Appendix K
Estimating Fuel Loading

Fuel, in the context of wildland or agricultural fire, refers to all combustible material available to burn on an area of land. Grass, field crops, brush, timber and slash or thinning residue are the most common fuels found in New Mexico. Each fuel has its own burning characteristics based on several inherent factors. These factors include its moisture content, volume, arrangement and the plant's genetic make up. All of these contribute to how a fire spreads, its intensity, and its smoke production and emissions.

Fuel loading is measured in tons per acre. Grass is considered a light fuel with approximately ¾ tons per acre. On the other end of the spectrum, thick brush, a heavy fuel, can have a volume of over 21 tons per acre. The intensity of the fire is directly related to fuel loading. Grass burns rapidly with a short period of intense, maximum heat output; brush, on the other hand, has a long sustained high heat output making it more difficult to control.

There are several ways to estimate fuel loading. One is to take measurements of the current vegetation or debris. Brown's transects (Brown 1974) can be used for woody fuels and clip, dry and weigh can be used for grass fuels. Other methods include using fuel models (Fire Behavior or NFDRS, others), photo series, or ocular estimates. There are numerous other methods of measuring vegetation, but the most common are listed here.

See the list of publications in sections K.6.1. and K.6.2. that follow for further guidance in determining fuel loading.

K.1. Broadcast Burns

Procedures for use of the photo series to determine gross woody fuel (there are currently no photo series specifically just for grass although they are being developed) loading are:

1. Observe each specific fuel size class of residue on the ground (for example, three to nine inch diameter size class).
2. Select a photo or photos that nearly match or bracket the observed fuel class.
3. Obtain the quantitative value for the characteristic being estimated from the data sheet accompanying the selected photo (or interpolate between photos).
4. These steps are repeated for each fuel size class or fuel characteristic as needed.
5. The total gross woody fuel loading can then be calculated by summing the estimates.
6. If the general area being inventoried has areas with obvious differences in residue loading, the user should make separate determinations for each area and then weigh and cumulate the loading for the whole area.

The procedures for inventorying downed woody material are provided in two U.S. Forest Service technical reports published by the Inter-Mountain Forest Range and Experiment Station in Ogden, UT. The "Handbook for Inventorying Downed Woody Material" by James K. Brown (USDA General Technical Report INT-16, 1974) and the "Graphic Aids for Field Calculation of

Dead, Downed Forest Fuels" by Hal E. Anderson (USDA General Technical Report INT-45, August 1978) are the reference documents to be followed when doing a planar intersect sample.

K.2. Grass/Non-Woody Fuels

Direct Measurement Method

1. Harvest or Clip-and-Weigh Methods:
    a. Clipping vegetation to ground level and then weighing it is the most direct and objective way to measure herbaceous biomass.
    b. Clipping can be accomplished with grass shears, sheep shears, power grass shears, sickles, and hand lawnmowers equipped with grass catchers.
    c. Though "clip-and-weigh" methods are highly accurate, they are very time consuming.
    d. Before clipping some things to think about are:
        i. Are you clipping plants rooted in the plot or those that occur within or above the perimeter of the quadrat?
        ii. Will species be clipped and weighed separately or will all plants be clipped and weighed together?
        iii. A general rule of thumb is one quadrat per 10 acres. (For the purposes of the NM SMP)
        iv. Quadrats (a 3 ft x 3 ft square or 1 yard x 1 yard square) should be randomly located.
        v. Are the plants evenly distributed across the area or is there a lot of variability? The more variability the more quadrats you may want.
        vi. The NM NRCS recommends at least 800 lbs/acre for prescribed burning in grassy fuels.
2. Weighing and Drying Harvested Material:
    a. The weight of plant material includes inter- and intra-cellular water and external water such as dew and precipitation. Therefore the weight of freshly harvested plant material is highly variable and depends on recent weather, atmospheric conditions, and the water status of the plant.
    b. Once a sample is dried the percent dry matter equals dry weight divided by fresh weight, multiplied by 100. The dry weight is the weight of the sample after oven drying, and the fresh weight is the weight of the sample after it was just clipped.
    c. Recommended drying procedures:
        i. Dry sample within 24 hours of clipping.
        ii. Place samples in paper bags (grocery bags, lunch bags). Know the weight of the bag. One quadrat or species per bag.
        iii. A forced air oven is best at 60-70° C and will take 24-48 hours to dry.
        iv. The samples can be checked every 4-8 hours until there is no change in weight.
        v. If an oven is not available, the samples can be air dried and placed in a dry room until the weight stabilizes. A drying room can be established by simply turning the heat up in a room.

vi. Once you have the dry weight, subtract the weight of the bag.
vii. To estimate the pounds per acre use the following formula:
Dry Weight in pounds per square yard x 2.42 (conversion factor) = tons per acre

For example, a square yard of pasture was clipped, producing two pounds per square yard of totally dry material. The following calculation provides the tons per acre.

2 lbs per square yard x 2.42 = 4.84 tons per acre

K.3. Pile Burns

To determine tonnage in units that will be (but have not yet been) piled, the transect method or photo series method as described above can be used.

If units have already been piled, one of the two following methods can be used:

1. Visual estimates of piles.
2. Statistical sample of pile volume.

These methods are described in a publication from the Pacific Northwest Research Station, Fire and Environmental Research Applications, "Guidelines for Estimating Volumes, Biomass, and Smoke Production For Piled Slash," 1996, by Colin C. Hardy.

A simpler, but less accurate method for determining pile volume is length multiplied by width multiplied by height, all in feet. This will provide the cubic feet of the pile. Multiplying this by the number of total piles will give an estimate of the piled volume on the unit.

For example the project is to burn yearly orchard trimmings. Typical pile dimensions are 10ft long by 8ft wide by 8ft high and there are 25 total piles. To calculate volume in cubic feet (cu ft), multiply length by width by height. In this example, (10)(8)(8) = 640 cubic feet per pile. Pile shapes may be more like pyramids than cubes. Due to the pyramid shape, divide by three (the constant). In this case, 640 cu ft divided by 3 equals 213 cubic feet per pile. To obtain the cubic feet for all 25 piles multiply 25 by 213 which equals 5325 cubic feet for the whole burn project.

K.4. Fuel Loadings

The following table can be used to provide fuel loading estimates if measured fuel loadings are not available.

ROW CROPS	**FUEL LOADING (TONS/ACRE)**
Alfalfa	0.8
Barley	1.7
Corn	4.2
Oats	1.6
Rice	3.0
Safflower	1.3
Sorghum	2.9
Wheat	1.9
Orchard and Vine Crops	
Almond	1.0
Apple	2.3
Apricot	1.8
Avocado	1.5
Bean/Pea	2.5
Cherry	1.0
Citrus	1.0
Date Palm	1.0
Fig	2.2
Grape	2.5
Nectarine	2.0
Olive	1.2
Orchard – average of all tree EFs*	1.7
Peach	2.5
Pear	2.6
Prune	1.2
Walnut	1.2
Other	
Grassland	.5 to 3.2
Chaparral/Brush	5 to 23
Forest	5 to 23+
Slash (not piled)	9-46

* EFs = emission factors

K.5. Definitions

Biomass – the amount of living matter (as in a unit area or volume of habitat).

Broadcast burning – intentional burning within well-defined boundaries for numerous objectives.

Brush – a collective term that refers to stands of vegetation dominated by shrubby, woody plants, or low growing trees.

Clean piles – piles that have little to no (less than 10%) dirt or other debris mixed in with the vegetative material.

Dead fuels – fuels with no living tissue in which moisture content is governed almost entirely by absorption or evaporation of atmospheric moisture (relative humidity and precipitation).

Forest residue – accumulation in the forest of living or dead (mostly woody) material that is added to and rearranged by human activities such as harvest, cultural operations, and land clearing.

Fuel – combustible vegetative material.

Fuel loading – the amount of fuel present expressed quantitatively in terms of weight of fuel per unit area, usually tons per acre.

Fuel model – information describing a particular combination of vegetation, represented in numerical terms, that is used to simulate fire activity in that vegetation type.

Fuel size class – a category used to describe the diameter of down dead woody fuels. Fuels within the same size class are assumed to have similar wetting and drying properties, and to preheat and ignite at similar rates during the combustion process.

Herbaceous – having little or no woody tissue and persisting usually for a single growing season.

Packing ratio – the percentage of a fuel bed/pile that is composed of fuel particles; the remainder being air space among the individual particles.

Photo series – a collection of photos that provides a basis for quantifying and describing existing fuel loads based on vegetation type and fuel size class.

Pile – materials that have been relocated either by hand or machinery and heaped together.

Planar intersect – involves counting intersections of woody pieces with vertical sampling planes that resemble guillotines dropped through the downed material.

Quadrat – a two-dimensional sample unit of any size or shape.

Slash – debris resulting from such natural events as wind, fire, or snow breakage; or human activities as road construction, logging, pruning, thinning, or brush cutting. It includes logs, chunks, bark, branches, stumps, and broken understory trees or brush. The material is not piled, but distributed throughout the landscape.

Transect – a specific area of predetermined size used for sampling, for example, a narrow strip (measuring tape) used for point-intercept sampling (i.e., sampling points along a line).

K.6. References

This list is not all inclusive and new photo series are being developed at this time.

K.6.1 Photo Series

Blonski, Kenneth S. and Schramel, John L. 1981. Photo series for quantifying natural forest residues: Southern Cascades, Northern Sierra Nevada. USDA Forest Service general Technical Report PSW-56. Pacific Southwest Forest and Range Experiment Station, Berkeley California. 145 pages. (Ponderosa pine, mixed conifer, lodgepole pine, white fir, red fir, mountain hemlock)

Fischer, William C. 1981. Photo guide for appraising downed woody fuels in Montana forests: grand fir – larch – Douglas fir, western hemlock, western hemlock – western redcedar, and western redcedar cover types. USDA Forest Service General Technical Report INT-96. Intermountain Forest and Range Experiment Station, Ogden, Utah. 53 pages.

Fischer, William C. 1981. Photo guide for appraising downed woody fuels in Montana forests: interior ponderosa pine, ponderosa pine-larch-Douglas fir, larch-Douglas fir, and interior Douglas fir cover types. USDA Forest Service General Technical Report INT-97. Intermountain Forest and Range Experiment Station, Ogden, Utah. 133 pages.

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National Wildfire Coordinating Group. 1997. Photo series for quantifying forest residues in the southwestern Region: Data compiled from Black Hills ponderosa pine and spruce type 1990; GTR-PNW-105; GTR_PNW-52, 1976; GTR-PSW-56, 1981. PMS 822. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center.227 pages. (Ponderosa pine pre-commercial thinning, partial cut, natural, white fir, juniper, mixed conifer)

Ottmar, Rodger D. and Hardy, Colin C. 1989 Stereo photos series for quantifying forest residues in coastal Oregon forests: second growth Douglas fir-western hemlock type, western hemlock-Sitka spruce type, and red alder type. USDA Forest Service General Technical Report PNW-231. Pacific Northwest Research station, Portland, Oregon. 67 pages.

Ottmar, Rodger D., Hardy, Colin C., and Vihnanek, Robert E. 1990 Stereo photo series for quantifying forest residues in the Douglas fir - hemlock type of the Wilamette National Forest. USDA Forest Service General Technical Report PNW-258. Pacific Northwest Research Station. Portland, Oregon. 63 pages.

Ottmar Rodger D., Vihnanek, Robert E., and Wright, Clinton S. 1998. Stereo photo series for quantifying natural fuels. Volume 1: mixed conifer with mortality, western juniper, sagebrush, and grassland types in the interior Pacific Northwest. PMS 830. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 73 pages.

Ottmar, Rodger D. and Vihnanek, Robert E. 1999. Stereo photo series for quantifying natural fuels. Volume V: Midwest red and white pine, northern tall grass prairie, and mixed oak types in the Central and Lake States. PMS 834. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 99 pages.

Ottmar Rodger D.; Vihnanek, Robert E. 2000. Stereo photo series for quantifying natural fuels. Volume III: Lodgepole pine, quaking aspen, and gambel oak types in the Rocky Mountains. PMS 832. Boise, ID: National Wildfire Coordinating Group, National Interagency Fire Center. 85 pages.

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K.6.2. Fuel Models

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