on decant/backwash line in annex leads to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure, Seismic switch, Dead man operating switch, Pump operating timer.	None	
S-11	Hoses disconnected at sand filter or decant box or STSC during backwash	NPH Seismic	Spray leak Splash and splatter	Decant/backwash line failure leading to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure and decant box and STSC and sand filter and hoses, Seismic switch, Dead man operating switch, Pump operating timer.	None	
S-12	Modified Annex Structure collapses due to KW basin super-structure failure after sludge retrieval and loading	NPH Seismic	Deflagration in STSC	Impact to ventilation hoses, ducting, stack, or ventilation equipment shuts down STSC headspace active ventilation, resulting in buildup of hydrogen leading to Uncontrolled release of sludge, worker and public dose.	Seismic separation between Annex Structure and Basin structure to prevent interaction, even if basin structure fails.	Administrative requirement to establish purge following loss of ventilation.	
S-13	Modified Annex Structure collapse or crane drop after sludge retrieval and loading	NPH Seismic	Deflagration in STSC	Impact to ventilation hoses, ducting or ventilation equipment shuts down STSC headspace active ventilation, resulting in buildup of hydrogen leading to Uncontrolled release of sludge, worker and public dose.	Seismic qualification of annex structure and ventilation system	Administrative requirement to establish purge following loss of ventilation.	
S-14	Modified Annex Structure collapse or crane drop or cask lid drop during installation	NPH Seismic	Deflagration in STSC, STS	Impact to inerting equipment or STSC nozzles prevents purge and seal, leading to buildup of hydrogen and uncontrolled release of sludge, worker and public dose if STSC headspace involved.	Seismic qualification of annex structure, inerting equipment and crane.	None	
S-15	Modified Annex Structure damage, trailer damage or door damage preventing load departure	NPH Seismic	cask overpressure	STS load heats-up, hydrogen gas is generated leading to uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure, door and STSC/STS/trailer.	Administrative requirement to establish vent (and purge as required) if shipping delayed.	
S-16	Damage to nitrogen bottle rack leads to generation of bottle missile	NPH Seismic	Spray leak Splash and splatter Deflagration in STSC, STS	Potential to impact to transfer lines, ventilation equipment leading to event comparable to S-4, 5, 8, 10, 11, 13, 14 and uncontrolled release of sludge, worker and public dose.	Seismic qualification of structure, bottle rack, STSC/STS/Trailer, inerting equipment.	Administrative requirement to establish purge if ventilation lost, Administrative requirement to establish vent (and purge as required) if shipping delayed.	

TABLE C-1 "WHAT/IF" HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
S-17	Damage to T Plant or travel route significantly delays transfer	Seismic event	STS load heats up, hydrogen gas is generated leading to cask overpressure	Spread of contamination, worker and public dose.	Seismic qualification of inerting equipment, STS/Trailer.	Administrative requirement to establish vent (and purge as required) if shipping delayed.	
S-18	Damage to KW Stack	Seismic event	Postulate impact to transfer line or annex	N/A.	None	None	Scale drawing demonstrates the 175' stack does not reach new annex structure and would not reach the transfer path from the basin to the annex
S-19	STSC overturns after loading	Seismic event	Spill of sludge into loading bay	Spread of contamination, worker and public dose.	Seismic qualification of STSC/Trailer	None	
S-20	Fire initiated by DBE	Seismic event	Fire events FF-1 through FF-7 below are initiated by and taken in combination with seismic event failures	Spread of contamination, worker and public dose.	Seismic qualification of structure and equipment and fire suppression system, fire protection features as indicated under FF-1 through FF-7. Seismic switch, or dead man switch or timer limit spray or splash and splatter in this event.	Administrative limit on combustibles	
S-21	LOEP initiated by DBE (Structural Damage to electrical equipment)	Seismic event	LOEP-1 through LOEP-5 events below are initiated by and taken in combination with seismic event failures	Spread of contamination, worker and public dose. (See LOEP events below for failure configurations)	Seismic design of required equipment under LOEP-1 through LOEP-5 to ensure availability.	None	
S-22	DBE drops equipment into basin(Structural failure -Equipment falls into basin)	Seismic Event	Impact to installed equipment during transfer	Operational upset. Leak sludge to basin water, loss of visibility, delay in transfer to repair equipment.	None	None	
S-23	DBE drops floc into basin	Seismic event	Floc addition to stored sludge and filters in IWTS	Operational upset. May impact sludge mobility or IWTS operability.	None	None	
S-24	DBE leads to LOP(Structural Damage to instrument air equipment)	Seismic Event	Impact to instrument air system components leads to loss of pneumatics during any system operation/ configuration and taken in combination with seismic event failures	Spread of contamination, worker and public dose. (See LOP event below for failure configurations)	Seismic qualification of structure and equipment.	None	LOP events will be evaluated as part of FMEA. Valves are currently configured to prevent casualty.
S-25	Seismic event results in damage to annex structure or equipment	Seismic Event	Seismic event, perhaps less than DBE, leads to unanalyzed safety of structure or equipment for continued operation.	Operational upset, programmatic delay	None	None	

TABLE C-1 "WHAT/IF" HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
S-26	Loss of backup power (Structural failure of electrical equipment)	Seismic Event	Common cause LOEP and loss of backup power, leading to STSC heat up, hydrogen buildup Deflagration in STSC, STS	Spread of contamination, worker and public dose.	Covered in S-21 with qualification of backup power for DBE.	None	
S-27	Seismic event causes Modified Annex structure or equipment collapse on to transfer, decant or overfill recovery transfer lines	NPH Seismic	Spray leak in an interfacing line Splash and splatter release in an interfacing line.	Transfer line blockage results in high pressure and backward flow in lines interfacing with the transfer line, causing an Uncontrolled release of sludge, worker and public dose.	Seismically qualified Modified Annex structure and equipment Block/Check valves prevent backflow in interfacing systems, Seismic switch, Dead man switch.	None	
S-28	Seismic Event fails the lighting system in the annex	NPH Seismic	Industrial hazard	Personnel within facility and on high platforms are left without light causing operational upset and personnel safety hazard	None	None	
WIND							
W-1	Modified Annex structure or crane collapses due to KW basin super-structure failure prior to sludge retrieval and loading	High wind	Industrial hazard, facility impact from structural collapse	Personnel injury or fatality, programmatic impact	Wind damage separation of structures	None	Basin structure qualified to 100 MPH and for current PC-3 missile load – not to 111 mph PC-3 wind for ECRS major modification. Thus, a potential for wind load failure of the basin structure impact to the new annex structure or the transfer line exists.
W-2	Modified Annex structure or crane collapses due to KW basin super-structure failure during sludge retrieval and loading, decant or overfill recovery	High wind	Spray leak Splash and splatter	Impact on transfer line in annex leads to Uncontrolled release of sludge, worker and public dose.	Structural separation and/or structural qualification of annex to withstand impact.	None	Annex structure damage includes potential failure of any of the walls and upper levels or roof or support for valve boxes, and where applicable, ventilation stack or ducting/equipment. Secondary confinement, ventilation confinement, fire protection, instrumentation, interlocks could variously fail to function due to structure damage from high wind loads or from wind born missile.
W-3	KW Basin super-structure failure during sludge retrieval and loading, decant or overfill recovery	High wind	Spray leak Splash and splatter	Impact on transfer line above basin water and outside annex leads to Uncontrolled release of sludge, worker and public dose.	Hose barn PC-3 design prevents impact.	Administrative control to shut down transfers during extreme weather conditions if structure/barn are not qualified.	This kind of wind would certainly generate an adverse weather advisory, an operations shutdown, and likely a take cover.
W-4	Missile impact to sludge transfer lines external to the Modified Annex during loading, decant or overfill recovery	High wind, missile	Spray leak Splash and splatter	Impact on transfer line above basin water and outside annex leads to Uncontrolled release of sludge, worker and public dose.	Hose barn PC-3 design prevents impact.	Administrative control to shut down transfers during extreme weather conditions if structure/barn are not qualified.	This kind of wind would certainly generate an adverse weather advisory, an operations shutdown, and likely a take cover.

TABLE C-1 "WHAT/IF" HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
W-5	Modified Annex Structure collapses during transfer, decant or overfill recovery	High wind	Spray leak Splash and splatter	Impact on transfer line in annex leads to Uncontrolled release of sludge, worker and public dose.	Structure qualified to withstand PC-3 wind	Administrative control to shut down transfers during extreme weather conditions.	This kind of wind would certainly generate an adverse weather advisory, an operations shutdown, and likely a take cover.
W-6	Hoses impacted or disconnected at transfer box,sand filter, decant box or STSC during transfer, decant, backwash, or overfill recovery	High wind missile	Spray leak Splash and splatter	Transfer, decant/backwash line failure leading to Uncontrolled release of sludge, worker and public dose.	Structure qualified to withstand PC-3 missile	Administrative control to shut down transfers during extreme weather conditions.	This kind of wind would certainly generate an adverse weather advisory, an operations shutdown, and likely a take cover.
W-7	Modified Annex Structure failure onto loaded STSC	High wind	Spill Splash and splatter	Overturn trailer, spill contents leading to Uncontrolled release of sludge, worker and public dose.	Structure qualified to withstand PC-3 wind.	Administrative control to shut down transfers during extreme weather conditions.	This kind of wind would certainly generate an adverse weather advisory, an operations shutdown, and likely a take cover.
W-8	Wind damage to Modified Annex structure or door	High wind	overpressure	Loaded STS transfer delayed, resulting in heat up and hydrogen generation leading to Uncontrolled release of sludge, worker and public dose.	Structure/door qualified to withstand PC-3 wind.	Administrative control to shut down transfers during extreme weather conditions.	This kind of wind would certainly generate an adverse weather advisory, an operations shutdown, and likely a take cover.
W-9	Nitrogen bottle overturns, knocks off valve	High wind	Spray leak Splash and splatter deflagration	Gas bottle missile impacts vital equipment or hoses, leading to Uncontrolled release of sludge, worker and public dose.	Bottle rack protected from PC-3 high wind, missile resistance of lower building walls.	None	
W-10	Modified Annex Ventilation equipment damaged and/or inoperable	High wind, missile	deflagration.	Impact to duct manifold, stack collapse, impact to power or control panels, onsite LOEP lead to loss of STSC active ventilation and resultant hydrogen buildup, Uncontrolled release of sludge, worker and public dose.	Structure and ventilation equipment designed to be protected from PC-3 missile	None	
W-11	Modified Annex Ventilation filters become inoperable due to dust loading	High wind	deflagration	Dust loading plugs inlet and or outlet filters leading to ventilation inoperability, loss of active ventilation and Uncontrolled release of sludge, worker and public dose.	Ventilation filters designed to withstand PC-3 high wind loading of dust. Flow or DP monitoring on STSC exhaust. Inert purge of STSC designed to withstand high wind.	Administrative control to purge STSC if ventilation is lost.	
W-12	Wind missile caused Loss of pneumatics	High wind missile	LOP evaluated below. Could be common cause with other PC-3 wind/missile hazardous conditions.	N/A	PC-3 wind/missile protected pneumatic supply	None	
W-13	Wind initiated LOEP	High wind	Common cause LOEP-1 through 5 and dust loading or missile caused failure of backup power leading to ventilation inoperability.	Hazardous conditions, consequences and candidate controls as listed under LOEP. Common cause with wind and missile addressed under candidate controls listed here.	Backup power protection from PC-3 wind/missile Inert purge of STSC designed to withstand PC-3 high wind and missile.	Administrative requirement to establish inert purge following loss of ventilation.	

TABLE C-1 "WHAT/IF" HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
W-14	Modified Annex structure collapse leads to fire	High wind	overpressure	Fire initiated by modified annex structural failure in high wind results in common cause failure of fire suppression system, fire involves loaded STSC or STS, Uncontrolled release of sludge, worker and public dose.	Structure qualified to withstand PC-3 wind Fire resistant construction STS design fire resistance	Combustible loading limits	
W-15	Wind or missile damage leads to fire	High wind, missile	deflagration	Fire incapacitates the ventilation system, leading to hydrogen accumulation and Uncontrolled release of sludge, worker and public dose.	Structure and ventilation stack qualified to PC-3 wind and missile. Fire resistant construction, Fire suppression system Fire area separations. Wind and missile protected inert purge system.	Combustible loading limits, Administrative requirement to establish purge following loss of ventilation.	
W-16	Wind load topples KW stack	High wind	Postulate toppled stack impacts annex or hose barn leading to potential spray or Splash and splatter release	N/A	None	None	Stack height evaluated and 175' stack does not reach to the new Annex facility.
W-17	Wind load damages Modified Annex structure or roll up door or stack	High wind	Impacts from wind or missile prevent operation pending recovery and repair	Operational upset and programmatic delay	None	None	
W-18	Wind load damages Modified Annex structure or roll up door or stack	High wind	Industrial hazard.	Personnel hazard from structural collapse	None	None	Structure designed to qualified to withstand PC-3 wind because of safety significant
W-19	Wind load damages Modified Annex structure leading to collapse onto transfer lines	High Wind	Spray leak Splash and splatter release.	Transfer lines are impacted by a structure or equipment collapse, dead heading the transfer, decant or overflow recovery pumps, and over pressuring an interfacing service system pipe resulting in an Uncontrolled release of sludge, worker and public dose.	PC-3 Wind resistant design of structure. Relieve valves (rupture discs) on transfer line. Interfacing system block/check valves to prevent backflow.	Administrative control to shut down transfers during extreme weather conditions.	
W-20	Wind catches door and forces it to extreme	High Wind	Industrial hazard.	Personnel door is forced open and broken, or opened or closed impacting personnel during operation. Personnel safety impact and potential operational upset.	None	None	Ensure that door closer resists wind effects.
FLOOD							
FL-1	Flood damage prevents STS Transport	Flood	overpressure	Water line failure floods/undermines road and prevents STS transport leading to Uncontrolled release of sludge, worker and public dose.	STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	Facility above Columbia river PC-3 flood level
FL-2	Flood damages load cells, STS	Flood	Accidental sprinkler system actuation leads to flood of truck bay sump and impact to load cell instrumentation, or flooding of STS.	Operational upset, programmatic delay for recovery	None	None	

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Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
FL-3	Flood damages ventilation	Flood	deflagration	Accidental sprinkler actuation impacts ventilation controls incapacitating system operability with resulting loss of active ventilation, hydrogen accumulation and Uncontrolled release of sludge, worker and public dose.	Protect ventilation system from impact by sprinkler system actuation. Provide capability to purge STSC if ventilation is lost	Administrative control to purge STSC if ventilation flow is lost.	
SNOW							
SF-1	Snow load fails Modified Annex structure during transfer, decant or overfill recovery	Snowfall	Spray leak Splash and splatter release.	Structure failure impacts transfer lines, leading to Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall	Administrative control to shut down transfers during extreme weather conditions.	
SF-2	Snow load fails Modified Annex structure	Snowfall	deflagration	Structure failure impacts ventilation system and prevents STSC active ventilation leading to hydrogen buildup and Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, inert gas purge capability	Administrative control to purge STSC if ventilation flow is lost.	May not be able to access to install purge
SF-3	Snow load fails Modified Annex structure	Snowfall	overpressure	Structure failure prevents loaded STS from departing resulting in hydrogen gas generation, and Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
SF-4	Snowfall induced LOEP	Snowfall	See LOEP below	N/A	N/A	N/A	
SF-5	Snowfall induced LOP	Snowfall	Structure collapse in mechanical room or elsewhere impacting instrument air. See LOP below under FF-6	See LOP below under FF-6	N/A	N/A	
SF-6	Snowfall prevents transport to T Plant	Snowfall	overpressure	Road closure/transportation restriction prevents transport of STS, leading to build up of hydrogen and Uncontrolled release of sludge, worker and public dose.	STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
SF-7	Modified Annex Roof failure and loss of confinement	Snowfall	Loss of confinement integrity, and upset to ventilation system	Operational upset	N/A	N/A	
SF-8	Modified Annex Roof failure or ice dam and water inleakge	Snowfall	Water inleakge impacts electrical panels failing instrumentation, switchgear, interlocks	Operational upset and programmatic delay	N/A	N/A	
SF-9	Snowfall fails Modified Annex structure and impacts transfer lines	Snowfall	Spray leak Splash and splatter release.	Transfer lines are impacted by a structure or equipment collapse, dead heading the transfer, decant, or overfill recovery pumps, and over pressuring an interfacing service system pipe resulting in an Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, Block/check valves protecting interfacing lines	None	
SF-10	Snowfall fails Modified Annex structure	Snowfall	Industrial Safety	Personnel hazard from structural collapse	None	None	

TABLE C-1 “WHAT/IF” HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
SF-11	Snowfall blocks Modified Annex door closed	Snowfall	Industrial safety	Snowfall blocked door impacts egress paths and elevated platform life safety	Protect doorway from snow accumulation	Provide check of access prior to occupancy during snowfall periods	
SF-12	Modified Annex Roof failure or ice dam and water inleakge	Snowfall	deflagration	Water inleakge impacts HVAC Controls and prevents STSC active ventilation leading to hydrogen buildup and Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, inert gas purge capability	Administrative control to purge STSC if ventilation flow is lost.	
ASHFALL							
AF-1	Ashfall load fails Modified Annex structure during transfer, decant or overfill recovery	Ashfall	Spray leak Splash and splatter release.	Structure failure impacts transfer lines, leading to Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall	Administrative control to shut down transfers during extreme weather conditions.	
AF-2	Ashfall load fails Modified Annex structure	Ashfall	deflagration	Structure failure impacts ventilation system and prevents STSC active ventilation leading to hydrogen buildup and Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, inert gas purge capability	Administrative control to purge STSC if ventilation flow is lost.	May not be able to access to install purge
AF-3	Ashfall load fails Modified Annex structure	Ashfall	overpressure	Structure failure prevents loaded STS from departing resulting in hydrogen gas generation, and Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
AF-4	Ashfall induced LOEP	Ashfall	See LOEP- 1 through 5 for conditions, consequences and candidate controls	N/A	N/A	N/A	
AF-5	Ashfall induced LOP	Ashfall	See LOP below	N/A	N/A	N/A	
AF-6	Ashfall prevents transport to T Plant	Ashfall	overpressure	Road closure/transportation restriction prevents transport of STS, leading to build up of hydrogen and Uncontrolled release of sludge, worker and public dose.	STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
AF-7	Modified Annex Roof failure and loss of confinement	Ashfall	Loss of confinement integrity, and upset to ventilation system	Operational upset	N/A	N/A	
AF-8	Modified Annex Roof failure and subsequent rainfall	Ashfall	Water inleakge impacts electrical panels failing instrumentation, switchgear, interlocks	Operational upset and programmatic delay	N/A	N/A	
AF-9	Ashfall fails Modified Annex structure and impacts transfer lines	Ashfall	Spray leak Splash and splatter release.	Transfer lines are impacted by a structure or equipment collapse, dead heading the transfer, decant, or overfill recovery pumps, and over pressuring an interfacing service system pipe resulting in an Uncontrolled release of sludge, worker and public dose.	Design of structure to withstand snowfall, Block/check valves protecting interfacing lines	None	
AF-10	Ashfall fails Modified Annex structure	Ashfall	Industrial Safety	Personnel hazard from structural collapse	None	None	

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Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
AF-11	Ashfall blocks Modified Annex door closed	Ashfall	Industrial safety	Ashfall blocked door impacts egress paths and elevated platform life safety	None	None	
AF-12	Modified Annex Ventilation filters become inoperable due to ash	Ashfall	deflagration	Uncontrolled release of sludge, worker and public dose.	Ventilation filters designed to withstand ashfall loading of dust. Flow or DP monitoring on STSC exhaust. Inert purge of STSC designed to withstand ashfall.	Administrative control to purge STSC if ventilation is lost.	
RAIN							
R-1	Heavy rainfall delays transport	Heavy rainfall	overpressure	Delay in transportation of sealed cask leads to heat-up and hydrogen pressurization of STS, with eventual Uncontrolled release of sludge, worker and public dose.	STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
R-2	Heavy rainfall and winds result in wetting of electrical equipment	Heavy rainfall	deflagration	Wet electrical components cause failure of ventilation system, leading to buildup of hydrogen in STSC and Uncontrolled release of sludge, worker and public dose.	Structure design to maintain operation in heavy rainfall, STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
R-3	Heavy rainfall leads to LOEP	Heavy rainfall	LOEP related hazardous conditions listed below	See LOEP-1 through 5 conditions, consequences and candidate controls.	N/A	N/A	
LIGHTNING							
L-1	Initiates LOEP	Lightning	LOEP related hazardous conditions listed below	See LOEP-1 through 5 conditions, consequences and candidate controls.	N/A	N/A	
L-2	Lightning damages Modified Annex HVAC switchgear or control system	Lightning	deflagration	Loss of ventilation flow to loaded STSC leads to hydrogen buildup, and Uncontrolled release of sludge, worker and public dose.	Lightning protection of structure, Lightning protection of inert gas purge equipment	Administrative control to purge STSC if ventilation is lost.	
L-3	Lightning initiates a fire resulting in any of the hazardous conditions under Fire below.	Lightning	Fire related hazardous condition listed below	Process upset and Uncontrolled release of sludge, worker and public dose.	Lightning protection of structure, Fire protection features listed in events below.	None	
L-4	Transport of loaded STS delayed by lightning	Lightning	overpressure	Gas accumulation and Uncontrolled release of sludge, worker and public dose.	Lightning protection of structure, STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
L-5	Lightning damages interlocks or controls	Lightning	Splash and splatter	Lightning strike makes interlocks for process inoperable leading to overfill and leak, dose to worker and public. Operational upset and TSR Operability issue	Lightning protection for structure and circuitry. Fail-safe design of interlocks	Operability checks prior to operation, Operations restrictions during lightning storms	
HIGH AMBIENT TEMPERATURE							
HAT-1	Heat impacts shipping window	High ambient temperature	overpressure	Gas accumulation and Uncontrolled release of sludge, worker and public dose.	Design of STSC and Cask to accommodate high ambient temperature as part of shipping window analysis	None	
LOW AMBIENT TEMPERATURE							

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Identifier	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
LAT-1	Freezing conditions impact shipping window	Low ambient temperature	overpressure	Roll-up door inoperability or road closure delays shipping leading to gas accumulation and Uncontrolled release of sludge, worker and public dose.	Design of door ensures operability in freezing conditions; STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
LAT-2	Freezing conditions impact shipping	Low ambient temperature	STSC freezes during delay on road, resulting in damage to vessel.	Operational upset.	None	Transport times and limits on transport during extreme weather. Emergency response procedures	
LAT-3	Low temperatures freeze liquid in transfer line resulting in transfer line failure.	Low ambient temperature	Inner hose low temperature freezes, leaking liquid and prevents leak detection.	Operational upset, perhaps leading to additional failure.	Freeze damage resistance of hose, Freeze protection for leak detection Freeze protection for transfer line	Administrative control to shut down transfers during extreme weather conditions.	
LAT-4	Freezing condition impacts STSC vent	Low ambient temperature	deflagration.	Moisture separator freezes preventing gas flow. Buildup of hydrogen leading to Uncontrolled release of sludge, worker and public dose.	New annex HVAC conditioning capability, freeze protected inert gas purge system	Administrative control to purge STSC if ventilation is lost.	
LAT-5	Fire initiates during freezing condition which had frozen Modified Annex sprinkler system,	Low ambient temperature	deflagration Spray leak Splash and splatter.	Operational upset. Loss of safety SSC, potential for unmitigated fire. Unmitigated fire leads to loss of ventilation, leak and potential for Uncontrolled release of sludge, worker and public dose.	New annex HVAC conditioning capability Design of sprinkler system to prevent freeze	Administrative control to shut down or preclude transfers if temp below some value. Administrative control to purge STSC if ventilation is lost.	
LAT-6	Freezing Condition holds external door closed	Low ambient temperature	Industrial hazard	Frozen door jamb or lock prevents egress or access Life safety code issue, operational upset	None	None	
LOSS OF ELECTRICAL POWER							
LOEP-1	Loss of power during transfer or overfill recovery	LOEP	Spray leak Splash and splatter.	Sludge settles in line, or valve closes resulting in blocked line on restart and system overpressure with attendant uncontrolled release of sludge, worker and public dose.	Bladder tank flush of transfer line. Line design pressure prevents deadhead failure.	Emergency response program to control recovery	Valves are FL (fail as is) in transfer line. LOEP may reasonably result in LOP and LOW
LOEP-2	Loss of power to ventilation system when STSC is loaded	LOEP	deflagration.	Accumulation of hydrogen leading to uncontrolled release of sludge, worker and public dose.	Backup power to ventilation system, Inert gas purge capability	Administrative requirement to establish purge following loss of ventilation.	
LOEP-3	Loss of power when STS loaded.	LOEP	overpressure of STS.	Closed roll-up door prevents departure, leading to gas accumulation and uncontrolled release of sludge, worker and public dose.	Backup power to door, STS vent and purge ports, port tools, manual inert gas purge capability	Administrative requirement to monitor pressure and vent STS when delayed.	

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Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
LOEP-4	Loss of power when closing STS	LOEP	deflagration.	Stuck or dropped STS lid causes inability to purge or ventilate leading to hydrogen accumulation and uncontrolled release of sludge, worker and public dose.	Backup power to crane to clear and then purge.		
LOEP-5	Loss of power during cold weather	LOEP	Freeze of lines, or liquid in STSC damaging equipment	Operational upset	None	None	
RANGE FIRE							
RF-1	Delays departure of loaded STS	Range Fire	overpressure	Range fire prevents departure, leading to gas accumulation and Uncontrolled release of sludge, worker and public dose.	STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	
RF-2	Initiates Modified Annex facility fire	Range Fire	Range fire leads to facility fire and attendant hazardous conditions	See Facility Fire FF-1 through 5 hazardous conditions, consequences and candidate controls.	N/A	N/A	
RF-3	Initiates a LOEP	Range Fire	Range fire leads to LOEP and attendant hazardous conditions	See LOEP-1 through 5 for hazardous conditions, consequences and candidate controls	N/A	N/A	
RF-4	Modified Annex Structure failure	Range Fire	deflagration STSC overturn, spill	Range fire fails structure and prevents purge of STSC or overturns STSC leading to Uncontrolled release of sludge, worker and public dose.	Fire resistant structure and components, Fire resistance of inert gas purge	Administrative control to purge STSC if ventilation is lost.	
RF-5	Modified Annex Structure failure	Range Fire	Industrial hazard	Personnel hazard from structural collapse	None	None	
RF-6	Fire smoke and soot plugs HVAC filters	Range Fire	deflagration	Smoke and soot plugs HVAC, preventing ventilation of the STSC, buildup of hydrogen and Uncontrolled release of sludge, worker and public dose.	HVAC design that accommodates or mitigates range fire smoke, STSC inerting system that functions during and after range fire	Administrative requirement to establish purge if ventilation is lost	
VEHICLE IMPACT							
VI-1	Modified Annex Structure failure while backing trailer in	Vehicle Impact	Industrial hazard	Annex structure damaged while placing trailer in bay. Operational upset, programmatic delay	None	None	
VI-2	Vehicle impacts Modified Annex structure while loading STSC or overfill recovery	Vehicle impact	Spray leak Splash and splatter leak	Vehicle impact to structure results in transfer line failure and Uncontrolled release of sludge, worker and public dose.	Vehicle barriers around structure	Administrative traffic restrictions.	

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Identifier	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
VI-3	Vehicle Impacts Modified Annex structure with loaded STS inside	Vehicle impact	overpressure	Vehicle impact prevents loaded STS transport with gas accumulation and Uncontrolled release of sludge, worker and public dose.	Vehicle barriers around structure STS vent and purge ports, port tools Inert gas purge capability	Administrative traffic restrictions Administrative requirement to monitor pressure and vent STS when delayed.	
VI-4	Vehicle impact causes LOEP	Vehicle impact	Vehicle impact leads to LOEP and attendant hazardous conditions	See LOEP-1 through 5 for hazardous conditions, consequences and candidate controls	N/A	N/A	
VI-5	Vehicle impact causes facility fire	Vehicle impact	Vehicle impact leads to facility fire and attendant hazardous conditions	See Facility fire FF-1 through 5 for hazardous conditions, consequences and candidate controls	Vehicle barriers around structure	Administrative traffic restrictions.	
VI-6	Tractor impacts fuel tank during prep for departure	Vehicle impact	Fire overpressure	Vehicle fuel fire and tire fire impacts STS and facility. Programmatic impact and potential impact to STS if only type A qualified. Uncontrolled release of sludge, worker and public dose.	Sloped access pad that directs leaking fuel away from building.		STS analysis/qualification to survive the crash and fire would provide acceptable containment in this scenario. Not clear whether that analysis will be retained under the SPA.
VI-7	Vehicle impacts bottle storage	Vehicle Impact	deflagration	Uncontrolled release Loss of inerting capability, potential bottle missile damage to ventilation capability and hydrogen buildup to potential Uncontrolled release of sludge, worker and public dose.	Vehicle barriers around structure, especially inerting equipment; Robust structure around HVAC equipment	None.	
VI-8	Vehicle impacts personnel	Vehicle Impact	Industrial hazard	Personnel could be injured by vehicle impact	None	None	
AIR CRAFT CRASH							
ACC-1	Aircraft impacts Modified Annex	Air Craft Crash	Spray leak Splash and splatter, spill, deflagration, overpressure	Potential source of uncontrolled release of sludge, worker and public dose. Is expected to be BEU.	N/A	N/A	Aircraft crash is beyond extremely unlikely (need to provide updated analysis for annex profile).
EXTERNAL EXPLOSION							
EE-1	Damage to Modified Annex during departure prep	External Explosion (see remarks)	overpressure.	Damage prevents STS departure allowing gas accumulation and Uncontrolled release of sludge, worker and public dose.	Inert gas purge capability, STS vent and purge ports, port tools	Administrative requirement to monitor pressure and vent STS when delayed.	External explosion involves fueling vehicle or propane utility vehicles
EE-2	Initiates Modified Annex Facility Fire	External Explosion	External Explosion leads to facility fire and attendant hazardous conditions	See Facility Fire FF-1 through 5 for hazardous conditions, consequences, and candidate controls	Non combustible materials of construction (2 hour barrier)	Administrative traffic restrictions.	

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Identifier	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
EE-3	Initiates LOEP	External Explosion	External Explosion leads to LOEP and attendant hazardous conditions	See LOEP-1 through 5 for hazardous conditions, consequences and candidate controls	N/A	N/A	
EE-4	Damage to Modified Annex structure, impacting transfer lines in service	External Explosion	Spray leak Splash and splatter	Blocked or failed transfer lines result in Uncontrolled release of sludge, worker and public dose.	Robust structure design resists external explosion	Administrative traffic restrictions.	
EE-5	Damage to Modified Annex structure	External Explosion	Industrial hazard	Personnel could be injured by structural failure	None	None	
EXTERNAL FACILITY FIRE							
EFF-1	Initiates Modified Annex Facility Fire	External Facility Fire	External facility fire leads to facility fire and attendant hazardous conditions	See facility fire for hazardous conditions and consequences	2 hour and 3 hour barriers, fire suppression system	Combustible loading restrictions	Existing KW Basin Annex is the assumed location of the external facility fire
EFF-2	Initiates KW Basin super-structure collapse against modified Annex	External Facility Fire	deflagration overpressure.	Impacted structure prevents ventilation of STSC or departure of loaded STS, hydrogen accumulation and Uncontrolled release of sludge, worker and public dose.	3 hour barrier between structures, Structure separation from existing annex,	None	
EFF-3	Initiates KW Basin super-structure collapse against modified Annex	External Facility Fire	Industrial hazard	Personnel could be injured by structural collapse	None	None	
EFF-4	Initiates LOEP	External Facility Fire	LOEP Related hazardous conditions listed above.	LOEP Related consequences listed above.	N/A	N/A	
EFF-5	Smoke plugs ventilation	External Facility Fire	deflagration	Smoke and soot plugs HVAC, preventing active ventilation of the STSC, buildup of hydrogen and Uncontrolled release of sludge, worker and public dose.	HVAC design that accommodates or mitigates range fire smoke, STSC inerting system that functions during and after range fire	Administrative control to purge STSC if ventilation is lost	
FACILITY FIRE							
FF-1	Fire leads to transfer hose damage	Facility fire	Splash and Splatter Spray leak	Fire damages transfer, decant or overfill recovery transfer line (either directly or via structure failure) resulting in Uncontrolled release of sludge, worker and public dose.	Facility materials of construction, Shielded enclosure for transfer hoses, Fire suppression system	Limited combustible loading Control ignition sources	
FF-2	Fire causes loss of Modified Annex ventilation fans or plugging filters	Facility Fire	deflagration.	Loss of STSC active ventilation allows hydrogen accumulation and Uncontrolled release of sludge, worker and public dose.	Inert gas purge capability,	Limited combustible loading Control ignition sources Administrative control to purge STSC if ventilation is lost.	Assumes post fire access

TABLE C-1 “WHAT/IF” HAZARD ANALYSIS STUDY RESULTS - NPH AND EXTERNAL EVENTS							
Identifier	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls Engineered Features	Admin Controls	Remarks/Actions
FF-3	Modified Annex Facility fire impacts loaded STSC or STS	Facility Fire	Overpressure Deflagration	Fire heats STSC, fails hoses, or heats loaded STS. Leads to loss of active ventilation for STSC/deflagration and potentially an overpressure for the STS if loaded. Uncontrolled release of sludge, worker and public dose.	Material of construction limit combustibles, STS trailer resistance to fire, Fire suppression system, Inert gas purge system; STS vent and purge ports, port tools	Limited combustible loading, Control ignition sources Administrative control to purge STSC if ventilation is lost; Administrative requirement to monitor pressure and vent STS when delayed	Flammable conditions in STSC and overpressure in STS occur after substantial time based on CSDR analysis allowing fire suppression followed by hydrogen/gas vent and purge.
FF-4	Modified Annex Facility fire impacts structure	Facility Fire	Overturn STSC, Spill	Structure failure leads to overturn of loaded STSC and Uncontrolled release of sludge, worker and public dose.	Material of construction and fire resistance of structure; Fire suppression system	Limited combustible loading, Control ignition sources	
FF-5	Modified Annex Facility fire impacts structure	Facility Fire	Industrial hazard	Personnel could be injured by structural failures	Material of construction and fire resistance of structure; Fire suppression system	Limited combustible loading, Control ignition sources	
FF-6	Loaded STS not able to leave	Facility Fire	overpressure.	Fire damage prevents transfer of loaded STS, resulting in gas accumulation and potential Uncontrolled release of sludge, worker and public dose.	Material of construction and fire resistance of structure; Fire suppression system STS vent and purge ports, port tools; Inert gas purge capability	Limited combustible loading, Control ignition sources Administrative requirement to monitor pressure and vent STS when delayed.	Flammable conditions in STSC and overpressure in STS occur after substantial time allowing fire suppression followed by hydrogen/gas vent and purge.
FF-7	Mechanical room fire causes loss of pneumatics (LOP)	Facility Fire	Loss of pneumatics from various operating conditions to be considered as part of FMEA	N/A	N/A	N/A	

APPENDIX D

**“WHAT/IF” HAZARD ANALYSIS RESULTS
OPERATION SEQUENCES (GAP ANALYSIS)**

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
Mode 1 PREPARE STSC							
1-2	Position and align STS trailer on weigh scales						
1-2.1	Tractor exhaust in building	Tractor exhaust location, not connected to hose to route outside	industrial hazard	Exhaust is asphyxiant in high concentration, leading to personnel injury or death	N/A	N/A	
1-2.2	Back over person due to lack of visibility	Error during placement of tractor	industrial hazard	Moving vehicle impact results in personnel injury or death	N/A	N/A	
1-3	Secure STS trailer						
1-3.1	Trailer not secured	Steps not taken	industrial hazard	Trailer moves, potential impact to personnel or equipment	N/A	N/A	Step not performed
1-3.2	Trailer secured improperly	Steps not taken	None	Operational upset. Weight bias or erroneous results lead to wrong shipping weight.	N/A	N/A	Not a tare or loaded weight. Reference weights will be well known and easy to check.
1-4	Disconnect STS tractor and exit loading bay ramp						
1-4.1	Driver falls off tractor	Lack of railing	industrial hazard	Inadequate fall protection, personnel injury	N/A	N/A	
1-4.2	Tractor will not start	Mechanical failure	None	Operational upset. Door cannot close for confinement, fueled equipment cannot leave, cannot start processing.	N/A	N/A	
1-5	Close Annex loading bay door						
1-5.1	Door doesn’t close	Mechanical failure	None	Operational upset. Lack of confinement, cannot proceed to load, confinement not established	N/A	N/A	
1-6	Record trailer weight (WIT-740-401) and verify shipping manifest.						
1-6.1	Trailer mis-weighed	trailer mis-positioned	None	Operational upset. Inadequate monitoring of load weight.	N/A	N/A	Reference weights will be well known and easy to check. This is not the key tare value.
1-7	Remove IP-2 bag from Drain Port						
1-7.1	Zipper stuck on outer IP-2	Faulty bag	None	Operational upset. Process delay, repair bag	N/A	N/A	

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-7.2	Rip or damage IP-2	Error, operational event	None	Operational upset. Process delay, repair bag	N/A	N/A	
1-8	Remove Cask drain port cap and install drain port tool						
1-8.1	Contamination under cap	Previously contaminated	Spread of contamination,	Operational upset, RadCon event	N/A	N/A	
1-8.2	Tool won’t seat	Threads fouled	None	Operational upset, Repair	N/A	N/A	
1-9	Attach Purge Line H-602 to drain port tool. Align V-609 to "Cask" position. Verify V-607 and V-608 are closed.						
1-9.1	Purge line won’t connect	Connector failure	None	Operational upset, Repair	N/A	N/A	
1-9.2	Purge line connected, but leaking	Connector failure, error	None	Operational upset, Repair	N/A		
1-9.3	Valves not properly positioned closed	Error	None	Inerting gas to work area, personnel hazard at Step 1-11	N/A	N/A	
1.10	Attach drain line H-603 to drain port tool						
1.10.1	Purge line won’t connect	Connector failure	None	Operational upset, Repair	N/A	N/A	
1-10.2	Purge line connected, but leaking	Connector failure, error	None	Operational upset, Repair	N/A	N/A	
1-11	Open drain port						
1-11.1	Drain port won’t open	Frozen/locked threads	None	Operational upset, Repair	N/A	N/A	
1-11.2	Gas exits without being routed to drain tank	Pressure vents to operating area	spread of contamination	Operational upset, RadCon event	N/A	N/A	
1-12	Verify STS cask pressure is 0 psig (PI-760-606)						
1-12-1	Pressure indicator doesn’t read zero	HVAC pressure less than zero	None	Operational upset	N/A	N/A	

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-13	Unzip/remove Outer IP-2 bag.						
1-13.1	Operator falls off platform on trailer	Fall protection not provided on trailer	Industrial hazard	Personnel injury	N/A	N/A	
1-13.2	Zipper stuck on outer IP-2	Faulty bag	None	Operational upset. Process delay, repair bag	N/A	N/A	
1-13.3	Rip or damage IP-2	Error, operational event	None	Operational upset. Process delay, repair bag	N/A	N/A	Replace in this operating window
1-14	Unzip/remove Inner IP-2 bag.						
1-14.1	Operator falls off platform on trailer	Fall protection not provided on trailer	Industrial hazard	Personnel injury	N/A	N/A	
1-14.2	Zipper stuck on outer IP-2	Faulty bag	None	Operational upset. Process delay, repair bag	N/A	N/A	
1-14.3	Rip or damage IP-2	Error, operational event	None	Operational upset. Process delay, repair bag	N/A	N/A	
1-14.4	Outside cask contaminated under IP-2	Previously contaminated	Spread of contamination	Operational upset, RadCon event	N/A	N/A	Stop process and decon
1-15	Install Lid Lift Fixture on STS cask lid						
1-15.1	Lift fixture not properly attached	Rigging error	Industrial hazard	Operational upset. Drop of load, Damage to cask, STSC, personnel	N/A	N/A	
1-16	Remove the STS Lid bolts						
1-16.1	A bolt not removed	Error	None	Operational upset, Lid not free to remove	N/A	N/A	Lift with bolt on leads to cask or lid damage, see 1-17.2
1-17	Remove the STS Lid and install onto the Lid Inspection Station.						
1-17.1	Under side of lid contaminated	Previously contaminated	Spread of contamination	Operational upset, RadCon event	N/A	N/A	Add step to paper the inspection station
1-17.2	Lid stuck, crane overload or shear bolt	Bolts not all removed	Industrial hazard	Operational upset, Damage to cask or crane, personnel injury	N/A	N/A	Possible?

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-17.3	Access to lid inspection station leads to fall.	No fall protection	Industrial hazard	Personnel injury	N/A	N/A	
1-17.4	Wrong STSC type (annulus versus not)	Error at T Plant	None	Cask overpressure Potential to load material in wrong STSC type with future thermal transient, cask overpressure if not detected, or return to T Plant to get proper STSC.	N/A	N/A	Differences in loaded weights and Tares make detection of error fairly certain.
1-18	Verify V-103, V-109 are OPEN. Verify V-101, AOV-104 and AOV-105 are CLOSED						
1-18.1	Valves not properly positioned open	Error	None	Operational upset, Line not vented to transfer box, Potential spread of contamination at step 1-20	N/A	N/A	
1-18.2	Valve V-101 not properly positioned closed	Error	None	Operational upset, RadCon event Transfer line to basin open to transfer box, Some potential to spread contamination into valve box, leak detection at future step	N/A	N/A	
1-18.3	Valve AOV-104 not properly positioned closed	Error	None	Operational upset premature filling of STSC with IXM water	N/A	N/A	
1-19	Remove and store the 3-bolt blind flange from STSC Nozzle A.						
1-19.1	Outside of STSC/flange contaminated	Previously contaminated flange	Spread of contamination	Operational upset, RadCon event	N/A	N/A	
1.20	Remove contamination controls and end cap from Sludge line connector. Air flows from the room into the TLSB through H- 107 and H-107 annulus. IL-125 turns ON.						
1-20.1	Contaminated liquid in line connector	Thermal expansion or inadequate drying	spread of contamination	Operational upset, RadCon event Spill of contaminated liquid in work area, onto STSC, or into STS cask	N/A	N/A	
1-20.2	No noticeable vacuum	Valve alignment error at step 1-19	Spread of contamination	Operational upset, RadCon event Dry material in hose not contained by air flow leading to local contamination spread	N/A	N/A	
1-20.3	Light doesn’t light	Light burned out, connection not made.	None	Operational upset, repair	N/A	N/A	
1-20.4	Light doesn’t light	Flow instrument failure	None	Operational upset, repair	N/A	N/A	
1-21	Connect the Sludge Inlet Riverbend connector (Hose H-107) to the 3 bolt PUP connector on Nozzle A and torque the acorn nuts. Verify IL-118 is ON.						
1.21.1	Light doesn’t light	Light burned out, connection not made	None	Operational upset, interlock not cleared, Rework	N/A	N/A	

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-21.2	Connector will not seat	Faulty connector on STSC	None	Operational upset, interlock not cleared, Repair	N/A	N/A	
1-21.3	Inner line does not seal	Faulty o-ring or connector at STSC	None	Operational upset, Radcon event, potential leak at STSC upon start of pumping at step 2-7	Connector design and testing	N/A	Not clear how to detect seal is effective prior to pumping. Area not occupied when pumping initiated. Leak detector would detect leak. A second failure such as back pressure from within the STSC (e.g., plugged discharge header) or overfill would be required to result in a leak.
1-21.4	Acorn nuts not torqued	Error, step skipped	None	Operational upset, Radcon event, potential leak upon backing out. Leak at STSC upon start of pumping at step 2-7.	Connector design and testing	N/A	Not clear how to detect seal is effective prior to pumping. Area not occupied when pumping initiated. Leak detector would detect leak. A second failure such as back pressure from within the STSC (e.g., plugged discharge header) or overfill would be required to result in a leak.
1-22	Verify V-205 and V-201 are OPEN. Verify V-202 and V-206 are CLOSED						
1-22.1	Valves not opened	Error, step skipped	None	Line not vented to decant box, Potential spread of contamination at step 1-25	N/A	N/A	
1-22.2	V-202 not closed	Error, step skipped	None	Operational upset, RadCon event, ventilation suction of box connected to decant transfer line and decant pump, potential to lead to spread of contamination into box, potential liquid spill to box, leak detection.	N/A	N/A	The intent is to ensure backflow from the decant/backflush line into the decant box when removing cover and connecting to the STSC. If V-202 is open, contaminated fluids may be sucked into the decant box. F-201 would likely filter, but contamination is possible.
1-22.3	Valve V-206 not properly positioned closed	Error	None	Operational upset premature filling of STSC with IXM water	N/A	N/A	HVAC valve mis-positioned
1-23	Remove and store the 4-bolt blind flange from STSC Nozzle B.						
1-23.1	Outside of STSC/flange contaminated	Previously contaminated flange	Spread of contamination	Operational upset, RadCon event	N/A	N/A	
1-24	Remove contamination controls and end cap from Decant/backwash line connector. Air flows from the room into the decant box through H-203 and H-203 annulus. IL-223 turns on..						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-24.1	Contaminated liquid in line connector	Thermal expansion or inadequate drying	Spread of contamination	Operational upset, RadCon event Spill of contaminated liquid in work area, onto STSC, or into STS cask	N/A	N/A	Thermal expansion of liquid in line from last draining leads to liquid in hose at end. Consider adding a valve at P-101 outlet to drain the slurry transfer line back to the basin.
1-24.2	Light doesn’t light	Light burned out, connection not made.	None	Operational upset, repair	N/A	N/A	
1-24.3	Light doesn’t light	Flow instrument failure	None	Operational upset, repair	N/A	N/A	
1-25	Connect the Decant Outlet/Backflush Inlet Riverbend connector (Hose H-203) to the 4 bolt PUP connector on Nozzle B and torque the acorn nuts. Verify IL-218 is ON.						
1-25.1	Light doesn’t light	Light burned out, connection not made	None	Operational upset, interlock not cleared, Rework	N/A	N/A	
1-25.2	Connector will not seat	Faulty connector on STSC	None	Operational upset, interlock not cleared, Repair	N/A	N/A	
1-25.3	Inner line does not seal	Faulty o-ring or connector at STSC	Spread of contamination	Operational upset, Air Leak at STSC upon start of pumping, ineffective decant at 4-3 or 5-2. Leak at backflush 6-4, RadCon event	N/A	N/A	Not clear how to detect seal is effective prior to pumping/ backflush. Leak detector would detect leak.
1-25.4	Acorn nuts not torqued	Error, step skipped	Spread of contamination	Operational upset. Leak upon backing out. Air Leak at STSC upon start of pumping, ineffective decant 4-3 or 5-2. Leak at backflush 6-4, RadCon event	N/A	N/A	Not clear how to detect seal is effective prior to pumping/ backflush. Leak detector would detect leak.
1-26	Remove and store the 2 inch Camlok cap from Nozzle F2 and connect the IXM Water Inlet onto the 2 inch Camlok connection (Hose H-752).						
1-26.1	Connector not properly connected	Error, defective connector	Spread of contamination	Operational upset. RadCon event. Leak IXM water when used at 1-36, water on STSC, in STS	N/A	N/A	Low level of contamination
1-27	Remove and store the 4 inch Camlok cap from Nozzle F1 and connect the 4 inch STSC Vent Camlok connection (Hose H- 501).						
1-27.1	Improper connection	Error, defective connector	N/A		N/A	N/A	This would provide a leak path if there were a way to overfill the STSC up into the head connectors.
1-28	Connect the Purge Inlet 1 inch Quick Connect (Hose H-604).						
1-28.1	Improper, leaky connection	Error, defective connector	Industrial hazard.	Operational upset; Slow or ineffective inert; may not be effective if used for backup hydrogen control, potential for hydrogen buildup and deflagration; inerting gas discharge to work area	Connector design	N/A	Should hear leak due to low STSC pressure; if used as backup inerting

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-28.2	No flow due to plugged connector	Manufacturing defect	deflagration	Operational upset; Ineffective inert; not effective if used for backup hydrogen control, potential for hydrogen buildup and deflagration at future step	Connector design, purge flowmeter	Procedures Training Conduct of operations	Is the connection tested?
1-29	Connect I&C connector to LDE-710-103 (Leak Detector) and LE-740-401 (Level Detector) Safety Significant instruments						
1-29.1	Improper connection	Error	None	Operational upset, repair/replace Required instruments not available	N/A	N/A	Add in step description to turn on switch and check connection. Color coded and keyed to prevent cross connect
1-29.2	Detector(s) don’t work	Manufacturing defect, failed instrument	None	Operational upset, repair/replace Required instruments not available	N/A	N/A	
1-30	Connect I&C connector to LDE-720-204 (Leak Detector) and LSH-740-402 (Level Switch) General Service instruments						
1-30.1	Improper connection	Error	None	Operational upset, repair/replace Instruments not available	N/A	N/A	Add in step description to turn on switch and check connection. Color coded and keyed to prevent cross connect. One switch controls all four instrument connections. Faulty connection will cause I-1, I-2, I-3, or LIT Health light to turn on.
1-30.2	Detector(s) don’t work	Manufacturing defect, failed instrument	None	Operational upset, repair/replace Instruments not available	N/A	N/A	
1-31	Turn on STSC Instrument disconnect switch. Verify instrument Health is OK (IL-408 and IL-412 are ON)						
1-31.1	Fail to turn on switch	Error	None	Operational upset	N/A	N/A	
1-31.2	Light doesn’t light	Light burned out, connection not made.	None	Operational upset, repair	N/A	N/A	
1-32	Weigh and record initial filling condition weight (WIT-740-401).						
1-32.1	Initial condition not manually recorded	Error, step skipped	None	Operational upset	N/A	N/A	Data automatically recorded – need to verify that recording is functional in steps 1-30, 1-31 above
1-33	Select Sludge Type on PNL-401 (ECRT-KS-401 to 'K-East', 'KWest', or 'Settler' position) and reset PNL-401: Press HS-402 'reset' pushbutton.						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-33.1	Wrong selection	Error	Overpressure	Wrong calculations made in automatic system, potential to overload STSC, resulting in lower transport window and lesser thermal stability. Potential overpressure, worker and public dose after loading if manual calculation is also in error.		Reliance on manual calculation for safety analysis/TSR Procedures Training Conduct of operations	This anticipates potential overload of settler sludge based on use of automated recording system to determine load, which may be in error. May indicate error in manual recording/calculating
1-34	Initiate operability of LSH-740-402: Place ECRT-HS-113 in ‘DISABLE’ position.						
1-34.1	Fail to put in DISABLE position	Error	None	Operational upset. High level interlock will initiate bladder flush at future step (1-38) or plant condition	N/A	N/A	May result in bladder flush attempt
1-35	Record starting value of water meter FQI-770-701						
1-35.1	Wrong number recorded or not recorded	Error	None	Operational upset, Failure to measure water volume	N/A	N/A	Does not appear to be automatically logged
1-36	Open Valve STP-V-731 and begin initial fill of STSC with IXM water.						
1-36.1	Water spray/in cask if misconnected flange	Incomplete connection at step 1-27	Spread of contamination	Operational upset, some RadCon consequence due to leaked IXM water in STSC head and STS cask	N/A	N/A	Low level of contamination.
1-37	Close V-109 and V-205						
1-37.1	Fail to close V-109	error	Leak sludge to transfer box., Hydrogen Deflagration	Operational upset, RadCon upset with sludge in transfer box Future routing of sludge to transfer box, trip leak detector, interlock shutdown pump	Secondary confinement Leak detection	Procedures Training Conduct of operations	
1-37.2	Fail to close V-109	error	Spray leak Splash and splatter	Operational upset. Potential for Worker and public dose; Future routing of sludge to transfer box, trip leak detector, interlock shutdown pump	Secondary confinement Leak detection	Procedures Training Conduct of operations	
1-37.3	Fail to close V-205	error	None	Operational upset; air into suction of decant pump	N/A	N/A	
1-38	Level reaches LSH-740-402 level. IL-13 and IL-402 turn ON. Interlock I-3 trips and shuts off IXM water supply valve AOV-701. Bladder flush valve AOV-102 opens. HS-113 'DISABLE' mode prevents bladder flush from occurring) AOV-113 held closed.						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-38.1	Level switch does not function	Non functioning instrument	Spread of contamination	Operational upset, RadCon event Overfill STSC, into HVAC, potentially no indication, extensive water intrusion	N/A	N/A	Need to ensure that level indication is tracking fill volume incase switch does not function (manual back up).
1-38.2	Bladder flush	Test switch does not function	None	Operational upset, Extra water into STSC, but within head volume	N/A	N/A	
1-39	Close Valve STP-V-731 when indicator reflects full STSC.						
1-39.1	Fail to close V-731	error	None	Operational upset, Water flow will restart when decant starts at step 1-45/1-46 and run until interlock re-asserts	N/A	N/A	AOV-701 reset/open with high interlock clear.
1-40	Record ending value of water meter FQI-770-701						
1-40.1	Record wrong value	error	None	Operational upset, Calculate water volume that will differ from volume calculation for STSC	N/A	N/A	
1-41	Drain (V-736) and disconnect the IXM Water (H-752) from Nozzle F2						
1-41.1	Potential line water drain	Open connector	Spread of contamination	Operational upset, RadCon upset IXM water on STSC and into STS	N/A	N/A	No indication of closure on this connector when in the stored position.
1-42	Connect the Purge Outlet 1 inch Quick Connect (Hose H-659) to Nozzle F2.						
1-42.1	Not fully connected or action not taken	Faulty connector, step omitted	None	Operational upset, Unable to provide inerting oxygen monitoring when inerting at end of operation.	N/A	N/A	Should have an audible sound from open or partially open hole.
1-43	Verify pressure gauge PI-760-652 is reading at least 1 inch of water vacuum.						
1-43.1	Reading less than 1” wg vacuum	Faulty connector, step 1-41 omitted	None	Operational upset, Unable to provide good inerting oxygen monitoring when inerting at end of operation.	N/A	N/A	Leaky connection may cause poor inerting result if not detected during connection. Add step to vacate trailer and platform. Nobody can be on trailer when tare weights are measured.
1-44	Record first STSC tare weight and level W1 and L1 (WIT-740-401 and LIT-740-401). Initialize PNL-401 by pressing 'high tare' pushbutton HS-403. (Safety significant Measurement)						
1-44.1	Record weight with person on trailer	Error	None	Operational upset Future weights biased to allow too much sludge	N/A	N/A	Wrong recordings evaluated in HAZOP

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-45	Verify AOV-201 is in 'filter' position (HS-201 'filter') Verify IL- 201 indicates 'filter' Open V-202						
1-45.1	Position not set to filter.	Error	None	Operational upset, Water will recirculate back to STSC	N/A	N/A	
1-45.2	V-202 fails to open	Error	None	Operational upset, suction flow blocked,	N/A	N/A	
	Start decant pump P-201 by opening AOV-760 (HS-760 'start') Verify IL-761 indicates 'running'						
1-46	pump does not function	Pump diaphragm failure	None	Operational upset Can’t remove water from STSC	N/A	N/A	
1-46.1	P-201 sucks air	V-205 not closed during hookup	None	Operational upset Can’t remove water from STSC	N/A	N/A	
1-47	STSC level drops, resetting interlock I-3. Verify IL-13 and IL- 402 turn OFF.						
1-47.1	Interlock does not reset.	I&C fault	None	Operational upset	N/A	N/A	
1-47.2	IXM water flows out blank connector	V-731 not closed due to missed step 1-38 above	Spread of contamination	Operational upset, RadCon upset Water on STSC and into STS. If valve V-731 not closed at 1-38, IXM water flow that was stopped by interlock will flow through open hose onto STSC, STS and operators	N/A	N/A	Consider capping hose.
1-48	Pump until loss of suction. Turbidity meter AI-720-202 trips Interlock I-2 (ASH-720-202) and shuts off P-201 (AOV-760 closes) Verify IL-761 indicates 'stopped'						
1-48.1	not shut down by turbidity meter	Turbidity meter not valved in or failed low reading	None	Operational upset pump runs dry, fails diaphragm	N/A	N/A	
1-49	Record second STSC tare weight and level W2 and L2(WIT-740-401 and LIT-740-401). Initialize PNL-401 by pressing 'low tare' pushbutton HS-406. Calculate and verify STSC geometry factor. (Safety Significant Measurement)						
1-49.1	Low tare not set/ geometry factor not calculated.	Error	None	Operational upset Hand calculation and instrument calculation will not be in synch	N/A	N/A	Recording errors identified in HAZOP.
1-49.2	Record weight with person on trailer	Error	Overpressure	Potential to overfill container, beyond analyzed value, leading to reduced transportation window and potential for cask overpressure, potential worker and public dose	None	Procedures Training Conduct of operations	This anticipates overfill with settler sludge shortening the transport window. Recording errors identified in HAZOP. No one should be on trailer after step 1-43.

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-50	Secure from 'test' mode						
1-50.1	Not secured from “test” means that auto flush from tank not actuated	Error	Spray leak Splash and splatter	Operational upset, potential to plug line in loss of power transfer shut down, overpressure on restart: blow rupture disc or spray leak, worker or public dose	Rupture discs, Line design pressure Secondary confinement Leak detection Block/ check valves	Procedures Training Conduct of operations	This anticipates a worst case blockage from a failure to bladder tank flush when called upon at a future time.
1-51	Close V-109. Open V-101 and visually verify alignment of all manual valves in TLSB (V-101,V-103 OPEN, V-102 in 'transfer' position, all others closed). Verify IL-125 is OFF.						
1-51.1	Valve mis-positioned Both Valves not closed	Error	Uncontrolled Release Leak sludge to transfer box.	Operational upset, RadCon upset with sludge in transfer box Potential routing of sludge to valve box, trip leak detector, interlock shutdown pump	N/A	N/A	This anticipates a misdirected flow at a time during transfer if both valves are left open.
1-51.2	Valve mis-positioned - Valve not opened	Error	Spray leak Splash and splatter	Operational upset. Potential for Worker and public dose; Deadhead transfer pump when started at step 2-7, potential overpressure, spray leak. Or blow rupture disc and cloud basin water with discharged sludge	Rupture discs and interlock Primary line design pressure Secondary confinement Leak detection Block/check valves	Procedures Training Conduct of operations	This anticipates a line blockage and overpressure when the booster pump is started. V-102 not an “open” valve (it is a 3-way valve) as indicate in step description. Dead head/overpressure identified in HAZOP
1-51.2	Light is not off	Incorrect circuit	None	Operational upset. repair			
1-52	Close V-205. Open V-202, and visually verify alignment of all manual valves in decant box (V-201, V-202, V-204, V-210, V- 227 OPEN, all others closed) IL-223 is OFF.						
1-52.1	Valve mis-positioned V-205 left open	Error	None	Operational upset, potential Radcon upset Future misroute of flow to decant box or suck air at decant pump	N/A	N/A	
1-52.2	Valve not opened.	Error	Spray leak Splash and splatter	Operational upset; or worker and public dose Decant or recirc not aligned, pump dead headed	Limited pump discharge pressure Primary line design pressure, secondary confinement leak detection Block/check valves	Procedures Training Conduct of operations	V-227 intended to be a throttle valve, not “open”
1-52.2	Light is not off	Incorrect circuit	None	Operational upset. repair			
1-53	Exit and secure Annex loading bay						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
1-53-1	Not everyone leaves	Error	Direct dose	RadCon Upset Potential high dose during transfer	Shielded lines	Procedures Training Conduct of operations Administrative restriction on access to annex as part of RadCon program	
Mode 8 DISCONNECT STSC							
8-1	Enter Annex loading bay						
8-1.1	Airborne contamination	Leaked sludge material	Spread of contamination	Operational upset, Radcon event, Recovery plan	Primary confinement Secondary confinement Leak detection Ventilation zones	RadCon monitoring Procedures Training Conduct of operations	
8-1.2	Elevated direct dose rates	Lines not flushed or leaked material	Personnel direct dose Spread of contamination	Operational upset, Radcon event, Recovery plan	Primary confinement Secondary confinement Leak detection Ventilation zones	RadCon monitoring Procedures Training Conduct of operations	
8-1.3	Ventilation not running	Ventilation system fault	Industrial hazard	Operational upset, Recovery plan. Assume not habitable from industrial or Radcon perspective.	N/A	N/A	
8-2	Perform final IXM flush of sludge line: Close V-101, open AOV-104						
8-2.1	Valve-101 not closed	Step skipped, error	None	Operational upset, Recovery plan May get bladder flush , excess fill of STSC	N/A	N/A	Requires access to transfer box. Need to consider piping modification to enable remote IXM flush before entering Annex.
8-2.2	Valves- 712 and AOV-104 not opened	Step skipped, error	Personnel direct dose	Operational upset, Recovery plan Flush not performed, higher dose rates during access	N/A	N/A	Need to consider piping modification to enable remote IXM flush before entering Annex.
8-3	Secure from final sludge line flush: Close AOV-104						
8-3.1	Valves not closed	Step skipped, error	None	Operational upset, recovery plan Flush continues, interlock 3 shuts down flush	N/A	N/A	
8-3.2	Valves not closed	Step skipped, error	Spread of contamination	Operational upset, radcon upset Next step potentially introduces liquid to transfer box.	N/A	Procedures Training Conduct of operations	
8-4	Drain sludge line: Open V-109						

Table D-1 "What/If" HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-4.1	Valve not operated		Spread of contamination	Operational upset, RadCon upset, Line remains with liquid in it when disconnected	N/A	Procedures Training Conduct of operations	
8-5	Perform final Decant/backwash line flush: Close V-202, Open V-206						
8-5.1	V-202 not closed, V-206 opened	Performance error	None	Operational upset Flush both directions: to STSC and through filters	N/A	N/A	V-206 open all the way is a large flow.
8-6	Top off STSC with IXM water to final level for shipping using V-206						
8-6.1	Not topped off	Step skipped	Personnel dose	RadCon upset Dose not minimized with maximum shielding	N/A	Procedures Training Conduct of operations RadCon Monitoring	Not clear why previous step did not accomplish this action.
8-7	Secure from final Decant/backwash line flush: Close V-206						
8-7.1	Valves not closed	Performance error	None	Operational upset Flush continues, interlock 3 shuts down flush	N/A	N/A	
8-8	Drain decant/backwash line: Open V-205						
8-8.1	Step not done, line not drained	Performance error	spread of contamination	RadCon Upset, Decant/backwash line retains water for disconnect error, see 8-18.1	N/A	Procedures Training Conduct of operations	
8-9	Record STSC Weight and level(WIT-740-401 and LIT-740-401). Calculate and verify final buoyant weight of sludge transferred (DWI-740-401). Begin preparation of shipping manifest. (Safety Significant Measurement)						
8-9.1	Record wrongly	Performance error	Covered in HAZOP		N/A	N/A	There is also an automatic recording of weight and level. Nobody should be allowed on the truck until this step is completed.
8-9.2	Calculate wrongly	Performance error	Covered in HAZOP		N/A	N/A	There is also an automatic calculation and recording
8-10	Unbolt the Sludge Inlet Connection. Raise flange 2" to open the connector internal vent port. Verify IL-118 turns OFF.						

Table D-1 "What/If" HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	"What/If"	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-10.1	Not disconnected when lifted	Step not performed properly	None	Operational upset, recovery plan Potential to damage hose, break hose, damage bail	N/A	N/A	
8-10.2	Lift too high, drips	Step not performed properly	Spread of contamination	Operational upset, RadCon event Contaminated liquid drips on top of STSC	N/A	Procedures Training Conduct of operations	
8-10.3	Lift wrong hose/flange	Step not performed properly	Spread of contamination	Operational upset, RadCon event Potential to damage hose or bail, leak contamination	N/A	Procedures Training Conduct of operations	
8-11	Verify positive airflow through TLSB high point vent (IL-223 turns ON)						
8-11.1	No flow indication	Failed element, failed indicator, V-201 not open	None	Operational upset, Recovery plan required Line may not be drained down, or draining slowly	N/A	N/A	
8-12	Unbolt the Decant/backwash line Connection. Raise flange 2" to open the connector internal vent port. Verify IL-218 turns OFF.						
8-12.1	Not disconnected when lifted	Step not performed properly	None	Operational upset, recovery plan Potential to damage hose, break hose, damage bail	N/A	N/A	
8-12.2	Lift too high, drips	Step not performed properly	Spread of contamination	Operational upset, RadCon event Contaminated liquid drips on STSC	N/A	Procedures Training Conduct of operations	
8-12.3	Lift wrong hose/flange	Step not performed properly	Spread of contamination	Operational upset, potential RadCon event Potential to damage hose or bail, or release contamination	N/A	Procedures Training Conduct of operations	
8-13	Verify positive airflow through Decant box high point vent (IL- 125 turns ON)						
8-13.1	No flow indication	Failed element, failed indicator, V-205 not open	None	Operational upset, Recovery plan required Line may not be drained down, or draining slowly	N/A	N/A	
8-14	Note: At this point, air is flowing from the room into the decant box and the TLSB through the HIH annulus, and from the air breaks in the decant box and TLSB through the inner hose of HIH hoses H-107 and H-203 into the STSC. Leave nozzles in this configuration until the inner hoses are drip-free.						
8-14.1	N/A	N/A	N/A	N/A	N/A	N/A	
8-15	Disconnect the Sludge line connector from Nozzle A. Install 3- bolt blind flange on Nozzle A.						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-15.1	Drop hose and damage nozzle or impact personnel	Rigging or crane operation error	Industrial hazard	Operational upset, personnel injury, delay for repair	N/A	N/A	
8-15.2	Lift hose out of glove bag	Crane operation error	spread of contamination	Operational upset. Delay for RadCon recovery,	N/A	Procedures Training Conduct of operations	
8-16	Disconnect the Decant/backwash line connector from Nozzle B. Install 4-bolt blind flange on Nozzle B.						
8-16.1	Drop hose and damage nozzle or impact personnel	Rigging or crane operation error	Industrial hazard	Operational upset, Injure personnel, recovery plan	N/A	N/A	
8-16.2	Lift hose out of glove bag	Crane operation error	Spread of contamination	Operational upset, delay for RadCon recovery	N/A	Procedures Training Conduct of operations	
8-17	Note: At this point, air is flowing from the room up through both the inner hose and the annulus of H-107 and H-203 into the TLSB and the decant box .						
8-17.1	N/A	N/A	N/A	N/A	N/A	N/A	This step will be evaluated at MASF since dry hose may lead to fugitive emissions.
8-18	Install the end caps and contamination controls on the sludge and decant/backwash line connectors. Place the connectors in the storage position.						
8-18.1	Some liquid drops from lines	Thermal expansion of liquid in system, line not dry	Spread of contamination	Operational upset, RadCon recovery	N/A	None	Plan to be working in a glove bag.
8-19	Secure from Sludge line draining/venting: Close V-109						
8-19.1	N/A	N/A	N/A	N/A	N/A	N/A	If not closed, may be an issue in future valve alignment, but HVAC sucking on hose via box and open valve.
8-20	Secure from Decant/backwash line draining/venting: Close V-205						
8-20.1	N/A	N/A	N/A	N/A	N/A	N/A	If not closed, may be an issue in future valve alignment, but HVAC sucking on hose via box and open valve.

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-21	Disconnect the 4 inch STSC Vent connection and install the Camlok cap on Nozzle F1						
8-21.1	Drop line and damage nozzle, impact personnel	Rigging or crane operation error	Industrial hazard	Operational upset, personnel injury, recovery plan	N/A	N/A	
8-21.2	Lift hose out of glove bag	Crane operation error	Spread of contamination	Operational upset, delay for RadCon recovery	N/A	Procedures Training Conduct of operations	May not have glove bag
8-22	Initiate STSC Inert Gas Purge:						
8-22.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	
8-23	Align inert gas 3-way valve V-609 to 'STSC' position						
8-23.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	
8-24	Open V-608. Inert gas flows into the STSC.						
8-24.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	
8-25	Verify/adjust inert gas flow rate with rotameter FI-760-601						
8-25.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	
8-26	Close V-732. Air purge flow stops. Verify IL-651 is OFF.						
8-26.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	
8-27	Prior to securing from STSC Inerting, insure shipping window availability.						
8-27.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-28	Secure from STSC Inert Gas Purge upon O2 Sensor AI-760-601 reading less than 1 vol%: Close V-608.. Start the Cask Purge Clock.						
8-28.1	Covered in HAZOP	N/A	N/A	N/A	N/A	N/A	Note: If V-608 is not closed, purge flow would continue after disconnecting purge outlet connection (Step 8-30) and STSC could pressurize up to 65 psig. This is less than the design pressure of 150 psig. This will only create a hazard upon inserting of STSC vent filter which would fail and depressurize the STSC above a dp of approximately 9 psi.
8-29	Disconnect the Purge Outlet and install shipping Filter onto the 2 inch Quick Connect Nozzle F2						
8-29.1	Fail to install filter	Skip step or error	Spread of contamination Deflagration	RadCon event Inerting degraded due to air exchange, hydrogen accumulation, worker and public dose	None	Procedures Training Conduct of operations Administrative window	Test oxygen inert decay at MASF, affects duration of “clock”
8-29.2	Take too long	Delay in operation	Deflagration	Inerting degraded due to air exchange, hydrogen accumulation worker and public dose	None	Procedures Training Conduct of operations Administrative window	Test oxygen inert decay at MASF, affects duration of “clock”
8-30	Disconnect the STSC Purge Gas inlet hose and install the shipping filter onto the 1 inch Quick Connect Nozzle S2						
8-30.1	Fail to install filter	Skip step or error	Spread of contamination Deflagration	RadCon event. Inerting degraded due to air exchange, hydrogen accumulation ,worker and public dose	None	Procedures Training Conduct of operations Administrative window	Test oxygen inert decay at MASF, affects duration of “clock”
8-30.2	Take too long	Delay in operation	Deflagration	Inerting degraded due to air exchange, hydrogen accumulation, worker and public dose	None	Procedures Training Conduct of operations Administrative window	Test oxygen inert decay at MASF, affects duration of “clock”
8-31	Disconnect I&C connector to LDE-710-103 (Leak Detector) and LE-740-401 (Level Detector) Safety Significant instruments						
8-31.1	N/A	N/A	N/A	N/A	N/A	N/A	Filling and Recording complete. Add step to turn off instrument disconnect switch.
8-32	Disconnect I&C connector to LDE-720-204 (Leak Detector) and LSH-740-402 (High Level Switch) General Service instruments						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-32.1	N/A	N/A	N/A	N/A	N/A	N/A	
8-33	Concurrent with Purging operations, Inspect the STS Lid o-ring and replace Helicoflex seal.						
8-33.1	Skip replace	Error	None	Operational Upset, Lid won’t seal. Unable to inert and ship	N/A	N/A	Trailer access issue, consider replace seal at setup
8-33.2	Encounter contamination	Previous contamination	None	Operational Upset, Requires decon prior to maintenance adds to time against inerting clock.	N/A	N/A	
8-34	Install the STS Lid and torque Lid Bolts.						
8-34.1	Bolts won’t seat	Bad threads	None	Operational upset, Requires rework, added time against inerting clock	N/A	N/A	
8-35	Remove Lid Lift Fixture from STS cask lid						
8-35.1	Drop it, damage to STS, personnel	Rigging error	Industrial hazard	Personnel injury, Require rework added time against inerting clock	N/A	N/A	
8-36	Perform leak test on STS Lid:						
8-37	Remove leak test plug						
8-37.1	Plug won’t come out.	Threads damaged	None	Operational upset Repair/Rework. May need to remove cask lid and re-inert STSC or purge cask while repairing seal test.	N/A	N/A	
8-38	Install leak test tool in test port						
8-38.1	Tool not installed	Threads damaged	None	Operational upset, Repair/Rework. May need to remove cask lid and re-inert STSC or purge cask while repairing seal test.	N/A	N/A	
8-39	Pressurize the lid seal annulus and monitor for specified time						
8-39.1	Step not performed	Error	None	Cask boundary not verified. Cask not ready to ship. Potential for cask to leak if a fault occurs.	N/A	Procedures Training Conduct of operations	
8-39.2	Fail leak test						
8-40	Release pressure and remove leak test tool						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
8-40.1	Step not performed	Error	None	Operational upset. Tool must be removed to ship.	N/A	N/A	
8-41	Install leak test port plug						
8-41.1	Step not performed	Error, or bad threads	None	Operational upset, Cask boundary not complete, added time against inerting clock	N/A	N/A	
Mode 9 PREPARE FOR SHIPPING							
9-1	Remove STS Cask drain port cap and install drain port tool.						
9-1.1	Thread problems	Error or bad threads	None	Operational upset, Delay start of STS purge, rework, added time against inerting clock,	N/A	N/A	Need to check for liquid
9-2	Attach vent line(H-659) to vent port tool						
9-2.1	Not connected or partially connected	Error, faulty connector	None	Operational upset, Delay start of STS purge, rework added time against inerting clock,	N/A	N/A	Leak of nitrogen identified below in step 9-7.
9-3	Open STS drain port and STS vent port						
9-3.1	STS drain port not opened	Error	None	Operational Upset, No flow to STS at next step	N/A	N/A	
9-3.2	Vent port not opened,	Error	None	Operational Upset, Pressurize STS at next step	N/A	N/A	
9-4	Align inert gas three way valve V-609 to STS Cask position						
9-4.1	three way valve not aligned to STS	Error	None	operational upset, inerting gas to working area if V-610 not closed; if closed, no flow	N/A	N/A	Inerting gas in operating area addressed in step 9-5
9-5	Open V-608 to Purge STS cask with inert gas. Stop the Cask Purge Clock.						
9-5.1	No flow	Valve alignment not accomplished	None	Operational upset, STS purge not started, added time against inerting clock.	N/A	N/A	
9-5.2	Flow through poor connection or wrong pathway	Errors in steps 9-3, 9-5, 9-6	Industrial hazard	Inerting gas to work area, personnel hazard	N/A	N/A	

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
9-6	Secure from STS Cask Inert Gas Purge upon O2 Sensor AI-760- 601 reading less than 1 vol%: Close V-608. Start the Shipping Window Clock						
9-6.1	Oxygen sensor not functioning	Faulty instrument or valves not open or sampling pump not operation	Deflagration	Operational upset, Not acceptable for transport (TSR) STS not inert, may have flammable environment in cask, leading to potential deflagration in cask.	None	Procedures Training Conduct of operations	
9-6.2	Stop early on purge	error	Deflagration	Operational upset, Not acceptable for transport (TSR) STS not inert, may have flammable environment in cask, leading to potential deflagration in cask	Oxygen sensor	Procedures Training Conduct of operations	
9-7	Close STS vent port						
9-7.1	Step not performed	Error	None	Operational upset Cask will not pressurize on next step	N/A	N/A	
9-8	Open needle valve V-607 to pressurize the STS with Inert Gas to approximately 3 psi (PI-760-606). Close V-607.						
9-8.1	Too much pressure	Error	overpressure	Not acceptable for transport (TSR) Shorten shipping window based on pressure	Pressure gauge	Procedures Training Conduct of operations	
9-8.2	Can’t measure pressure	V-608 not open	None	Not acceptable for transport (TSR)	N/A	N/A	
9-9	Disconnect vent line from vent port tool						
9-9.1	Contaminated tool	Connector contaminate when connected to STSC	Spread of contamination	Operational upset, recovery/decon	None	RadCon Program	
9-10	Close STS drain port						
9-10.1	Doesn’t work	Threads fouled	None	Operational Upset, Rework, delay Potential shipment delay	N/A	N/A	How to know?
9-11	Relieve inert gas line pressure and disconnect inert gas supply line from drain port tool						
9-11.1	Vent the line and the STS if port not closed	Error in order of operations	None	Operational Upset, Rework, delay, Potential shipment delay	N/A	N/A	How to know that pressurization is lost?
9-12	Remove vent port tool and install vent port cap						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
9-12.1	Cap not installed	Threads fouled, error	None	Operational upset. Rework, delay Must be capped for transport (TSR)	N/A	N/A	
9-13	Install/zip up Inner IP-2 STS lid bag						
9-13.1	Fail bag	Error, operational event	None	Operational Upset, Rework, delay	N/A	N/A	
9-14	Install/zip up Outer IP-2 STS lid bag						
9-14.1	Fail bag	Error, operational event	None	Operational Upset, Rework, delay,	N/A	N/A	
9-15	Remove drain port tool and install drain port cap						
9-15.1	Drain port not capped	Threads fouled ,error	None	Operational upset, must be capped for transport (TSR) Rework, delay	N/A	N/A	
9-16	Close/install IP-2 closure on STS drain port						
9-16.1	Failure to perform	Step skipped, error	None	Operational upset, must be capped for transport (TSR, rework, delay	N/A	N/A	
9-17	Weigh and record final STS loaded weight (WIT-740-401).						
9-17.1	Failure to record	Error	None	Operational upset, Transportation issue – required on manifest Rework, delay	N/A	N/A	
9-18	Complete preparation of shipping manifest						
9-18.1	Failure to complete	Error	None	Operational upset, Transportation issue, required to transport, Rework, delay	N/A	N/A	
9-19	Open loading bay door						
9-19.1	Won’t open	Mechanism problem	None	Operational upset Cannot connect tractor to trailer, shipping window clock ticking	N/A	N/A	
9-20	Position tractor and connect to STS trailer						

Table D-1 “What/If” HAZARDS ANALYSIS RESULTS- OPERATION SEQUENCES (GAP ANALYSIS)

Identifier*	“What/If”	Causes	Hazardous Condition	Consequences	Candidate Controls		Remarks/Actions
					Engineered Features	Admin Controls	
9-20.1	Tractor mis-positioned, won’t connect	Error, impact	None	Operational upset, Cannot connect tractor to trailer, shipping window clock ticking	N/A	N/A	
9-21	Receive and verify shipping manifest						
9-21.1	Manifest not complete/ correct	error	None	Operational upset Cannot leave, shipping window clock ticking	N/A	N/A	
9-22	Remove loaded STS trailer from annex loading bay						
9-22.1	Damage structure/trailer	Error	None	Operational Upset, Cannot transport, shipping window clock ticking	N/A	N/A	
9-23	Close loading bay door						
9-23.1	Won’t close	Mechanism failure	None	Operational upset Potential delay for setup of next STSC	N/A	N/A	
Modes and activities within a mode are as defined in Appendix A							

APPENDIX E
FREQUENCY AND CONSEQUENCE LEVEL RESULTS

TABLE E-1. FREQUENCY AND CONSEQUENCE LEVEL RESULTS - SPRAY LEAK/ SPLASH AND SPLATTER SCENARIOS

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
SEISMIC						
S-2	Modified Annex structure or crane collapses due to basin structure failure during sludge retrieval and loading or overflow recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	H	H	L
S-4	Modified Annex Structure or crane collapses during transfer or overflow recovery					
S-5	Hoses disconnected at transfer box during transfer or overflow recovery					
S-3	KW Basin super-structure failure during sludge retrieval and loading or overflow recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery line in KW Basin area leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.				
S-6	Modified Annex structure collapses due to basin structure failure during decant	Uncontrolled Release of Sludge: Impact on decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	L	L	L
S-7	Basin super-structure collapses during decant					
S-8	Hoses disconnected at decant box or sand filter or STSC during decant or circulation to inject floc					
S-09	Modified Annex structure collapses due to KW basin super-structure failure during backwash	Uncontrolled Release of Sludge: Impact on decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	L	L	L
S-10	Modified Annex structure collapses during backwash					
S-11	Hoses disconnected at sand filter or decant box or STSC during backwash					
S-16	Damage to nitrogen bottle rack leads to generation of bottle missile	Uncontrolled Release of Sludge: Potential to impact transfer lines, to event comparable to S-4, 5, & 8.	U	H	H	L
S-20	Fire initiated by DBE	Uncontrolled Release of Sludge: Fire event FF-1 is initiated by and taken in combination with seismic event failure. Fire damages transfer, decant or overflow recovery transfer line (either directly or via structure failure)	U	H	H	L
S-21	LOEP initiated by DBE (structural damage to electrical equipment or distribution)	Uncontrolled Release of Sludge: LOEP-1 event below are initiated by and taken in combination with seismic event failures. Sludge settles in line, or valve closes resulting in blocked line on restart and system overpressure and line failure	U	L	L	L
S-27	Seismic event causes Modified Annex structure or equipment collapse on to transfer, decant or overflow recovery transfer lines	Uncontrolled Release of Sludge: Transfer line blockage results in high pressure failure and backward flow in lines interfacing with the transfer line/decant/overflow recovery lines.	U	H	H	L
HIGH WIND						
W-2	Modified Annex structure or crane collapses due to KW basin super-structure failure during sludge retrieval and loading, decant or overflow recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	H	H	L

TABLE E-1. FREQUENCY AND CONSEQUENCE LEVEL RESULTS - SPRAY LEAK/ SPLASH AND SPLATTER SCENARIOS

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
W-3	KW Basin super-structure failure during sludge retrieval and loading, decant or overfill recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line outside annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.				
W-4	Missile impact to sludge piping external to the Modified Annex during loading, decant or overfill recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.				
W-5	Modified Annex Structure collapses during transfer, decant or overfill recovery					
W-6	Hoses impacted or disconnected at transfer box or sand filter or decant box or STSC during transfer, decant, backwash, overfill recovery					
W-8	Nitrogen bottle overturns, knocks off valve	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line in annex from gas bottle missile leads to loss of primary containment, then a spray or splash and splatter release of slurry.	U	H	H	L
W-19	Wind load damages Modified Annex structure leading to collapse onto transfer lines, decant, backwash, overfill recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	H	H	L
SNOW						
SF-1	Snow load fails Modified Annex structure during transfer, decant or overfill recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	H	H	L
SF-9	Snowfall fails Modified Annex structure and impacts transfer lines	Uncontrolled Release of Sludge: Transfer lines are impacted by a structure or equipment collapse, dead heading the transfer or decant or overfill recovery, and over pressuring an interfacing service system pipe with resulting spray or splash and splatter	U	H	H	L
ASHFALL						
AF-1	Ashfall load fails Modified Annex structure during transfer, decant or overfill recovery	Uncontrolled Release of Sludge: Impact on transfer/overflow recovery/decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	U	H	H	L
AF-9	Ashfall fails Modified Annex structure and impacts transfer lines	Uncontrolled Release of Sludge: Transfer lines are impacted by a structure or equipment collapse, dead heading the transfer or decant or overfill recovery, and over pressuring an interfacing service system pipe with resulting spray or splash and splatter	U	H	H	L
LIGHTNING						
L-5	Lightning damages interlocks or controls	Uncontrolled Release of Sludge: Lightning strike makes interlocks for process inoperable leading to overfill and leak	U	L	L	L
LOW AMBIENT TEMPERATURE						
LAT-5	Fire initiates during freezing condition which had frozen Modified Annex sprinkler system,	Uncontrolled release of sludge: Loss of safety SSC, potential for unmitigated fire. Unmitigated fire leads to loss of ventilation or leak.	U	H	H	L

TABLE E-1. FREQUENCY AND CONSEQUENCE LEVEL RESULTS - SPRAY LEAK/ SPLASH AND SPLATTER SCENARIOS

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
LOSS OF ELECTRICAL POWER						
LOEP-1	Loss of power during transfer or overfill recovery	Uncontrolled Release of Sludge: Sludge settles in line, or valve closes resulting in blocked line on restart and system overpressure with attendant overpressure with resulting spray or splash and splatter	U	H	H	L
VEHICLE IMPACT						
VI-2	Vehicle impacts Modified Annex structure while loading STSC or overfill recovery	Uncontrolled Release of Sludge: Vehicle impact to structure results in transfer line failure resulting in a spray or splash and splatter release of slurry	U	H	H	L
AIR CRAFT CRASH						
ACC-1	Aircraft impacts Modified Annex	Uncontrolled Release of Sludge: Impact on transfer/overfill recovery/decant/backwash line in annex leads to loss of primary containment, then a spray or splash and splatter release of slurry could occur.	BEU	H	H	L
EXTERNAL EXPLOSION						
EE-4	Damage to Modified Annex structure, impacting transfer lines in service	Uncontrolled Release of Sludge: Blocked or failed transfer lines result in a spray or splash and splatter release of slurry	U	H	H	L
FACILITY FIRE						
FF-1	Fire leads to transfer hose damage	Uncontrolled Release of Sludge: Fire damages transfer, decant or overfill recovery transfer line (either directly or via structure failure) leads to a spray or splash and splatter release of slurry	U	H	H	L

Table E-2. FREQUENCY AND CONSEQUENCE LEVEL RESULTS –HYDROGEN DEFLAGRATION

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
SEISMIC						
S-12	Modified Annex Structure collapses due to KW basin super-structure failure after sludge retrieval and loading	Hydrogen Deflagration: Impact to ventilation hoses, ducting, stack, or ventilation equipment shuts down STSC headspace purge, resulting in buildup of hydrogen with potential for deflagration.	U	H	L	L
S-13	Modified Annex Structure collapse or crane drop after sludge retrieval and loading					
S-14	Modified Annex Structure collapse or crane drop or cask lid drop during installation					
S-16	Damage to nitrogen bottle rack leads to generation of bottle missile					
S-26	Loss of normal and backup power (structural damage to backup electrical equipment)	Hydrogen Deflagration: Common cause LOEP and loss of backup power, leading to STSC heat up, hydrogen buildup with potential for deflagration.	U	H	L	L
HIGH WIND						
W-9	Modified Annex Ventilation equipment damaged and/or inoperable	Hydrogen Deflagration: Nitrogen bottle overturns, knocks off valve with loss of purge and hydrogen buildup	U	H	L	L
W-10	Modified Annex Ventilation equipment damaged and/or inoperable	Hydrogen Deflagration: Impact to duct manifold, stack collapse, impact to power or control panels, on site LOEP lead to loss of STSC purge and hydrogen buildup	U	H	L	L
W-11	Modified Annex Ventilation filters become inoperable due to dust	Hydrogen Deflagration: Dust loading plugs inlet and or out filters leading to ventilation inoperability, loss of purge and hydrogen buildup	U	H	L	L
W-15	Wind or missile damage leads to fire	Hydrogen Deflagration: Fire incapacitates the ventilation, leading to hydrogen accumulation	U	H	L	L
FLOOD						
FL-3	Flood damages ventilation	Hydrogen Deflagration: Accidental sprinkler actuation impacts ventilation controls incapacitating system operability with resulting loss of purge, hydrogen accumulation	U	H	L	L
SNOW						
SF-2	Snow load fails Modified Annex structure	Hydrogen Deflagration: Structure failure impacts ventilation and prevents STSC purge leading to hydrogen buildup	U	H	L	L
SF-12	Modified Annex Roof failure or Ice dam and water inleakge	Hydrogen Deflagration: Water inleakge impacts HVAC Controls and prevents STSC purge leading to hydrogen buildup	U	H	L	L
ASHFALL						
AF-2	Ashfall load fails Modified Annex structure	Hydrogen Deflagration: Structure failure impacts ventilation and prevents STSC purge leading to hydrogen buildup	U	H	L	L

Table E-2. FREQUENCY AND CONSEQUENCE LEVEL RESULTS –HYDROGEN DEFLAGRATION

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
AF-12	Modified Annex Ventilation filters become inoperable due to ash	Hydrogen Deflagration:	U	H	L	L
RAIN						
R-2	Heavy rainfall and winds result in wetting of electrical equipment	Hydrogen Deflagration: Wet electrical components cause failure ventilation system, leading to buildup of hydrogen in STSC and Uncontrolled release of sludge, worker and public dose.	U	H	L	L
LIGHTNING						
L-2	Lightning damages Modified Annex HVAC switchgear or control system	Hydrogen Deflagration: Loss of ventilation flow to loaded STSC leads to hydrogen buildup, and Uncontrolled release of sludge, worker and public dose.	U	H	L	L
LOW AMBIENT TEMPERATURE						
LAT-4	Freezing condition impacts STSC vent	Hydrogen Deflagration: Moisture separator freezes preventing gas flow. Buildup of hydrogen leading to Uncontrolled release of sludge, worker and public dose.	U	H	L	L
LAT-5	Fire initiates when freezing condition freezes Modified Annex sprinkler system	Hydrogen Deflagration: Loss of safety SSC, potential for unmitigated fire. Unmitigated fire leads to loss of ventilation and Potential for Uncontrolled release of sludge, worker and public dose.	U	H	L	L
LOSS OF ELECTRICAL POWER						
LOEP-2	Loss of power to ventilation system when STSC is loaded	Hydrogen Deflagration: Accumulation of hydrogen leading to uncontrolled release of sludge, worker and public dose.	U	H	L	L
LOEP-4	Loss of power when closing STS	Hydrogen Deflagration: Stuck or dropped STS lid causes inability to purge or ventilate leading to hydrogen accumulation and uncontrolled release of sludge, worker and public dose.	U	H	L	L
RANGE FIRE						
RF-4	Modified Annex Structure failure	Hydrogen Deflagration: Range fire fails structure and prevents purge of STSC or overturns STSC leading to Uncontrolled release of sludge, worker and public dose.	U	H	L	L
RF-6	Fire smoke and soot plugs HVAC filters	Hydrogen Deflagration: Smoke and soot plugs HVAC, preventing ventilation of the STSC, buildup of hydrogen and Uncontrolled release of sludge, worker and public dose.	U	H	L	L
VEHICLE IMPACT						
VI-7	Vehicle impacts bottle storage	Hydrogen Deflagration: Loss of inerting capability, potential bottle missile damage to ventilation capability and hydrogen buildup to potential	U	H	L	L
AIR CRAFT CRASH						
ACC-1	Aircraft impacts Modified Annex	Hydrogen Deflagration: Impact on ventilation system, then a hydrogen build up.	BEU	H	H	L

Table E-2. FREQUENCY AND CONSEQUENCE LEVEL RESULTS –HYDROGEN DEFLAGRATION

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
EXTERNAL FACILITY FIRE						
EFF-2	Initiates KW Basin super-structure collapse against modified Annex	Hydrogen Deflagration: Impacted structure prevents ventilation of STSC or departure of loaded STS, hydrogen accumulation	U	H	L	L
EFF-5	Smoke plugs ventilation	Hydrogen Deflagration: Impacted structure prevents ventilation of STSC or departure of loaded STS, hydrogen accumulation	U	H	L	L
FACILITY FIRE						
FF-2	Fire causes loss of Modified Annex ventilation fans or plugging filters	Hydrogen Deflagration: Loss of vessel ventilation allows hydrogen accumulation	U	H	L	L
FF-3	Modified Annex Facility fire impacts loaded STSC or STS	Hydrogen Deflagration: Fire heats STSC, fails hoses, or heats loaded STS. Leads to loss of ventilation for STSC/deflagration	U	H	L	L

Table E-3 FREQUENCY AND CONSEQUENCE LEVEL RESULTS –OVERPRESSURE

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
SEISMIC						
S-15	Modified Annex Structure damage, trailer damage or door damage preventing load departure	Overpressurization: STS load heats up, hydrogen gas is generated leading to uncontrolled release of sludge, worker and public dose.	U	L	L	L
S-17	Damage to T Plant or travel route significantly delays transfer	Overpressurization: STS load heats up, hydrogen gas is generated leading to uncontrolled release of sludge, worker and public dose.	U	L	L	L
S-20	Fire initiated by DBE	Overpressurization: Fire events FF-1 through FF-6 below are initiated by and taken in combination with seismic event failures uncontrolled release of sludge, worker and public dose.	U	L	L	L
S-21	LOEP initiated by DBE (structural damage to electrical equipment or distribution)	Overpressurization: LOEP-1 through LOEP-5 events below are initiated by and taken in combination with seismic event failures. Uncontrolled release of sludge, worker and public dose. (See LOEP events below for failure configurations)	U	L	L	L
HIGH WIND						
W-8	Wind damage to Modified Annex structure or door	Overpressurization: loaded STS delayed, resulting in heat up and hydrogen generation leading to Uncontrolled release of sludge, worker and public dose.	U	L	L	L
W-14	Modified Annex structure collapse, fire	Overpressurization: Fire initiated by some modified annex structural failure in high wind results in common cause failure of fire suppression system, fire involves loaded STSC or STS, Uncontrolled release of sludge, worker and public dose.	U	L	L	L
FLOOD						
FL-1	Flood damage prevents STS Transport	Overpressurization: Water line failure floods/undermines road and prevents STS transport leading to Uncontrolled release of sludge, worker and public dose.	U	L	L	L
SNOW						
SF-3	Snow load fails Modified Annex structure	Overpressurization: Structure failure prevents loaded STS from departing resulting in hydrogen gas generation,	U	L	L	L
SF-6	Snowfall prevents transport to T Plant	Overpressurization: Road closure/transportation restriction prevent transport of STS, leading to build up of hydrogen	U	L	L	L

Table E-3 FREQUENCY AND CONSEQUENCE LEVEL RESULTS –OVERPRESSURE

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
ASHFALL						
AF-3	Ashfall load fails Modified Annex structure	Overpressurization: Structure failure prevents loaded STS from departing resulting in hydrogen gas generation,	U	L	L	L
AF-6	Ashfall prevents transport to T Plant	Overpressurization: Road closure/transportation restriction prevent transport of STS, leading to build up of hydrogen	U	L	L	L
RAIN						
R-1	Heavy rainfall delays transport	Overpressurization: Delay in transportation of sealed cask leads to heat up and hydrogen pressurization of STS	U	L	L	L
LIGHTNING						
L-4	Transport of loaded STS delayed by lightning	Overpressurization: Delay in transportation of sealed cask leads to heat up and hydrogen pressurization of STS	U	L	L	L
HIGH AMBIENT TEMPERATURE						
HAT-1	Heat impacts shipping window	Overpressurization: Delay in transportation of sealed cask leads to heat up and hydrogen pressurization of STS	U	L	L	L
LOW AMBIENT TEMPERATURE						
LAT-1	Freezing conditions impact shipping window	Overpressurization: Delay in transportation of sealed cask leads to heat up and hydrogen pressurization of STS	U	L	L	L
LOSS OF ELECTRICAL POWER						
LOEP-3	Loss of power when STS loaded.	Overpressurization: Closed roll up door prevents departure, leading to gas accumulation	U	L	L	L
RANGE FIRE						
RF-1	Delays departure of loaded STS	Overpressurization: Range fire prevents departure, leading to gas accumulation	U	L	L	L
VEHICLE IMPACT						
VI-3	Vehicle Impacts Modified Annex structure with loaded STS inside	Overpressurization: Vehicle impact prevents loaded STS transport with gas accumulation	U	L	L	L
VI-6	Tractor impacts fuel tank during prep for departure	Overpressurization: Vehicle fuel fire and tire fire impacts STS heating	U	L	L	L

Table E-3 FREQUENCY AND CONSEQUENCE LEVEL RESULTS –OVERPRESSURE

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
AIR CRAFT CRASH						
ACC-1	Aircraft impacts Modified Annex	Overpressure: Impact on STS in annex leads excess time in closed vessel and build up of pressure..	BEU	H	H	L
EXTERNAL EXPLOSION						
EE-1	*Damage to Modified Annex during departure prep	Overpressurization: Damage prevents STS departure allowing gas accumulation	U	L	L	L
EXTERNAL FACILITY FIRE						
EFF-2	Initiates KW Basin super-structure collapse against modified Annex	Overpressurization: Impacted structure prevents ventilation of STSC or departure of loaded STS, hydrogen accumulation	U	L	L	L
FACILITY FIRE						
FF-3	Modified Annex Facility fire impacts loaded STSC or STS	Overpressurization: Fire heats STSC, fails hoses, or heats loaded STS. Leads to loss of ventilation with potentially an overpressure	U	L	L	L
FF-6	Loaded STS not able to leave	Overpressurization: Fire damage prevents hauling loaded STS, resulting in gas accumulation	U	L	L	L

Table E-4 FREQUENCY AND CONSEQUENCE LEVEL RESULTS –OVERTURN/SPILL SCENARIOS

Node	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
SEISMIC						
S-19	STSC overturns after loading	STSC Overturn Spill: Spill of sludge into loading bay	U	L	L	L
HIGH WIND						
W-7	Modified Annex Structure failure onto loaded STSC	STSC Overturn Spill: Spill of sludge into loading bay	U	L	L	L
LIGHTNING						
L-5	Lightning damages interlocks or controls	STSC Overfill Spill : Lightning strike makes interlocks for process inoperable leading to overfill and spill of sludge into loading bay	U	L	L	L
RANGE FIRE						
RF-4	Modified Annex Structure failure	STSC Overturn Spill: Spill of sludge into loading bay	U	L	L	L
FACILITY FIRE						
FF-4	Modified Annex Facility fire impacts structure	STSC Overturn Spill: Spill of sludge into loading bay	U	L	L	L

Table E-5 FREQUENCY AND CONSEQUENCE LEVEL RESULTS –GAP ANALYSIS SCENARIOS						
Identifier*	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
Mode 1 PREPARE STSC						
1-17	Remove the STS Lid and install onto the Lid Inspection Station.					
1-17.4	Wrong STSC type (annulus versus not)	Cask overpressure. Potential to load material in wrong STSC type with future thermal transient, cask overpressure if not detected, or return to T Plant to get proper STSC.	A	L	L	L
1-33	Select Sludge Type on PNL-401 (ECRT-KS-401 to 'K-East', 'KWest', or 'Settler' position) and reset PNL-401: Press HS-402 'reset' pushbutton.					
1-33.1	Wrong selection	Overpressurization: Wrong calculations made in automatic system, potential to overload STSC, resulting in lower transport window and lesser thermal stability. Potential overpressure,	A	L	L	L
1-37	Close V-109 and V-205					
1-37.1	V-109 not closed	Hydrogen Deflagration: Sludge release to transfer box hydrogen buildup	A	H	L	L
1-37.2	V-109 not closed	Uncontrolled Release of Sludge: overpressure on transfer resulting in a spray or splash and splatter release of slurry:	A	H	H	L
1-50	Secure from 'test' mode (HS-701 to 'auto' position)					
1-50.1	Not secured from 'test' mode (HS-701 to 'auto' position) auto flush from tank not actuated	Uncontrolled Release of Sludge: potential to plug line in loss of power transfer shut down, overpressure on restart resulting in a spray or splash and splatter release of slurry:	A	H	H	L
1-51	Close V-109 and AOV-104. Open V-101 and visually verify alignment of all manual valves in TLSB (V-101, V-102, V-103 open, all others closed)					
1-51.1	Valve mis-positioned Both Valves not closed	Hydrogen Deflagration: Sludge release to transfer box hydrogen buildup	A	H	L	L
1-51.2	Valve mis-positioned - Valve (V-101, or V-103) not opened	Uncontrolled Release of Sludge: Deadhead transfer pump when started, potential overpressure, resulting in a spray or splash and splatter release of slurry:	A	H	H	L
1-52	Close V-205. Open V-202, and visually verify alignment of all manual valves in decant box (V-201, V-202, V-204, V-210, V- 227 OPEN, all others closed)					
1-52.2	Valve not opened.	Uncontrolled Release of Sludge: Deadhead transfer pump when started, potential overpressure, resulting in a spray or splash and splatter release of slurry:	A	H	H	L
Mode 8 DISCONNECT STSC						
8-29	Disconnect the Purge Outlet and install shipping Filter onto the 1 inch Quick Connect Nozzle F2					
8-29.1	Fail to install filter	Hydrogen Deflagration: Inerting degraded due to air exchange, hydrogen accumulation	A	H	L	L
8-29.2	Take too long					
8-30	Disconnect the STSC Purge Gas inlet hose and install the shipping filter onto the 2 inch Quick Connect Nozzle S2					

Table E-5 FREQUENCY AND CONSEQUENCE LEVEL RESULTS –GAP ANALYSIS SCENARIOS						
Identifier*	What-If	Unmitigated Consequence	Event Freq	Consequence		
				FW	Onsite	Offsite
8-30.1	Fail to install filter	Hydrogen Deflagration: Inerting degraded due to air exchange, hydrogen accumulation	A	H	L	L
8-30.2	Take too long					
* Identifier is Mode-Step from Attachment 4						

APPENDIX F
HAZARDS ANALYSIS
PEER REVIEW CHECKLIST

CHPRC REVIEW CHECKLIST

Document Reviewed:

PRC-STP-00473, Sludge Treatment Project Preliminary Design Hazard Analysis Supplement 1

ECATS 2/27/11

Scope of Review:

The review was a peer review of the complete document.

Yes No N/A

☐	☐	☒	* Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☐	☐	☒	Accident scenarios developed in a clear and logical manner.
☐	☐	☒	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☐	☐	☒	Data used in calculations explicitly stated in document.
☐	☐	☒	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivation checked including dimensional consistency of results.
☐	☐	☒	Models appropriate and used within range of validity or use outside range of established validity justified.
☐	☐	☒	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☐	☐	☒	Software input correct and consistent with document reviewed.
☐	☐	☒	Software output consistent with input and with results reported in document reviewed.
☒	☐	☐	Limits/criteria/guidelines applied to analysis results are appropriate and referenced.
			Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☒	☐	☐	* Format consistent with appropriate NRC Regulatory Guide or other standards.
☐	☐	☒	Review calculations, comments, and/or notes are attached.
☐	☐	☒	For calculations in which codes/spreadsheets (e.g., RADDOSE, GENII, etc) are used, is the latest revision used? Is the User Authorized?
☒	☐	☐	Document approved.

CA Carro

Reviewer (Printed Name and Signature)

7-12-2011

Date

*Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.