S

ENGINEERING CHANGE NOTICE

HNF-2978, Rev. 5, Updated Pumpable Liquid Volume Estimates and Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks

☒ DM ☐ FM ☐ TM

1a. ECN 720379 R 0

1b. Proj. ECN W- -

2. Request Information	3a. Design Inputs –N/A	3b. Design References – N/A	3c. Engineering Evaluation / Estimate / Approval to Proceed w/ the Design – N/A
Record Information on the ECN-1 Form			

4. Originator's Name, Organization, MSIN, & Phone No.	5. USQ Number	6. Date
J. M. Conner, Process/Waste Transfer Engineering, R2-11, 373-2711	No. TF-03-3221-S ☐ N/A Init. JC Date 6/30/03	6/16/03

7. Title	8. Bldg. / Facility No.	9. Equipment / Component ID	10. Approval Designator
Updated Pumpable Liquid Remaining Volume Estimates . . .	SSTs	N/A	N/A

11. Document Numbers Changed by this ECN (For FM or TM Changes Record Information on the ECN-5 Form) Sheet and Rev.	12. Design Basis Documents?	13. Safety Designation	14. Expedited / Off-Shift ECN?
HNF-2978, Rev. 4	☐ Yes ☒ No	☐ SC ☐ SS ☐ GS ☒ N/A	☐ Yes ☒ No

15a. Work Package Number	15b. Modification Work Completed	15c. Restored to Original Status (TM)	16. Fabrication Support ECN?
N/A	N/A Responsible Engineer / Date	N/A Responsible Engineer / Date	☐ Yes ☒ No

17. **Description of the Change** (Use ECN Continuation pages, as needed)

Complete revision of the document. Incorporates saltwell pumping information up to April 1, 2003. Updates estiamtes of pumpable liquid remaining in unstabilized tanks as well as estimated pumping durations.

The methodology of calculating pumpable liquid remaining has been modified to conform to RPP-12324. This document notes that previous versions of HNF-2978 were conservative, in that liquid predicted to be pumpable was typically left in stabilized tanks, and provided estimates of this empirically unpumpable volume for all tanks still being interim stabilized.

18. **Justification of the Change** (Use ECN Continuation pages, as needed)

Updated estimates are necessary to more accurately track the progress of interim stabilization.

19. **ECN Category**

☒ Direct Revision

☐ Supplemental

ECN Revision Type

☐ Void/Cancel

☐ Closure

☐ Revision

20. **Distribution** (Name and MSIN)

Distribution sheet attached

Release Stamp

JUL 01 2003

DATE:

STA: 4

HANFORD RELEASE

ID: 21

ENGINEERING CHANGE NOTICE	☒ DM ☐ FM ☐ TM	1a. ECN 720379 R 0
Page 2 of 7		1b. Proj. ECN W- -

21. **Design Check** Record Information on the ECN-6 Form	22. **Design Verification Required?** ☐ Yes ☒ No If Yes, as a minimum attach the one page checklist from TFC-ENG-DESIGN-P-17.	23. **Closeout / Cancel / Void** ☐ Yes ☒ No If Yes, Record Information on the ECN-7 Form and attach form(s).

24. **Revisions Planned** (Include a brief description of the contents of each revision)

None.

Note: All Revisions shall have the approvals of the affected organizations as identified in block 9 "Approval Designator," on page 1 of this ECN.

25a. **Commercial Grade Item Dedication Numbers** (associated with this design change)	25b. **Engineering Data Transmittal Numbers** (associated with this design change, e.g., new drawings, new documents)
N/A	N/A

26a. **Design Cost Estimate**	26b. **Materials / Procurement Costs**	26c. **Estimated Labor Hours**
N/A	N/A	**N/A**

27. **Field Change Notice(s) Used?** (Used for ECN Revisions only) ☐ Yes ☒ No If Yes, Record Information on the ECN-8 Form attach form(s) and identify permanent changes.	NOTE: ECN Revisions are required to record and approve all FCN's issued during the field modification work process. If the FCN's have not changed the original design media then they are just incorporated into the ECN file via an ECN revision. If the FCN did change the original design media then the ECN Revision will include the necessary engineering changes to the original design media changes.

28. **Approvals**

	Signature	Date		Signature	Date
Design Authority			Originator/Design Agent		
Team Lead/Lead Engr. J. M. Conner	JM Conner	6-17-03	Professional Engineer		
Resp. Engineer J. M. Conner	JM Conner	6-17-03	Project Engineer		
Resp. Manager T. M. Horner	T.M. Horner	6/24/03	Quality Assurance		
Quality Assurance			Safety		
IS&H Engineer			Designer		
NS&L Engineer			Environ. Engineer		
Environ. Engineer			Other		
Project Engineer			Other		
Design Checker J. A. Lechelt	Jeanne A Lechelt	6/18/03	DEPARTMENT OF ENERGY / OFFICE OF RIVER PROTECTION		
Design Verifier			Signature or a Control Number that tracks the Approval Signature		
Operations					
Radcon			ADDITIONAL SIGNATURES		
Interim Stabil. Proj. D. T. Vladimiroff	DT Vladimiroff	6-25-03			
Other					

ECN - 1 ENGINEERING REQUEST FORM Page 3 of 7	☒ DM ☐ FM ☐ TM	1a. ECN 720379 R 0 1b. Proj. ECN W- -

Requestor's Name (Print)	Date	REA Reference
J. M. Conner	6/16/03	N/A

Equipment Name	Estimated Need Date
Interim Stabilization Consent Decree Tanks	6/17/03

Problem/Issue Statement

Periodic updates to the estimated volume remaining to be pumped for interim stabilization are required.

Purpose for the Proposed Modification

Update estimate of pumpable liquid remaining as well as estimated pumping durations.

Basis for the Estimated Need Date

To provide sufficient time for Interim Stabilization to meet target volumes based on the estimated pumpable liquid remaining in this document.

Requestor's Signature	Date	Requestor's Manager's Signature	Date
JM Conner	6-17-03	TM HORNER T.M. Horner	6/24/03

Responsible Manager Approval

Work Package Number (If Known)	Estimated Evaluation ROM Cost	CACN
N/A	$	500846
Process as a Simple Modification? ☒ Yes ☐ No	**Assigned to (Team Lead)** J. M. Conner	**Date** 6/24/03
Responsible Manager's Signature TM HORNER T.M. Horner	☒ Approve ☐ Reject	**Date** 6/24/03

If rejected, explain reason for rejection:

(Once rejected the Responsible Manager returns the request to the Requestor's Manager)

Italicized text items need to be addressed. Standard text items need to be addressed as applicable to the problem/issue described.

ECN - 5 DRAWING / DOCUMENT CHANGE LIST FORM Sheet 1 of ECN – 5 Page 4 of 7	☒ DM ☐ FM ☐ TM	1a. ECN 720379 R 0 1b. Proj. ECN W- -

List of Engineering Drawings/Documents to be Modified (Use the attached checklist for guidance)

Dwg./Doc. Number (Sheet/Page, Rev)	Title/Type	Shared	Existing Change Document Nos.
HNF-2978, Rev. 4	Updated Pumpable Liquid Volume Estimates and Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks	☐	
		☐	
		☐	
		☐	
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		☐	
		☐	
		☐	
		☐	

Submitted to Document Service Center Prior to ECN Release?

☐ Yes ☒ No	Team Lead	Date

List of Non-Engineering Documents Needed to be Modified

Document Number/Revision, Sheet/Page (If Available)	Document Title	Document Owner (Organization)	Individual Notified	Method	Date Notified
N/A					

ECN - 5 DRAWING / DOCUMENT CHANGE LIST FORM	☒ DM ☐ FM ☐ TM	1a. ECN 720379 R 0
Sheet 2 of ECN – 5 Page 5 of 7		1b. Proj. ECN W- -

Drawings/Documents to be Modified Checklist			
System Design Description	☐ Yes ☐ No ☒ N/A	Operating Procedure	☐ Yes ☐ No ☒ N/A
Functional Design Criteria	☐ Yes ☐ No ☒ N/A	System/Subsystem Specifications	☐ Yes ☐ No ☒ N/A
Functional Requirements	☐ Yes ☐ No ☒ N/A	Engineering Flow Diagram Drawing	☐ Yes ☐ No ☒ N/A
Operating Specification	☐ Yes ☐ No ☒ N/A	General Arrangement Drawing	☐ Yes ☐ No ☒ N/A
Criticality Specification	☐ Yes ☐ No ☒ N/A	Material Specification	☐ Yes ☐ No ☒ N/A
Conceptual Design Report	☐ Yes ☐ No ☒ N/A	Sampling Plan	☐ Yes ☐ No ☒ N/A
Detailed Design Report	☐ Yes ☐ No ☒ N/A	Inspection Plan	☐ Yes ☐ No ☒ N/A
Equipment Specification	☐ Yes ☐ No ☒ N/A	Radiation Control Procedure	☐ Yes ☐ No ☒ N/A
Procurement Specification	☐ Yes ☐ No ☒ N/A	Spare Parts List	☐ Yes ☐ No ☒ N/A
Construction Specification	☐ Yes ☐ No ☒ N/A	Test Specification	☐ Yes ☐ No ☒ N/A
Vendor Information	☐ Yes ☐ No ☒ N/A	Test Plan	☐ Yes ☐ No ☒ N/A
Operations / Maintenance Manual	☐ Yes ☐ No ☒ N/A	Acceptance Test Procedure	☐ Yes ☐ No ☒ N/A
Safety Analysis / FSAR / SAR / DSA	☐ Yes ☐ No ☒ N/A	Pre-Operational Test Procedure	☐ Yes ☐ No ☒ N/A
Technical Safety Requirement	☐ Yes ☐ No ☒ N/A	Operational Test Procedure	☐ Yes ☐ No ☒ N/A
Master Equipment List	☐ Yes ☐ No ☒ N/A	ASME Coded Item / Vessel	☐ Yes ☐ No ☒ N/A
Safety Equipment List	☐ Yes ☐ No ☒ N/A	Human Factor Consideration	☐ Yes ☐ No ☒ N/A
Radiation Work Permit	☐ Yes ☐ No ☒ N/A	Automated Control Configuration Procedure	☐ Yes ☐ No ☒ N/A
Environmental Requirement	☐ Yes ☐ No ☒ N/A	Computer / Automated Control Software Plan	☐ Yes ☐ No ☒ N/A
Environmental Permit	☐ Yes ☐ No ☒ N/A	Raceway / Cable Schedules	☐ Yes ☐ No ☒ N/A
Seismic / Stress / Structural Analysis	☐ Yes ☐ No ☒ N/A	Work Control Procedure	☐ Yes ☐ No ☒ N/A
Design Report	☐ Yes ☐ No ☒ N/A	Corrective Maintenance Procedure	☐ Yes ☐ No ☒ N/A
Interface Control Drawing	☐ Yes ☐ No ☒ N/A	Process Control Plan	☐ Yes ☐ No ☒ N/A
Calibration Procedure	☐ Yes ☐ No ☒ N/A	Process Control Procedure	☐ Yes ☐ No ☒ N/A
Preventive Maintenance Procedure	☐ Yes ☐ No ☒ N/A	Flow Sheet	☐ Yes ☐ No ☒ N/A
Engineering Procedure	☐ Yes ☐ No ☒ N/A	Purchase Requisition	☐ Yes ☐ No ☒ N/A
Security Plan	☐ Yes ☐ No ☒ N/A	Hazards Analysis	☐ Yes ☐ No ☒ N/A
Emergency Plan	☐ Yes ☐ No ☒ N/A	JCS PM Activity Datasheet	☐ Yes ☐ No ☒ N/A
	☐ Yes ☐ No ☐ N/A		☐ Yes ☐ No ☐ N/A
	☐ Yes ☐ No ☐ N/A		☐ Yes ☐ No ☐ N/A

ECN - 6 DESIGN CHECK LIST	☒ DM ☐ FM ☐ TM	1a. ECN 720379 R 0
Sheet 1 of ECN – 6 Page 6 of 7		1b. Proj. ECN W- -

Design Details/Attributes (to be filled out by the change originator) identified in the ECN.			
1. Issue/Problem Statement included	☒ Yes ☐ No ☐ N/A	*21. Basis for Selected Alternative explained, including assumptions*	☐ Yes ☐ No ☒ N/A
2. Safety/Commitment/Programmatic Impacts identified – NEPA Documentation completed	☐ Yes ☐ No ☒ N/A	*22. Potential Component/System Impacts identified and resolved*	☐ Yes ☐ No ☒ N/A
3. System/Equipment/Personnel Impacts identified	☐ Yes ☐ No ☒ N/A	*23. Potential Software Impacts identified and resolved*	☐ Yes ☐ No ☒ N/A
4. Technical Evaluation included	☒ Yes ☐ No ☐ N/A	*24. Potential Safety Impacts are identified and resolved (e.g., energized electrical equipment)*	☐ Yes ☐ No ☒ N/A
5. Compliance w/ Design Basis identified	☐ Yes ☐ No ☒ N/A	*25. Modification is Constructible and can be implemented*	☐ Yes ☐ No ☒ N/A
6. Assumptions/Sources clearly identified	☒ Yes ☐ No ☐ N/A	*26. Design considers Operational Impacts*	☐ Yes ☐ No ☒ N/A
7. Affected Documents and Databases clearly identified	☒ Yes ☐ No ☐ N/A	*27. Contamination Controls are planned*	☐ Yes ☐ No ☒ N/A
8. Inputs Verified	☒ Yes ☐ No ☐ N/A	*28. Pre-Installation/Mockup/Prototype Testing planned*	☐ Yes ☐ No ☒ N/A
9. Required Function(s) / changes clearly identified	☒ Yes ☐ No ☐ N/A	*29. Sketches/Drawings for Tools/Fabricated Components included*	☐ Yes ☐ No ☒ N/A
10. Safety Basis/Commitments/Concerns evaluated	☐ Yes ☐ No ☒ N/A	*30. Hardware Design described*	☐ Yes ☐ No ☒ N/A
11. Application of Industry Standards/Codes explained	☐ Yes ☐ No ☒ N/A	*31. Software/Firmware Design described*	☐ Yes ☐ No ☒ N/A
12. Proper Analytical Techniques employed	☒ Yes ☐ No ☐ N/A	*32. Inspections (per Codes & Standards) / Quality Checks included*	☐ Yes ☐ No ☒ N/A
13. Interfaces evaluated and identified	☐ Yes ☐ No ☒ N/A	*33. Dimensions and Tolerances included*	☐ Yes ☐ No ☒ N/A
14. Material/Component Compatibility evaluated	☐ Yes ☐ No ☒ N/A	*34. Sketches/Drawings for Installation included*	☐ Yes ☐ No ☒ N/A
15. ALARA/Radiological controls/chemical hazards evaluated	☐ Yes ☐ No ☒ N/A	*35. Housekeeping/Personnel Safety Requirements identified*	☐ Yes ☐ No ☒ N/A
16. Human/Machine Interface evaluated	☐ Yes ☐ No ☒ N/A	*36. Walkdown(s) performed/Labeling Correct*	☐ Yes ☐ No ☒ N/A
17. Program impacts evaluated	☐ Yes ☐ No ☒ N/A	*37. Acceptance Test generated and Acceptance Criteria included*	☐ Yes ☐ No ☒ N/A
18. Design Basis Calculations updated	☐ Yes ☐ No ☒ N/A	*38. M&TE Requirements identified*	☐ Yes ☐ No ☒ N/A
19. Alternatives described/evaluated and address resolution of problem	☐ Yes ☐ No ☒ N/A	*39. Training/Qualification of Test Personnel identified*	☐ Yes ☐ No ☒ N/A
20. Impacts on Maintenance and OPS described	☐ Yes ☐ No ☒ N/A	*40. Safety and Hazards Analysis assessed*	☐ Yes ☐ No ☒ N/A

Design Originator (Print/Sign) J. M. Conner JM Conner	***Date*** 6-17-03

Italicized text items need to be addressed. Standard text items need to be addressed as applicable to the change as described.

ECN - 6 DESIGN CHECK LIST	☒ DM ☐ FM ☐ TM	1a. ECN 720379 R 0
Sheet 2 of ECN – 6 Page 7 of 7		1b. Proj. ECN W- -

Design Check Method (Select method(s) and provide explanation of how to be performed):

☒ Peer Check	☐ Design Check Team*	☐ Other _____

Design Check Explanation:

Complete review of document.

* Design check team members other than the originating organization normally should consist of personnel representing: Operations, Maintenance & Reliability Engineering, Maintenance Management, Maintenance Crafts, Safety, and Projects.

Design Check Details

Design inputs correctly identified?	☒ Yes ☐ No ☐ N/A	*Design changes properly documented?*	☒ Yes ☐ No ☐ N/A
Calculations checked and are correct?	☒ Yes ☐ No ☐ N/A	*Test procedures reviewed and are correct?*	☐ Yes ☐ No ☒ N/A
Design assumptions are stated and verified?	☒ Yes ☐ No ☐ N/A	*Is the design change adequate?*	☒ Yes ☐ No ☐ N/A
Design criteria incorporated into the design?	☒ Yes ☐ No ☐ N/A	*Is the design change complete?*	☒ Yes ☐ No ☐ N/A
Interfaces clearly identified in the design?	☒ Yes ☐ No ☐ N/A	*Is the design change correct?*	☒ Yes ☐ No ☐ N/A
EQRG pre-release review required?	☐ Yes ☒ No	EQRG Pre-release Approval	Date

Comments:

No test procedures

Reference TFC-ENG-DESIGN-P-17, Design Verification

Design Checker (Print/Sign)	***Date***
JA Lechelt Jeanne A Lechelt	6/18/03

Italicized text items need to be addressed. Standard text items need to be addressed as applicable to the problem/issue described.

RECORD OF REVISION	(1) Document Number HNF-2978	Page 1

(2) Title
Updated Pumpable Liquid Volume Estimates and Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release (5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) Initially released 07/15/98 on EDT-622455.	R.D. Schreiber	J.W. Hunt
1 RS	Incorporate per ECN-655980.	J.G. Field JG Field 9/7/99	N.W. Kirch NWKirch 9/7/99
2 RS	Incorporate per ECN-660352.	L.A. Fort LAFort 8/30/00	N.W. Kirch NWKirch 8/30/00
RS 3	Incorporate per ECN-657017	L.A. Fort LAFort 6/13/02	M.A. Knight LAFort for 6/13/02
4 RS	Incorporate per ECN-672213	J.M. Conner JM Conner 8-22-02	M.A. Knight MA Knight 8/22/02
5 RS	Incorporate per ECN 720379-R0	JM Conner JM Conner 6-17-03	TM HORNER T.M. Horner 6/24/03

DISTRIBUTION SHEET

To	From	Page 1 of 2
Distribution	Process/Waste Transfer Engineering	Date 6/17/03
Project Title/Work Order		**EDT No.** N/A
HNF-2978, Rev. 5, *Updated Pumpable Liquid Volume Estimates and Jet Pumping Durations for Interim Stabilization of Remaining SSTs*		**ECN No.** 720379-R0

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
CH2M HILL Hanford Group, Inc.		X			
D. I. Allen	H6-03	X			
J. N. Appel	R2-12	X			
S. J. Bensussen	H6-18	X			
V. C. Boyles	S5-13	X			
J. W. Cammann	S7-83	X			
R. J. Cash	S7-90	X			
J. M. Conner	S5-13	H X			
R. A. Dodd	S7-83	X			
J. N. Doeler	T4-07	X			
K. C. Dorwick	S7-83	X			
B. M. Hanlon	R1-14	X			
T. M. Horner	S5-13	X			
N. W. Kirch	R3-73	X			
M. A. Knight	R1-14	X			
M. R. Koch	S7-83	X			
C. E. Leach	R2-37	X			
J. A. Lechelt	S5-13	X			
D. C. Lowe	R2-58	X			
A. N. Naiknimbalkar	R2-12	X			
T. C. Oten	S5-07	X			
D. W. Reberger	S5-13	X			
L. M. Sasaki	R2-12	X			
D. J. Saueressig	S5-07	X			
J. N. Strode	R3-73	X			
M. J. Sutey	S7-24	X			
S. L. Swaney	S7-24	X			
R. P. Tucker	S7-20	X			
D. T. Vladimiroff	S7-20	X			
D. J. Washenfelder	H6-03	X			
W. F. Zuroff	S7-24	X			
TCSRC	R1-10	H			
Numatec Hanford Company					
T. M. Hohl	R3-73	X			

DISTRIBUTION SHEET

To	From	Page 2 of 2
Distribution	Process/Waste Transfer Engineering	Date 6/18/03
Project Title/Work Order		**EDT No.** N/A
HNF-2978, Rev. 5, *Updated Pumpable Liquid Volume Estimates and Jet Pumping Durations for Interim Stabilization of Remaining SSTs*		**ECN No.** 720379-R0

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Office of River Protection					
D. C. Bryson	H6-60	X			
L. Erickson	H6-60	X			
M. J. Royack	H6-60	X			
A. J. Stevens	H6-60	X			
S. D. Stubblebine	H6-60	X			
J. H. Swailes	H6-60	X			
DOE Reading Room	H2-53	H			
Pacific Northwest National Laboratory					
C. W. Stewart	K7-15	H			
B. E. Wells	K7-15	H			

Updated Pumpable Liquid Volume Estimates and Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks

J. M. Conner
CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: ECN-~~720179~~ 720379-R0 UC: 2070
Org Code: 7G300 Charge Code: 12214-62
B&R Code: EW 3120074 Total Pages: 74

Key Words: Interim stabilization, pumpable liquid, liquid volumes, jet pump, pumping, durations, pumping days, pump time, single-shell tanks, SST

Abstract: The document calculates the pumpable liquid remaining in the 11 unstabilized Consent Decree tanks, as well as updating the estimated pumpable liquid volume in the 29 Consent Decree tanks in June 1, 1998. Data in this document are updated to April 1, 2003.

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7/1/03
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HNF-2978
Revision 5

Updated Pumpable Liquid Volume Estimates and Jet Pump Durations for Interim Stabilization of Remaining Single-Shell Tanks

J. M. Conner
CH2M HILL Hanford Group, Inc.

Date Published
June 2003

CH2MHILL
Hanford Group, Inc.

Post Office Box 1500
Richland, Washington

Prepared for the U.S. Department of Energy
Office of River Protection

Approved for public release; distribution unlimited

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EXECUTIVE SUMMARY

Part of the legacy from the Hanford Site's production of weapon-grade plutonium was the large volumes of radioactive waste stored in 149 underground single-shell tanks (SST), constructed from 1943 to 1964; and 28 underground double-shell tanks (DST), constructed from 1968 to 1986. To limit the number of new DSTs that had to be constructed to store liquid radioactive waste, the U.S. Department of Energy (DOE) authorized the concentration of waste liquids until the soluble salts were precipitated. These precipitated salts were allowed to settle in the SSTs. Significant free supernatants were pumped from most of the SSTs by 1980, and were concentrated and stored in DSTs. No new waste additions were made to the SSTs after 1980. However, the tanks have exceeded their design life and suspected leakage from 67 SSTs has been identified (Vladimiroff et al. 2002).

To reduce the risk of further SST leakage, saltwell pumping was initiated to drain and remove interstitial liquid. When the maximum practicable interstitial liquid is removed, a tank is said to be "interim stabilized." As of June 1, 1998, 119 of the 149 SSTs have been declared interim stabilized, and 30 tanks remained to be interim stabilized. In March 2002, Revision 5 of the *Single-Shell Tank Interim Stabilization Project Plan* (Vladimiroff et al. 2002) was issued to document the path to complete the interim stabilization of 29 of the remaining 30 tanks. Tank 241-C-106 is to be stabilized by another project.

A Consent Decree between the DOE and the State of Washington establishes the requirements for stabilizing the 29 tanks. The criteria established in the Consent Decree to declare a tank interim stabilized are that the tank must contain less than 50,000 gallons of drainable interstitial

liquid (DIL), less than 5,000 gallons of supernatant, and the pumping rate must be at 0.05 gallons per minute (gpm) or less before pumping can be discontinued. The Consent Decree establishes milestones based on estimated waste volumes as of June 1, 1998. The milestones include the requirements that DOE will complete interim stabilization of all 29 SSTs by September 30, 2004; and that the percentage of Pumpable Liquid Remaining (PLR) to be removed from the 29 tanks will be 2 percent (or less) of the total pumpable liquid by September 30, 2003. The terms of the Consent Decree also require a confirmation that the project is on schedule to meet the milestones specified, and provide the opportunity to update the volume projections each October.

As of April 2003, 17 of the 29 tanks addressed by the Consent Decree have been declared interim stabilized or interim stabilization is pending. This document uses the best available information as of April 1, 2003, to provide an updated estimate of the total pumpable liquid originally contained in the 29 tanks as of June 1, 1998, together with an estimate of the pumpable liquid remaining in the 12 SSTs that remain to be stabilized and a projection of future pumping durations. The estimated pumpable liquid volume remaining in the 12 tanks that remain to be stabilized as of April 1, 2003 was 399 kilogallons (kgal), and a total of 2,880 kgal had been pumped since June 1998. The latest estimate of total pumpable liquid in the 29 SSTs (on June 1,1998) has been reduced to approximately 3.3 million gallons compared with 6.2 million gallons reported June 1, 1998, in Revision 0. The most recent previous estimate had been 3.9 million gallons in Revision 4, published in August 2002.

The large decrease with this revision (from 3.9 million gallons in Revision 4 down to 3.3 million gallons) is mostly attributed to a change in the methodology from previous revisions. Revision 4

noted that the historical calculation methodology resulted in conservative estimates of the volume to be pumped. This conservatism was evident by liquid calculated to be pumpable being left in stabilized tanks. Since the release of Revision 4, the document *Interim Stabilization Calculations for Pumpable Liquid Remaining* (Pauly 2002) was released in September 2002. This document estimated the conservatism in PLR calculations by averaging the PLR left in stabilized tanks of three types: saltcake, sludge, and mixed saltcake/sludge. These averages were then applied to the tanks with similar waste types remaining to be stabilized. Removing the systematic conservatism in this way reduced the PLR for the tanks remaining to be stabilized. The document further noted that PLR was incorrectly attributed to stabilized tanks. The liquid left in tanks that are declared interim stabilized is, by definition, not practically pumpable.

Discussions between the DOE and the State of Washington have led to a tentative agreement to remove tanks 241-S-102 and 241-S-112 from the Consent Decree (Schepens 2003). Removing the requirement to interim stabilize these tanks allows the waste to be retrieved according to an accelerated schedule. Assuming that these two tanks will not be in the Consent Decree, the revised PLR estimate (as of April 1, 2003) would be 290 kgal, and the total pumpable liquid present in the remaining 27 tanks as of June 1, 1998 would have been 3.1 million gallons.

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CONTENTS

EXECUTIVE SUMMARY III

1.0 INTRODUCTION 1

2.0 OBJECTIVE AND SCOPE 2

3.0 DESCRIPTION OF INTERIM STABILIZATION PROCESS 2

4.0 METHODOLOGY 4
- 4.1 CONCEPTUAL MODEL 4
  - 4.1.1 Waste Layering and Retained Gas 4
  - 4.1.2 Capillary Height 4
  - 4.1.3 Unpumpable Volume 5
  - 4.1.4 Conceptual Model and Calculation Model 6
- 4.2 INPUT VALUES 8
  - 4.2.1 Waste Volume Estimates 8
  - 4.2.2 Measured Liquid Levels 9
  - 4.2.3 Drainable Liquid Porosity Estimates 10
  - 4.2.4 Pumping Rates 11
- 4.3 CALCULATIONS 12
  - 4.3.1 Drainable Interstitial Liquid 12
  - 4.3.2 Pumpable Liquid Remaining 13
  - 4.3.3 Pumping Time and Efficiencies 13

5.0 ASSUMPTIONS 13

6.0 RESULTS 14
- 6.1 ESTIMATED PUMPABLE LIQUID REMAINING AND PUMPING DURATIONS 14
- 6.2 UNCERTAINTIES 16
- 6.3 RECONCILIATION OF REVISION 5 WITH REVISION 4 18

7.0 CONCLUSIONS 19

8.0 REFERENCES 20

APPENDICES

A CALCULATION OF PUMPABLE LIQUID REMAINING A-1

B ELECTRONIC MAIL CORRESPONDENCE: SALTWELL SCREEN DIP TUBE HEIGHTS RELATIVE TO TANK BOTTOM FOR SELECTED TANKS B-1

LIST OF FIGURES

Figure 4-1. Conceptual Model of Saltwell, Capillary, and Slow Draining Regions During Pumping. 7

Figure 4-2. Calculation Model of Pumpable, Unpumpable, and Capillary Liquid.....8

Figure 4-3. Surface and Interstitial Liquid Levels for Tank 241-S-106. 12

Figure A-1. Simplified Waste Configuration for a Typical Tank..... A-7

Figure A-2. Simplified Waste Configuration of the Capillary Region; Mixed Sludge and Saltcake..... A-11

Figure A-3. Level Plot for Tank 241-BY-106. ..... A-15

Figure A-4. Level Plot for Tank 241-S-101..... A-17

Figure A-5. Level Plot for Tank 241-S-102..... A-19

Figure A-6. Level Plot for Tank 241-S-107..... A-21

Figure A-7. Level Plot for Tank 241-S-111..... A-23

Figure A-8. Level Plot for Tank 241-SX-101..... A-25

Figure A-9. Level Plot for Tank 241-U-107..... A-28

Figure A-10. Level Plot for Tank 241-U-108..... A-30

LIST OF TABLES

Table 4-1. Historical Drainable Porosity Estimates for Sludge and Saltcake.....11

Table 6-1. Pumpable Liquid Remaining and Pumping Duration as of April 1, 2003 15

Table 6-2. Estimated Pumpable Liquid in the 29 Tanks on June 1, 1998 16

Table A-1. Analysis of Capillary Region A-11

Table A-2. Calculation of Pumpable Liquid Remaining as of April 1, 2003 ..... A-12

Table A-3. Saltwell Liquid Pumped June 1998 Through March 2003..... A-31

LIST OF TERMS

BBI	Best-Basis Inventory
CAP	liquid volume in the capillary region
CH2M HILL	CH2M HILL Hanford Group, Inc.
DIL	drainable interstitial liquid volume
DLR	drainable liquid volume remaining
DOE	U.S. Department of Energy
DST	double-shell tank
ft	feet
gal	gallons
gpm	gallons per minute
ILL	interstitial liquid level
ILT	total interstitial liquid volume
in.	inches
kgal	kilogallons
kgal/in.	kilogallons per inch
LOW	liquid observation well
PLR	pumpable liquid remaining
SST	single-shell tank
SUP	supernatant liquid volume
TOE	total operating efficiency
TWINS	Tank Waste Information Network System
UNP	liquid volume considered physically or economically unpumpable
%	percent

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1.0 INTRODUCTION

The production of weapons-grade plutonium at the Hanford Site resulted in large volumes of radioactive waste stored in 149 underground single-shell tanks (SST), constructed from 1943 to 1964 and 28 underground double-shell tanks (DST), constructed from 1968 to 1986. To limit the number of new DSTs that had to be constructed to store liquid radioactive waste, the U.S. Department of Energy (DOE) authorized the concentration of waste liquids until the soluble salts were precipitated. These precipitated salts were allowed to settle in the SSTs. Significant free supernatants were pumped from most of the SSTs by 1980, and were concentrated and stored in DSTs. No new waste additions were made to the SSTs after 1980. However, the tanks have exceeded their design life, and leakage from 67 SSTs is assumed or has been confirmed (Vladimiroff et al. 2002).

To reduce the risk and the potential environmental impacts resulting from waste leaking from SSTs, saltwell pumping was initiated to drain and remove interstitial liquid. As of June 1, 1998, of the 149 original SSTs, 119 SSTs had been declared interim stabilized, and 30 tanks remained to be interim stabilized. A Consent Decree between the State of Washington Department of Ecology and the U.S. Department of Energy became effective as of that date to govern the stabilization of 29 of the remaining tanks. Tank 241-C-106 is to be stabilized by another project.

In March 2002, Revision 5 of the *Single-Shell Tank Interim Stabilization Project Plan* (Vladimiroff et al. 2002) was issued to document the path to complying with the Consent Decree. The Project Plan details both the schedules and costs for completing this activity, and is referenced in the Consent Decree. The Consent Decree requires the remaining 29 tanks be interim stabilized by September 30, 2004. The criteria to stabilize a tank are that the tank must contain less than 5,000 gal of supernatant, less than 50,000 gal of drainable interstitial liquid (DIL), and the pump flow must be at 0.05 gpm or less before pumping can be discontinued (Vladimiroff et al. 2002). If the pump suffers a major equipment failure, and it can be justified that replacement is not cost effective, then the 0.05-gpm pumping rate criterion can be waived. As of April 2003, 17 of the 29 tanks have been determined interim stabilized or interim stabilization is pending. The 17 tanks are 241-BY-105, 241-C-103, 241-S-103, 241-S-106, 241-S-109, 241-SX-103, 241-SX-104, 241-SX-105, 241-SX-106, 241-T-104, 241-T-110, 241-U-102, 241-U-103, 241-U-105, 241-U-106, 241-U-109, and 241-U-111.

The terms of the Consent Decree require a confirmation that the project is on schedule to meet the milestones specified, and provide the opportunity to update the volume projections each October. The Consent Decree milestones are based on the estimated pumpable waste volumes as of June 1, 1998. The purpose of this document is to provide the estimate of pumpable tank waste volume remaining for the unstabilized tanks, project future pumping durations, and to estimate the pumpable waste volume in the 29 tanks as of June 1, 1998.

Revision 4 of this document (Appel and Conner 2002) constituted a complete reevaluation of the technical basis, assumptions, supporting data, and calculations. One of the conclusions was that the conceptual model for calculating pumpable liquid resulted in conservative (higher) volumes of pumpable liquid. The conceptual model assumed an 18-inch unpumpable region at the bottom

of the tank, with a 6- to 24-inch capillary region above it. This typically overstated the pumpable liquid volume. This was evident by liquid predicted to be pumpable being left in tanks after they were declared interim stabilized.

Following the release of Revision 4, an attempt was made to quantify that conservatism (Pauly 2002). This study evaluated the predicted pumpable liquid remaining in tanks that were stabilized and calculated average volumes remaining for sludge, saltcake, and mixed tanks. These averages were then applied to the 16 tanks remaining to be stabilized at that time. This resulted in a "best estimate" of the pumpable liquid remaining in those tanks, which was used to evaluate pumping performance versus the 18 percent consent decree milestone of September 30, 2002.

Discussions between the DOE and the State of Washington have led to an tentative agreement to remove tanks 241-S-102 and 241-S-112 from the Consent Decree, eliminating the requirement to interim stabilize these tanks and allowing the waste in these tanks to be retrieved on an accelerated schedule (Schepens 2003).

2.0 OBJECTIVE AND SCOPE

As stated above, the purpose of this document is to:

- Calculate the pumpable liquid remaining (PLR) in the 12 remaining unstabilized tanks as of April 1, 2003;
- Estimate the duration of pumping for each of those tanks; and
- Estimate the volume of pumpable liquid in all 29 tanks as of June 1, 1998.

This revision of the document refines the previous pumpable liquid volume estimates as a result of liquid pumped since the last revision of the document, emerging information, and updated evaluation of surveillance data and waste phase volumes (supernatant, saltcake, and sludge). The calculation of PLR has been modified in accordance with the established precedent (Pauly 2002) to remove conservatism from the estimates. In addition, the practice of reporting PLR for stabilized tanks has been discontinued. Saltwell pumping is complete in these tanks, and the liquid remaining is not economically retrievable. Therefore, it should not be considered pumpable liquid. Calculations of PLR and the volume of pumpable liquid present as of June 1, 1998 are summarized both with and without tanks 241-S-102 and 241-S-112.

3.0 DESCRIPTION OF INTERIM STABILIZATION PROCESS

As a result of previous production history, various waste slurries were transferred to the 149 SSTs. Through settling, concentration, or subsequent precipitation, solids were deposited in various layers, usually in relatively small particle sizes. More recently, vacuum

evaporator-crystallizers were operated in both the 200 East and 200 West Areas to reduce overall waste volume, producing slurries with relatively large particle sizes. The slurries produced by the evaporator-crystallizers were deposited in SSTs that had significant available space. Once the solids settled from the waste slurries, the clarified supernatant waste was transferred into the DST system. No new waste additions have been made to the SSTs since 1980.

The solids remaining in the SSTs are porous, and the pores are filled with interstitial liquid and retained gases generated within the waste. The various layers of precipitated solids have widely differing particle sizes and, as a result, varying pore sizes. The chemical and physical characteristics of the interstitial liquid varies from tank to tank. The solutions are generally in chemical equilibrium with the solids they contact at the local waste temperature. The pore sizes of the sediment bed are small enough to exhibit significant capillary potential, ranging from a few inches of head for some large solids to tens of feet for fine sludge solids. Whenever the liquid level is higher than the capillary head, the interstitial liquid can flow to areas of lower potential. Any time an SST develops a leak, free liquid and the interstitial liquid at a pressure above the capillary potential of the solids bed can flow out of the tank.

Saltwell pumping reduces the leak potential by removing the interstitial liquid that could flow out. To accomplish saltwell pumping, a screened well is installed in the center of the tank, and a specially designed jet pump is installed in the well. Liquid drains to this central well, driven by the hydrostatic pressure of the interstitial liquid in the waste. To maximize the drainage rate, the liquid in the well is kept at the lowest possible level. After enough liquid is removed, the hydrostatic pressure is reduced to the point where inflow into the well falls below 0.19 liter per minute (0.05 gallon per minute). At this rate, the vast majority of the drainable liquid is removed, and it is no longer efficient or productive to continue pumping. At this point, saltwell pumping is declared complete provided the other criteria are met, and the tank is then isolated to minimize the risk of further leakage until retrieval. The PLR is considered zero at this point.

At the completion of the saltwell pumping activities, the solids remaining in the tank still contain liquid in crevices and pore throats between the particles, along with saturated solids areas that still retain liquid by capillary wicking, and a small "heel" of saturated solids that is not pumpable or is considered not economically recoverable. Depending on the particle sizes in the solid beds, varying amounts of liquid are trapped. However, because most of the remaining liquid is not mobile, waste leakage will be minimized unless water is added to the tank.

4.0 METHODOLOGY

4.1 CONCEPTUAL MODEL

4.1.1 Waste Layering and Retained Gas

The waste layering is assumed as follows. Sludge is always at the bottom of the tank. Saltcake lies on top of sludge. Supernatant floats on the solids. This layering is generally consistent with processing history and sampling experience. Although some tanks may have floating crusts with free liquid underneath, any free liquid below the crust should easily flow into the saltwell screen, and the crust should settle on the settled solids. Therefore, assuming the free liquid is on top would yield the same results in a calculation.

Retained gas exists in essentially all tanks. The Best-Basis Inventory (BBI) states a retained gas inventory for several of the tanks remaining to be stabilized. For those tanks, the volumes of solids and interstitial liquid reported in the BBI are reduced to maintain the correct overall waste volume for the tank. However, retained gas is distributed throughout the wet or saturated solids.

Drainable liquid porosity is derived independent of retained gas and, by its derivation, accounts for retained gas. The drainable porosity is determined by dividing the liquid volume pumped by the drawdown volume as observed by the change in liquid level. The change in liquid level is caused by both the volume of liquid pumped and changes in the volume of retained gas released. To explicitly include retained gas in equations for PLR by reducing the volume of waste by the retained gas would be double counting. Therefore, interstitial liquid is calculated from the measured interstitial liquid level (ILL), or, if BBI data are used, from the combined volume of wetted solids and gas multiplied by the appropriate porosity.

4.1.2 Capillary Height

Porous media typically exhibit a capillary height, which will sustain a saturated liquid level that will not drain. The capillary height is defined as the height where internal hydrostatic forces equal external hydrostatic forces within the waste material (Kirk 1980). Because of these forces, liquid in the capillary region will not drain from the waste. Kirk (1980) and DeWeese (1988) show capillary heights for saltcake ranging from 6 inches to 24 inches. A height of 6 inches was assumed for saltcake for the PLR calculations. Because it is at the low end of the range of historical estimates, this assumption will tend to overestimate the amount of drainable (and pumpable) liquid in the saltcake.

Sludge is a finer, more porous material than saltcake and generally holds more liquid by virtue of its higher capillary potential. Previous studies have suggested that "true" sludge material is unpumpable and all of the liquid is held in the capillary region (Brown 1996). Studies show that sludge decreases in water content only when it is compressed by its own weight or by a drained overburden of saltcake. Atherton (1975) appears to be the primary basis for the current capillary height of 24 inches assumed for sludge. Atherton (1975) predicted capillary heights based on

particle size as follows: 2 inches for 1,000 micron particles, 2 ft for 100 micron particles, and 20 ft for 10 micron particle sizes. Kirk (1980) states, "...more data needs to be collected for sludges....Due to the uncertainty of which tanks actually contain a true sludge material no changes should be made in the two foot level of capillary height." Although some data are available to suggest that Hanford Site sludges have significantly higher capillary heights, the estimates in this document continue to use the 24-inch height.

Most of the tanks have saltcake above a sludge region. If the transition from sludge to saltcake occurs in the capillary region when pumping is stopped, the capillary region is referred to as a mixed saltcake/sludge capillary region. This prompts the question of how mixed capillary regions should be treated. Three of the 12 unstabilized tanks will have mixed capillary regions when pumping is stopped based on the assumptions used in the calculation of PLR (18-inch historically unpumpable height discussed in Section 4.1.3 and a 24-inch sludge capillary height). Based on extensive research that Pacific Northwest National Laboratory (PNNL) has conducted with Hanford Site sludges, it is believed that sludges will only drain when they are compressed (Stewart 2002). Therefore, PNNL concluded that rather than prorating the mixed capillary region between sludge and saltcake, the full 6-inch saltcake capillary height should be added to the partial sludge capillary height (< 24 inches). Despite this, the calculations have continued the approach of the past to prorate the saltcake region. This is a conservative assumption.

4.1.3 Unpumpable Volume

In early revisions of this document, the unpumpable region in a tank was considered to be the bottom 18 inches. This region was attributed to the operational and design considerations. A nominal depth of 2 inches from the screen bottom to the tank bottom and an additional 2 inches from the screen bottom to the pump suction were assumed. A nominal value of 10 inches was assumed for the distance from the pump inlet to the process control shutoff or the bottom of the specific gravity dip tube. Further, a nominal value of 4 inches is assumed above the capillary region to provide enough head (pressure) to support a minimum pumping rate of 0.05 gpm.

Revision 4 retained the assumption of an 18-inch unpumpable region, and pointed out that although the assumptions were not entirely consistent with actual practice, the resulting calculations of PLR were conservative. This was demonstrated in Appendix E of Revision 4 (Appel and Conner 2002), which showed that the final equilibrium ILL in stabilized tanks was significantly higher than the liquid level estimated from the standard unpumpable region and capillary height assumptions. Pauly (2002) addressed the conservatism inherent in the previous PLR calculations. This document noted that a volume of liquid previously predicted to be pumpable was typically left in stabilized tanks. This was true even for tanks that met the 0.05 gpm stabilization criterion. Pauly calculated the average PLR after stabilization for a number of saltcake, sludge, and mixed sludge/saltcake tanks, and used these averages to estimate the "unpumpable PLR" (calculated using the traditional methodology) predicted to remain in the unstabilized tanks. The results were 22.8 kgal for saltcake tanks, 17.5 kgal for sludge tanks, and 37 kgal for tanks that had both saltcake and sludge in the drawdown region. That is, for a saltcake tank such as 241-A-101, 22.8 kgal of liquid predicted to be pumpable by the old methodology is predicted to be unpumpable by Pauly (2002).

This modified estimate method was discussed with the Office of River Protection and regulators prior to reaching the September 2002 interim stabilization milestone of 18 percent PLR. The modified method was accepted as a reasonable attempt to achieve a best estimate of the PLR. Therefore, this modified method has been adopted in this document.

An embedded assumption in applying the empirical adjustment to the remaining unstabilized tanks is that the remaining tanks will behave, on average, as the tanks used in the Pauly (2002) calculation. A similar assumption applies to the porosity estimates as well.

Several conservatisms inherent in the previous methodology that result in predictions of excess pumpable liquid are noted here:

- Saltwell screens are not always installed to within 2 inches of the tank bottom because of tank design/riser locations, or more typically, because the waste hardness may limit the ability to sluice the screen down to the desired elevation.
- The capillary region assumptions are generally conservative, as shown in the previous section.
- Previous assumptions on the height of the slow draining layer appear to have been conservative.

These conservatisms should be captured by using the empirical correction. One additional, and perhaps minor, conservatism that is not captured is that tanks can, and have been, stabilized as a result of major equipment failure. In order to stabilize a tank based on a major equipment failure, the tank must meet two of the three stabilization criteria: they must contain less than 50,000 gal of drainable interstitial liquid and less than 5,000 gal of supernatant. An analysis of the cost, radiation exposure (ALARA), and waste generation estimated for replacing or repairing the failed equipment is then prepared and sent to the Office of River Protection. If the analysis is accepted as reasonable justification for not performing the repairs, then the 0.05-gpm pumping rate criterion can be waived. The Pauly (2002) adjustments were calculated using only tanks that met the 0.05-gpm pumping rate criterion (not stabilized by major equipment failure). Tanks stabilized by major equipment failure will have more liquid remaining than had they been stabilized by meeting the 0.05 gpm criterion.

In summation, the total unpumpable volume consists of the interstitial liquid volume in the bottom 18 inches of the tank (the historical unpumpable region), along with the empirically estimated volume identified as not pumpable (Pauly 2002).

4.1.4 Conceptual Model and Calculation Model

The conceptual model of the unpumpable and capillary regions remains the same as in Revision 4 (see Figure 4-1). The conceptual model is the best estimate of the actual current operation of the saltwell. The nominal depth of 2 inches from the screen bottom to the tank bottom and an additional 2 inches from the bottom of the screen to pump suction have been assumed. The actual distances from the bottom of the tank can be significantly higher because the hardness of the waste can prevent the saltwell screen from being lowered to this nominal

value. It also includes a 6-inch height to maintain pump operations, plus the capillary height, plus the slow draining region. The low-level pump shutoff is 4 inches. Operations can and does operate below the specific gravity dip tube in the saltwell. As the rates approach 0.05 gpm, the flow is automatically controlled between the specific gravity dip tube and the weight factor dip tube. Typically, this control point is approximately 6 inches above the low-level pump shutoff to minimize the number of pump shutdowns due to cavitation. Despite the fact that the level inside the saltwell is nominally 10 inches (6 + 4) from the bottom of the tank, the liquid level outside of the saltwell is considerably higher.

The calculation model retains the 18-inch historically unpumpable region and the 6- to 24-inch capillary region, but now includes an additional unpumpable liquid volume empirically identified by Pauly (2002). This additional volume can be thought of as reducing the conservatism found in applying the methodology. The application of the correction to the calculation model is shown in Figure 4-2.

Figure 4-1. Conceptual Model of Saltwell, Capillary, and Slow Draining Regions During Pumping.

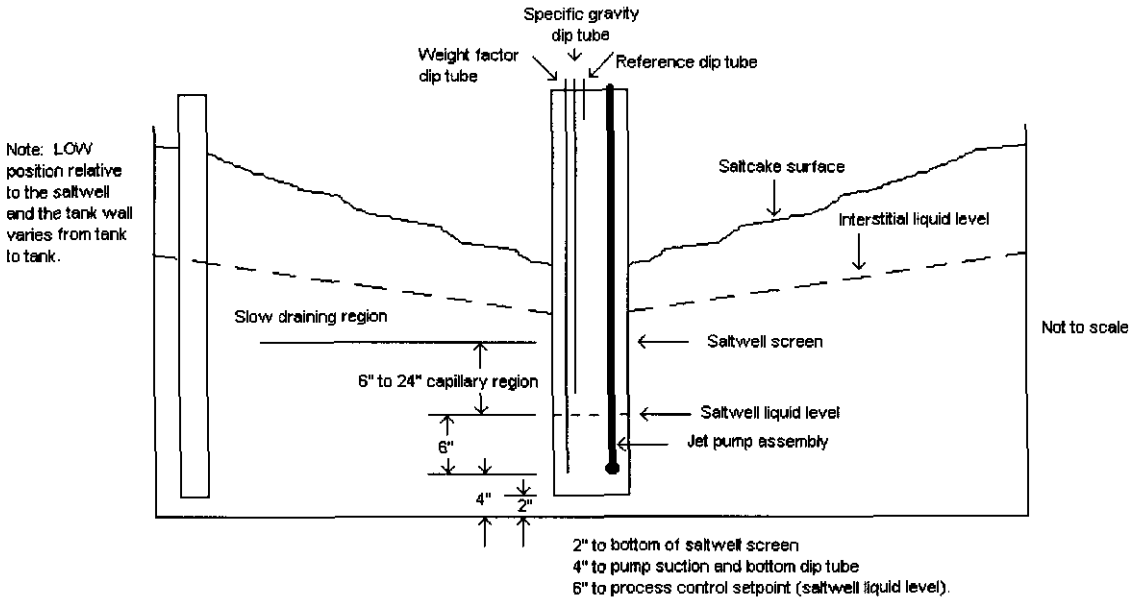
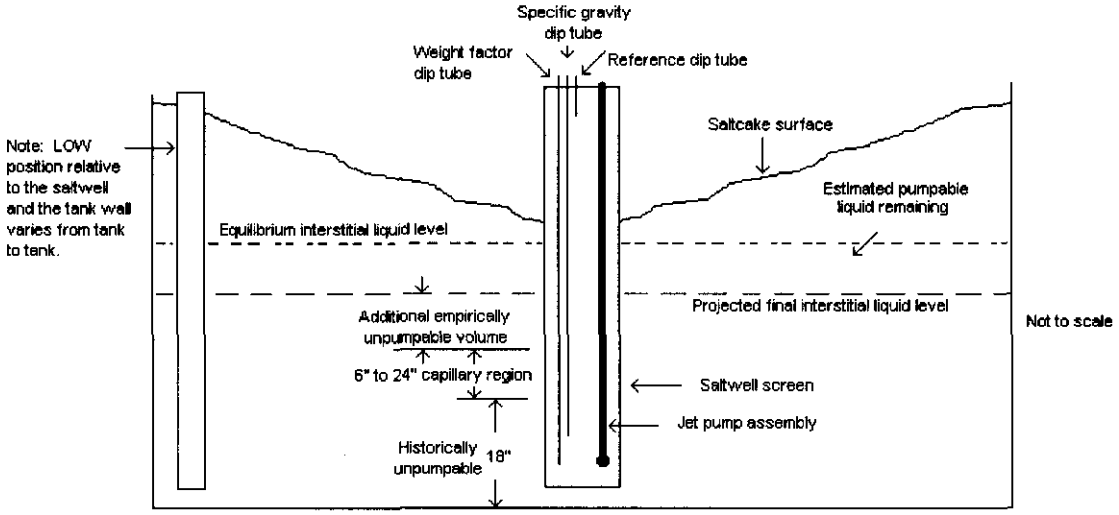


Figure 4-2. Calculation Model of Pumpable, Unpumpable, and Capillary Liquid.



4.2 INPUT VALUES

4.2.1 Waste Volume Estimates

Three waste volume estimates for each unstabilized tank are required to determine the volume of PLR. The basic quantities necessary are the liquid volumes – supernatant, interstitial saltcake liquid, and interstitial sludge liquid. The interstitial liquid volumes can be derived in a number of ways. Often, the interstitial liquid volumes are reported directly in the BBI. In some cases, the overall sludge or saltcake volumes are known and the interstitial liquid components are determined by multiplying by the estimated porosities. In cases where a part of the solids are drained, the wet solids volume must be calculated from the interstitial liquid level, and then the interstitial liquid volume is calculated from the porosity.

If sufficient information is available from surveillance data such as ILL measurements by neutron probe, or an estimated saltwell screen liquid height from dip tube measurements, then the existing BBI estimates may be modified. If the surveillance data are not considered more accurate than the previous estimates, then the existing BBI estimates are updated based on the volume of liquid pumped since the estimate was made.

For all tanks, the current BBI was reviewed as a starting point to determine liquid volumes. Retained gas was added back to the saltcake volume for tanks that had retained gas subtracted from the total saltcake (includes both solid and liquid) volume in the BBI. Transfers of waste from the tank since the BBI was determined were subtracted from the appropriate BBI volumes (supernatant first, then drainable liquid from saltcake, then the drainable liquid from the sludge). For tanks that were actively being pumped, an evaluation of the surface and liquid level readings was done. For this evaluation, if the liquid level and surface level were at about the same level prior to and during pumping, the wet solids volume was assumed to be equal to the total solids volume. For tanks whose liquid level declined faster than the surface level, the wet solids

volume was determined by subtracting the liquid pumped from the calculated interstitial liquid volume. Details of the rationale for each tank's calculations are contained in Appendix A under input data (Section A3.1). The results are used as input values to determine the amount of PLR.

The information needed to estimate pumpable liquid volume and pumping durations include measured liquid levels, tank waste volume estimates, drainable liquid porosity estimates for each waste type, and drain rates or pumping rates for different types of waste. Each of these is discussed in the following sections.

4.2.2 Measured Liquid Levels

The liquid level in the tanks was typically determined by measurements taken by a neutron probe. The probe is lowered into a liquid observation well (LOW) or drywell installed in the tank. LOW measurements are available in 10 of the 12 tanks still being pumped. The LOW in tank 241-A-101 has failed, but neutron measurements are now being taken in a drywell as of March 2003. The LOW in tank 241-SX-102 has failed. Neutron probes detect the presence of hydrogen in the waste and by inference, the water and, therefore, liquid in the waste. These probes give their best indication of liquid level when the change in the probe's indication is observed over time as the liquid level is changing. There is only one LOW in a fixed location in each tank. The ILL varies across the tank during saltwell pumping, and for an extended period after pumping is completed. This makes it difficult to determine the exact volume of liquid in the tank during pumping or recently after pumping has stopped. For 6 of the tanks (241-S-101, 241-S-102, 241-S-107, 241-SX-101, 241-U-107, and 241-U-108), the neutron probe was used to determine or confirm the liquid level.

For three additional tanks, neutron measurements were available but were not used in the PLR calculations. For tank 241-S-112, no waste was pumped since the most recent BBI determination. Therefore, reevaluation of the interstitial liquid level was not necessary. For tanks 241-BY-106 and 241-S-111, pumping has been ongoing. The ILLs in these tanks have not equilibrated. Therefore, the PLR is estimated based on the most recent BBI estimate, updated for the volume of liquid pumped in the interim.

Dip tube measurements from the saltwell screen were used to determine the liquid level for 3 tanks (241-A-101, 241-AX-101, and 241-SX-102). For tank 241-A-101, neutron measurements were recently resumed using an existing drywell in the tank. However, an equilibrated ILL is not yet available because the tank is being actively pumped. For tank 241-AX-101, neither neutron nor gamma scans are providing a useful measure of the ILL. For tank 241-SX-102, the LOW has failed. A description of dip tube level measurements follows.

Dip tubes have been used for many years in the Hanford Site processing plants. Dip tubes are hollow, open-ended tubes installed in the saltwell screen. The weight factor dip tube is installed at the height of the pump suction, typically 2 inches from the bottom of the screen. The bottom of the specific gravity dip tube is 10 inches above the bottom of the weight factor dip tube. The reference dip tube does not extend into the waste. When disconnected, the dip tubes will fill to the level of liquid in the saltwell screen. Dip tube measurements are taken by pressurizing the dip tube with air. The weight factor and specific gravity dip tube instrumentation register

different backpressures because of the different lengths of the tubes. The pressure measurements are in inches of water. The liquid waste density can be calculated from the difference in pressure between the specific gravity and weight factor dip tubes. The density is then used to correct the pressure measurement in the weight factor dip tube and calculate the liquid waste height.

4.2.3 Drainable Liquid Porosity Estimates

To aid in estimating interstitial liquid volumes, the average drainable porosity of the waste has historically been calculated for stabilized tanks based on the volume of liquid pumped relative to the drawdown of the ILL. This calculated drainable porosity is different from the true porosity. The pore spaces in the waste are understood to be filled with liquid and gas. Any gas or residual liquid retained in the pores after draining is not included in the drainable porosity. The term drainable porosity or drainable liquid porosity is used in this document to differentiate from true porosity. The drainable liquid porosity is treated as though it is a liquid fraction in the calculations.

Previous drainable liquid porosity estimates for SST wastes have varied significantly (see Table 4-1). The latest evaluation was performed for Revision 4 of this document (Appel and Conner 2002). Calculated drainable porosity data from a total of 44 stabilized, jet-pumped tanks were evaluated, and a total of 7 sludge tanks and 24 saltcake tanks were included in the updated estimates. The remaining tanks were excluded from the analysis for various reasons, such as having both sludge and saltcake in the drawdown region (and not being able to distinguish the two). The average drainable liquid porosity estimates were 17 percent for sludge and 24 percent for saltcake. From the release of Revision 4 until April 1 (the data date of this document), only tank 241-BY-105 has been declared stabilized. A saltcake porosity of approximately 21 percent was calculated for this tank. Revising the saltcake porosity calculation from Revision 4 (based on 24 tanks) with an estimate from one additional tank would not significantly affect the calculated average. Therefore, the porosity estimates remain unchanged from Revision 4.

These drainable porosity estimates should be considered rather imprecise. There is significant variability in the data for both saltcake and sludge porosities. In addition, uncertainty and bias may arise from a variety of sources. Several are listed here:

- Previously stabilized tanks may contain different wastes with characteristics different from those currently being stabilized. As an example, all TX-Farm tanks have been stabilized, and most are considered saltcake. These wastes may be inherently different (e.g., retained gas, true porosity, particle size) from the waste in the tanks being stabilized now.
- Porosities are calculated over different drawdown volumes. Porosities calculated based on the total drawdown may differ from those calculated in the upper region of the bed or in the lower region of the bed.
- At low pump flow rates, the determination of volume pumped is not very accurate. Although the volume of flush water added to the tank is subtracted from the total volume pumped, the resulting volume pumped does not fully account for the impact of the flush. The flush increases the liquid volume in the tank by dissolving waste.

- Estimates of supernatant volume may be crude and may significantly affect the calculated drainable porosity.
- Free liquid layers beneath floating crusts may not be detected by sampling or surveillance data or appropriately accounted for in the calculations.
- The relative volumes of sludge or saltcake in a tank may not be well known.

Table 4-1. Historical Drainable Porosity Estimates for Sludge and Saltcake.

Reference and Year	Drainable Porosity		Comments
	Saltcake	Sludge	
Handy (1975)	30-35%	-	Based on simulant studies.
Kirk (1980)	40-48%	12.5%	Saltcake data based on actual pump rates from 5 tanks. This resulted in 45% being assumed for several years. 12.5% sludge drainable porosity was the previously held assumption (reference unknown), with no data to change it.
DeWeese (1988)	35%	12.5%	Recommendations based on measured data for saltcake: 31% drainable porosity average for 22 stabilized tanks. Data available for 3 sludge tanks, but not enough information to recommend changing the 12.5% sludge estimate.
Brown (1996)	50%	21%	Based on methodology attempting to account for liquid pockets and free liquid layers
Field and Vladimiroff (1999)	25%	15%	Based on review of porosities calculated in Single-Shell Interim Stabilization Evaluation forms.
Appel and Conner (2002)	24%	17%	Based on updated review of porosities calculated in Single-Shell Interim Stabilization Evaluation forms and updated BBI waste type estimates.

4.2.4 Pumping Rates

The mean pumping rates were determined using daily pumping data for 13 tanks that have been interim stabilized since June 1, 1998. The pumping data includes the amount pumped during the day as well as the number of hours that the pump operated. For the analysis (Naiknimbalkar 2002), only data for days when the pump operated a full 24 hours were selected. This was done as an easy way to cull data that may be biased high. Other days may have contained good data but flush water is occasionally added to the saltwell when the pump is shut down. This can artificially inflate the pump rates.

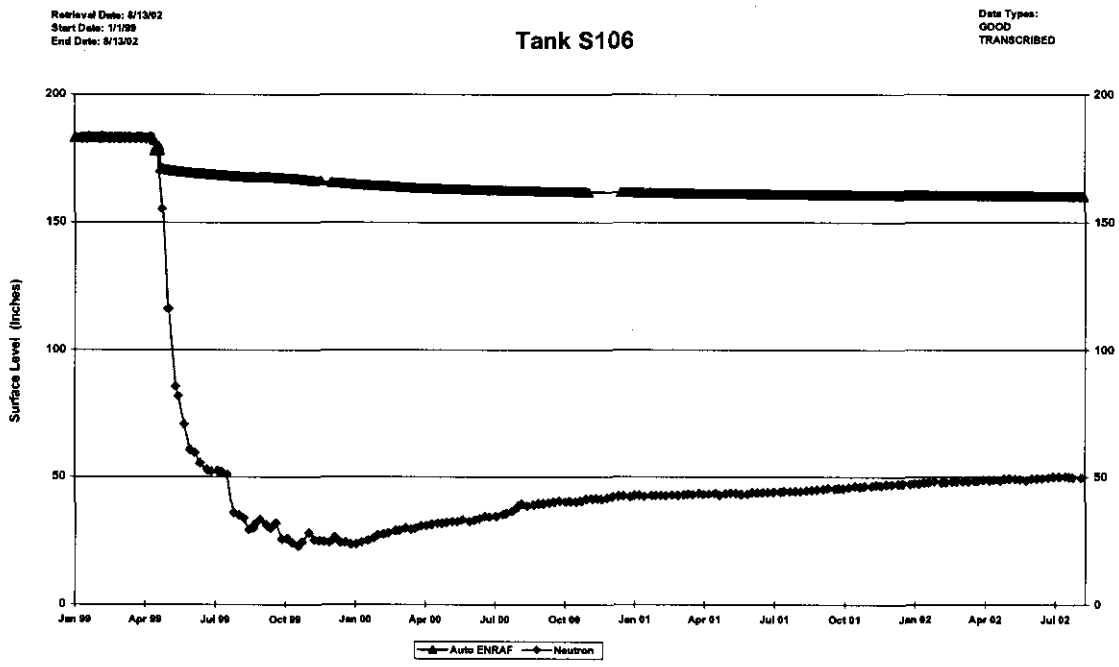
The data were then broken down between supernatant and interstitial liquid. To do this, trends in the data for pumping rates around 1 gpm were investigated. If there was a sharp drop in rates, the higher rates were declared supernatant. For example, if the rates dropped suddenly from 1.2 gpm to 0.8 gpm, the 1.2 gpm was considered to be a supernatant pumping rate, and the 0.8 gpm was considered to be an interstitial liquid rate. If there was not a sharp drop in rates, the liquid level measured by the neutron probe was compared with the ENRAF[1] surface level. The break point for supernatant to interstitial liquid was determined to be the point that the neutron liquid level began departing from the surface level. Therefore, when the liquid and surface levels were the same or nearly so, it was assumed that the rates were supernatant rates. When the

[1] ENRAF is a trademark of the ENRAF Corporation, Houston, Texas.

liquid level began dropping below the surface level, it was assumed that the rates were interstitial liquid rates. See Figure 4-3 for an example of the interstitial liquid level falling below the surface level. Finally, the interstitial liquid rates were split between sludge and saltcake by using the information from the drainable porosity determination (contained in Appendix B of Appel and Conner 2002).

The average pump rate for the supernatant, saltcake, and sludge was determined to be 1.82 gpm, 0.33 gpm, and 0.14 gpm, respectively (Naiknimbalkar 2002). These rates were used to estimate pumping durations for the 12 unstabilized tanks.

Figure 4-3. Surface and Interstitial Liquid Levels for Tank 241-S-106.



4.3 CALCULATIONS

This section describes the terms that are calculated and the overall equations used to calculate these terms. Calculations used are presented in Appendix A.

4.3.1 Drainable Interstitial Liquid

The drainable interstitial liquid is the volume of interstitial liquid that might leak from the waste solids if a hole was located in the bottom of the tank. It does not include supernatant, which is also assumed to be drainable. The drainable interstitial liquid volume (DIL) is the sum of interstitial liquid volume in each waste layer (sludge and saltcake), less the interstitial liquid volume in the capillary region (see Section 4.1.2).

4.3.2 Pumpable Liquid Remaining

The PLR is the sum of the drainable interstitial liquid and the supernatant (free liquid) minus the unpumpable volume. The unpumpable volume includes the liquid in the bottom 18 inches of the tank (the historical unpumpable region) plus the additional empirically estimated volume for each tank calculated by Pauly (2002).

4.3.3 Pumping Time and Efficiencies

To calculate how many days each tank will take to be pumped, the pumpable liquid volume was divided by the average pumping rate for each type of waste (see Section 4.2.4).

The pumping durations for 100 percent pumping efficiencies are shown in Table 6-1. Actual pumping durations can be estimated by dividing the durations in Table 6-1 by the operating efficiency. The projected total operating efficiency (TOE) will be estimated by the operating organization and modeled separately.

5.0 ASSUMPTIONS

The following assumptions were used to perform the PLR and jet pump duration calculations:

- The calculations performed estimated the volume of waste in the tank as of April 1, 2003 (through the end of March 2003).
- Waste volumes include retained gas.
- All dilution water used passes into the saltwell jet pump inlet and does not affect the waste still in the tank. Therefore, dilution does not affect the calculated pumping duration, nor the volume to be pumped.
- The saltwell pumping system is located in the center of the tank, and all calculations are referenced to the tank bottom centerline.
- The neutron ILL readings represent the distance from the bottom centerline of the tank to the liquid level. The waste above this level has been drained, even though it retains some moisture.
- A dip tube level measurement from inside the saltwell screen (corrected to the elevation of the tank bottom) plus the capillary height is comparable to an ILL by neutron probe.
- The waste is layered from top to bottom in the following order: supernatant, saltcake, and sludge. Liquid is drained from the top to the bottom, e.g., supernatant is the first liquid to be drained. Free liquid layers surrounded by solids in the tank are treated similarly to supernatant, i.e., they are drained prior to saltcake or sludge.

- All interfaces between layers are assumed to be abrupt, horizontal, and extend over the entire area of the tank.
- Average drainable porosities in unstabilized tanks are 0.17 and 0.24 for sludge and saltcake, respectively.
- The pumping flow rates for supernatant, saltcake, and sludge are uniform for all tanks.
- All solids below the liquid level are assumed to be saturated with liquid.
- There is only one capillary region in the tank. A 6-inch capillary region is used for saltcake and a 24-inch region is used for sludge. If the height of sludge is more than 18 inches and less than 42 inches, the capillary height is prorated proportionally between the sludge and saltcake capillary heights.

6.0 RESULTS

6.1 ESTIMATED PUMPABLE LIQUID REMAINING AND PUMPING DURATIONS

The revised pumpable liquid volumes and jet pump durations for 100 percent efficiency are shown in Table 6-1. The table lists the supernatant, saltcake, and sludge volume estimates used to calculate pumping durations for the unstabilized tanks. The estimated PLR for the 12 tanks not yet stabilized is 399 kgal as of April 1, 2003. As of April 1, 2003, the estimated initial pumpable liquid volume in the 29 Consent Decree tanks was approximately 3.3 million gallons (refer to Table 6-2) on June 1, 1998.

If the tanks slated for early retrieval (241-S-102 and 241-S-112) are not considered, then the estimated PLR in the remaining 10 tanks being interim stabilized is 290 kgal, and the estimated initial (June 1, 1998) pumpable volume in the remaining 27 Consent Decree tanks is 3.1 million gallons.

As noted in Section 1.0, the revised pumpable liquid estimates are based on additional characterization and pumping information with less uncertainty than previous estimates. However, with the data currently available, there is still a degree of uncertainty in the estimated pumpable liquid volume for a tank. Actual pumping durations will vary depending on the permeability of saltcake and sludge, actual supernatant/free liquid volumes, pumping rates, and pumping efficiencies achieved. Some of the major uncertainties are discussed in Section 6.2.

Table 6-1. Pumpable Liquid Remaining and Pumping Duration as of April 1, 2003

Unstabilized Tanks	DIL (kgal)	PLR in the Supernatant (kgal)	PLR in the Sludge (kgal)	PLR in the Saltcake (kgal)	Total PLR (kgal)	Supernatant Pumping Duration (days)	Sludge Pumping Duration (days)	Saltcake Pumping Duration (days)	Total Pumping Duration (days)
A-101	60	0	0	25	25	0	0	53	53
AX-101	38	0	0	3	3	0	0	6	6
BY-106	38	0	0	16	16	0	0	33	33
S-101	73	0	0	51	51	0	0	107	107
S-102	101	0	0	73	73	0	0	153	153
S-107	45	0	21	2	23	0	103	4	107
S-111	77	0	0	35	35	0	0	73	73
S-112	66	0	0	37	37	0	0	77	77
SX-101	52	0	0	30	30	0	0	63	63
SX-102	71	0	0	30	30	0	0	63	63
U-107	57	0	0	28	28	0	0	59	59
U-108	77	0	0	49	49	0	0	104	104
Total Unstabilized	**n/a**	**0**	**21**	**378**	**399**	**n/a**	**n/a**	**n/a**	**n/a**
Total without S-102, S-112	**n/a**	**0**	**21**	**269**	**290**	**n/a**	**n/a**	**n/a**	**n/a**

Notes:

1. Not all values may sum exactly because of rounding. The spreadsheet uses unrounded values except for the totals.
2. Durations are calculated by applying the average rates of 1.82 for supernatant, 0.14 gpm for sludge liquid and 0.33 gpm for saltcake liquid from Naiknimbalkar (2002).
3. DIL = drainable interstitial liquid, PLR = pumpable liquid remaining., n/a = not applicable.

Table 6-2. Estimated Pumpable Liquid in the 29 Tanks on June 1, 1998

Tank	Volume Pumped (kgal)	PLR (kgal) as of 4/1/03	Total Pumpable Liquid (kgal)	Status
A-101	531	25	556	Pumping
AX-101	366	3	369	
BY-105	45		45	Stabilized
BY-106	71	16	86	Pumping
C-103	114		114	In evaluation
S-101	32	51	82	Pumping
S-102	62	73	135	
S-103	24		24	Stabilized
S-106	107		107	
S-107	56	23	79	Pumping
S-109	34		34	Stabilized
S-111	74	35	109	Pumping
S-112	8	37	44	
SX-101	32	30	62	
SX-102	76	30	106	
SX-103	134		134	In evaluation
SX-104	118		118	Stabilized
SX-105	153		153	
SX-106	148		148	
T-104	29		29	
T-110	33		33	
U-102	87		87	
U-103	99		99	
U-105	87		87	
U-106	39		39	
U-107	96	28	124	Pumping
U-108	63	49	113	
U-109	78		78	Stabilized
U-111	85		85	In evaluation
Total	**2880**	**399**	**3278**	
Total without S-102, S-112	**2810**	**290**	**3099**	

6.2 UNCERTAINTIES

There are a number of uncertainties in the estimation of PLR in the tanks that require interim stabilization. Three of the largest uncertainties are the waste volume estimates, the estimated drainable porosities, and the unpumpable volume. The following is only intended as a cursory examination of uncertainty.

The uncertainty in the waste volume estimates consists of uncertainty in the supernatant, saltcake, and sludge volumes. These are derived from surface level, solids level, ILL, and waste interface measurements. The uncertainty in surface level measurement is very small if there is a free liquid surface. Jensen and Wilmarth (2002) have estimated the uncertainty (one standard

deviation from the mean) as less than 1 kgal on a volume basis for a standard 75-foot diameter tank. If there is not a free liquid surface, then the interstitial liquid level measurement is needed to determine the wet solids volume. The uncertainty in the stabilized ILL measurement is typically fairly small. However, because of the interpretive nature of the measurement, significant errors have been observed in the past. Significant errors will be evident by comparison of ILL measurements to saltwell screen measurements (e.g., by dip tube pressure readings).

Finally, if the ILL or dip tube measurement has not had time to equilibrate, then additional uncertainty will be introduced. Liquid in the tank will flow from regions of higher potential (e.g., from the outer region of the waste) towards the saltwell screen as liquid is removed by saltwell pumping. This flow continues for some time after pumping is halted, until the ILL has equilibrated. Depending on where the LOW is located, the ILL measurement could be a region of higher potential relative to the saltwell, and thus continue to decrease when saltwell pumping stops. However, the ILL typically rises when pumping is halted. The level rise could be up to 20 inches or more. For that reason, unequilibrated ILL data are only be used if no better data are available (for example, if updating a prior, accepted estimate based on the volume pumped in the interim and the assumed porosity results in an obviously incorrect estimate).

There are potentially larger uncertainties in the estimated supernatant, saltcake, and sludge volumes. Solids volumes are determined either from historical solids level measurements such as sludge weights or core sample analytical data. Supernatant volumes are typically determined from the difference between surface and solids level measurements, and saltcake volumes by difference from total solids and sludge volume. An inherent problem in solids level measurements is that often few risers are available for measurements or sampling. Jensen and Wilmarth (2002) have estimated that solids level measurements by sludge weights have an uncertainty (one standard deviation) of 6.5 inches or approximately 18 kgal. For solids level measurements by core sample results, the uncertainty (one standard deviation) is 9.5 inches or 26 kgal.

Another major uncertainty is the drainable liquid porosity. Appendix B of Revision 4 (Appel and Conner 2002) showed the reported drainable liquid porosity for 7 sludge and 24 saltcake tanks. Drainable liquid porosity for sludge varied from 6 percent to 27 percent. The PLR for the 12 tanks not stabilized would be 350 kgal and 413 kgal, respectively, for this variation in sludge drainable porosity. Saltcake drainable porosity varied from 9.9 percent to 42.3 percent. The PLR for the 12 tanks would be 286 kgal to 509 kgal based on these extremes. The reason the saltcake drainable porosity has a greater effect on the PLR is that the sludge is smaller in volume and tends to be in the unpumpable region or capillary region because it is assumed to be on the bottom of the tank.

The third major uncertainty deals with total unpumpable volume. Pauly (2002) uses data from stabilized tanks to remove the conservatism identified using the model described in Revision 4. The conservatism was evident by liquid that had been calculated to be pumpable being left in tanks after stabilization. Factors affecting this uncertainty include the actual installed pump elevation, the waste characteristics (e.g., actual drainage rates, capillary height), and saltwell pumping practices (e.g., excessive flushes and over-dilution could lead dissolution of solids and

an apparent increase in the porosity). Given all of the potential factors involved, the empirical approach adopted from Pauly (2002) is reasonable. However, it must be understood that for an individual tank, the PLR estimate may not be conservative. That is, pumping may exceed the estimated PLR.

6.3 RECONCILIATION OF REVISION 5 WITH REVISION 4

The basis of the PLR estimate has been changed for Revision 5. The two major differences in Revision 5 from Revision 4 are:

- The estimated PLR remaining in already stabilized tanks (or tanks in evaluation for stabilization) is set to zero. This liquid will not be pumped; and
- The estimated PLR in unstabilized tanks has been adjusted to reflect Pauly's analysis.

The total reduction in PLR from Revision 4 (3887 kgal) to Revision 5 (3278 kgal) is 609 kgal of liquid. The Revision 4 estimate included 421 kgal attributed to PLR in stabilized tanks. If the Pauly (2002) adjustment were applied to the Revision 4 estimate, an additional 400-kgal reduction of PLR for the unstabilized tanks would be made. Therefore, using the basis of Revision 5, the Revision 4 equivalent estimate would be 3,066 kgal, or 212 kgal below the current Revision 5 estimate. The changes from Revision 4 to Revision 5 can largely be attributed to uncertainty in the volume estimates as discussed in Section 6.2. For example, the supernatant volume in tank 241-C-103 turned out to be 30 kgal larger than estimated; surveillance data indicate that the supernatant volume in tank 241-U-111 was also about 30 kgal higher than estimated; and pumping data indicated that over 20 kgal of free liquid was pumped from tank 241-SX-102, when no free liquid was estimated. Other factors, such as actual drainable porosities and unpumpable volumes (as discussed in Section 6.2) are likely involved as well.

7.0 CONCLUSIONS

The estimated pumpable liquid volume remaining in the 12 tanks that remain to be stabilized as of April 1, 2003 is 399 kgal, and a total of 2,880 kgal had been pumped since June 1998. The latest estimate of total pumpable liquid in the 29 SSTs has been reduced to 3.3 million gallons. The initial estimate of total pumpable volume was 6.2 million gallons reported June 1, 1998, in Revision 0. As better information became available, the estimate was reduced to 3.9 million gallons as reported in Revision 4 in August 2002.

Note that the current calculation basis has been modified to be less conservative, and liquid remaining in stabilized tanks is no longer counted towards the total pumpable volume. The reported estimate of 3.3 million gallons can be thought of as the estimate of the final pumped liquid volume when interim stabilization is complete for all 29 tanks.

If tanks 241-S-102 and 241-S-112 are not considered (Schepens 2003), the estimated PLR is 290 kgal, the volume pumped is 2,810 kgal, and the estimated total pumpable liquid back on June 1, 1998 is 3.1 million gallons.

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APPENDIX A

CALCULATION OF PUMPABLE LIQUID REMAINING

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CALCULATION OF PUMPABLE LIQUID REMAINING

A1.0 OBJECTIVE/PURPOSE

There are two objectives of this Appendix:

- Determine the pumpable liquid remaining for the 12 single-shell tanks (SST) that are still being interim stabilized as of April 1, 2003, and
- Estimate the total amount of pumpable liquid present in the 29 tanks as of on June 1, 1998.

Also tabulated will be the totals without counting tanks 241-S-102 and 241-S-112. The waste in these tanks will be retrieved on an accelerated schedule, making interim stabilization unnecessary (Schepens 2003).

A2.0 METHODS OF ANALYSIS

A2.1 DESCRIPTION OF METHOD USED

This sub-section contains a brief discussion of the methodology used in each of the succeeding sub-sections. The definition of terms and derivation of equations used to calculate the pumpable liquid remaining for the 12 tanks still being interim stabilized is shown in Section A2.2.

The spreadsheets used in the calculations are shown in subsection A2.3. The first spreadsheet, Table A-1, is used to determine the height of the sludge and the capillary region. The height is used to determine the appropriate equations to use in the second spreadsheet for interstitial liquid volumes.

The second spreadsheet, Table A-2, is used to calculate the four terms used in the governing equation and the resulting pumpable liquid remaining for the 12 tanks that are still being pumped for interim stabilization. Finally, this spreadsheet calculates the pumpable liquid remaining as of June 1, 1998 by adding the total of pumpable liquid remaining for the interim stabilized tanks, the volume of liquid pumped from June 1, 1998 to April 1, 2003 attributed to interim stabilization, and the total of the liquid remaining to be pumped for the 12 tanks still being interim stabilized.

A2.2 DERIVATION OF EQUATIONS

The definitions and equations used to determine the amount of pumpable liquid remaining in each of the 12 tanks still being interim stabilized are provided below. Relevant assumptions are provided in Section A3.4.

A2.2.1 Derivation of the Governing Equation

The governing equation is shown in Equation 1. The following terms are used:

SUP = Supernatant liquid volume,

PLR = Pumpable liquid volume remaining,

ILT = Total interstitial liquid volume,

DIL = Drainable interstitial liquid volume,

DLR = Drainable liquid volume remaining,

CAP = Liquid volume in the capillary region, and

UNP = Liquid volume that is considered unpumpable.

The drainable liquid remaining is the sum of the supernatant and the drainable interstitial liquid:

$$DLR = DIL + SUP$$

The drainable interstitial is the difference between the total volume of interstitial liquid in a tank and the volume that will not drain because of capillary action:

$$DIL = ILT - CAP$$

The pumpable liquid remaining is the difference between the drainable liquid remaining and the volume of interstitial liquid in the unpumpable region.

$$PLR = DLR - UNP$$

By substituting for DLR:

$$PLR = DIL + SUP - UNP$$

Substituting for DIL:

$$PLR = ILT + SUP - CAP - UNP \quad (1)$$

The supernatant volume is a direct input; no supporting equation is required. The other variables are derived as supporting equations below.

A2.2.2 Definitions Used in Supporting Equations

The detailed supporting equations are used to determine the interstitial liquid volume, the unpumpable region liquid volume, and the capillary region liquid volume. These terms vary depending on the dish bottom characteristics and the height and/or volume of the solids. The inputs to the supporting equations are defined herein.

Volume, in kilogallons (kgal):

V_D = Volume of tank dish,

V_{TWS} = Volume of all wetted solids,

V_{WSL} = Volume of wet sludge in tank,

V_{WSC} = Volume of wet saltcake in tank,

V_{ILSC} = Volume of interstitial liquid in saltcake,

V_{ILSL} = Volume of interstitial liquid in sludge, and

PLR_u = empirically unpumpable liquid volume (previously would have been considered pumpable but under the new, best estimate approach, is considered unpumpable)

Height, in inches:

H_D = Height of tank dish,

H_{ILL} = Interstitial liquid level (a measured value),

H_{SL} = Height of sludge in tank,

H_{SC} = Height of saltcake in tank,

$H_{SL\text{-}CAP}$ = Height of the sludge in mixed capillary region, and

$H_{SC\text{-}CAP}$ = Height of the saltcake in mixed capillary region.

Conversion Factor and Constants:

C_V = Volume to height (2.75 kgal/in.),

$H_{CAP(SL)}$ = Sludge capillary height constant (24 inches),

$H_{CAP(SC)}$ = Saltcake capillary height constant (6 inches),

H_{UNP} = Unpumpable liquid height constant (18 inches),

P_{SC} = Drainable liquid porosity of wetted saltcake (24%), and

P_{SL} = Drainable liquid porosity of wetted sludge (17%).

A2.2.3 Derivation of Supporting Equations

The inputs for PLR are developed in this section. SUP is a direct input. ILT, UNP, and CAP are dependent on the dish bottom characteristics, the type of solids in each region, and the height/volume of the sludge. UNP also includes an empirically estimated volume of liquid for each tank from Pauly (2002).

A2.2.3.1 Supporting Equations for ILT

From Equation 1, ILT is the total interstitial liquid left in the solids. ILT is comprised of the interstitial liquid in the sludge and the interstitial liquid in the wetted saltcake:

$$ILT = V_{ILSC} + V_{ILSL} \tag{2}$$

The volume of interstitial saltcake liquid is sometimes determined by the volume of wet saltcake multiplied by the drainable porosity:

$$V_{ILSC} = (V_{WSC})(P_{SC}) \tag{3}$$

Likewise for the sludge:

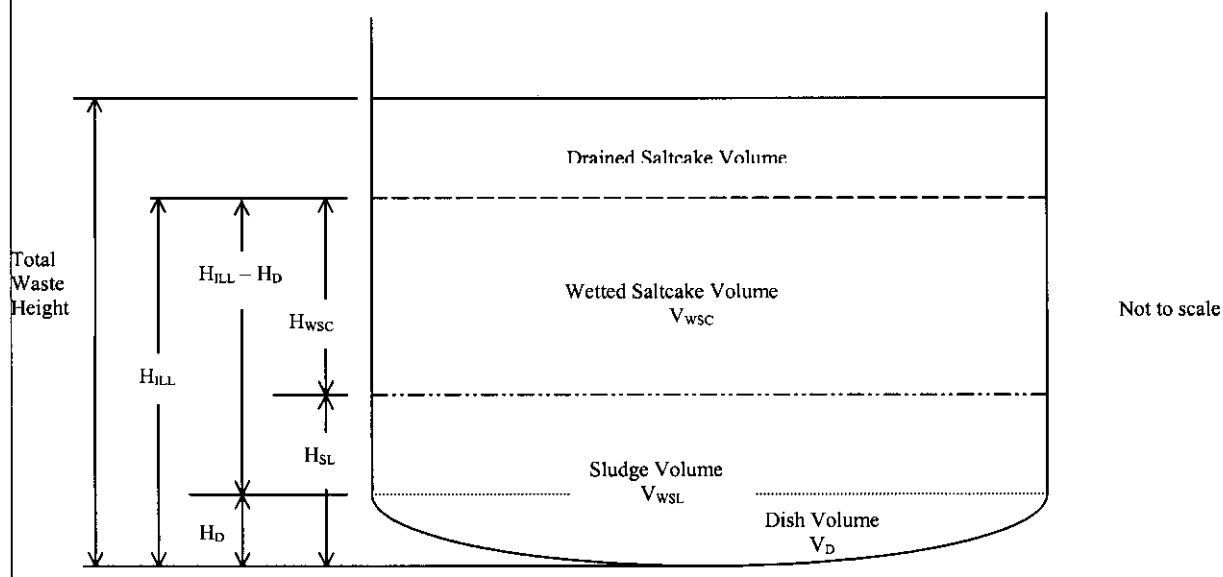
$$V_{ILSL} = (V_{WSL})(P_{SL}) \tag{4}$$

The general equation is given below by combining Equations 2 through 4:

$$ILT = (V_{WSC})(P_{SC}) + (V_{WSL})(P_{SL}) \tag{5}$$

When V_{WSC} and V_{WSL} are known, Equations 2 through 5 are used for determining ILT. The wetted saltcake in the equation can be either all the saltcake when there is a supernatant, or a portion of the saltcake that is below the level of the drained saltcake in a tank where the supernatant and some of the interstitial liquids have been removed. Likewise, the wetted sludge is typically the total sludge volume. For a couple of tanks, the sludge is partially drained. In these cases, the wet saltcake is zero.

Figure A-1. Simplified Waste Configuration for a Typical Tank.



If the volumes are not all known, then ILT must be calculated from the interstitial liquid level (H_{ILL}) and other known quantities. Figure A-1 shows a simplified drawing of a typical tank's waste configuration. The volume of the total wetted solids (V_{TWS}) describes the volume of solids up to the interstitial liquid level (H_{ILL}). In areas of a tank where the diameter is constant, the conversion factor, C_V, is used to convert a height to a volume. The dish volume and height are known values:

$$V_{TWS} = (H_{ILL} - H_D)(C_V) + V_D$$

If V_{TWS} is greater than the sludge volume, then all of the sludge is wet, and V_{WSC} can be expressed by substitution as:

$$V_{WSC} = (H_{ILL} - H_D)(C_V) + V_D - V_{WSL}$$

Substituting this expression for V_{WSC} into Equation 5 yields the following equation:

$$ILT = [(H_{ILL} - H_D)(C_V) + V_D - V_{WSL}](P_{SC}) + (V_{WSL})(P_{SL}) \quad (6)$$

Equation 6 is the general equation for calculating ILT using an interstitial liquid level (H_{ILL}) reading. If a tank has a flat bottom, the height of the dish and volume of the dish are set to 0. If a tank has only sludge, the saltcake portion of the equation would be set to 0; likewise, the sludge portion would be set to 0 if there were no saltcake.

If the ILL is in the sludge region, then the sludge interstitial liquid may be calculated by the following equation:

$$ILT = IL_{SL} = [(H_{ILL} - H_D)(C_V) + V_D](P_{SL}). \quad (7)$$

A2.2.3.2 Supporting Equations for UNP

The volume of interstitial liquid that is considered unpumpable includes the liquid in the bottom 18 inches (the historical unpumpable region) plus the empirically estimated additional volume of unpumpable liquid (PLR_u) from Pauly (2002). Note that the unpumpable volume is split; the capillary region (discussed below) is between the 18 inch historically unpumpable region and the empirically unpumpable volume (PLR_u) taken from Pauly (2002). This is because the PLR_u adjustments estimated in Pauly (2002) for the tanks being interim stabilized were assuming an 18-inch unpumpable region plus the capillary region. To remain consistent with the precedent of Pauly (2002), the same methodology is followed in this document.

The liquid volume in the bottom 18 inches is dependent on whether the waste in that region is all sludge or a mixture of saltcake and sludge and whether the sludge volume is less than or greater than the dish volume. The general equation for finding the unpumpable volume of interstitial liquid is given below. In an effort to reduce the number of variables in this appendix, the equation is written in a simplified manner.

$$UNP = [(V_{WSC})(P_{SC}) + (V_{WSL})(P_{SL})]_{\text{bottom 18 inches}} + PLR_u$$

where PLR_u is taken directly from Pauly (2002).

The wet sludge height is a useful quantity for calculations in the unpumpable and capillary regions. The height of the wet sludge in a dish bottom tank can be described as:

$$H_{SL} = (V_{WSL} - V_D)/C_V + H_D \quad (8)$$

This equation is only valid if the wet sludge volume is greater than the dish volume.

It is also useful to compute the volume of the historically unpumpable region, or the bottom 18 inches ($V_{18"}$). The general equation for $V_{18"}$ is:

$$V_{18"} = (18" - H_D)C_V + V_D$$

For tanks where the sludge height exceeds the height of the historically unpumpable region, the liquid volume is easily calculated.

For 18 inches < H_{SL}:

$$UNP = (V_{18"})(P_{SL}) + PLR_u$$

And by substitution for $V_{18"}$:

$$UNP = [(18" - H_D)(C_V) + V_D](P_{SL}) + PLR_u. \quad (9)$$

Additional calculations are required if the historically unpumpable region contains both saltcake and sludge. Similar to the development of Equation 6 for ILT, if the solids in the bottom 18 inches are mixed saltcake and sludge, the saltcake portion is determined by subtracting the sludge volume from the volume of the bottom 18 inches.

$$[V_{WSC}]_{\text{bottom 18 inches}} = V_{\text{bottom 18 inches}} - V_{WSL} + PLR_u$$

And the unpumpable liquid volume can be calculated as:

$$UNP = (V_{\text{bottom 18 inches}} - V_{WSL})(P_{SC}) + (V_{WSL})(P_{SL}) + PLR_u$$

By substitution:

$$UNP = [(18" - H_D)(C_V) + V_D - V_{WSL}](P_{SC}) + (V_{WSL})(P_{SL}) + PLR_u \quad (10)$$

As with Equation 6, this is the general equation. If the tank has no dish bottom, then the dish height and volume are zero. If the tank had no sludge, then the sludge volume would be zero. However, all tanks being analyzed are considered to contain sludge.

A2.2.3.3 Supporting Equations for CAP

The equations used for the capillary region liquid volume are dependent on solids type in the capillary region. The capillary region is always assumed to be directly above the historically unpumpable region (bottom 18 inches) and is always in a cylindrical portion of the tank; the tank dish does not affect CAP. Figure A-2 shows a simple depiction of the waste in the capillary region of the tank. Note that the unpumpable volume is split; part is in the 18-inch historically unpumpable region and the rest is in the empirically unpumpable volume (PLR_u) taken from Pauly (2002). The PLR_u is considered to be above the capillary region.

The capillary volume equations are dependent on the region in which the tank finishes pumping. The height of the saltcake capillary region is 6 inches; the height of the sludge capillary region is 24 inches.

If $H_{SL} < 18$ inches, then the capillary region is in the saltcake. The following equation for calculating the volume of liquid in the capillary region applies:

$$CAP = (H_{CAP(SC)})(C_V)(P_{SC}) \quad (11)$$

If $H_{SL} > (18" + H_{CAP(SL)})$ (i.e., H_{SL} is greater than 42 inches), then the capillary region is in the sludge. The following equation for calculating the volume of liquid in the capillary region applies:

$$CAP = (H_{CAP(SL)})(C_V)(P_{SL}) \quad (12)$$

If $18" < H_{SL} < 18" + H_{CAP(SL)}$ (i.e., H_{SL} is between 18 inches and 42 inches), then the capillary region is in a mixed sludge/saltcake region. The capillary heights are different for sludge and saltcake; therefore, Equation 9 is used to prorate them. The sludge capillary height cannot be more than 24 inches and the saltcake capillary height cannot be more than 6 inches.

The sludge capillary height in a mixed capillary region can be described as:

$$H_{SL\text{-}CAP} = H_{SL} - 18"$$

The saltcake capillary height is calculated by prorating:

$$H_{SC\text{-}CAP} = [(1 - H_{SL\text{-}CAP}/H_{CAP(SL)})(H_{CAP(SC)})]$$

Therefore, by substitution:

$$H_{SC\text{-}CAP} = [1 - (H_{SL} - 18")/H_{CAP(SL)})(H_{CAP(SC)}]$$

The equation for the capillary liquid volume in a mixed sludge/saltcake capillary region is the sum of these two heights multiplied by the height to volume conversion factor and the respective porosities:

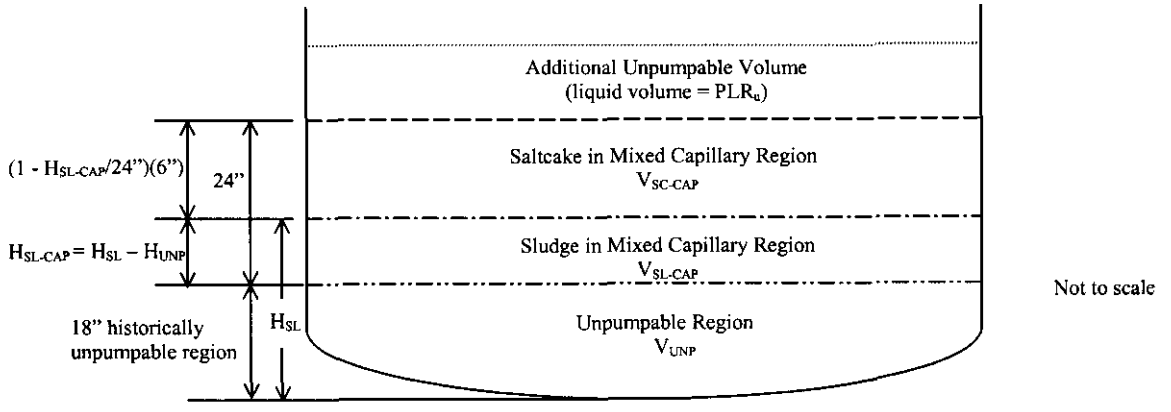
$$CAP = (H_{SC\text{-}CAP})(C_V)(P_{SC}) + (H_{SL\text{-}CAP})(C_V)(P_{SL})$$

Or by substitution for $H_{SC\text{-}CAP}$ and $H_{SL\text{-}CAP}$:

$$CAP = [1-(H_{SL} - 18")/H_{CAP(SL)}](H_{CAP(SC)})(C_V)(P_{SC}) + (H_{SL} - 18")(C_V)(P_{SL}) \quad (13)$$

Again, Equation 13 is only valid if the capillary region is mixed saltcake and sludge.

Figure A-2. Simplified Waste Configuration of the Capillary Region; Mixed Sludge and Saltcake.



A2.3 SPREADSHEET CALCULATIONS

Table A-1. Analysis of Capillary Region

Tank	Sludge Volume (kgal)	Dish Height (in.)	Dish Volume (kgal)	Height of Sludge (in.)	Type of Capillary Region
A-101	3	0	0	1.09	Saltcake
AX-101	3	0	0	1.09	Saltcake
BY-106	32	12	12.5	19.09	Mixed Sludge/Saltcake
S-101	122	12	12.5	51.82	Sludge
S-102	22	12	12.5	15.45	Saltcake
S-107	336	12	12.5	124.91	Sludge
S-111	76	12	12.5	35.09	Mixed Sludge/Saltcake
S-112	6	12	12.5	< Dish height	Saltcake
SX-101	144	14.9	18.5	60.54	Sludge
SX-102	55	14.9	18.5	28.17	Mixed Sludge/Saltcake
U-107	15	12	12.5	12.91	Saltcake
U-108	29	12	12.5	18.00	Saltcake

Notes:

CAP is above the 18-inch historically unpumpable region.
$H_{CAP(SL)}$ = 24 in; $H_{CAP(SC)}$ = 6 in
If H_{SL} < 18", CAP is in the saltcake.
If $H_{SL} < H_D$, CAP is in the saltcake (dish height is always less than the unpumpable height).
If H_{SL} > 18" + $H_{CAP(SL)}$, CAP is in the sludge.
If 18" < H_{SL} < 18"+ $H_{CAP(SL)}$, CAP is in the mixed sludge/saltcake region.

Table A-2. Calculation of Pumpable Liquid Remaining as of April 1, 2003

Unstabilized Tanks	Wet Sludge Volume (kgal)	Wet Saltcake Volume (kgal)	ILL (in.)	Dish Height (in.)	Dish Volume (kgal)	IL_{SC} (kgal)	IL_{SL} (kgal)	ILT (kgal)	SUP (kgal)	Bottom 18" (kgal)	PLR_u Adj (kgal)	CAP (kgal)	DIL (kgal)	PLR (kgal)
A-101	3	-	-	0	0	63.0	0.5	63.5	0	11.7	22.8	4.0	59.6	25.1
AX-101	3	-	-	0	0	41.0	0.5	41.5	0	11.7	22.8	4.0	37.6	3.1
BY-106	32	-	-	12	12.5	37.0	5.4	42.4	0	4.9	17.5	4.3	38.2	15.7
S-101	122	-	148.3	12	12.5	63.7	20.7	84.4	0	4.9	17.5	11.2	73.2	50.8
S-102	22	418	168.5	12	12.5	101.0	3.7	104.8	0	5.4	22.8	4.0	100.8	72.6
S-107	320	-	127.0	12	12.5	2.1	54.4	56.5	0	4.9	17.5	11.2	45.3	22.9
S-111	76	-	-	12	12.5	73.0	12.9	85.9	0	4.9	37.0	9.1	76.8	34.9
S-112	6	-	-	12	12.5	69.0	1.0	70.0	0	6.5	22.8	4.0	66.1	36.7
SX-101	144	-	-	14.9	18.5	39.0	24.5	63.5	0	4.6	17.5	11.2	52.3	30.2
SX-102	55	-	-	14.9	18.5	69.0	9.4	78.4	0	4.6	37.0	7.0	71.3	29.7
U-107	15	-	101.0	12	12.5	58.1	2.6	60.7	0	5.9	22.8	4.0	56.7	28.0
U-108	29	-	-	12	12.5	76.0	4.9	80.9	0	4.9	22.8	4.0	77.0	49.2
Total Pumpable Liquid Remaining in Unstabilized Tanks														398.8
Total PLR in Unstabilized Tanks without Tanks S-102 and S-112														289.5

Notes:

Calculation based on sludge porosity of 0.17 and saltcake porosity of 0.24.
DIL is defined as ILT – CAP.
ILL = interstitial liquid level
The bottom 18 inches constitutes the historical unpumpable region.
UNP (not called out as a separate column) is the sum of the historical unpumpable region (bottom 18") and PLR_u (Pauly 2002).
Because rounded values are shown in the table, minor inconsistencies (0.1 kgal) may appear when columns are added or subtracted.
The PLR_u for BY-106 in Pauly (2002) is 37.0. Using this value in the equations results in a calculated PLR of 0; that is, the tank should be done pumping based on the Pauly correction. However, since pumping is still ongoing, the PLR_u is arbitrarily set to 17.5 kgal (sludge tank) resulting in the calculated PLR of 15.7 kgal. This results in a more conservative (higher) overall estimate of the PLR.
A "-" indicates that this data was not needed for the calculations.

A3.0 INPUT DATA

A3.1 VOLUME AND LIQUID LEVEL DATA USED IN CALCULATION SPREADSHEET

Tank 241-A-101

The BBI for tank 241-A-101 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 2, 2003. There have been net transfers of 22 kgal from January 2, 2002 until April 1, 2003 (Conner 2003b-d). As of January 2, 2003, the BBI volume estimates were:

Retained gas	63 kgal
Saltcake liquid	85 kgal
Saltcake solids	298 kgal
Sludge	3 kgal

The LOW for this tank failed over a year ago. Data collection resumed in March 2003 using an existing drywell in the tank. However, as saltwell pumping was ongoing during most of February and March, an equilibrated ILL cannot be determined from the drywell measurements. Therefore, the current BBI estimate will be updated for the volume pumped during the past 3 months. The estimated saltcake liquid of 85 kgal was calculated based on the estimated ILL as of January 2 and the assumed porosity of 24%. Therefore, it is consistent with the methodology of this document and does not need to be adjusted for retained gas. The 22 kgal of liquid pumped from January through March is subtracted from the 85 kgal of saltcake liquid estimated at the beginning of January.

Therefore, the estimates used in the calculation of pumpable liquid remaining (as of April 1, 2003) are:

Saltcake liquid	63 kgal
Wet sludge	3 kgal

Tank 241-AX-101

The BBI for tank 241-AX-101 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 6 kgal from January through March (Conner 2003b-d). As of January 1, 2003, the BBI volume estimates were:

Saltcake liquids: 20 kgal
Saltcake solids: 305 kgal
Sludge: 3 kgal

Neither the neutron nor gamma scans in the LOW are currently providing useful information on the interstitial liquid level in tank 241-AX-101. The BBI estimate was derived from information provided in Revision 4 of this document (Appel and Conner 2002).

For this revision, saltwell pumping process data from network drive \\ap003\saltwell were reviewed to determine whether the liquid level in the saltwell screen could be calculated. From the data for December 21, 2002, a saltwell screen liquid level of 64 inches was calculated. As saltwell pumping had not occurred for about 25 days, the liquid level should have equilibrated somewhat. For tank 241-AX-101, the offset between the bottom of the saltwell screen and the bottom of the tank is 7 inches (see Appendix B). In addition, the liquid level is the saltwell screen is assumed to be related to the ILL by the capillary height, which is 6 inches for saltcake. Therefore, an ILL of 77 inches (64+7+6) can be estimated for the tank at that time. This corresponds to 212 kgal of wetted solids, 209 of which are wet saltcake. At the assumed 24 percent porosity, this corresponds to 50 kgal of interstitial saltcake liquid. There was 9 kgal of saltwell pumping production from December 21 to March 31, 2003.

Therefore, the estimates used in the calculation of pumpable liquid remaining (as of April 1, 2003) are:

Saltcake liquid	41 kgal
Wet sludge	3 kgal

Tank 241-BY-106

The BBI for tank 241-BY-106 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 13 kgal from January through March (Conner 2003b-d). As of January 1, 2003, the BBI volume estimates were:

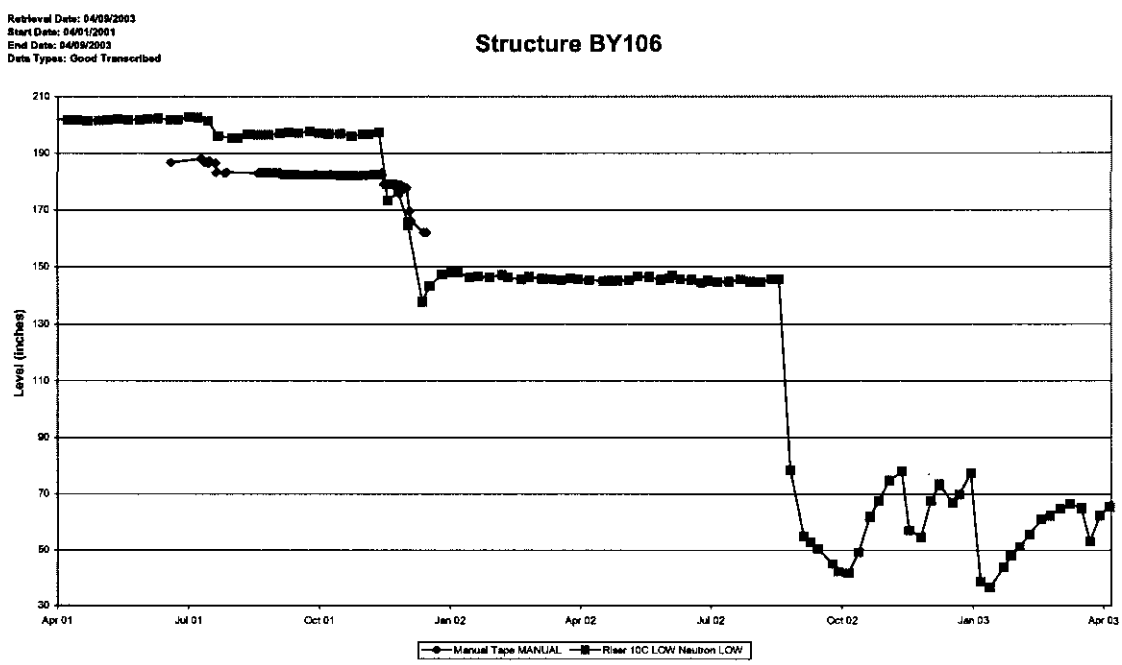
Sludge: 32 kgal
Saltcake liquid: 50 kgal
Saltcake solids: 422 kgal

Updating the saltcake liquid estimate for the volume pumped since January results in an estimate of 37 kgal. Using the calculation methods described earlier in Appendix A and the estimated sludge volume of 32 kgal, an ILL of 75 inches can be estimated at the end of March.

A review of pumping records indicates that there was very little pumping from January 14 through March 16. In that time, the ILL rose from 36 inches to 66 inches (see Figure A-3). Pumping resumed before the ILL equilibrated, but a projected ILL of 75 inches would not be unreasonable. Therefore, the updated saltcake liquid volume of 37 kgal is accepted as a reasonable estimate. The estimates used in the calculation of pumpable liquid remaining (as of April 1, 2003) are:

Saltcake liquid:	37 kgal
Wet sludge	32 kgal

Figure A-3. Level Plot for Tank 241-BY-106.



Tank 241-C-103

Pumping in tank 241-C-103 was halted in February 2003. The tank was placed in evaluation mode in March in expectation of being declared interim stabilized. Therefore, no additional liquid is planned to be pumped, and no estimates of pumpable liquid remaining were prepared.

Tank 241-S-101

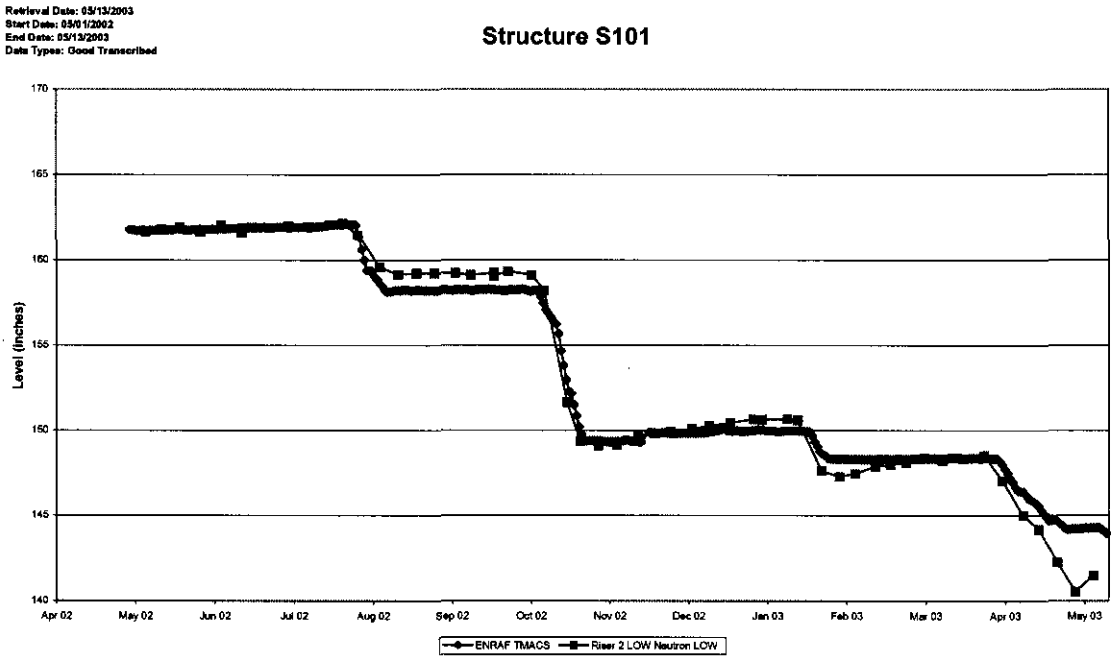
The BBI for tank 241-S-101 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 6 kgal in January through March (Conner 2003b-d). As of April 1, 2002, the BBI volume estimates were:

Total sludge: 122 kgal
Saltcake liquid: 47 kgal
Saltcake solids: 230 kgal

No saltwell pumping occurred from late October to mid-January. During this period, the ILL slowly rose to the same level as the surface (see Figure A-4). After approximately 10 days of saltwell pumping, no pumping was performed until late March. The ILL approached, but did not quite reach, the surface level in late March. Recent pumping rates have been approximately 0.4 gpm, indicating that interstitial liquid is being pumped. Therefore, the ILL will be assumed to be equal to the surface level on April 1, 2003, or approximately 148.3 inches.

ILL	148.3 inches
Wet Sludge:	122 kgal

Figure A-4. Level Plot for Tank 241-S-101.



Tank 241-S-102

The BBI for tank 241-S-102 was issued in January 2003 (CH2M HILL 2003). This BBI includes information up to October 1, 2002. A total of 1 kgal was pumped for the period from October through March (Conner 2002 a-e; 2003a-d). As of October 1, 2002, the BBI volume estimates were:

Saltcake retained gas	108 kgal
Sludge retained gas	6 kgal
Saltcake solids	211 kgal
Saltcake liquid	99 kgal
Sludge	16 kgal

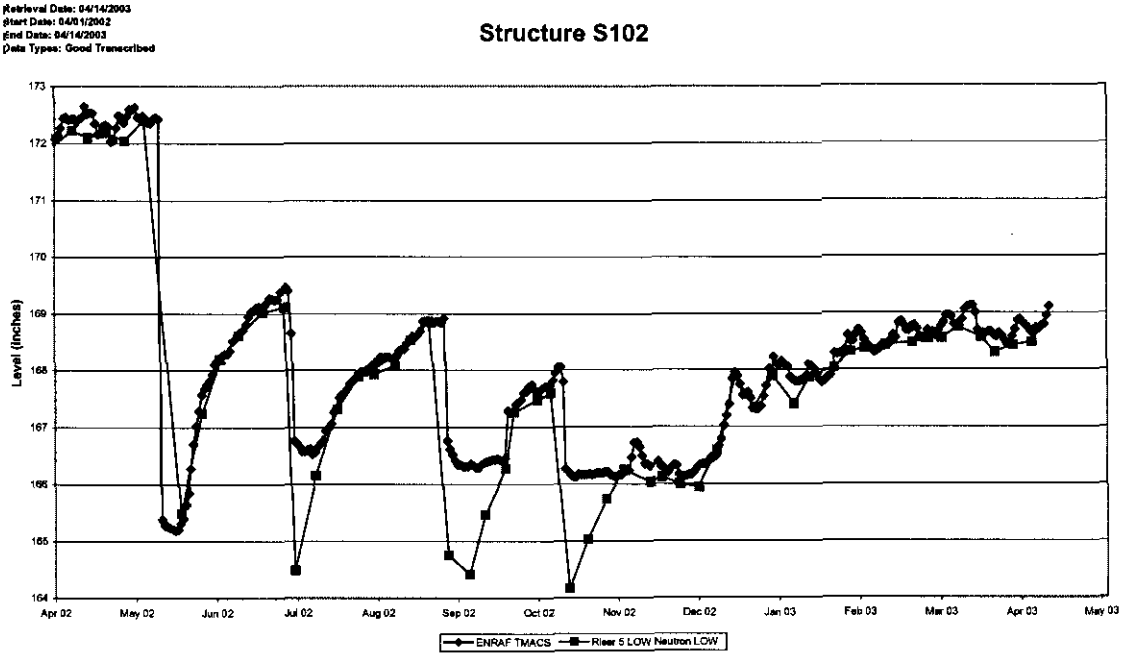
The BBI has subtracted retained gas from the saltcake and sludge. For this document, the retained gas will be added back into the saltcake and sludge since the methodology for accounting for the retained gas in the calculation of pumpable liquid remaining is not fully developed. Therefore, the total sludge volume is 22 kgal. Because of the recent increases in the surface level and ILL, the ILL can be rebaselined at 168.5 inches as of April 1, 2003. The waste still appears to be full of liquid based on the similar surface level and ILL readings. It may be that the ENRAF plummet is in a hole or depression and a portion of drained saltcake above the measured level. However, this does not affect the PLR calculation. The recent fluctuations in the level and ILL seem to indicate the presence of retained gas (See Figure A-5).

Note that negotiations are ongoing to remove tank 241-S-102 from the Consent Decree because the tank will be taken over by Retrieval Programs for early retrieval. When this is finalized, the PLR calculations will no longer apply to this tank.

The volume estimates used in the calculation of pumpable liquid remaining are:

ILL	168.5 inches
Wet sludge	22 kgal

Figure A-5. Level Plot for Tank 241-S-102.



Tank 241-S-107

The BBI for tank 241-S-107 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to October 1, 2002. There have been net transfers of 3 kgal from October 1, 2002 until January 1, 2003, plus an additional 17 kgal pumped in January and February (Conner 2002d-e; 2003a-c). As of October 1, 2002, the BBI volume estimates were:

Sludge: 320 kgal
Saltcake: 20 kgal

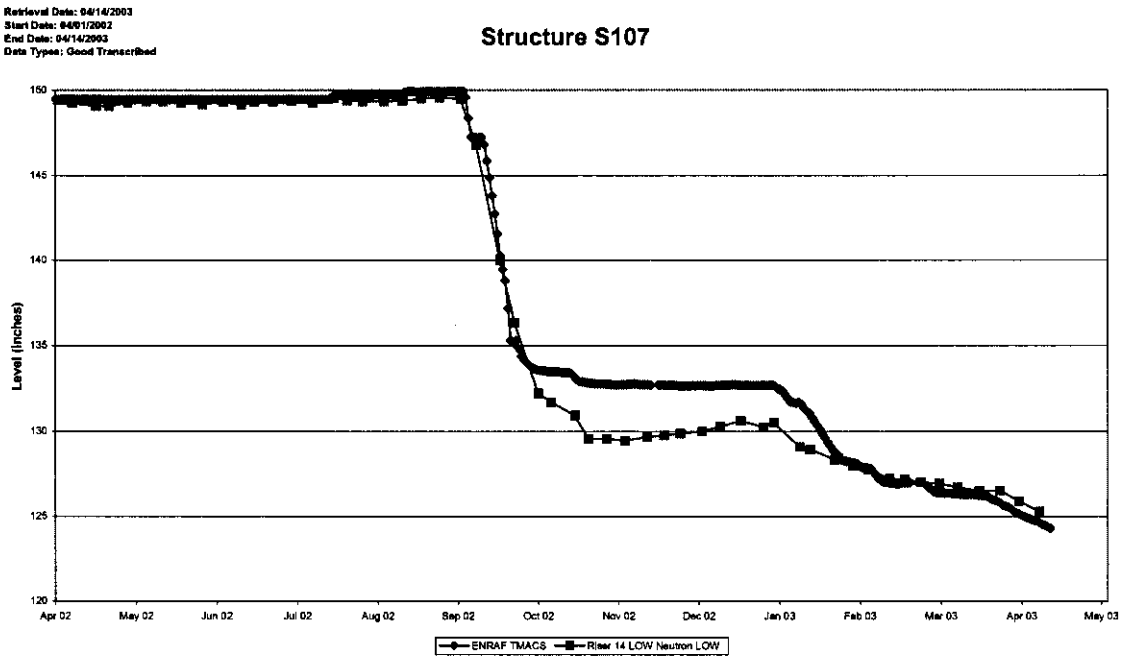
The total volume is consistent with the surface level of 132.7 in late December 2002 (see Figure A-6). The level and ILL both dropped as a result of pumping in January –March quarter. The ILL appears to be responding sluggishly to pumping. No waste was pumped from October 18 to December 25, and the ILL rose only ~1 inch in that time. The 20 kgal pumped in the first three months of 2003 would be expected to cause a significant drop in the ILL. The 20 kgal pumped corresponds to 7.3 inches of level drop if supernatant were being pumped, and significantly more if interstitial liquid were being pumped. Yet the ILL dropped only ~5 inches in those three months. Note that from pumping records, it appears that interstitial liquid is being pumped, as the pumping rate is well below 0.5 gpm. The dip tube data were also examined. The dip tube data indicate a saltwell screen liquid height of approximately 95 inches in early February when saltwell pumping was ongoing, with little other data available. Although it appears that the ILL measurement is conservative (higher than can be explained from the pumped volume), the ILL will be used as the basis for determining the liquid volume.

The level and ILL at the end of March were both between 125 and 127 inches (see Figure A-6). An ILL of 127 inches will be used to determine the interstitial liquid volume as of April 1, 2003.

Therefore, the volume estimates used in the calculation of pumpable liquid remaining are:

ILL:	127 inches
Wet sludge:	320 kgal

Figure A-6. Level Plot for Tank 241-S-107.



Tank 241-S-111

The BBI for tank 241-S-111 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 16 kgal from January through March (Conner 2002b-d). The recommended BBI volume estimates as of January 1, 2003 are:

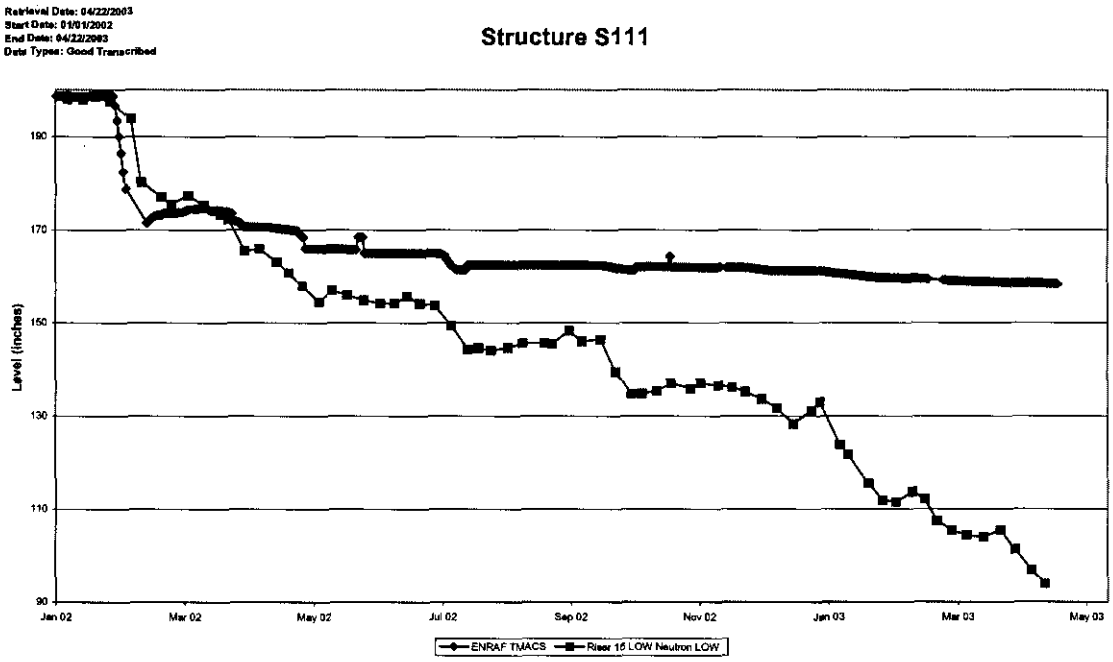
Sludge (including retained gas)	76 kgal
Retained gas saltcake	56 kgal
Saltcake liquid	89 kgal
Saltcake solids	254 kgal

The derivation of the BBI saltcake liquid estimate was consistent with HNF-2978 methodology (this document). That is, the saltcake liquid was estimated as 24% of the total saltcake volume when the tank was baselined on April 1, 2002. The retained gas in the saltcake was subtracted from the saltcake solids. Then, the estimates were updated for the volume pumped between April and December 2002. Thus, these estimates may be used directly.

After updating for the 16 kgal pumped in January through March, the estimated saltcake liquid volume is 73 kgal. At an assumed 24% drainable porosity, this corresponds to 304 kgal of wet saltcake. With 76 kgal of sludge, the total wet solids volume would be 380 kgal, which corresponds to an ILL of 146 inches. The recent surface level and ILL history is shown in Figure A-7. The ILL at the end of March 2003 was about 106 inches. During recent periods of pumping inactivity, most notably from July 11 to September 17 and again from October 2 to November 26, 2002, the ILL rose very little. Therefore, it is not likely that the ILL would reach 145 inches as predicted by updated saltcake liquid estimate. Nevertheless, there are insufficient data to predict where the equilibrium ILL might be based on the surveillance data. Therefore, the volume estimates used in the calculation (as of April 1, 2003) are:

Saltcake liquid	73 kgal
Wet sludge	76 kgal

Figure A-7. Level Plot for Tank 241-S-111.



Tank 241-S-112

The BBI for tank 241-S-112 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. No waste has been pumped since October 2002 (Conner 2002d-e; 2003a-d). As of January 1, 2003, the BBI volume estimates were:

Saltcake solids	539 kgal
Saltcake liquid	69 kgal
Total sludge	6 kgal

Because no waste has been pumped, there is no need to update the BBI estimates. Note that negotiations are ongoing to remove tank 241-S-112 from the Consent Decree because the tank will be taken over by Retrieval Programs for early retrieval. When this is finalized, the PLR calculations will no longer apply to this tank.

The estimates used in the calculation of pumpable liquid remaining (as of April 1, 2003) are:

Saltcake liquid	69 kgal
Wet sludge	6 kgal

Tank 241-SX-101

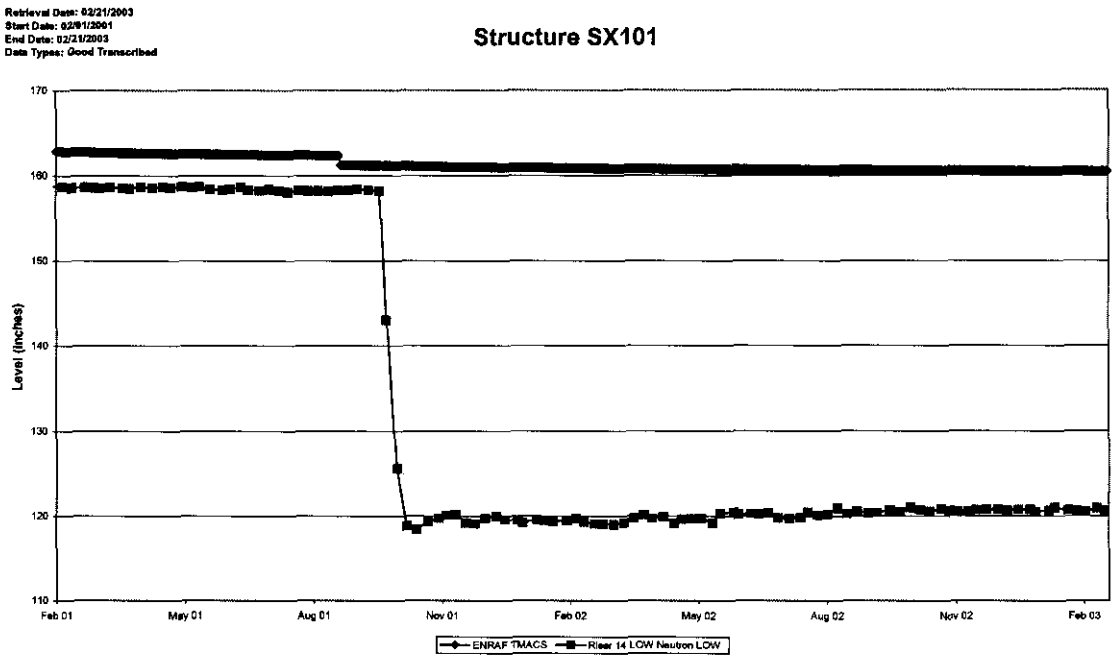
The BBI for tank 241-SX-101 was issued in January 2003 (CH2M HILL 2003). This BBI includes information up to October 1, 2002. There have been net transfers of less than 1 kgal from October 1, 2002 until March 31, 2003 (Conner 2002 a-e; 2003a-d). As of October 1, 2002, the BBI volume estimates were:

Saltcake liquid	39 kgal
Saltcake solids	230 kgal
Sludge	144 kgal

As can be seen on the level plot (see Figure A-8), there has been virtually no variation in the ILL. Therefore, there is no need to update the volume estimates. The estimates used in the calculation of pumpable liquid remaining are:

Saltcake liquid	39 kgal
Wet sludge	144 kgal

Figure A-8. Level Plot for Tank 241-SX-101.



Tank 241-SX-102

The BBI for tank 241-SX-102 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 33 kgal from January 1 until March 31, 2003 (Conner 2003b-d). As of January 1, 2003, the BBI volume estimates were:

Saltcake liquid	65 kgal
Saltcake solids	343 kgal
Sludge	55 kgal

The LOW has failed and is not expected to be replaced. However, saltwell pumping process data from network drive \\ap003\saltwell were reviewed to determine whether the liquid level in the saltwell screen could be calculated. From the data for January 4, 2003, a saltwell screen liquid level of 145 inches was calculated. For tank 241-SX-102, the offset between the bottom of the saltwell screen and the bottom of the tank is 6.5 inches (see Appendix B). In addition, the liquid level in the saltwell screen is assumed to be related to the ILL by the capillary height, which is 6 inches for saltcake. Therefore, an ILL of 157.5 inches (145+6.5+6) can be estimated for the tank on January 4, for a wetted volume of 411 kgal.

Note that the ILL by neutron probe in the LOW and the corrected dip tube measurement were consistent on July 17, 2002, the last valid reading for the LOW. This provides some assurance that the corrected dip tube reading and the ILL are comparable.

In late January, saltwell pumping resumed. The initial pumping rate was as high as 1.8 gpm, indicating that supernatant or free liquid was being pumped. From February 16 to February 17, the daily average pumping rate dropped from 1.0 to 0.7 gpm, providing an estimated cutoff between pumping supernatant and interstitial liquid. Therefore, the net 21 kgal pumped from February 1 through February 17 can be attributed to free liquid.

From the wetted solids volume of 411 kgal estimated on January 4, the 22 kgal pumped through February 16 (all considered free liquid) can be subtracted, resulting in a revised estimate of 389 kgal of wet solids at that date. With 55 kgal of sludge, that leaves an estimated 334 kgal of wet saltcake on February 17. Using the estimated saltcake drainable porosity of 24%, the saltcake liquid volume on that date was 80 kgal. From that, the 11 kgal pumped from February 17 to March 31 can be subtracted. Therefore, the volume estimates used in the calculation of pumpable liquid remaining (as of April 1, 2003) are:

Saltcake liquid:	69 kgal
Wet sludge	55 kgal

Tank 241-SX-103

Tank 241-SX-103 was placed in evaluation mode in September 2002 in expectation of being declared interim stabilized. Therefore, no additional liquid is planned to be pumped, and no estimates of pumpable liquid remaining were prepared.

Tank 241-U-107

The BBI for tank 241-U-107 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 5 kgal from January through March, 2003 attributed to saltwell pumping towards the Consent Decree milestone (Conner 2003b-d). As of January 1, 2003, the BBI volume estimates were:

Saltcake liquid	28 kgal
Saltcake solids	274 kgal
Sludge	15 kgal

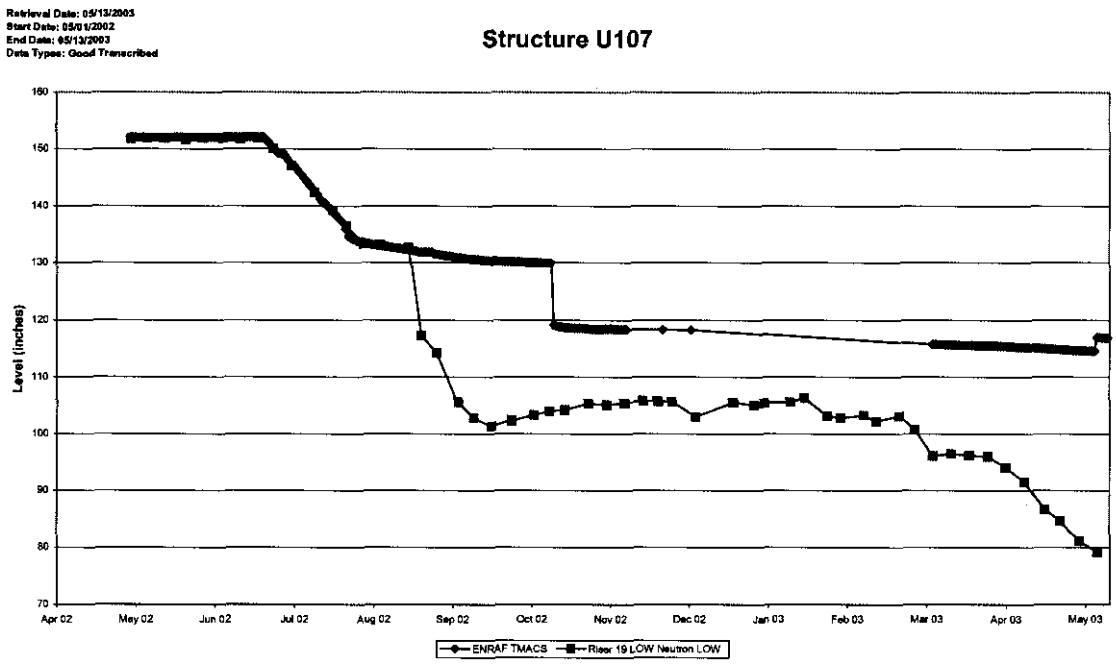
As of December 3, responsibility for tank 241-U-107 was taken by retrieval programs. Water additions and retrieval through saltcake dissolution and saltwell pumping began. A management decision was made to not count the volume pumped towards meeting the Consent Decree milestone. As of February 21, 2003, the retrieval of this tank was halted, and the volume pumped after that date was again counted for the Consent Decree milestone.

The tank was not pumped from September 13 until November 27, 2002. As can be seen in Figure A-9, the ILL rose about 5 inches and appeared to stabilize at about 106 inches. From that time until December 3, when retrieval began, a total of 1 kgal was pumped from the tank. During the retrieval status of this tank, water additions were made and saltwell pumping continued intermittently. The ILL fluctuated between 100 and 110 inches. The tank was not pumped from March 2 to March 28, and the ILL stayed between 96 and 97 inches. Assuming a similar 5-inch rise before equilibration as was exhibited in the fall, an estimated ILL of 101 inches is considered reasonable.

Therefore, the volume estimates used in the calculation of pumpable liquid remaining as of April 1, 2003 are:

ILL	101 inches
Wet sludge	15 kgal

Figure A-9. Level Plot for Tank 241-U-107.



Tank 241-U-108

The BBI for tank 241-U-108 was issued in April 2003 (CH2M HILL 2003). This BBI includes information up to January 1, 2003. There have been net transfers of 10 kgal from January 1, 2003 until March 31, 2003 (Conner 2003b-d). As of January 1, 2003, the BBI volume estimates were:

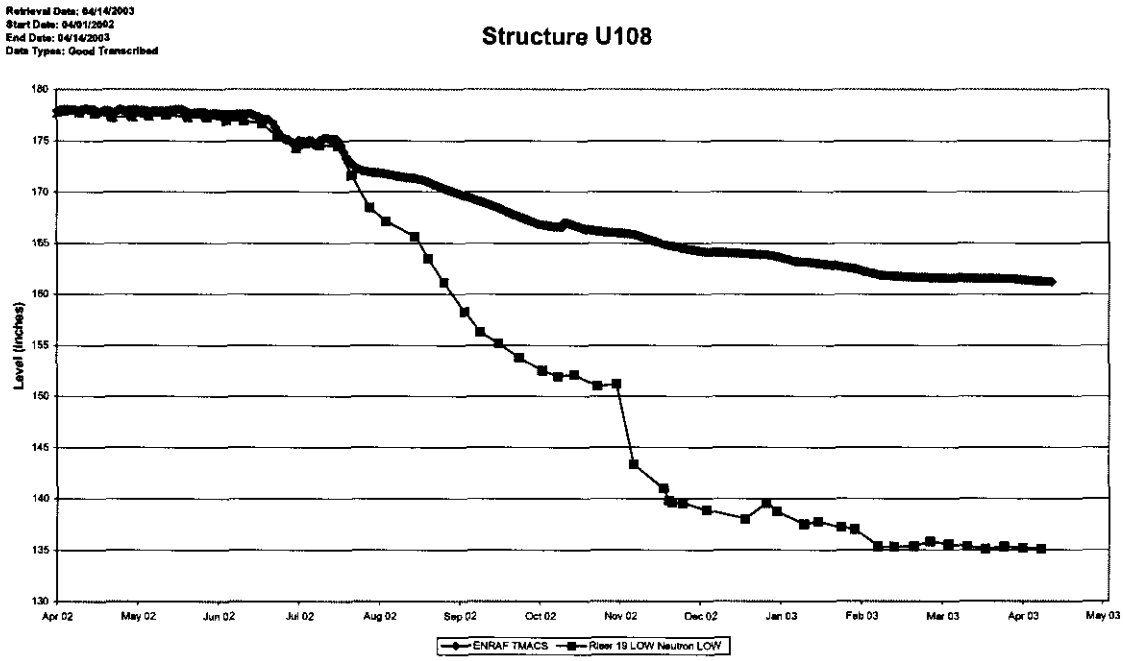
Saltcake liquid	71 kgal
Saltcake solids	315 kgal
Sludge	29 kgal

The recent surface level and ILL data are shown in Figure A-10. If the latest BBI estimate were adjusted for the 10 kgal pumped since the BBI data date, an ILL of approximately 110 inches would be projected using the calculation methods presented earlier in Appendix A. However, the most recent ILL measurements have been around 136 inches.

Pumping has been intermittent over the last few months. The largest gap in pumping has been recently from February 9 through March 28. During that time, the ILL increased by less than an inch, and then dropped slightly. This indicates that the ILL may have equilibrated already. The ILL in late March was between 135 and 136 inches. An ILL of 136 inches corresponds to 354 kgal of wet solids, 325 kgal of which is wet saltcake. From the wet saltcake volume and an assumed drainable porosity of 24%, a saltcake liquid volume of 78 kgal can be estimated as of March 28. From that, the 2-kgal liquid pumped from March 28 to March 31 can be subtracted to calculate an estimate of 76 kgal saltcake liquid as of April 1, 2003. Therefore, the estimates used in the calculation of pumpable liquid remaining are:

Saltcake liquid	76 kgal
Wet sludge	29 kgal

Figure A-10. Level Plot for Tank 241-U-108.



Tank 241-U-111

Tank 241-U-111 stopped pumping in February 2003 and was placed in evaluation mode in March in expectation of being declared interim stabilized. Therefore, no additional liquid is planned to be pumped, and no estimates of pumpable liquid remaining were prepared.

A3.3 LIQUID PUMPED SINCE JUNE 1, 1998

The total saltwell liquid pumped from June 1, 1998 to March 31, 2003 is 2880 kgal, and the total not counting tanks 241-S-102 and 241-S-112 is 2810 kgal. The data are compiled for the project on network computer drive \\ap012\dpu and can also be derived from Naiknimbalkar (2002) and Conner (2002 a-e; 2003a-d). The data for each tank are presented in Table A-3.

Table A-3. Saltwell Liquid Pumped June 1998 Through March 2003.

Tank	Volume Pumped (kgal)
A-101	531
AX-101	366
BY-105	45
BY-106	71
C-103	114
S-101	32
S-102	62
S-103	24
S-106	107
S-107	56
S-109	34
S-111	74
S-112	8
SX-101	32
SX-102	76
SX-103	134
SX-104	118
SX-105	153
SX-106	148
T-104	29
T-110	33
U-102	87
U-103	99
U-105	87
U-106	39
U-107[1]	96
U-108	63
U-109	78
U-111	85
Total	2880
Total without S-102 and S-112	2810

Note:
[1] For tank 241-U-107, the volume pumped from 12/3/02 to 2/21/03 is attributed to the saltcake dissolution/retrieval project and not counted towards interim stabilization. That volume is not reflected in the table.

A3.4 ASSUMPTIONS

Assumptions are noted throughout the calculation. The following is a summary.

- Capillary heights of 24 inches will be assumed for sludge and 6 inches for saltcake. The justification for these assumptions is provided in Section 4.1.2 of the main body of this document.

- If the capillary region is a mixture of saltcake and sludge, the saltcake will be prorated. For instance, if there were 12 inches of sludge, the prorated saltcake capillary would be 3 inches ([1-12/24] x 6). The justification for this assumption is provided in Section 4.1.2 of the main body of this document.

- In addition to the historical 18-inch unpumpable region, an additional empirically unpumpable volume of liquid is assumed for each tank in accordance with Pauly (2002). For the calculations, the 18-inch region is below the capillary region, and the additional volume from Pauly (2002) is assumed to be above the capillary region.

- The porosity of the saltcake is assumed to be 24 percent, and the porosity of the sludge is assumed to be 17 percent.

- The dish bottom for SX-Farm tanks is assumed to be 14.9 inches deep from the bottom of the tank to the top of the dish (Drawing H-2-39511). The volume of an SX dish is 18,500 gallons (Joncus 1982). The A- and AX-Farm tanks do not have dish bottoms. All other tanks have a 12-inch depth from the bottom of the tank to the top of the dish and a dish volume of 12,500 gallons (Joncus 1982).

- The sludge is assumed to be in a flat layer on the very bottom of the tank. Historically, the sludge has generally been the first waste transferred to the single-shell tanks. Generally, saltcake has been transferred on top of sludge. Note that is not always the case. There are some tanks that have had sludge transferred after saltcake and, therefore, sludge may lie on top of the saltcake. Such multi-layered tanks may have capillary regions that are not drainable in various regions of the tank. There is no good way to estimate any non-drainable regions in these tanks. For consistency, all sludge is assumed to be on the bottom of the tank.

- Interim stabilized tanks and tanks that are in evaluation for stabilization are assumed to have zero pumpable liquid remaining.

A4.0 RESULTS

- As of April 1, 2003, the total pumpable liquid remaining for the 12 tanks that have not been stabilized is 399 kgal. Tank by tank results are presented in Table A-2.
- The total pumpable liquid predicted to be present in the 29 Consent Decree tanks as of June 1, 1998 is 3278 kgal. Tank by tank results are presented in Table A-2 (PLR) and Table A-3 (liquid volume pumped from June 1998 through March 2003).
- If the tanks slated for accelerated retrieval (241-S-102 and 241-S-112) are not considered, then the PLR is 290 kgal, and the estimated volume of pumpable liquid present in the 27 tanks on June 1, 1998 is 3099 kgal.

A5.0 CONCLUSIONS

Not applicable.

A6.0 RECOMMENDATIONS

Not applicable.

A7.0 REFERENCES

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APPENDIX B

ELECTRONIC MAIL CORRESPONDENCE:

SALTWELL SCREEN DIP TUBE HEIGHTS RELATIVE TO TANK BOTTOM FOR SELECTED TANKS

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From: Swaney, Stephen L
Sent: Tuesday, January 21, 2003 5:00 PM
To: Conner, John M
Subject: RE: offsets (bottom of SW screen to bottom of tank)

Tank	Offset	References
A-101	19.25 inches	H-14-103084, sht. 2 (pump details) H-2-73388 (isolation/riser elevations) ECN-663052 (16" cribbing) H-2-69757, shts 1-4 (saltwell screens)
AX-101	7.00 inches	H-14-103083, sht 2 (pump details) H-2-73376 (isolation/riser elevations) H-2-69757, shts 1-4 (saltwell screens)
SX-102	6.50 inches	H-14-104485, sht 2 (pump details) H-2-73219 (isolation/riser elevations) H-2-69757, shts 1-4 (saltwell screens)

Steve Swaney
IS Engineering
373-3472

-----Original Message-----
From: Conner, John M
Sent: Tuesday, January 21, 2003 4:41 PM
To: Swaney, Stephen L
Subject: offsets (bottom of SW screen to bottom of tank)

Steve,

In the next rev of HNF-2978, due out in February, I will probably end up using dip tube readings to estimate PLR for several of the tanks. The tanks are A-101, AX-101, SX-102. Could you tell me what the offsets are for those tanks? Also, if you had a reference (drawing, document, or ECN), that would be great.

Thanks

John Conner

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