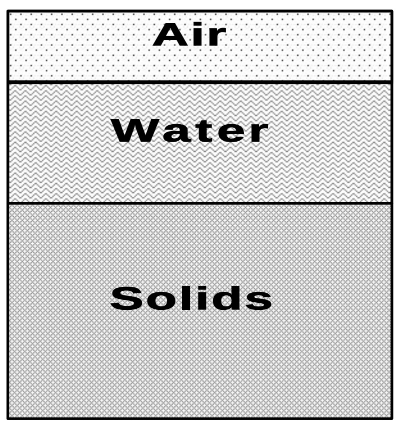
Discussion of Gravimetric and Volumetric Water Content

The DMM600 standard calibration output gives the water content measurement results in volumetric terms. Most fire managers and fire behavior modeling programs, such as FOFEM and FARSITE, use gravimetric water content to describe duff moisture content. It is important to understand the difference between the gravimetric and volumetric water content when using the DMM600.

- Volumetric Water Content (*VWC*) is a ratio that compares the volume of water in the sample to the total volume of the sample.
- Gravimetric Water Content (*GWC*) is a ratio of the mass of water in a sample to the mass of non-water material within a sample.

Both the VWC and GWC are expressed in percent. These two moisture content measurements are graphically represented for a lodgepole pine duff sample in figure 1.

VOLUME	DUFF SAMPLE	MASS
$14\ cm^3$ =	Air	= ~ 0 g
$35\ cm^3$ =	Water	= 35 g
$51\ cm^3$ =	Solids	= 25 g



Sample Volume = $100\ cm^3$

60 g = Sample Mass

VWC = $35\ cm^3 / 100\ cm^3$

VWC = 35 %

GWC = 35 g / 25 g

GWC = 140 %

Figure 1. Duff material is a mixture of solids, water and air. The water content can be measured on the basis of volume or mass. This lodgepole pine duff sample has a volumetric water content (VWC) of 35 percent which, in this case, is equivalent to a gravimetric water content (GWC) of 140 percent.

Calibrating the DMM600 for *GWC*

The DMM600 can be set up to give two output values—one will always be the VWC based on the standard calibration and the second value is chosen by the user. Most fire managers choose to program the GWC as the second value.

A duff bulk density value, expressed in SI units of g/cm^3, is used with the VWC standard calibration equation to derive the GWC user calibration.

The bulk density (BD) of a material is the mass of the dry sample divided by the volume of the wet sample*. In the lodgepole pine duff sample shown in figure 1, the bulk density would be calculated as shown:

$$\mathrm{BD} = \mathrm{Mass}_{\text{dry sample}} / \mathrm{Volume}_{\text{wet sample}}$$

$$= 25\ \mathrm{g} / 100\ \mathrm{cm}^3 = \mathbf{0.25\ g/cm^3}$$

The VWC standard calibration equation is converted to a GWC user calibration by dividing the three coefficients (C0, C1, and C2) by the bulk density value .

*Volumetric Water Content (VWC) = 5.277 + 5.905 * freq – 0.142 * freq^2*
Standard Calibration (C0) (C1) (C2)

Using the lodgepole pine duff sample shown in figure 1, the user calibration coefficients would be calculated as follows:

Standard VWC calibration coefficients	Divide by BD (g/cm^3)	User GWC calibration coefficients
C0 = 5.277	0.25	$C0_{GWC}$ = 21.152
C1 = 5.905	0.25	$C1_{GWC}$ = 23.620
C2 = -0.142	0.25	$C2_{GWC}$ = -0.568

With the DMM600 connected through a serial port to a PC, the new coefficients are entered in the software interface window (fig. 2) and downloaded to the DMM600.

Using the coefficients calculated for the lodgepole pine example, figure 2 shows the DMM600 interface window with the user GWC calibration coefficients entered, the new calibration name entered, and the <send calibration> button highlighted.

* The DMM600 can be used to determine the sample volume at the time of measurement. This information, when combined with a laboratory-determined mass of water in the sample, allows the user to determine the bulk density of the sample directly. For complete instructions refer to DMM600 Duff Moisture Meter Instruction Manual.
(Online:ftp://ftp.campbellsci.com/pub/outgoing/manuals/dmm600.pdf).

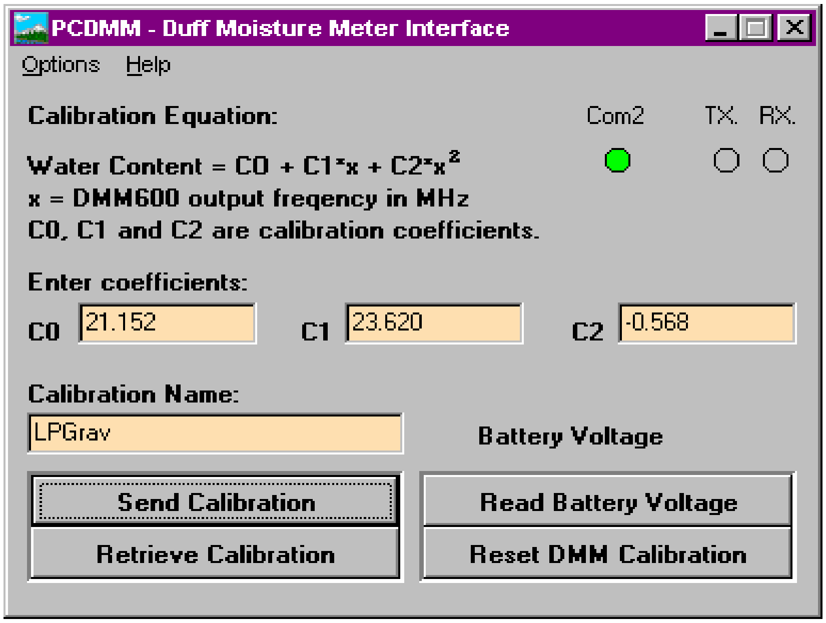


Figure 2. Using the values generated for the lodgepole pine example, the coefficients that will be downloaded to the DMM600 are shown in the interface window. Sending the LPGrav calibration to the DMM600 will add the GWC to each measurement reading.

After the user GWC calibration is downloaded to the DMM600, the GWC and the standard VWC will alternate every three seconds in the output window for each measurement.

With the user GWC calibration from the lodgepole pine example, each DMM600 measurement would include the frequency reading (Freq: xx.xMHz), VWC (`Std Cal: xx%`), and the GWC (`LPGrav Cal: xx%`). The `Std Cal` and `LPGrav Cal` alternate every 3 seconds on the top line of the output and the `Freq` is constant on the bottom line of the output.

Figures 3 and 4 show the VWC and the GWC output values for a range of frequency readings based on the standard calibration and the LPGrav calibration.

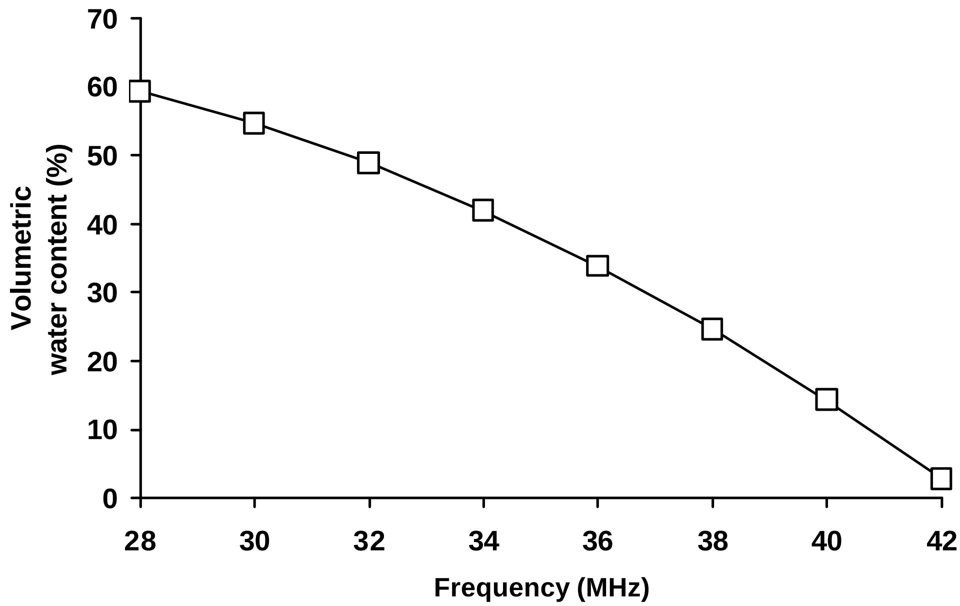


Figure 3. DMM600 standard calibration (VWC)output for a range of frequency outputs.

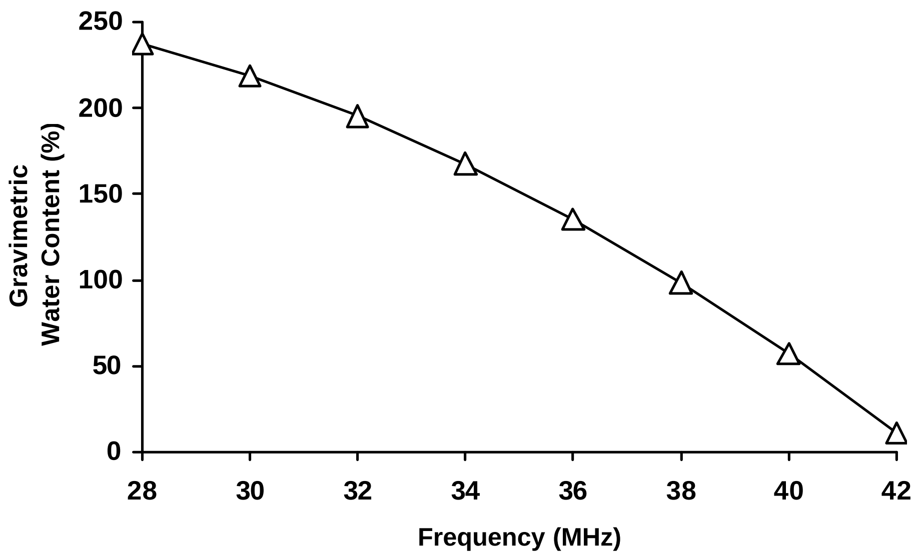


Figure 4. DMM600 LPGrav calibration (GWC for lodgepole pine assuming a sample bulk density of 0.25 g/cm^3) output for a range of frequency outputs.

Results from the DMM600 can be used with computer models, such as FOFEM (First Order Fire Effects) or FARSITE (Fire Area Simulator),* to predict fire effects from prescribed fire. In the following example duff moisture data is used in FOFEM to illustrate the importance of duff moisture in retaining an acceptable duff layer to protect the mineral soil from excessive erosion and to provide a suitable seed bed.

The screens copied in figures 5, 6, and 7 show FOFEM predictions for prescribed fires done with 10 percent, 100 percent, and nearly 200 percent GWC. The rule of thumb for most prescribed fires in the western forests is a duff moisture content of greater than 100 percent GWC, as illustrated in figure 6. Figures 5 and 7 illustrate the two extremes around this general rule of thumb—too dry and too wet.

Figure 5. With inputs of 10 percent gravimetric water content for duff moisture content, PINPON/ PSEMEN forest type, and a pre-burn duff depth of 1.0 inch, an 85 percent reduction in duff depth is predicted. This would leave a postfire average of 0.15 inches, or 2 ton/ac, of duff. Such conditions would further predict that nearly 67 percent of the mineral soil would be exposed (33% ground cover), which would likely lead to high erosion rates and a poor seedbed for natural recovery and planting.

* These fire behavior models are online and available to the public through links at: <http://fire.org/>

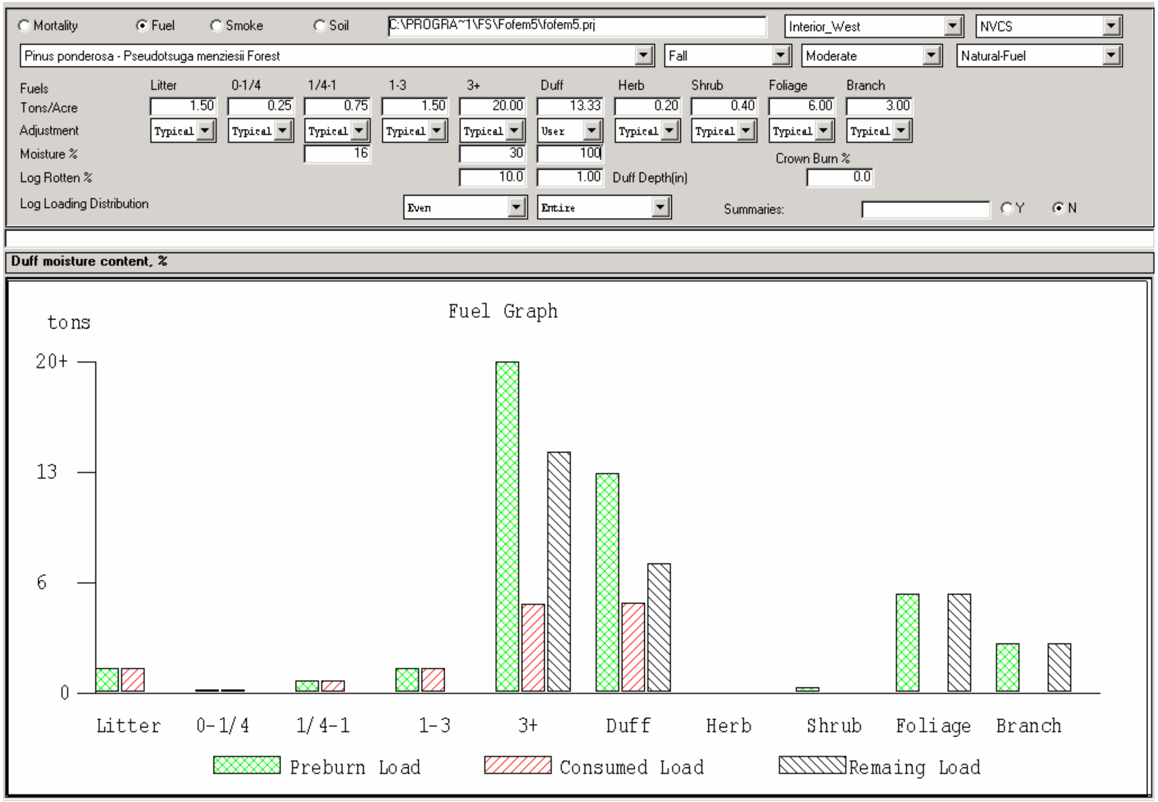


Figure 6. Land managers typically recommend using a “rule of thumb” duff moisture of greater than 100 percent gravimetric water content before ignition. With inputs of 100 percent gravimetric water content for duff moisture content, PINPON/ PSEMEN forest type, and a pre-burn duff depth of 1.0 inch, a 35 percent reduction in duff depth is predicted. This would leave a postfire average of 0.65 inches, or 7 ton/ac, of duff, further predicting 22 percent of the mineral soil exposed (78 percent ground cover). These conditions will have limited effect on erosion.

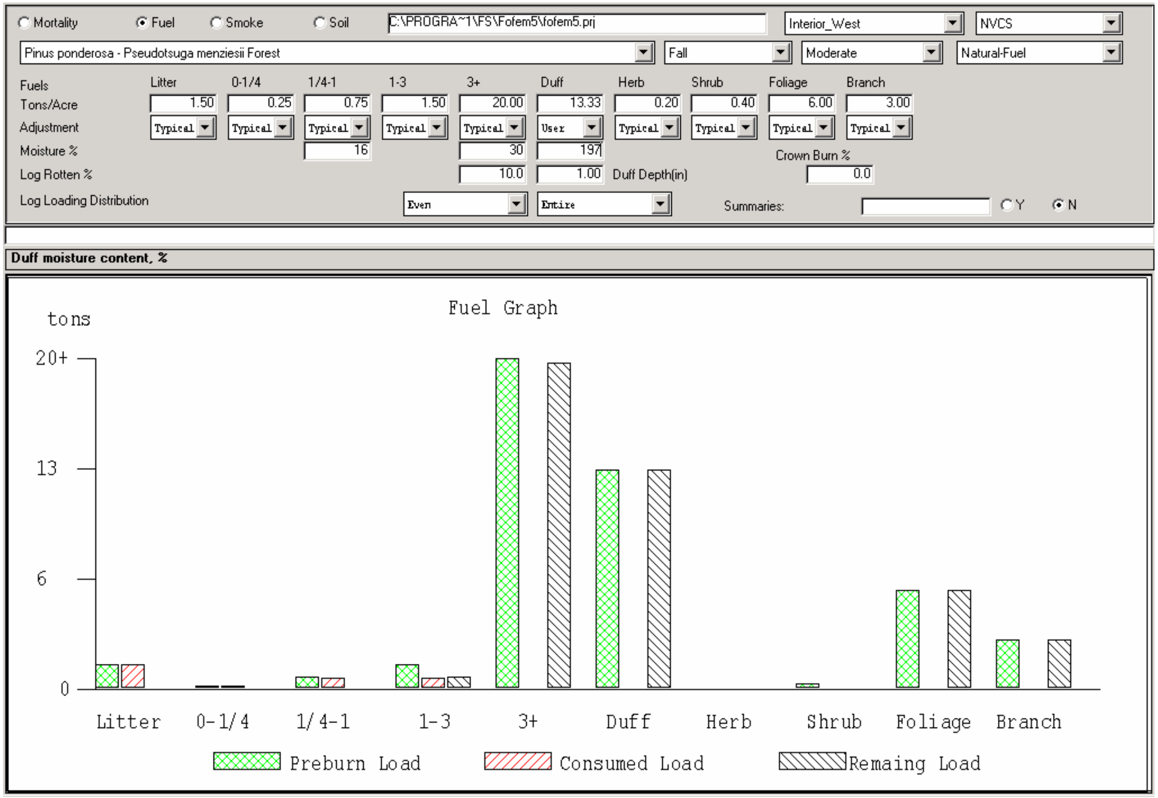


Figure 7. The maximum duff moisture input value in FOFEM is 197 percent GWC, and as expected, no duff consumption is predicted when moisture contents are that high.

Newton, Lonnie. 2003. How the duff moisture meter works. USDA Forest Service, Idaho Panhandle National Forest, Coeur d'Alene, ID. 7 p. Unpublished report. Available online at <http://forest.moscowfsl.wsu.edu/engr/DuffMoistureMeter/>