SCIENTIFIC NOTEBOOK # 779E
Rubble Flow Laboratory Experiment

by

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Southwest Research Institute®
Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

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INITIAL INFORMATION

Scientific Note book:	# 779E
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Project Title:	Rubble Flow Laboratory Experiment
Project Number:	14002.01.121 previously 06002.01.262
Principal Investigator:	Chandrika Manepally
Notebook Contributors:	Don Bannon, Robert J. Lenhard, Ph.D., and Chandrika Manepally
Project Description:	The Rubble Flow Laboratory Experiment involves understanding of factors that affect flow processes in rubble. These efforts are intended to improve realism of TPA code parameters controlling convergence and divergence of water in rubble.

By agreement with the CNWRA QA, this notebook is to be printed at approximate semiannual intervals. This computerized scientific notebook is intended to address the criteria of CNWRA QAP-001.

In-process entries documented in this notebook were made by the staff member performing the activities. No original text entered into this scientific notebook has been removed.

Specific entries are organized into chapters.

CHAPTER 1
Receipt of Rock Samples from Sample Management Facility

16 Jan. 2006, Don Bannon
Four 55-gallon drums were received from
Sample Management Facility
Yucca Mountain Characterization Project
P.O. Box 617
Mercury, NV 89023-0617

Specimen ID: 01016729
Sample ID: ECRB-01016729-DR1
Description of sample: ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 1

Specimen ID: 01016729
Sample ID: ECRB-01016729-DR2
Description of sample: ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 2

Specimen ID: 01016729
Sample ID: ECRB-01016729-DR3
Description of sample: ESF ECRB Sta 16+69 Right Rib Mixed Fraction Drum 3

Specimen ID: 01016729
Sample ID: ECRB-01016729-DR4
Description of sample: ESF ECRB Sta 16+69 Right Rib Mixed Fraction Drum 4

CHAPTER 2
Subsample details

16 Jan. 2006, Don Bannon
Approx. one gallon of mixed fraction material from ECRB-01016729-DR3 was removed and placed into doubled zip-lock clear plastic bags. Sample ID of this sample is: ECRB-01016729-DR3-001. Sample is located in Bldg. 51.

09 Feb. 2006, Don Bannon
Subsamples A and B were made from Drum 1. Contents of 55-gallon drum were placed into two blue plastic 30-gallon containers; A and B.
That is, ECRB-01016729-DR1-A and ECRB-01016729-DR1-B
Samples are located in Bldg. 51.

From ECRB-01016729-DR1-A was made approx. 2.5 gallons, stored in a 5 gallon container labelled: ECRB-01016729-DR1-A-01.
This was sieved using a 5/16 inch sieve (ASTM E-11), 8 mm opening.
Sample is located in Bldg. 51.

24 Apr. 2006, Don Bannon
P.O. 682292E, Raba-Kistner performs sieving of 55-gallon drums 2 and 4; ECRB-01016729-DR2 and ECRB-01016729-DR4.

34 five gallon buckets now hold the sieved material,
19 buckets from ECRB-01016729-DR2 located in GED lab in Bldg. 51.
15 buckets from ECRB-01016729-DR4 located in GED lab in Bldg. 51.

14 July 2010, Don Bannon
The 34 five gallon buckets which are noted in the previous entry are located in GED Trailer 52.

In this scientific notebook, Sample Custody/Control Log Entry Forms serve the purpose of being the Sample Control Log.

GEOSCIENCES AND ENGINEERING DIVISION **SAMPLE CUSTODY/CONTROL LOG ENTRY FORM**
SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR1
DESCRIPTION OF SAMPLE (Mandatory): ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 1
Received from Sample Management Facility, Yucca Mountain Characterization Project,
P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729
REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:
AMOUNT OF SAMPLE: Qty of 1 SIZE: 55 gallon drum
DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 12 DEC 05
PERSON(S) WHO COLLECTED SAMPLE:
DATE OF INITIAL LOG ENTRY (Mandatory): 16 JAN 2006 BY(Mandatory): Don Bannon
SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.
Bldg. 51
COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:
OTHER: Original shipment consisted of four 55 gal. drums. Two originally marked ESF ECRB Sta 16+69 Right Rib Large Fraction are per sample control log ECRB-01016729-DR1 and ECRB-01016729-DR2. Two originally marked ESF ECRB Sta 16+69 Right Rib Mixed Fraction are per sample control log ECRB-01016729-DR3 and ECRB-01016729-DR4.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION

SAMPLE CUSTODY/CONTROL LOG ENTRY FORM

SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR1-A

DESCRIPTION OF SAMPLE (Mandatory): Subsample A from ECRB-01016729-DR1, ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 1

Received from Sample Management Facility, Yucca Mountain Characterization Project,

P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729

REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:

AMOUNT OF SAMPLE: Qty of 1 SIZE: 30 gallon container

DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 12 DEC 05

PERSON(S) WHO COLLECTED SAMPLE:

DATE OF INITIAL LOG ENTRY (Mandatory): 09 FEB 2006 BY(Mandatory): Don Bannon

SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.

Bldg. 51

COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:

OTHER: This container is a large blue plastic barrel.
Original shipment consisted of four 55 gal. drums.
Two originally marked ESF ECRB Sta 16+69 Right Rib Large Fraction are per sample control log ECRB-01016729-DR1 and ECRB-01016729-DR2.
Two originally marked ESF ECRB Sta 16+69 Right Rib Mixed Fraction are per sample control log ECRB-01016729-DR3 and ECRB-01016729-DR4.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION **SAMPLE CUSTODY/CONTROL LOG ENTRY FORM**
SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR1-A-01
DESCRIPTION OF SAMPLE (Mandatory): Subsample 01 from ECRB-01016729-DR1-A from ECRB-01016729-DR1, ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 1
Received from Sample Management Facility, Yucca Mountain Characterization Project,
P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729
Sample obtained using 5/16 inch sieve (ASTM E-11), 8 mm opening.
REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:
AMOUNT OF SAMPLE: Approx. 2-1/2 gallons. SIZE: 5 gallon container
DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 9 FEB 2006
PERSON(S) WHO COLLECTED SAMPLE:
DATE OF INITIAL LOG ENTRY (Mandatory): 09 FEB 2006 BY(Mandatory): Don Bannon
SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.
Bldg. 51
COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:
OTHER: The container is a white translucent round container with handle on top.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION

SAMPLE CUSTODY/CONTROL LOG ENTRY FORM

SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR1-B

DESCRIPTION OF SAMPLE (Mandatory): Subsample B from ECRB-01016729-DR1, ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 1

Received from Sample Management Facility, Yucca Mountain Characterization Project,

P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729

REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:

AMOUNT OF SAMPLE: Qty of 1 SIZE: 30 gallon container

DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 12 DEC 05

PERSON(S) WHO COLLECTED SAMPLE:

DATE OF INITIAL LOG ENTRY (Mandatory): 09 FEB 2006 BY(Mandatory): Don Bannon

SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.

Bldg. 51

COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:

OTHER: This container is a large blue plastic barrel.
Original shipment consisted of four 55 gal. drums.
Two originally marked ESF ECRB Sta 16+69 Right Rib Large Fraction are per sample control log ECRB-01016729-DR1 and ECRB-01016729-DR2.
Two originally marked ESF ECRB Sta 16+69 Right Rib Mixed Fraction are per sample control log ECRB-01016729-DR3 and ECRB-01016729-DR4.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION

SAMPLE CUSTODY/CONTROL LOG ENTRY FORM

SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR2

DESCRIPTION OF SAMPLE (Mandatory): ESF ECRB Sta 16+69 Right Rib Large Fraction Drum 2

Received from Sample Management Facility, Yucca Mountain Characterization Project,

P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729

REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:

AMOUNT OF SAMPLE: Qty of 1 SIZE: 55 gallon drum

DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 12 DEC 05

PERSON(S) WHO COLLECTED SAMPLE:

DATE OF INITIAL LOG ENTRY (Mandatory): 16 JAN 2006 BY(Mandatory): Don Bannon

SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.

Container is in custody of Raba-Kistner for sieve analysis; purchase requisition 06019428.

COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:

OTHER: Original shipment consisted of four 55 gal. drums.
Two originally marked ESF ECRB Sta 16+69 Right Rib Large Fraction are per sample control log ECRB-01016729-DR1 and ECRB-01016729-DR2.
Two originally marked ESF ECRB Sta 16+69 Right Rib Mixed Fraction are per sample control log ECRB-01016729-DR3 and ECRB-01016729-DR4.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION

SAMPLE CUSTODY/CONTROL LOG ENTRY FORM

SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR3

DESCRIPTION OF SAMPLE (Mandatory): ESF ECRB Sta 16+69 Right Rib Mixed Fraction Drum 3

Received from Sample Management Facility, Yucca Mountain Characterization Project,

P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729

REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:

AMOUNT OF SAMPLE: Qty of 1 SIZE: 55 gallon drum

DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 12 DEC 05

PERSON(S) WHO COLLECTED SAMPLE:

DATE OF INITIAL LOG ENTRY (Mandatory): 16 JAN 2006 BY(Mandatory): Don Bannon

SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.

Bldg. 51

COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:

OTHER: Original shipment consisted of four 55 gal. drums.
Two originally marked ESF ECRB Sta 16+69 Right Rib Large Fraction are per sample control log ECRB-01016729-DR1 and ECRB-01016729-DR2.
Two originally marked ESF ECRB Sta 16+69 Right Rib Mixed Fraction are per sample control log ECRB-01016729-DR3 and ECRB-01016729-DR4.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION

SAMPLE CUSTODY/CONTROL LOG ENTRY FORM

SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR3-001

DESCRIPTION OF SAMPLE (Mandatory): Approx. one gallon of mixed fraction material. ESF ECRB Sta 16+69 Right Rib Mixed Fraction Drum 3

Received from Sample Management Facility, Yucca Mountain Characterization Project,

P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729

REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:

AMOUNT OF SAMPLE: Qty of 1 SIZE: Approx. one gallon stored in two zip-lock clear plastic bags.

DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): 16 JAN 2006

PERSON(S) WHO COLLECTED SAMPLE: Don Bannon

DATE OF INITIAL LOG ENTRY (Mandatory): 16 JAN 2006 BY(Mandatory): Don Bannon

SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.

Bldg. 51

COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:

OTHER: Sample is contained in double zip-lock bags.

FORM TOP-004 (8/2005)

GEOSCIENCES AND ENGINEERING DIVISION

SAMPLE CUSTODY/CONTROL LOG ENTRY FORM

SAMPLE IDENTIFICATION (Mandatory): ECRB-01016729-DR4

DESCRIPTION OF SAMPLE (Mandatory): ESF ECRB Sta 16+69 Right Rib Mixed Fraction Drum 4

Received from Sample Management Facility, Yucca Mountain Characterization Project,

P.O.Box 617, Mercury, NV 890223-0617. Specimen ID: 01016729

REFERENCE TO DOCUMENTATION OR SCIENTIFIC NOTEBOOK ENTRY:

AMOUNT OF SAMPLE: Qty of 1 SIZE: 55 gallon drum

DATE OF SAMPLE RECEIPT, COLLECTION, OR SYNTHESIS (Mandatory): Collected 12 DEC 05

PERSON(S) WHO COLLECTED SAMPLE:

DATE OF INITIAL LOG ENTRY (Mandatory): 16 JAN 2006 BY(Mandatory): Don Bannon

SAMPLE STORAGE LOCATION (Mandatory) Note: Update location when sample is moved.

Bldg. 51

COLLECTION SITE (Reference Maps or Field Notes As Required) or SUPPLIER:

OTHER: Original shipment consisted of four 55 gal. drums.
Two originally marked ESF ECRB Sta 16+69 Right Rib Large Fraction are per sample control log ECRB-01016729-DR1 and ECRB-01016729-DR2.
Two originally marked ESF ECRB Sta 16+69 Right Rib Mixed Fraction are per sample control log ECRB-01016729-DR3 and ECRB-01016729-DR4.

FORM TOP-004 (8/2005)

Received Shipment ID 01000911 consisting of:

Specimen ID
01042600 55 gal. drum Plot 1 Subarea A
01042601 55 gal. drum Plot 2 Subarea A
01042602 55 gal. drum Plot 2 Subarea B
01042603 55 gal. drum Plot 3
01042604 rock sample on pallet
01042605 rock sample on pallet
01042606 rock sample on pallet
01042607 rock sample on pallet
01042608 rock sample on pallet

Returned acknowledgment that samples (Shipment ID 01000911, above) were received, to:
Sample Management Facility
Yucca Mountain Site Characterization Project
P.O. Box 617
Mercury, NV 89023-0617

These samples are housed in SwRI Bldg. 51.

11MAY2007
Per Robert Lenhard, removed contents of Specimen ID containers (55 gal. drums) 01042601 and 01042602, placed on back dock of SwRI 51, covered by tarp.

15 MAY 2007
Objective:
Determine bulking factor associated from samples collected. A description of the samples and methods used to collect the samples are discussed in trip report AI20.06002.01.262.706. The approach will be to measure the rubble mass that can be packed into two test containers possessing different surface area to volume relationships (one container 0.61 meter cubed; one container 0.915 x 0.61 x 0.405 meter). This will yield the bulk density of the rubble mass and associated void spaces in a total volume unit.
The next step will be to measure the associated rubble volume that is contained in the containers. The bulking factor is the rubble volume, without void spaces, divided by the total volume (rubble plus void volume) occupied by the same rubble mass.

Procedures:
1. Removed samples from Plot 2 Subareas A and B containers (55 gal. drums), placed on plastic sheet to observe relative size distribution.
2. Measure the specific density of the rubble. This will be done by measuring the mass of individual rubble sections and their associated volume via displacement of water. Rubble sections will be placed into containers completely filled with water. The mass of the displaced water, which will be an indirect measurement of rubble volume, will be measured. A 50mL, adjusted, Gay-Lussac bottle will be used to measure the density of water for conditions at which we conduct the measurements. This will yield the specific density of the displaced water. Knowing the mass of the displaced water, we can determine the volume of the displaced water, which is equal to the volume of the rubble section. The specific density of the rubble sections can be determined by dividing the mass of the rubble section by it's associated volume. This process will be conducted for several rubble sections to determine a range in specific density of the rubble and an average value.

15MAY2007
3. Using a subsample of the samples in step 1 above, consisting of similar size distributions, a test container will be packed. The mass of all rubble sections contained in the test container will be recorded.
4. From the mass of all rubble sections packed into a test container, we can determine the volume of the rubble sections from the average specific density of the rubble (determined in step 2 above).
5. The bulking factor associated with each packing of the test containers is determined by dividing the volume of the test containers by the rubble volume contained in those test containers that are adjusted to account for fracture and lithophysal porosity. The rubble volume is determined in step 4.

Steps 3 - 5 will be performed multiple times to obtain a range of bulking factors.

16MAY2007
Measurements:
1. Determination of water density (same water used to determine rock densities).
A 50 ml Gay-Lussac bottle was filled with water and the mass determined.

Mass of water: replicate 1 = 49.817 grams; replicate 2 = 49.816 grams (average 49.8165 g.).

Mass density of water: 49.8165 g / 50 ml = 0.996 g/cm3

(Water used reflect those conditions existing for measurements conducted in 2 below.)

2. Determination of rock density.

The volume of water displaced from a water filled container was determined for each rock sample.

Rock sample	Mass (g)	Mass - displaced water (g)	Volume - displaced water (cm^3)	Rock mass density (g/cm^3)
2a	643.5	278.14	279.26	2.30
2b	643.5	276.65	277.76	2.32
4a	1701.3	732.09	735.03	2.31
4b	1701.3	729.99	732.92	2.32
1a	1416.2	606.06	608.49	2.33
1b	1416.2	614.41	616.88	2.30

Note: Because of the close grouping of measured densities, we felt further measurements were not required.

Range of rock mass densities: 2.30 g/cm^3 to 2.33 g/cm^3.

Average rock mass density: 2.31 g/cm^3.

16MAY2007
(The above average rock mass density will be used to convert rubble mass contained in the test containers to rubble volume contained in the test container.)

Assuming a fracture/lythophysal porosity of 1 per cent (1%), the mass density of the intact rock can be determined from:

$$0.99 = x/2.31 \text{ g/cm}^3$$

3. Determination of bulk density using the test containers and rubble volume in those containers.

Container 1: 61cm x 61cm x 61cm = 226981 cm^3

Container 2: 91.5cm x 40.5cm x 61cm = 226050.8 cm^3

17MAY2007
A majority portion of rubble was removed from the plastic sheet and placed, or packed, in Container #1 (61 cm x 61 cm x 61 cm) approximating the same rubble distribution. Rubble fragments were oriented in the container to minimize open spaces along container walls. Mass of samples was determined by measuring rubble portions using Sartorius balance, AN001444, cal. due date 11-03-07. Containers were packed with different size rocks to represent distribution of rock sizes in drums as arrived.

Rubble samples were removed from Container #1 and packed alternately in Container #2, each time measuring mass and orienting samples within container so as to minimize open spaces along container walls. Unused rubble samples still on plastic sheet occasionally were substituted for previously used rubble samples so as to imitate various rubble distributions.

Packing	Container	Total Mass (g)	Container volume (cm^3)	Mass density (g/cm^3)
1	1	244047.2	226981	1.075
2	2	256285.3	226050.7	1.134

18MAY2007
Accomplished packings 3 and 4 in Containers 1 and 2, respectively.

Packing	Container	Total Mass (g)	Container volume (cm^3)	Mass density (g/cm^3)
3	1	257121.6	226981	1.133
4	2	260736.1	226050.8	1.153

23MAY2007
Accomplished packing 5 this date. This packing was performed with greater percentage of fines relative to distribution in drums as originally supplied.

Packing	Container	Total Mass (g)	Container volume (cm^3)	Mass density (g/cm^3)
5	1	284343.7	226981	1.253

25MAY2007
Accomplished packing 6 this date.

Packing	Container	Total Mass (g)	Container volume (cm^3)	Mass density (g/cm^3)
6	2	273166.8	226050.8	1.208
7	1	276323.5	226981	1.217

Summary Packing table consisting of above tables:

Packing	Container	Total Mass (g)	Container volume (cm^3)	Mass density (g/cm^3)
1	1	244047.2	226981	1.075
2	2	256285.3	226050.8	1.134
3	1	257121.6	226981	1.133
4	2	260736.1	226050.8	1.153
5	1	284343.7	226981	1.253
6	2	273166.8	226050.8	1.208
7	1	276323.5	226981	1.217

1JUNE2007
Total volume of 55 gal. drum: 215854.559 cm^3 based on:
r=28.6 cm, derived from d=57.2 cm
h=84 cm

Plot2 SubareaA
Determine volume of material in 55 gallon drum Plot 2 Subarea A:
pi*r^2*h = cylinder volume

Plot2 Subarea A volume of empty space = 51393.943 cm^3 based on:
r=28.6 cm
h=20 cm (see picture PLOT2SubA-open2.jpg)

Plot2 Subarea A volume of full space = total volume - empty volume
164460.616 cm^3

1JUNE2007
Plot2 SubareaB
Determine volume of material in 55 gallon drum Plot 2 Subarea B:
pi*r^2*h = cylinder volume

Plot 2 Subarea B volume of empty space = 33406.063 cm^3 based on:
r=28.6 cm
h=13 cm (see picture PLOT2SubB-open2.jpg)

Plot2 Subarea B volume of full space = total volume - empty volume
182448.496 cm^3

Plot 1
Determine volume of material in 55 gallon drum Plot 1:
pi*r^2*h = cylinder volume

Plot 1 volume of empty space = 61672.731 cm^3 based on:
r=28.6 cm
h=24 cm (see picture PLOT1SubA.jpg)

Plot 1 volume of full space = total volume - empty volume
154181.828 cm^3

Plot 3
Determine volume of material in 55 gallon drum Plot 3:
pi*r^2*h = cylinder volume

Plot 3 volume of empty space = 143903.039 cm^3 based on:
r=28.6 cm
h=56 cm (see picture PLOT3-open2-56cm.jpg)

Plot 3 volume of full space = total volume - empty volume
71951.520 cm^3

8JANUARY2008
Information this date was provided by Robert J. Lenhard, Ph.D.

The purpose of the following two sections is to estimate the in-situ rock mass density and the bulking factor utilizing the measurements conducted earlier to determine the mass density of rubble and the bulk mass density of rubble packings, including void spaces between the rubble fragments.

A. Estimation of In-Situ Rock Mass Density
To estimate *in-situ* rock mass density form measured mass densities of rubble fragments, an adjustment is necessary to account for void spaces in fractures and lithophysal. If in a given rock mass, the fracture and lithophysal porosity is 'X' percent, then the corresponding mass density of the *in-situ* rock can be determined from

in-situ mass density = [1-(X/100)] (mass density of rock with no fractures or lithophysal)

In the mass density measurements of the individual rubble fragments, there was no void space in fractures and no lithophysal was observed. Using the average mass density of the rubble fragments for the mass density of rock with no fractures or lithophysal, the estimated *in-situ* rock mass density for fracture and lithophysal porosities of 1, 5, 10, 20, and 35 percent, respectively, are shown under the two left-most columns (columns titled "Fracture/Lithophysal Porosity" and "*In-Situ* Rock Mass Density") of Table 1.

Table 1

Fracture/Lithophysal Porosity	*In-Situ* Rock Mass Density	Packed Rubble Mass Density	Bulking Factor
1%	2.29 g/cm^3 [142.96 lbs/ft^3]	1.08 g/cm^3 [67.42 lbs/ft^3]	2.12
		1.25 g/cm^3 [78.04 lbs/ft^3]	1.83
5%	2.19 g/cm^3 [136.72 lbs/ft^3]	1.08 g/cm^3 [67.42 lbs/ft^3]	2.03
		1.25 g/cm^3 [78.04 lbs/ft^3]	1.75
10%	2.08 g/cm^3 [129.85 lbs/ft^3]	1.08 g/cm^3 [67.42 lbs/ft^3]	1.93
		1.25 g/cm^3 [78.04 lbs/ft^3]	1.66
20%	1.85 g/cm^3 [115.50 lbs/ft^3]	1.08 g/cm^3 [67.42 lbs/ft^3]	1.71
		1.25 g/cm^3 [78.04 lbs/ft^3]	1.48
35%	1.50 g/cm^3 [93.87 lbs/ft^3]	1.08 g/cm^3 [67.42 lbs/ft^3]	1.39
		1.25 g/cm^3 [78.04 lbs/ft^3]	1.20

The Department of Energy (Sanchez, 2001) reported average total porosity values from modern and historical geophysical data for the *in-situ* upper lithophysal rock at Yucca Mountain of approximately 20 percent. However, the fracture and lithophysal porosity is likely to vary and be spatially variable.

Sanchez, P. 2001. Data Qualification Report: Calculated Porosity and Porosity-Derived Values for Lithostratigraphic Units for Use on the Yucca Mountain Project. *U.S. Department of Energy*, TDR-NBS-GS-000020, Rev. 00.

B. Estimation of Bulking Factor

Utilizing the above *in-situ* rock mass density estimates and the measured packed rubble mass densities, an estimate of the bulking factor can be calculated by dividing the *in-situ* rock mass density estimate by the measured packed rubble mass density. Using low and high values for the packed rubble mass densities, estimates for bulking factors are found in the two right-most columns (columns titled "Packed Rubble Mass Density" and "Bulking Factor") of Table 1. The estimated bulking factor are consistent with other reported values. A bulking factor of 1.72 is listed for granite, 1.60 for porous sandstone, 1.63 for limestone, and 1.64 for basalt (Department of Transport, *Manual of Contract Documents for Highway Works*, Vol. 1, Specification of Highway Works, Series 600 - Earthworks, 1993). In a building catalogue listing densities of materials used in building and construction (found on the web site http://www.orequalonline.com/BCWebsite/infotables/Densities.html), the difference between solid and rubble limestone yields a bulking factor of 2.0, and the difference between solid and

rubble shale yields a bulking factor of 1.55. In a pocket reference (Pocket PCRerf by Glover and Young, 1999, Sequoia Publishing, Inc., Littleton, CO), rock bulking factors for granite, limestone, and sandstone are listed in the Mine, Mill & Aggregate section. The bulking factors for granite, limestone, and sandstone are 1.75, 1.75, and 1.75, respectively. All in relative agreement with the above estimates and other reported values. Additionally, the measured porosities of talus rubble in the Rocky Mountains of Colorado (Davinroy, 2000) suggest that the bulking factor may vary from 1.75 to 2.5.

Davinroy, T. 2000. Hydrologic and Biogeochemical Characteristics of Alpine Talus, Colorado Front Range. Ph.D. dissertation, Department of Geography, *University of Colorado*, Boulder.

28JANUARY2008
Information this date was provided by Chandrika Manepally

Based on discussion with ENG2 staff (G. Ofegbu, L. Ibarra) and Center management team (S. Mohanty, G. Wittmeyer, and B. Sagar), it was decided that instead of using the laboratory determined *In-Situ* Rock Density, DOE values should be used. The basis for DOE values is available in the DOE AMR Subsurface Geotechnical Parameters Report (Bechtel SAIC Company, LLC. "Subsurface Geotechnical Parameters Report" 800-K0C-WIS0-00400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003). The attached memo by G.I. Ofoegbu (BulkDensity_TopopahSpringTuff_04-03-2007.pdf) provides details related to the values. The dry bulk density values are appropriate for this calculation because (i) the rubble fragments used in determining the rubble bulk densities were dry; and (ii) the rubble is expected to remain dry in the drift at Yucca Mountain for significant duration of the performance period.

The bulking factor calculation of the rubble using DOE value for *in-situ* rock density is provided in the attached spreadsheet (DOEvaluesBF-SN779E.xls). The following table shows the estimated bulking factors.

Packing Number	Container	Rubble Density (kg/m3)	Bulking Factor assuming Insitu rock density of 1979 kg/m3	Bulking Factor assuming Insitu rock density of 1979 kg/m3
1	1	1080	1.83	83.2
2	2	1130	1.75	75.1
3	1	1130	1.75	75.1
4	2	1150	1.72	72.1
5	1	1250	1.58	58.3
6	2	1210	1.64	63.6
7	1	1220	1.62	62.2

ENDING STATEMENT

Entries into Scientific Notebook No. 779E for pages 1 to 19 in the period between February 28, 2006 to 20 MAY 2011 have been made by Don Bannon and other project staff (see staff listed in the initial information section). In-process entries documented in this notebook were made by the staff member performing the activities, and the staff member is identified in those cases. No original text entered into this Scientific Notebook has been removed.

Don Bannon

20 MAY 2011
Date