Standard Operating Procedure No. 35

Volumetric Moisture Content

REVISION LOG		
Revision Number	Description	Date
35.0	Original SOP	11/6/03
35.1	Revisions by PJP	1/14/04
35.2	Revisions by JMS	8/30/04
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1.0 PURPOSE AND SCOPE

This Standard Operating Procedure describes one method for determining volumetric moisture content (θ). Volumetric moisture content is a measure of the proportion of void (pore) volume occupied by water or some other liquid in a sample of porous material at a specific time. Volumetric moisture content can be calculated from the gravimetric moisture content (SOP 40) and either the bulk density (SOP 32 or SOP 70) or the sample volume (also determined in SOP 32) and the porosity (SOP 42) of the material. Degree of saturation (also called saturation) can be calculated from volumetric moisture content and the porosity. Variably saturated flow models, e.g., FEHM [Zyvoloski, 1997], HYDRUS-2D [Simunek et al, 1999], and VS2D [Lappala et al, 1987], as well as seepage models such as SoilVision's SVFlux, use volumetric moisture content or saturation as a state variable.

Unlike gravimetric moisture content (SOP 40), correctly determining *in situ* volumetric moisture content requires knowledge of the sample's bulk density or the volume of the undisturbed sample. If either bulk density (SOP 32) or sample volume are known, then

the volumetric moisture content can be determined by measuring the gravimetric moisture content and then applying an appropriate correction factor. If undisturbed sample volume or bulk density is not known, then the sample must be collected without disturbing its bulk density (or volume). Once the sample volume is known, its bulk density and porosity (SOP 42) can be determined easily.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The Team Leader and Characterization Team will have the overall responsibility for implementing this SOP. They will be responsible for assigning appropriate staff to implement this SOP and for ensuring that the procedures are followed accurately.

All personnel performing these procedures are required to have the appropriate health and safety training. In addition, all personnel are required to have a complete understanding of the procedures described within this SOP, and receive specific training regarding these procedures, if necessary.

All environmental staff and assay laboratory staff are responsible for reporting deviations from this SOP to the Team Leader.

3.0 DATA QUALITY OBJECTIVES

This SOP addresses objectives 1 and 7 in the data quality objectives outlined by Virginia McLemore for the "Geological and Hydrological Characterization at the Molycorp Questa Mine, Taos County, New Mexico".

- Determine how the hydrogeochemistry and water balance dynamics influence rock pile weathering and stability.
- Determine if pyrite oxidation, moisture content, and microbe populations affect rock pile weathering and stability.

4.0 RELATED STANDARD OPERATING PROCEDURES

The procedures set forth in this SOP are intended for use with the following SOPs:

- SOP 1 Data management (including verification and validation)
- SOP 2 Sample management (chain of custody)
- SOP 4 Taking photographs
- SOP 5 Sampling outcrops, rock piles, and drill core (solid)
- SOP 6 Drilling, logging, and sampling of subsurface materials (solid)
- SOP 7 Decontamination of sampling equipment
- SOP 32 Bulk Density
- SOP 40 Gravimetric moisture content
- SOP 42 Porosity

The procedures set forth in this SOP are also intended for use with the drill plans and sampling plans.

5.0 EQUIPMENT LIST

The following materials are required for collecting samples for volumetric moisture content (field):

- Aluminum foil or plastic wrap
- Plastic or metal coring cylinders (if needed)
- Coring device (if needed)
- Ziploc bags
- Weatherproof labels
- Bubble wrap and tape
- Boxes or coolers to store and transport wrapped samples in an undisturbed state
- Thermometer
- Indelible marker
- Gravimetric moisture content field sample forms (Appendix 1)

The following materials are required for analyzing samples for volumetric moisture content (laboratory):

- Scale
- Weights to calibrate scale
- Aluminum weighing tares
- Drying oven
- Gravimetric moisture content field sample forms (Appendix 1)

6.0 COLLECTION OF SAMPLES

Samples from drill holes, test pits, trenches, and outcrop faces should be collected immediately to minimize exposure to the atmosphere and to avoid gaining or losing moisture. Exposure of samples to ambient surface conditions can cause significant changes in moisture content through evaporation, precipitation, spills, etc., if the exposure is longer than a few minutes. The rate of change in moisture content is a function of the differences in temperature and relative humidity between the sample's original environment and the surface environment.

If the bulk density is not known, then samples should only be collected if their undisturbed volume (or density) can be maintained and measured. The sampling method, including split spoon, coring device, or hand collection, must not cause cracks, expansion, compaction, or shearing of the sample materials. It is essential that the initial sample volume and shape be carefully maintained throughout the collection, transport, and laboratory analysis steps.

If the bulk density is not known and it is not possible to collect a completely undisturbed sample, the sample should be collected in a manner which affords the best possible estimate of sample volume. One such approach is to carefully drive or insert a coring

cylinder with a known internal volume into the rock pile material, fill the cylinder with rock pile material as best as possible, seal the sample, and determine the volumetric moisture content as described below, noting that the sample volume is only an estimate. Making the volume of the coring cylinder as large as possible can help reduce the significance of the errors introduced by loss or rotation of clasts. Collect one or more companion samples for gravimetric moisture content if the sample volume will only be estimated rather than measured in the lab according to SOP 32.

If bulk density is known or can be estimated from field methods such as the sand cone method (SOP 65, ASTM D1556-00), sand replacement (SOP 70) or nuclear density gauge (SOP 61) measurements, then the sample can be collected and analyzed according to SOP 40 (Gravimetric Moisture Content).

Samples must be quickly sealed in aluminum foil or similar wrapping, sealed again in a ziploc bag, wrapped with bubble wrap or plastic foam, and stored in a cooler to prevent moisture loss and disturbance of sample during transport. The sample wrapping must be labeled with the sample ID, the date and time of collection, and the collector's initials. Use an indelible marker and weatherproof labels.

At the time of sample collection, record the time in minutes that elapsed between the removal of the sample from its original placement to its sealing.

Refer to SOPs 1, 2, and 36 for relevant requirements regarding the collection, labeling, preservation, and transportation of samples.

7. 0 PROCEDURES

7.1 Collecting undisturbed samples

1. Photograph the core, pit, outcrop face, or trench where the sample will be collected with a scale bar .
2. Measure the ambient air temperature and the temperature of the rock pile material at a nearby location and record it on the field sample form.
3. Collect intact samples by hand or with a coring device. Wrap the sample with aluminum foil or plastic wrap. Seal the wrapped sample in a Ziploc bag and wrap the bag with bubble wrap or plastic foam. Label it appropriately. Complete the field sample form and chain of custody form (Appendix 1). Keep samples cool, in an ice chest if necessary. Transport to the laboratory (See SOP 36 for shipping procedures).

7.2 Laboratory procedures for undisturbed samples

1. Log samples into the laboratory, following SOP 2 Chain of Custody Procedures
2. Calibrate scales using standard weights.
3. Remove wrapped sample from Ziploc bag. Weigh wrapped sample to within 0.01 g and record weight.
4. Weigh empty aluminum weighing tare to within 0.01 g and record as tare weight.

5. Carefully remove sample from wrapping, place the sample in the empty tare you just weighed, and weigh the tare and the sample to within 0.01 g. Subtract tare weight (step 4) and record the result as sample wet weight.
6. Weigh sample wrapping to within 0.01 g. Compare the sum of this weight and the sample wet weight to the wrapped sample weight for quality control.
7. Oven dry the sample in the tare at 105° C for 24 hr, cool, then weigh dried sample and tare to within 0.01 g. Subtract the tare weight (step 4) and record the result as the sample dry weight. If the sample is contained within a coring cylinder, subtract the dry weight of the coring cylinder from the sample's wet and dry weights.
8. Calculate the gravimetric water content using this formula:
   (sample wet weight – sample dry weight) / sample dry weight
9. Determine the sample volume by measurement according to SOP 32 or by estimate, such as from the internal volume of the coring cylinder. Record whether the sample volume was measured or estimated.
10. If the bulk density of the sample is not known, calculate the volumetric water content using this formula:

    Volumetric water content (cm^3/ cm^3) = (sample wet weight – sample dry weight) * liquid density / sample volume.
    If the bulk density is known, the following (equivalent) equation can be used: volumetric water content = gravimetric water content * bulk density.

8.0 QUALITY ASSURANCE/QUALITY CONTROL

Verify the accuracy of the thermometer used. Laboratory scales should be calibrated using standard weights prior to measuring. Oven temperature should be checked and maintained to within 5 ° C. Minimize sample handling and record all losses of sample mass (spalled grains, sample tipped and spilled, etc.)

9.0 DOCUMENTATION

Data fields to be captured using the form in the database should include the following
Hole_ID
Test_pit_ID
Field_ID
Elevation (ft)
Depth (m)
Date sample collected
Time sample collected
Collector's initials
Soil temp (deg C)
Air temp (deg C)

Location (feature ID, UTM coords, description, etc.)
Sampling method description
Disturbed or undisturbed sample?
Repacked sample? Y/N
Time between exposure and sealing (min)
Container+sample wet weight (g)
Container+sample dry weight (g)
Sample wet weight (g)
Sample dry weight (g)
Container weight (g)
Sample water weight (g)
Gravimetric water content (g/g)
Sample volume (cm^3)
Source of volume (measured in lab, estimated from bulk density, etc.)
Sample bulk density (g/cm^3)

Source of bulk density (measured in lab, estimated from nuclear gauge, estimated from sand cone or other field method, etc.)
Volumetric water content (cm^3/cm^3)
Matric suction
Instrument for matric suction
Lab ID
Date analyzed
SOP number
Deviation from SOP
Analyzed by (initials)
Comments
Reference

10.0 REFERENCES

Gardner, W.H., 1986, Water Content, in *Methods of Soil Analysis Part 1. Physical and Mineralogical Methods*, Agronomy Monograph No. 9, Soil Science Society of America, Madison, WI, USA, p. 493-509.

Jury, W.A., W.R. Gardner, and W.H. Gardner, 1991, *Soil Physics*, John Wiley and Sons, New York, p. 45.

Lappala, E.G., Healy, R.W., and E.P. Weeks, 1987, Documentation of computer program VS2D to solve the equations of fluid flow in variably saturated porous media: U.S. Geological Survey Water- Resources Investigations Report 83-4099, 184 p.

Simunek, J., M. Sejna, and T. van Genuchten, The HYDRUS-2D software package for simulating the two-dimensional movement of water, heat, and multiple solutes in variably saturated media, Version 2.0, U.S. Salinity Lab, Agricultural Research Service, U.S. Dept. of Agriculture, Riverside, CA, USA, April, 1999.

Zyvoloski, G. A., B. A. Robinson, Z. V. Dash, and L. L. Trease, Summary of the models and methods for the FEHM application – A finite-element heat-and mass-transfer code, Los Alamos National Lab. Rep. LA-13307-MS, Los Alamos, NM, 1997.

APPENDIX 1. FORM

Gravimetric Moisture Content form sample