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Task Technical and QA Plan: Saltstone Grout and Vault Concrete Sample Preparation and Testing

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I. INTRODUCTION

A. Task and Scope Definition

The task and scope of this effort is to support Site Regulatory Integrated Planning (SRIP) in determining the hydraulic and physical properties of three saltstone grout formulations and two vault concrete formulations. The hydraulic and physical properties of the saltstone grouts and vault concretes are inputs to the modeling work to be performed in support of the revision to the Performance Assessment (PA) for the Saltstone Disposal Facility (SDF).

A performance assessment of DOE LLW disposal operations is required by DOE Order 435.1, Radioactive Waste Management. The LLW chapter of the Order requires revision of the PA when changes in waste forms or containers, radionuclide inventories, facility design and operations, or closure concepts alter the conclusions or the conceptual models of the existing PA. Since initial design and facility construction, the SDF has undergone revisions in the anticipated radiological inventory, vault design and the models used to evaluate compliance with performance objectives. Thus, over the course of time, the performance objective compliance evaluations have been calculated in various documents to reflect new information and methodologies. The current PA was approved in 1992 and was based upon disposal of decontaminated salt solution from the In-Tank Precipitation Facility (ITP). A Special Analysis was approved in 2002 to account for suspension of the ITP process and disposal of low curie salt solution. The latest information on the SDF feed solutions, updated modeling methods, updated closure cap design and evaluations are captured in the 2005 Special Analysis, which supplements the 1992 SDF Performance Assessment and supersedes the 2002 Saltstone Special Analysis. Since the last PA revision, a new Saltstone vault concept has been designed; a pre-fabricated, post-tensioned, thin wall concrete tank (Vault 2). This design is being proposed as the replacement for the poured-in-place vaults (Vaults 1 and 4) currently in use in the SDF. This PA revision will include both the old and new proposed vault design.

The purpose of this task is to measure the hydraulic and physical properties of three saltstone grout formulations (DDA, ARP/MCU, and SWPF) and two vault concrete formulations (Vault 1/4 and Vault 2). Wet properties will be measure for the saltstone grout formulations including flow consistency, wet unit weight, bleed water, gel time, set time and heat of hydration. Compressive strength will be measured for each saltstone grout and vault concrete formulation at 14, 28, 56, and 90 days. Hydraulic and physical properties to be measured on the cured samples include saturated hydraulic conductivity, moisture retention, porosity, and dry bulk density. These properties will be determined following a minimum 28 day curing period. Depending on the results of the compressive strength testing, some samples of each mix may be tested following a 90 day minimum curing period.

This task will support the SDF Performance Assessment by performing the following work requested in Q-TTR-Z-00001 [1]:

1) Prepare and provide samples of Vault 1/4 concrete (modified as necessary with respect to admixture availability) for:
   - physical property measurements
   - hydraulic property measurements
   - compressive strength testing

2) Prepare and provide samples of Vault 2 concrete (modified as necessary with respect to admixture availability) for:
   - physical property measurements
   - hydraulic property measurements
   - compressive strength testing
3) Prepare and provide grout samples using Deliquification, Dissolution, and Adjustment (DDA) salt simulant and premix at w/c 0.60 for:
   - wet property measurements
   - physical property measurements
   - hydraulic property measurements
   - compressive strength testing
4) Prepare and provide grout samples using Actinide Removal Process (ARP)/ Modular Caustic Side Solvent Extraction Unit (MCU) salt simulant and premix at w/c 0.60 for:
   - wet property measurements
   - physical property measurements
   - hydraulic property measurements
   - compressive strength testing
5) Prepare and provide grout samples using Salt Waste Processing Facility (SWPF) salt simulant and premix at w/c 0.60 for:
   - wet property measurements
   - physical property measurements
   - hydraulic property measurements
   - compressive strength testing
6) Measure wet properties of the following saltstone materials by utilizing onsite facilities::
   - DDA saltstone grout formulation (w/c 0.6)
   - ARP/MCU saltstone grout formulation (w/c 0.6)
   - SWPF saltstone grout formulation (w/c 0.6)
7) Measure compressive strength of the following materials by utilizing onsite facilities:
   - DDA saltstone grout (w/c 0.60)
   - ARP/MCU saltstone grout (w/c 0.60)
   - SWPF saltstone grout (w/c 0.60)
   - Vault 1/4 concrete
   - Vault 2 concrete
8) Measure hydraulic and physical properties of the following materials by utilizing facilities at an offsite subcontract laboratory:
   - DDA saltstone grout (w/c 0.60)
   - ARP/MCU saltstone grout (w/c 0.60)
   - SWPF saltstone grout (w/c 0.60)
   - Vault 1/4 concrete
   - Vault 2 concrete
9) Conduct a computed tomographic scan of selected samples of the following materials.
   - DDA saltstone grout (w/c 0.60)
   - ARP/MCU saltstone grout (w/c 0.60)
   - SWPF saltstone grout (w/c 0.60)
   - Vault 1/4 concrete
   - Vault 2 concrete

10) Prepare a technical report summarizing saltstone grout and vault concrete sample preparation and property measurements

B. Customer/Requester

This work was requested by J. L. Newman, SRIP Planning and Integration Team (PIT) Q-TTR-Z-00001 [1].

C. Task Responsibilities

SRIP: J. L. Newman or designee is responsible for providing and/or approving the following:

- Review and approval of the Task Technical/Quality Assurance Plan (TT/QAP).
- Review of the test results as they are generated and input for further testing.
- Review and approval of the technical report documenting work performed under this TT/QAP.

SRNL/ES&BT: K. L. Dixon is responsible for preparing the TT/QAP for sample preparation, physical property testing, and hydraulic property testing.

SRNL/PS&E: J. R. Harbour is responsible for implementing the SRNL Conduct of Research and Development on the saltstone sample preparation and wet physical property testing portions of this task prior to initiating the laboratory work. This includes performance of a Hazards Assessment.

SRNL/PS&E: J. R. Harbour is responsible for identifying laboratory space and for obtaining supplies and materials for preparing the saltstone grout formulations and for performing wet physical property testing. This includes the receipt of cementitious materials from SDF.

SRNL/PS&E: J. R. Harbour is responsible for preparing the various salt simulants used to batch and test the saltstone grout formulations. This includes measurement of chemical composition by Process Science Analytical Laboratory (PSAL) and Analytical Development Section (ADS) as well as measurement of density and percent solids (by weight) as measured by J Harbour.

SRNL/PS&E: J. R. Harbour is responsible for performing the saltstone sample preparation and wet physical property testing portions of this task. This includes:

- Identifying any prerequisites.
- Providing coordination and technical guidance.
- Preparing saltstone grout samples per test specimen requirements in the TT/QAP.
- Coordinating with the on-site civil engineering test laboratory operated by WGI Quality and Test Programs to obtain strength testing of the various saltstone grout formulations at 14, 28, 56, and 90 days.
- Coordinating with the on-site civil engineering test laboratory operated by WGI Quality and Test Programs to cure the various saltstone grout formulations as required.
- Delivering samples to K. L. Dixon and/or M. Phifer for hydraulic and physical property testing
- Providing the three salt simulants in sufficient volume for the hydraulic and physical testing (~2 gallons of each).

- Disposal of any waste generated as part of the saltstone sample preparation and wet physical property testing work.
- Communicating sample preparation and wet physical property test results to K. L. Dixon and M. A. Phifer.
- Providing input to a technical report on preparation of the specified saltstone grout formulations and on the wet physical property test results.

SRNL/ES&BT: K. L. Dixon and M. A. Phifer are responsible for having the on-site civil engineering test laboratory operated by WGI Quality and Test Programs prepare the vault concrete formulations (Vault 1/4 and Vault 2) and make the necessary test specimens. This includes curing the test specimens.

SRNL/ES&BT: K. L. Dixon and M. A. Phifer are responsible for having the on-site civil engineering test laboratory operated by WGI Quality and Test Programs conduct compressive strength testing of the vault concrete formulations at 14, 28, 56, and 90 days.

SRNL/ES&BT: K. L. Dixon and M. A. Phifer are responsible for setting up a task order on the existing site contract for geotechnical services to measure hydraulic and physical properties of the saltstone grout and vault concrete formulations.

SRNL/ES&BT: K. L. Dixon and M. A. Phifer are responsible for obtaining computed tomography (CT) scans of selected samples used to obtain saturated hydraulic conductivity results.

SRNL/ES&BT: K. L. Dixon, M. A. Phifer, and J. R. Harbour are responsible for preparing a report on the hydraulic and physical properties of the saltstone grout and vault concrete formulations. The report will include sample preparation and testing details and results.

SRNL/PS&E Coordinator: H. H. Burns is responsible for:
- Tracking schedule and budget.
- Interfacing with the PIT personnel to provide status updates as required.

SRNL/QA: E. T. Booth is responsible for reviewing and approving this Task Technical Plan and Quality Assurance Plan and providing QA guidance and oversight of this work.

D. Task Deliverables

1) Schedule and Budget
   - A schedule and budget will be provided by H. H. Burns.

2) Task Technical/Quality Assurance Plan (TT/QAP)

3) Hazards Assessment Package
   - A hazard assessment will be performed for the saltstone sample preparation and physical property testing to be conducted at the Aiken County Technology Laboratory (ACTL) by J Harbour. Based on the assessment, either a new HAP will be written or an existing HAP will be used to cover the testing.
   - The SRNL Conduct of R&D will be followed.

- A new or existing Job Hazards Analysis (JHA) will be used.
- A new or existing Environmental Evaluation Checklist (EEC).

4) Technical Report
   - A draft report will be prepared which will summarize the sample preparation, wet physical property test results, dry physical property test results and hydraulic property test results as obtained from all laboratories contracted for this work. The draft report will be provided to SRIP for review and comment.
   - A final report will be prepared which will incorporate the SRIP comments on the draft report.

II. TASK ACCEPTANCE CRITERIA

Acceptance testing is not an element of this task. Issuance of technical report(s) will complete this task.

III. TASK ACTIVITIES

1) Prepare Task Technical and Quality Assurance Plan: Write task and QA plan and complete conduct of R&D submittals.

2) Preparation of Saltstone Grout Formulations. Saltstone grout samples will be prepared at the Aiken County Technology Laboratory (ACTL) by J. R. Harbour. Three saltstone grout formulations will be prepared. These formulations include DDA saltstone grout (w/c=0.60), ARP/MCU saltstone grout (w/c=0.60), and SWPF saltstone grout (w/c =0.60). Each formulation will consist of the same dry ingredients which are identified in Table 1. The simulants used in each of the three saltstone formulations are identified in Table 2, Table 3, and Table 4. The viscosity, density, weight percent solids , and chemical composition of each simulant will be determined. Each of the three simulants will be prepared in sufficient quantity for the preparation of the samples and the hydraulic and physical property testing to be conducted by the offsite laboratory (~ 2 gallons each).

   Table 5 provides the total number of samples of each saltstone formulation needed to support this task. Compressive strength samples of each saltstone formulation will be 2-in. cube mold samples. Samples prepared for hydraulic testing will be ~2.8 x 6 inch mold samples. A total of seven samples of each saltstone formulation will be prepared for hydraulic testing. The preparation of the samples will be staggered so that each formulation will be tested as closely as possible to a 28 and 90 day curing period. This is necessary because the offsite testing laboratory is limited in the number of samples that can be tested for saturated hydraulic conductivity simultaneously. The tentative schedule for sample preparation is given in Table 6 with preference given to the higher priority formulations. The schedule may be altered depending on the progression of testing at the offsite laboratory.

Table 1. Saltstone Cementitious Materials[1].

Ingredient	Vendor	Premix Blend (wt%)
Portland Cement (Type II)	Holcim	0.10
Blast Furnace Slag (Grade 1)	Holcim	0.45
Fly Ash (Class F)	Cross Station	0.45

[1]A water to premix ratio of 0.60 will be used for each batch.

Table 2. Recipe for DDA Simulant used to Prepare Simulated Saltstone Grout Samples and used as Permeant for Hydraulic and Physical Testing.

Ingredient	Molarity (Moles/Liter)	Mass (g/Liter H_2O)
Sodium Hydroxide, NaOH (50 % by weight)	0.769	61.52
Sodium Nitrate, $NaNO_3$	2.202	187.15
Sodium Nitrite, $NaNO_2$	0.110	7.56
Sodium Carbonate, Na_2CO_3	0.145	15.36
Sodium Sulfate. Na_2SO_4	0.044	6.31
Aluminum Nitrate Nonahydrate, $Al(NO_3)_3$ (9 H_2O)	0.071	26.63
Trisodium Phosphate Dodecahydrate, Na_3PO_4 (12 H_2O)	0.008	3.22

Table 3. Recipe for ARP/MCU Simulant used to Prepare Simulated Saltstone Grout Samples and used as Permeant for Hydraulic and Physical Testing.

Ingredient	Molarity (Moles/Liter)	Mass (g/Liter H_2O)
Sodium Hydroxide, NaOH (50 % by weight)	1.59	127.50
Sodium Nitrate, $NaNO_3$	3.16	268.48
Sodium Nitrite, $NaNO_2$	0.37	25.39
Sodium Carbonate, Na_2CO_3	0.18	18.65
Sodium Sulfate. Na_2SO_4	0.06	8.37
Aluminum Nitrate Nonahydrate, $Al(NO_3)_3$ (9 H_2O)	0.05	20.33
Trisodium Phosphate Dodecahydrate, Na_3PO_4 (12 H_2O)	0.01	4.40

Table 4. Recipe for SWPF Simulant used to Prepare Simulated Saltstone Grout Samples and used as Permeant for Hydraulic and Physical Testing.

Ingredient	Molarity (Moles/Liter)	Mass (g/Liter H_2O)
Sodium Hydroxide, NaOH (50 % by weight)	2.87	229.28
Sodium Nitrate, $NaNO_3$	1.97	167.66
Sodium Nitrite, $NaNO_2$	0.48	33.43
Sodium Carbonate, Na_2CO_3	0.12	12.46
Sodium Sulfate. Na_2SO_4	0.06	7.84
Aluminum Nitrate Nonahydrate, $Al(NO_3)_3$ (9 H_2O)	0.1144	42.90
Trisodium Phosphate Dodecahydrate, Na_3PO_4 (12 H_2O)	0.0073	2.76

Table 5. Saltstone Sample Needs for Compressive Strength, Hydraulic and Physical Property Testing, K_d Measurement, and SRIP.

Test Type	Cure Time (days)	DDA Saltstone	ARP/MCU Saltstone	SWPF Saltstone	Total Number of Samples
Compressive Strength[1]	14	3	3	3	9
	28	3	3	3	9
	56	3	3	3	9
	90	3	3	3	9
Total Number of Compressive Strength	-	**12**	**12**	**12**	**36**
Hydraulic Properties[2]	28	4	4	4	12
	90	3	3	3	9
Total Number of Hydraulic Property Samples	-	**7**	**7**	**7**	**21**
Other Samples: K_d Samples[2]	28	1	1	1	3
SRIP Samples[2]	28	1	1	1	3
Total Number of Other Samples	-	**2**	**2**	**2**	**6**
Total Number of Samples	-	**21**	**21**	**21**	**63**

[1]Compressive strength samples will be 2-in. cube.
[2]Hydraulic property, K_d, and SRIP samples will be ~2.8 x 6 inch mold samples.

Table 6. Tentative Preparation Schedule for Saltstone Grout Formulations and Vault Concrete Formulations (in order of priority).

Preparation Schedule[1]	**Mix**
Week 1	DDA Saltstone Grout (w/c = 0.6)
Week 4	Vault 2 Concrete (Mix 1, Table 8)
Week 7	Vault 1/4 Concrete
Week 10	ARP/MCU Saltstone Grout (w/c = 0.6)
Week 13	SWPF Saltstone Grout (w/c = 0.6)

[1]Sample preparation is staggered so that samples will be tested as closely as possible to a 28 and 90 day curing period. The schedule may be adjusted as necessary depending on the progression of the hydraulic testing.

3) Preparation of Vault 1/4 and Vault 2 Concrete Formulations. Samples of the Vault 1/4 and the Vault 2 concrete will be prepared at the on-site civil engineering test laboratory operated by WGI Quality and Test Programs. The formulation for the Vault 1/4 concrete is given in Table 7. Ingredients for the Vault 1/4 concrete will be obtained from local cement, fly ash, slag, and sand suppliers. Admixtures will be obtained from commercial suppliers. In the case where a specific admixture is no longer available, an equivalent admixture will be identified by WGI and used with the approval of SRNL. Molds for the hydraulic property samples will be supplied by WGI. For the compressive strength testing and saturated hydraulic conductivity testing, 6 x 12 inch concrete test cylinder molds will be used. For the water retention testing, 3 x 6 inch concrete test cylinder molds will be used.

Three variations of the Vault 2 formulation will be prepared with the difference being the amount of cementitious material in each mix. The formulations to be prepared are identified in Tables 8 through 10. The cementitious materials and aggregate are to be obtained from the suppliers as identified in Tables 8 through 10. Admixtures will be obtained from commercial suppliers. Molds for the hydraulic property samples will be supplied by WGI. For the compressive strength testing and saturated hydraulic conductivity testing, 6 x 12 inch concrete test cylinder molds will be used. For the water retention testing, 3 x 6 inch concrete test cylinder molds will be prepared.

Table 7. Saltstone Vault 1/4 Concrete Formulations. (taken from Phifer et al. 2006 Tables 4-5 and 4-6

Ingredient	Vault 1/4 Concrete Samples Formulation
Type II cement (ASTM C 150)	419
Grade 100 Blast furnace slag (ASTM C 989)[1]	278
Type F Fly ash (ASTM C 618)	0
Sand (ASTM C 33)	1133
No. 67 aggregate (maximum ¾ in) (ASTM C 33)	1798
Microair AEA (oz/yd^3)	5.9
Master Builders 300N WRA (oz/yd^3)	40
Water (maximum)	268 (32.1 gal/cu yd)
Water to cementitious material ratio	0.385
Minimum compressive strength at 28 days	4000 psig
Maximum slump	3 in

[1]The original formulation called for Grade 120 Blast furnace slag. Currently, only Grade 100 Blast furnace slag is available.

Table 8. Saltstone Vault 2, Mix 1 Concrete Formulation (670 lbs/cu yd Cementitious Material) (Class 3 Sulfate Resistant Concrete) (taken from Phifer et al. 2006 Tables 4-6, DCR: AC51636A-001 Supplier Document, and personal correspondence with Carlos Chiappetto)

Ingredient	Quantity (lbs/cu yd)
Type V cement (Lehigh T-V #2 ; ASTM C 150)	201
Grade 100 Blast furnace slag (Holcim Grade 100 Slag; ASTM C 989)	268
Silica Fume (W. R. Grace Silica Fume; ASTM C 1240)	44.7
Type F Fly ash (SEFA Class “F” Fly Ash; ASTM C 618)	156.3
sand (Rinker Aggregates Company - Augusta Sand - Natural Washed Sand); ASTM C 33)	911
aggregate (Rinker Aggregates Company - Dogwood Quarry - #67 Granite; ASTM C 33)	1850
Water (maximum)	254.6
Water (maximum; gal/ cu yd)	30.5
Maximum water to cementitious material ratio	0.38
Grace WRDA 35 (oz/cwt c+p)	5
Grace Darex II (oz/cwt c+p)	0.4 to 0.5
Grace Adva 380 (oz/cwt c+p)	3 to 4
Minimum compressive strength of at 28 days	5000 psig
Slump range/target of before Super-P	1 – 3 inches / 2 inches
Slump range/target of after Super-P	6 – 8 inches / 7 inches

[1]Confirm mix order with Lafarge (Carl Darlak 706-823-4471)

Table 9. Saltstone Vault 2, Mix 2 Concrete Formulation (710 lbs/cu yd Cementitious Material) (Class 3 Sulfate Resistant Concrete) (taken from Phifer et al. 2006 Tables 4-6, DCR: AC51636A-001 Supplier Document, and personal correspondence with Carlos Chiappetto)

Ingredient	**Quantity (lbs/cu yd)**
Type V cement (Lehigh T-V #2 ; ASTM C 150)	213
Grade 100 Blast furnace slag (Holcim Grade 100 Slag; ASTM C 989)	284
Silica Fume (W. R. Grace Silica Fume; ASTM C 1240)	47.3
Type F Fly ash (SEFA Class “F” Fly Ash; ASTM C 618)	165.7
sand (Rinker Aggregates Company - Augusta Sand - Natural Washed Sand); ASTM C 33)	911
aggregate (Rinker Aggregates Company - Dogwood Quarry - #67 Granite; ASTM C 33)	1850
Water (maximum)	269.8
Water (maximum; gal/ cu yd)	32.3
Maximum water to cementitious material ratio	0.38
Grace WRDA 35 (oz/cwt c+p)	5
Grace Darex II (oz/cwt c+p)	0.4 to 0.5
Grace Adva 380 (oz/cwt c+p)	3 to 4
Minimum compressive strength of at 28 days	5000 psig
Slump range/target of before Super-P	1 – 3 inches / 2 inches
Slump range/target of after Super-P	6 – 8 inches / 7 inches

[1]Confirm mix order with Lafarge (Carl Darlak 706-823-4471)

Table 10. Saltstone Vault 2, Mix 3 Concrete Formulation (750 lbs/cu yd Cementitious Material) (Class 3 Sulfate Resistant Concrete) (taken from Phifer et al. 2006 Tables 4-6, DCR: AC51636A-001 Supplier Document, and personal correspondence with Carlos Chiappetto)

Ingredient	Quantity (lbs/cu yd)
Type V cement (Lehigh T-V #2 ; ASTM C 150)	225
Grade 100 Blast furnace slag (Holcim Grade 100 Slag; ASTM C 989)	300
Silica Fume (W. R. Grace Silica Fume; ASTM C 1240)	50
Type F Fly ash (SEFA Class “F” Fly Ash; ASTM C 618)	175
sand (Rinker Aggregates Company - Augusta Sand - Natural Washed Sand); ASTM C 33)	911
aggregate (Rinker Aggregates Company - Dogwood Quarry - #67 Granite; ASTM C 33)	1850
Water (maximum)	284
Water (maximum; gal/ cu yd)	34
Maximum water to cementitious material ratio	0.38
Grace WRDA 35 (oz/cwt c+p)	5
Grace Darex II (oz/cwt c+p)	0.4 to 0.5
Grace Adva 380 (oz/cwt c+p)	3 to 4
Minimum compressive strength of at 28 days	5000 psig
Slump range/target of before Super-P	1 – 3 inches / 2 inches
Slump range/target of after Super-P	6 – 8 inches / 7 inches

[1]Confirm mix order with Lafarge (Carl Darlak 706-823-4471)

Table 11. Vault Concrete Sample Needs for Compressive Strength, Hydraulic Property Testing, K_d Measurement, and SRIP.

Test Type	Cure Time (days)	Vault 1/4 Concrete	Vault 2 Concrete Mix 1[a]	Vault 2 Concrete Mix 2[b]	Vault 2 Concrete Mix 3[c]	Total Number of Samples
Compressive Strength[d]	14	2	2	2	2	8
	28	2	2	2	2	8
	56	2	2	2	2	8
	90	2	2	2	2	8
Total Number of Compressive Strength	-	**8**	**8**	**8**	**8**	**32**
Hydraulic Properties[d]	28	3	3	3	3	12
	90	3	3	3	3	12
Total Number of Hydraulic Property Samples	-	**7**	**7**	**7**	**7**	**24**
Water Retention[e]	28	4	4	4	4	4
	90	3	3	3	3	3
Total Number of Water Retention Samples	-	**7**	**7**	**7**	**7**	**28**
Other Samples: K_d Samples[e]	28	1	1	1	1	4
SRIP Samples[d]	28	1	1	1	1	4
Total Number of Other samples	-	**2**	**2**	**2**	**2**	**8**
Total Number of Samples	-	**24**	**24**	**24**	**24**	**92**

[a]Vault 2, Mix 1, with 670 lb of cementitious materials.
[b]Vault 2, Mix 2, with 710 lbs of cementitious materials.
[c]Vault 2, Mix 3, with 750 lbs of cementitious materials.
[d]Samples will be 6 x 12 inch mold samples.
[e]Samples will be 3 x 6 inch mold samples.

4) Use SRNL procedures for preparing and curing samples and for physical property and hydraulic property testing (saltstone and concrete samples).

Wet property measurements include:

- Flow consistency
- Wet unit weight
- Bleed water
- Set Time

- Gel Time – gel time will be measure according to the SRNL method.
- Heat of Hydration - heat of hydration will be measured according to the SRNL method using the SRS isothermal calorimeter.

Applicable ASTM Standards for the compressive strength testing.

- ASTM C 39 (Concrete Samples) – Compressive Strength (at 14, 28, 56, and 90 days)
- ASTM C 109 (Saltstone Samples) – Compressive Strength (at 14, 28, 56, and 90 days)

Applicable ASTM Standards for the hydraulic and physical property testing tasks include:

- ASTM D 5084 – Saturated Hydraulic Conductivity
- ASTM D 2325, 3152, and 6836 – Moisture Retention
- ASTM C 642 – Dry bulk density, porosity

5) Perform compressive strength testing. Compressive strength testing will be conducted on each saltstone grout formulation and vault concrete formulation at 14, 28, 56, 90 days. This includes testing all three variations for the Vault 2 concrete formulation.

6) Perform hydraulic property tests according to the following approach:

- An offsite hydraulic property analysis will be conducted on 3 saltstone grout formulations and two vault concrete formulations (Vault 1/4 and Vault 2 concrete with 670 lbs of cementitious materials). Sample specifications are provided below:

  a. Saltstone Grout Samples:
  - o Seven ~2.8 x 6 inch samples of each saltstone grout formulation will be prepared by SRNL. These samples will be cured in the humid room at the onsite civil engineering test laboratory. Three samples of each formulation will be sent to an offsite subcontract laboratory for testing following a 28 day curing period. The remaining samples will continue to be cured to 90 days. These samples may also be sent to the offsite subcontract laboratory for testing pending the results of the compressive strength testing.

  b. Vault Concrete Samples:
  - o Six 6 x 12 inch mold samples and seven 3 x 6 inch mold samples of the Vault 1/4 concrete formulation (Table 7) will be prepared by WGI Quality and Test Programs at the onsite civil engineering test laboratory. These samples will be cured in the humid room at the onsite civil engineering test laboratory. Three 6 x 12 inch and three 3 x 6 inch mold samples will be sent to an offsite subcontract laboratory for testing following a 28 day curing period. The remaining samples will continue to be cured to 90 days. These samples may also be sent to the offsite subcontract laboratory for testing pending the results of the compressive strength testing.
  - o Six 6 x 12 inch mold samples and seven 3 x 6 inch mold samples of the Vault 2, Mix 1 concrete formulation (Table 8) will be prepared by WGI Quality and Test Programs at the onsite civil engineering test laboratory. These samples will be cured in the humid room at the onsite civil engineering test laboratory. Three 6 x 12 inch and three 3 x 6 inch mold samples will be sent to an offsite subcontract laboratory for testing following a 28 day curing period. The remaining samples will continue to be cured to 90 days. These samples may also be sent to the

offsite subcontract laboratory for testing pending the results of the compressive strength testing.

- Six 6 x 12 inch mold samples and seven 3 x 6 inch mold samples of the Vault 2, Mix 2 concrete formulation (Table 9) will be prepared by WGI Quality and Test Programs at the onsite civil engineering test laboratory. These samples will be cured in the humid room at the onsite civil engineering test laboratory. These samples will be held for potential future testing.
- Six 6 x 12 inch mold samples and seven 3 x 6 inch mold samples of the Vault 2, Mix 3 concrete formulation (Table 10) will be prepared by WGI Quality and Test Programs at the onsite civil engineering test laboratory. These samples will be cured in the humid room at the onsite civil engineering test laboratory. These samples will be held for potential future testing.

- **Saltstone Grout Hydraulic and Physical Properties (Offsite Subcontract Laboratory):** Each saltstone grout formulation will be tested with the simulant used to batch the grout. The simulants will be prepared by J. Harbour and provided to the offsite testing laboratory in sufficient quantity to conduct the required tests (~ 2 gallons of each simulant). A list of the properties to be measured and methods that will be used by the offsite Subcontract Laboratory are listed below.

a. Saturated hydraulic conductivity using method ASTM D 5084 using a flexible wall permeameter.

b. Moisture retention characteristics will be determined using method ASTM D 2325, 3152, and 6856 by pressure plate apparatus. This method will provide the moisture retention properties of each grout sample to 15 bars. Measurements will be made at the following pressures: 0.1, 0.5, 1.0, 5.0, 10.0, and 15.0 bars.

c. Dry bulk density of the grout samples will be determined by dividing the dry weight of the sample by the measured volume (volume determined as stated under bullet d). Because the simulant used to batch each saltstone grout formulation contains salts, the dry bulk density as measured by the offsite lab must be corrected for precipitation of salts. This is accomplished as follows:

The mass of interstitial liquid contained within the sample and corrected dry bulk density are calculated using the following equations.

$$M_{liquid} = \frac{M_{sat} - M_{dry}}{\chi_{wil}}$$

$$\rho_{dry} = \frac{M_{sat} - M_{liquid}}{V_{total}}$$

M_{liquid} = mass of interstitial liquid in sample
M_{sat} = mass of saturated sample
M_{dry} = mass of oven dried sample
χ_{wil}= mass fraction of water in interstitial liquid
V_{total} = total volume of sample
ρ_{dry} = dry bulk density

d. Porosity (*n*) of the saltstone grout samples will be determined following a modified method of ASTM C 642 as follows:
   1) Determine sample volume (Vol) by measuring the cylindrical grout specimens. A minimum of 3 height measurements at 120° from each other and top and bottom diameter measurements at 120° from each other shall be made to determine the volume. Additional measurements shall be made as necessary to compensate for any substantial irregularities in the sample.
   2) Determine the saturated mass (M_{sat}) of the vacuum saturated, surface dried specimen. Follow the requirements of ASTM C 642 Section 5.2 for determining the saturated mass of the specimen (i.e. criteria for acceptable mass measurement).
   3) Determine the oven-dried mass (M_{dry}) of the specimen. Follow the requirements of ASTM C 642 Section 5.1 for determining the oven-dried mass of the specimen (i.e. criteria for acceptable mass measurement). It may take several days to a week to obtain an acceptable oven-dried mass measurement.
   4) Porosity is calculated as:

      $n_o = ((M_{sat} - M_{dry})/p_w) / Vol$

      where p_w = density of water at the temperature used to determine M_{sat} and n_o = uncorrected porosity.

      Because the simulant used to batch each saltstone grout formulation contains salts, the porosity as measured by the offsite lab must be corrected for precipitation of salts. This is accomplished as follows

$$M_{liquid} = \frac{M_{sat} - M_{dry}}{\chi_{wil}}$$

$$V_{liquid} = \frac{M_{liquid}}{\rho_{liquid}}$$

$$\phi = \frac{V_{voids}}{V_{total}} = \frac{V_{liquid}}{V_{total}}$$

M_{liquid} = mass of interstitial liquid in sample
M_{sat} = mass of saturated sample
M_{dry} = mass of oven dried sample
χ_{wil}= mass fraction of water in interstitial liquid
V_{voids} = total volume of voids
V_{liquid} = volume of interstitial liquid in sample
V_{total} = total volume of sample
ρ_{liquid} =density of interstitial liquid
ϕ = corrected porosity

- **Vault Concrete Hydraulic and Physical Properties (Offsite Subcontract Laboratory):** The vault concrete samples will be tested with tap water. A list of the properties and methods that will be used by the offsite Subcontract Laboratory are listed below:
  a. Saturated hydraulic conductivity using method ASTM D 5084 using a flexible wall permeameter using enhanced pressure apparatus.
  b. Water retention characteristics will be determined using method ASTM D 2325, 3152, and 6856 by pressure plate apparatus. This method will provide the water retention properties of each grout/concrete sample to 15 bars. Measurements will be made at the following pressures: 0.1, 0.5, 1.0, 5.0, 10.0, and 15.0 bars.
  c. Dry bulk density of the concrete samples will be determined by dividing the dry weight of the sample by the measured volume (volume determined as stated under bullet d).
  d. Porosity (n) of the concrete samples will be determined following a modified method of ASTM C 642 as follows:
     1) Determine sample volume (Vol) by measuring the cylindrical concrete specimens. A minimum of 3 height measurements at 120^o from each other and top and bottom diameter measurements at 120^o from each other shall be made to determine the volume. Additional measurements shall be made as necessary to compensate for any substantial irregularities in the sample.
     2) Determine the saturated mass (M_{sat}) of the vacuum saturated, surface dried specimen. Follow the requirements of ASTM C 642 Section 5.2 for determining the saturated mass of the specimen (i.e. criteria for acceptable mass measurement).
     3) Determine the oven-dried mass (M_{dry}) of the specimen. Follow the requirements of ASTM C 642 Section 5.1 for determining the oven-dried mass of the specimen (i.e. criteria for acceptable mass measurement). It may take several days to a week to obtain an acceptable oven-dried mass measurement.
     4) Porosity is calculated as:

$$\phi = ((M_{sat} - M_{dry})/p_w) / Vol$$

     where p_w = density of water at the temperature used to determine M_{sat} and ϕ = porosity.

- **Computed Tomography:** Computed tomography (CT) will be performed at SRNL to qualitatively evaluate selected samples of each saltstone grout formulation and vault concrete formulation that was utilized to determine saturated hydraulic conductivity, after they are returned from the testing laboratory (offsite subcontract laboratory). K. Dixon and M. Phifer are responsible for obtaining the computed tomography (CT) scans. Tomographic reconstructions perpendicular to the cylindrical axis will be used to provide cross sectional views of the samples. These views will show pores, cracks, voids, aggregate, cementitious matrix as well as other internal features. Additionally, these scans will show any segregation of materials and provide a general assessment of heterogeneity within the samples. The images from these scans will be used to assess the general quality of each sample. Still images will be captured to show the internal characteristics of each scanned sample.

7) Provide samples for Leach Testing.
One sample of each saltstone grout formulation and the two vault concrete formulations (Vault 1/4 and Vault 2, Mix 1) will be provided to D. Kaplan. Sample dimensions are as noted in Table 5 and Table 11. Samples will be 500 grams minimum and will be provided to D. Kaplan within a week of casting for K_d measurements. This work will be described in a separate TT/QAP.

8) Provide samples to SRIP for demonstration.
One sample of each saltstone grout formulation and the two vault concrete formulations (Vault 1/4 and Vault 2, Mix 1) will be provided to J. Newman. Sample dimensions are as noted in Table 5 and Table 11.

9) Comply with record keeping requirements per SRNL procedure.
Information and results will be recorded in laboratory notebooks and maintained as permanent records. Results from the offsite testing laboratory will be documented in the final technical report in an attachment.

10) Set up and manage a contract with an off site testing laboratory to perform the hydraulic property testing.
Coordinate with an offsite Subcontract Laboratory via the Subcontract Technical Representative, B. Triplett.

11) Transmit results to site customer per the schedule.
Results will be transmitted to J. Newman, PIT. If problematic observation/results are encountered, J. Newman will be notified as soon as possible. A final technical report will be prepared and issued. The report will be provide details on sample preparation (saltstone grout and vault concrete), physical property testing, and hydraulic properties. The report will be prepared and provided by K. Dixon, J Harbour, and M. Phifer. A separate technical report will be prepared by D. Kaplan detailing the results of the K_d measurements.

12) Waste Management and Sample Storage. Waste generated at SRS will be managed and disposed of per the EEC for these activities.

13) SRNL Conduct of R&D. The work performed in this task consists of baseline R&D activities as determined by the Savannah River National Laboratory Procedure L1-7.10, "Control of Technical Work," current revision and the SRNL Conduct of Research and Development Manual. A Hazards Assessment Packages will be prepared for the sample preparation and physical property testing and leach testing.

IV. TASK SCHEDULE

The task activities and associated durations and responsibilities will be provided by H. Burns.

V. RESEARCH FACILITY PLANNING

1) **Products and By-Products.** Job control waste generated during this study will be disposed of as non-hazardous solid non radioactive solid waste.

2) **Disposition of Test Equipment.** The equipment used in this study is expected to be available for future use. Equipment components that can not be reused, empty sample containers and job control waste will be disposed of as non-hazardous solid waste.

3) **Exposure of Personnel.** This work does not involve radioactive materials. Consequently, exposure to radioactivity is not expected. Powders will be handled according to procedures in place at WGI Quality and Testing Programs.

VI. PROGRAMMATIC RISK REVIEW

1) **Impact of delays in setting up needed laboratory equipment.** The technology required to perform this task is mature. Any delays in approving, locating, or setting up test equipment or in preparation of saltstone grout and vault concrete samples will impact the schedule. Unexpected delays at the offsite testing laboratory will impact the schedule. These items will be closely monitored and discussed with the customer.

2) **Impact of failed equipment or technology on the programmatic cost and schedule.** Any delays due to equipment failure will impact the schedule. These items will be closely monitored and discussed with the customer.

3) **Impact of accountable radioisotopes.** No reportable quantities of radioactive material will be received by SRNL as part of this task.

VII. R&D HAZARDS SCREENING CHECKLIST

The R&D Hazards Screening Checklist will be completed prior to start of task activities as part of the HAP.

VIII. REFERENCES

1. Newman, J. L., 2008. "Hydraulic and Physical Testing of Selected Saltstone Grout and Vault Concrete Formulations," Technical Task Request, Q-TTR-Z-00001, Savannah River National Laboratory, Washington Savannah River Company, Aiken SC 29808.

IX. QA Plan Checklist

The following QA Procedures apply for this task (indicate Yes, No or "AR" - as required).

Yes	No	AR	
			1-0 ORGANIZATION
X			1Q, QAP 1-1, Organization
X			L1, 1.02, SRNL Organization
		X	1Q, QAP 1-2, Stop Work
			2-0 QUALITY ASSURANCE PROGRAM
X			1Q, QAP 2-1, Quality Assurance Program
X			L1, 8.02, SRNL QA Program Clarifications, Attachment 8.2-1
X			1Q, QAP 2-2, Personnel Training & Qualification
X			L1, 1.32, Read & Sign
X			1Q, QAP 2-3, Control of Research & Development Activities
X			L1, 8.02, SRNL QA Program Clarifications, Attachment 8.2-3
X			L1, 7.10, Control of Technical Work
X			L1, 7.16, Laboratory Notebooks & Logbooks
	X		1Q, 2-4 Auditor/Lead Auditor Qualification & Certification - does not apply to Immobilization Technology Section Tasks
	X		1Q, 2-5 Qualification & Certification of Independent Inspection Personnel - does not apply to Immobilization Technology Section Tasks
X			1Q, QAP 2-7, QA Program Requirements for Analytical Measurement Systems
			3.0 DESIGN CONTROL
	X		1Q, QAP 3-1, Design Control
	X		L1, 7.10, Control of Technical Work
			4-0 PROCUREMENT DOCUMENT CONTROL
		X	1Q, QAP 4-1, Procurement Document Control
		X	E7, 3.10, Determination of Quality Requirements for Procured Items
		X	7B, Procurement Management Manual (For Reference Only)
		X	3E, Procurement Specification Manual (For Reference Only)
			5-0 INSTRUCTIONS, PROCEDURES & DRAWINGS
X			1Q, QAP 5-1, Instructions, Procedures & Drawings
	X		E7, 2.30, Drawings
X			L1, 1.01, SRNL Procedure Administration
			6-0 DOCUMENT CONTROL
X			1Q, QAP 6-1, Document Control
X			1B, MRP 3.32, Document Control

Yes	No	AR	
			7-0 CONTROL OF PURCHASED ITEMS & SERVICES
		X	1Q, QAP 7-2, Control of Purchased Items & Services
		X	7B, Procurement Management Manual (for reference)
		X	3E, WSRC Procurement Specification Manual (for reference)
	X		1Q, QAP 7-3, Commercial Grade Item Dedication
	X		E7, 3.46, Replacement Item Evaluation/Commercial Grade Item Dedication
			8-0 IDENTIFICATION & CONTROL OF ITEMS
		X	1Q, QAP 8-1, Identification & Control of Items
		X	L1, 8.02, SRNL QA Program Clarifications, Attachment 8.8-1
	X		**9-0 CONTROL OF PROCESSES**
			10-0 INSPECTION & VERIFICATION
	X		1Q, QAP 10-1, Inspection & Verification
	X		L1, 8.10, Inspection
			11-1 TEST CONTROL
	X		1Q, QAP 11-1, Test Control
			12-1 CONTROL OF MEASURING & TEST EQUIPMENT
X			1Q, QAP 12-1, Control of Measuring & Test Equipment
	X		1Q, QAP 12-2, Control of Installed Process Instrumentation
	X		1Q, QAP 12-3 Control & Calibration of Radiation Monitoring Equipment - does not apply to Immobilization Technology Section Tasks
			13-0 PACKAGING, HANDLING, SHIPPING & STORAGE
X			1Q, QAP 13-1, Packaging, Handling, Shipping & Storage
X			L1, 8.02, SRNL QA Program Clarifications, Attachment 8.13-1
			14-0 INSPECTION, TEST & OPERATING STATUS
	X		1Q, QAP 14-1, Inspection, Test & Operating Status
	X		L1, 8.02, SRNL QA Program Clarifications, Attachment 8.14-1
			15-0 CONTROL OF NONCONFORMING ITEMS
		X	1Q, QAP 15-1, Control of Nonconforming Items
		X	L1, 8.02, SRNL QA Program Clarifications, Attachment 8.15-1
		X	1B, 4.23, STAR

Yes	No	AR	
			16-0 CORRECTIVE ACTION SYSTEM
		X	1Q, QAP 16-3, Corrective Action Program
		X	1.01, MP 5.35, Corrective Action Program
		X	1B, 4.23, STAR
			17-0 QA RECORDS MANAGEMENT
X			1Q, QAP 17-1, QA Records Management
X			L1, 8.02, SRNL QA Program Clarifications, Attachment 8.17-1
X			L1, 7.16, Laboratory Notebooks & Logbooks
			18-0 AUDITS
		X	1Q, QAP 18-2, Quality Assurance Surveillance
		X	1Q, QAP 18-3, Quality Assurance External Audits
		X	1Q, QAP 18-4, Management Assessments
		X	12Q, Assessment Manual
		X	1Q, QAP 18-6, Quality Assurance Internal Audits
		X	1Q, QAP 18-7, Quality Assurance Supplier Surveillance
			19-0 QUALITY IMPROVEMENT
		X	1Q, QAP 19-2, Quality Improvement
		X	L1, 8.02, SRNL QA Program Clarifications, Attachment 8.19-2
			20-0 SOFTWARE QUALITY ASSURANCE
	X		1Q, QAP 20-1, Software Quality Assurance
	X		L1, 8.20, Software Management & Quality Assurance
	X		**21-1 ENVIRONMENTAL QUALITY ASSURANCE**
			In addition to procedures noted above, if RW-0333P requirements are invoked, the following procedures apply. These procedures may also apply at the discretion of the Task Leader to non-RW-0333P tasks.
	X		L1, 8.21, Supplemental QA Requirements for DOE/RW-0333P
			Sample Control:
X			L1, 7.15, Obtaining Analytical Support
			Scientific Investigation:
X			L1, 7.16, Laboratory Notebooks & Logbooks

Note: This is a technical baseline task.

X. Identify any exceptions or additions to the procedures listed in the QA Matrix:

None

XI. Complete this part only if Section 20 procedures (software) are invoked. Identify who will act in each of the following capacities. If Section 20 is N/A, mark these N/A.

Owner: NA
Designer: NA
Maintainer: NA
Tester: NA

XII. Document Approval:

List of documents requiring management, customer, and/or CQF approval:

Document	**Management**		**Customer**		**CQF**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Technical & QA Plan	**X**		**X**		**X**	
SRNL Work Instructions if required in addition to ASTM procedures	X					
Final Report: Sample preparation, wet property testing, hydraulic property testing	**X**		**X**			

XIII. Anticipated Records:

The following records are anticipated from this task. Yes, No or AR (as required)

Yes	**No**	**AR**	**Description**
X			Task Technical & QA Plan
X			Technical Notebooks
X			Task Technical Reports
	X		Data Qualification Reports
		X	Supporting Documentation
X			Offsite Test Results

XIV. Attachment

None