Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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Calculated Roughness Length Changes due to Alteration of Forest Characteristics

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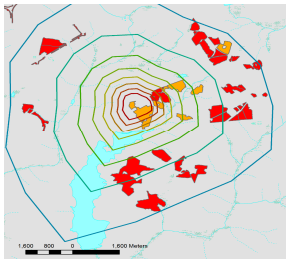
Background

As part of the Documented Safety Analysis (DSA) process, Savannah River Site (SRS) analyzes potential radiological dose to workers and the public from postulated releases of radioactivity to the atmosphere and must be re-evaluated if changes in the environment alter predicted doses by greater than 10% on average (Lowrie and O'Kula 2006). Proposed forest alterations at SRS will alter the roughness length parameter and may be sufficient to trigger a DSA re-evaluation. Recent thinning and clearing near a meteorological tower at SRS provides an opportunity to examine the impacts of forest alterations on roughness length. Based on the results, consideration will be given to what changes to roughness length may be expected for proposed alterations.

Visualization of the forests around the SRS tower where 2014 alterations took place.



Identification of clear-cut (red) and thinning (orange) regions. Contours depict the flux footprint of the meteorological tower in 10% increments (inner-most contour denotes 10% contribution, outermost depicts 80% contribution to the flux footprint).

Site and Measurement Descriptions

Forest stand is dominated by *c.* 50 year-old longleaf pine (*Pinus palustris*) with an average canopy height of 24 m and a small number of slash pine (*Pinus elliottii*) and white oak (*Quercus alba)* [Upper-Left]

Forest alterations consisted of a combination of clear-cut (red) and thinning (orange) in the Fall of 2014. [Lower-Left]

Measurements were taken from a 61 m tower with a RM Young 81000 3-D Sonic Anemometer at 10Hz. Averages were calculated in 15-minute periods. Stability was determined using the standard deviation of the vertical wind direction following US EPA (2000).

Roughness Length was calculated under neutral conditions using three methods (Weber et al. 2012):

$$z_o = (z-d)\exp(-\frac{kU}{u_*})$$
$$z_o = (z-d)\exp(-0.76/\sigma_a)$$
$$z_o = (z-d)\exp(-0.5/\sigma_e)$$

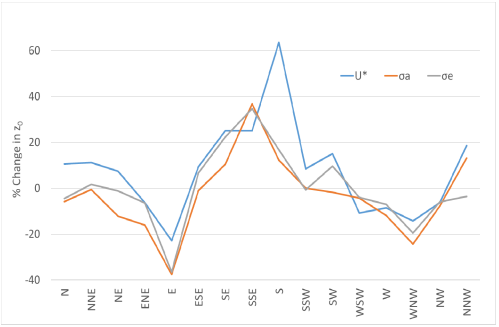
U = Wind Speed
u_* = Friction Velocity
k = 0.4
Z = Measurement Height (61 m)
d = Displacement Height (18m)
σ_a = Standard Deviation of the Horizontal Wind Direction
σ_e = Standard Deviation of the Vertical Wind Direction

Results

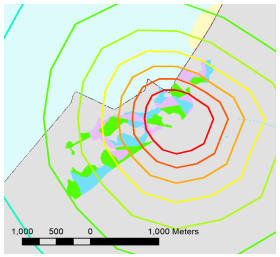
There were similar trends between methodology, though also noticeable differences between them for individual wind sectors [Right].

To assess natural variation, changes in the roughness length were also calculated for nearby 61 m towers were less alteration took place. Nearly no net change was found on average (-0.2%), though the standard deviation of ±11.6% (or approximately 0.2m). This suggests that while the long-term average of z_0 is not changing, there may be year-to-year variations occurring which balance out over time.

	Methodology		
Direction	U_*	σ_a	σ_e
N	10.5	-5.8	-4.5
NNE	11.2	-0.6	1.7
NE	7.4	-12.1	-1.1
ENE	-6.3	-16.0	-6.4
E	-22.8	-37.6	-36.5
ESE	9.4	-1.0	6.6
SE	25.0	10.4	22.3
SSE	25.1	36.7	34.7
S	63.6	12.2	16.8
SSW	8.4	0.0	-0.7
SW	15.1	-1.8	9.7
WSW	-10.8	-4.4	-4.0
W	-8.6	-11.8	-7.0
WNW	-14.3	-24.3	-19.6
NW	-6.3	-7.8	-6.0
NNW	18.5	13.1	-3.6



- Averaged over all directions, a net reduction in roughness length (-8.2% ± 15.4%) suggesting that the alterations had a measurable impact.
- Generally, clear-cuts were found to reduce roughness length while thinning tended to increase roughness length.
- Flux footprints were found to remain nearly unchanged regardless of direction or forest alterations.



Flux footprint and proposed cut regions, staggered by 10 year increments. While the alterations will be more densely spaced than the previous alterations, they are also smaller and more staggered than previous alterations studied here.

Implications for Proposed Cuts

Proposed clear-cuts staggered in 10-year increments are needed to maintain forest health and diversity.

New proposed clear-cuts are expected to have smaller changes than the previous cuts:

- Smaller increments and spacing between alterations may increase rather than decrease roughness, similar to a thinning effect (Sogachev et al. 2005).
- Displacement height has been assumed to remain constant; in practice, it would change as well and likely limit the effect of z_o