UPDATE: TUMOR INCIDENCE IN RESIDENTS ADJACENT TO THE LOOKOUT MOUNTAIN ANTENNA FARM 1979-2012

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I. INTRODUCTION

This study is an update of earlier reports released by the Colorado Department of Public Health and Environment (CDPHE) in June 1998, February 1999 and July 2004, which evaluated cancer incidence in the Lookout Mountain area for the period 1979-2002. [1,4,5] The current study updates the incidence of a variety of cancers, including brain and central nervous system (CNS) tumors in census tract 98.10 (see Figure 1), by including cases diagnosed during 2003-2012 and updated population estimates based on 2010 U.S. Census data. The current update also provides an analysis of radiofrequency (RF) exposure data collected by researchers at Colorado State University (CSU) prior to significant changes in the broadcast antenna tower configuration in 2008.[6]

In June 1998, the State Health Department completed an epidemiologic study that was initiated in response to concerns about the health status of people living in Jefferson County, Colorado adjacent to the Lookout Mountain antenna farm.[1] Prior to the initiation of the study, a scientific advisory panel consisting of researchers and epidemiologists from the Jefferson County Health and Environment Department, the Department of Environmental Health at Colorado State University, and the Colorado Department of Public Health and Environment was convened to develop a study protocol and provide peer review of the study results. The May 28, 1998 protocol was described in a document entitled *Protocol for a Study of Cancer Incidence in Residents Adjacent to the Lookout Mountain Antenna Farm*.[2]

At the time of the 1998 study, previously published epidemiologic studies had suggested a possible association between electromagnetic radiation (EMR) and increased rates of brain tumors, particularly in persons working in certain occupations. Some positive findings were also reported for populations with possible RF radiation exposure in residential settings, although the epidemiological evidence was not consistent or conclusive, in part due to limitations of the designs of the research studies. The panel determined that, while no conclusive association between RF exposure and increased risk of cancer had been established in the published scientific literature, there also was not sufficient information to exclude the possibility of increased risk under some circumstances.

The objective of the June 1998 study was to examine the incidence of a number of different types of cancer in census tract 98.10, which includes communities near the Lookout Mountain antenna farm, and to compare the incidence to that of the Denver metropolitan area. Cancer incidence data were available for the Denver metropolitan area from the CDPHE Colorado Central Cancer Registry (CCCR), a population-based registry of cancer diagnoses for the entire state of Colorado. The study looked at the incidence of several cancer types that had been hypothesized in other epidemiological studies to be potentially associated with RF field exposures. Overall, the number of cancers diagnosed in census tract 98.10 was not higher statistically than would be expected for the ages and numbers of males and females living there. An addendum to the June 1998 report was released in July 1998.[3] The addendum differed from the initial report in the comparison population selection. The July 1998 report relied on a comparison population that was restricted to 30 census tracts in the Denver metropolitan area with a median household income similar to census tract 98.10. The calculations presented in the addendum did not change the conclusions of the original study.

When the June 1998 report was released, analyses of areas smaller than the entire census tract had not been done. It was recommended in the June 1998 report that if additional RF exposure data become available, the CDPHE scientific advisory panel should convene "to determine if a relationship between exposure distribution and existing block groups can be identified, ...to guide the design of any further studies." In August 1998, a citizens group provided CDPHE with maps of RF measurements taken on Lookout Mountain and maps indicating the residence location of persons with suspected brain cancers, based on word-of-mouth information available to community members. The maps raised a concern among community members of possible spatial clustering of brain cancer cases in areas where the RF measurements were higher relative to other parts of Lookout Mountain. Based on the availability of the RF exposure measurements, the panel recommended additional study of cancer incidence for smaller geographic areas, called block groups (BG), within census tract 98.10. The advisory panel recommended that the block group analysis focus on brain and other central nervous system (CNS) tumor incidence, because these were the only consistently elevated ratios (although within expected statistical variation) reported in the 1998 study.

The 1999 block group analysis analyzed available brain/CNS tumor data for 1979-1997.[4] Observed/expected (O/E) ratios were calculated for malignant tumors, and for all malignant and benign tumors combined. The following results were presented for the seven block groups within census tract 98.10:

- For <u>benign and malignant tumors combined</u>, all O/E ratios were within expected statistical variation except for females living in <u>block group 2</u> (O/E=5.02, 95 % CI= 1.04-14.68; results based on 3 cases). Histology was consistent for all 3 cases diagnosed in women in BG2–all had benign meningiomas.

- For <u>malignant tumors only</u>, all O/E ratios were within expected statistical variation except for males living in block group 3 (O/E=4.40, 95 % CI= 1.20-11.25; results based on 4 cases). Cell types listed for the 4 cases diagnosed in men in BG3 were malignant astrocytomas and glioblastomas.

The report concluded that some evidence from the study supported an association between RF exposure from the antennas and brain/CNS tumors, and some did not.

Study findings that were **consistent** with an association included:

- BG2 and BG3 (where statistically elevated O/E ratios occurred) were the block groups located closest to the towers.
- All cases (or surviving family members) reported that the residence had an unobstructed view to the towers (i.e., potential for exposure).
- For all cases from BG2, interviews indicated individuals had lived in the Lookout Mountain area for 10 years or longer.

Study findings that were **inconsistent** with an association included:

- Two of the five cases diagnosed from BG3 had lived near the Lookout Mountain antennas less than 5 years.[1]
- Four of the five cases from BG3 had also worked in an occupation associated with an increased risk of developing a brain tumor (electrical or telecommunications work, aircraft pilot, work with meteorological radar).[2]
- Cell types were not the same for BG2 and BG3 cases, and men and women were not similarly affected in each block group.

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[1] - The panel noted that while latency, or time between exposure and clinical recognition of a disease, is believed to be at least 5 years and usually more than 10 years for a genotoxic environmental exposure and cancer, tumor promoters may shorten latency periods for disease already initiated. Non-ionizing radiation has been suggested to act as a promoter, however uncertainty remains regarding a potential biological mechanism by which RF radiation might act. Therefore, it is not yet possible to assign a scientifically based estimate of cancer latency associated with RF exposure.

[2] - The panel noted that these exposures could represent an alternative source of exposure to non-ionizing radiation or could be additive, with exposures to the towers as a contributory factor.

The 1999 study concluded that the inconsistencies noted above weaken the hypothesis of a common etiology of elevated brain/CNS tumors in the two block groups with statistically elevated O/E ratios. However, the study also acknowledged the prevailing uncertainty and inconsistencies in the state of the science regarding the plausibility of an association between RF exposure and cancer, as well as large uncertainty in using geographic area (residence by block group) to estimate RF exposure from the towers. The 1999 study recommended that O/E ratios be updated after the 2000 census data were available, and that CDPHE continue to monitor the evolving scientific evidence regarding health effects of non-occupational RF exposure.

The 2004 study of cancer incidence in residents in the Lookout Mountain community recalculated O/E ratios using the 2000 census population estimates for the geographic area defined by census tract 98.10, and for the block groups within the tract, for cases reported to the state Cancer Registry from 1979-2002.[5] Findings from the 2004 study were generally consistent with those reported in 1999. Literature published between the 1999 and 2004 studies had not yet established a conclusive association between electromagnetic radiation and cancer, nor had it identified a toxicological mechanism of action. A discussion of developments in the scientific literature since the 2004 study was released is presented in the discussion section of this report.

The current update was designed to address a previous recommendation from advisory panel members that any additional analysis of cancer statistics should also assess residential RF exposure measurements to the degree possible. To complete the 2015 update, CDPHE collaborated with researchers from the Department of Environmental Health at CSU familiar with street-level RF exposure data collected in the Lookout Mountain area, to determine how to best utilize the available data and to help develop exposure assessment methods. Detailed RF data collection methods and results were previously published by CSU in 2006.[6]

II. METHODS

The June 1998 study considered all of census tract 98.10 as one geographical unit for statistical purposes, using 1985-95 Cancer Registry data and 1990 census data. The February 1999 study of brain and CNS tumors examined incidence in the seven block groups of census tract 98.10 from 1979 (the first year of complete metro Denver data from the Cancer Registry) through 1997. Calculations were performed separately for 1979-84 and 1985-97 because of changes in population between 1980 and 1990 and changes in the geographic boundaries for some of the block groups between the 1980 and 1990 U.S. censuses. At that time, 2000 census data were not yet available to aid in population estimation between 1990 and 1997. The 2004 study used the 2000 census data to better estimate population changes over the entire 1979-2002 time period.

The present study uses the previous census data and the more recently available 2010 census data to better estimate population changes over the 1979-2012 time period. It also updates cancer statistics for the area for the same time period.

A new addition to the present study (Section II.F) is an evaluation of residential location of brain tumor cases in block group 3 compared to RF measurements collected by scientists at CSU during a curbside survey of residences along publicly-accessible streets.[6]

A. Definition of study areas and time periods selected for study

The area of study adjacent to the Lookout Mountain antenna farm was defined by census tract 98.10 boundaries established for the 1990 Census. The boundaries of this census tract are Clear Creek, U.S. Highway 6, I-70, the Dakota Hogback, Bear Creek, State Highway 74, Cold Springs Gulch, I-70 and Beaver Brook. The total population of census tract 98.10 was 12,281 in 2010, 11,601 in 2000, 8,897 in 1990, and 5,971 in 1980. As of the 2000 Census, the area covered by census tract 98.10 was defined as two census tracts 98.44 (with six block groups) and 98.45 (with four block groups). For the 2010 Census, the area covered by the original census tract 98.10 was defined as three census tracts: 98.45 (now with three block groups), 98.49 (with five block groups) and 98.50 (with two block groups). The latter two census tracts, 98.49 and 98.50 combined, were the same area as census tract 98.44 in 2000. For purposes of historical consistency with the earlier reports, references to the smaller areas within the original census tract 98.10, called block groups, have been maintained with their 1990 Census boundary definitions. These are presented schematically in Figure 1 and are described below.

- Block group 1 (1990 definition), generally located in the northwest portion of the census tract, is bounded by Lookout Mountain Road, I-70, Beaver Brook and Clear Creek. 2010 population = 1,897.

- Block group 2 (1990 definition) is a small area located mostly west of the corner of Highway 6 and Lookout Mountain Road. 2010 population = 464.

- Block group 3 (1990 definition) is generally bounded by Lookout Mountain Road, Highway 6, Heritage Road and I-70. 2010 population = 3,648.

- Block group 4 (1990 definition) is an "island", i.e., completely contained, within block group 5 (1990 definition); therefore analyses for block group 4 were combined with block group 5. Block groups 4 and 5 make up a triangle shaped area bounded by Highway 6, I-70 and Heritage Road. In 2010 this area was the same as block groups 2 and 5 from census tract 98.49. 2010 population = 2,242.

- Block group 6 (1990 definition) in the southeast portion of the census tract is bounded by I-70, the Dakota Hogback, Bear Creek, and Grapevine Road. In 2000 this area was the same as block group 4 from census tract 98.45. In 2010 this area was the same as the portion of block group 3 in census tract 98.45 east of Grapevine Rd. The 2010 population of this area was determined by aggregating populations of a number of individual blocks in this block group. 2010 population = 220.

- Block group 7 (1990 definition) in the southwest portion of the census tract is bounded by Bear Creek, State Highway 74, Cold Springs Gulch, I-70 and Grapevine Road. In 2010 this area was the same as the portion of block group 3 in census tract 98.45 west of Grapevine Rd. plus block groups 1 and 2 from this same census tract. 2010 population = 3,790.

Boundaries for the entire census tract and for block groups 1, 4/5, 6, and 7 were the same in the 1980 and 1990 Census definitions. For the areas covered in 2000 by this census tract and these same block groups, 2000 populations could be used directly or apportioned (especially to maintain the 1990 definition of block group 1 and still use 2000 population data), so analyses for these areas were performed for the entire time period from 1979 to 2002. Block groups 2 and 3 were separate in the 1990 census, but, in 1980, the area covered by these two block groups was one block group for census purposes with no sub-block group boundaries matching the 1990 block group boundaries. Because of this situation and slight changes in the original boundary between block groups 1 and 3 in 2000 and continuing into 2010 that required aggregating some individual block populations within these block groups, analyses for these two block groups were restricted to the years 1985-2012. The 1990 geographical definition of block group 3 was maintained even though 2000 and 2010 population data were used.

B. Tumor types selected for study

This study presents an update of all tumor types and age groups evaluated in the three previous studies.[1, 4, 5] Cancers included were leukemia, brain and central nervous system (CNS), non-Hodgkin lymphoma, female breast, eye melanoma, and all cancers combined. Benign brain and CNS tumors, in addition to malignant brain tumors, were investigated for all block groups to be consistent with previously published epidemiologic studies. For the 2004 and 2015 studies, tumors included in the 2002 Central Brain Tumor Registry of the U.S. (CBTRUS) standardized definition of brain tumor were also considered.[7] This included tumors from the pineal and pituitary glands and certain olfactory tumors of the nasal cavity. For leukemia, brain and CNS, and all cancers combined, tables were prepared for children age 0-14, cases age 15+, and all ages combined. All other cancer sites were evaluated for all ages combined.

Primary brain and CNS tumors are categorized in the CCCR according to the International Classification of Diseases for Oncology (ICD-O) anatomic site and histology codes. Tumors metastatic to the brain or CNS from a distant primary site are not included. Likewise, tumors originating in other structures of the face, head, and neck are not included.

The ICD-O codes include a classification for tumor behavior, i.e., benign, in-situ, malignant, or uncertain.

Acoustic neuromas (also called vestibular schwannomas) were included among the primary brain and CNS tumors identified for this study. There were five cases of acoustic neuromas reported in the Lookout Mountain study area compared to about seven cases expected over the 1979-2012 time period. These five cases were distributed throughout the area (one case in block group 1, and two cases each in block group 3 and 4/5 combined) with no block groups having statistically elevated case counts.

Additional tumors assessed based on the 2002 definition of brain tumors published by CBTRUS were pituitary and pineal glands (ICD-O site codes C75.1-C75.3) and olfactory tumors of the nasal cavity [ICD-O site C30.0 (histologies 9522-9523)]. There were no cases of olfactory tumors of the nasal cavity reported during 1979-2012 in the Lookout Mountain area. There were 12 cases of pituitary gland tumors (all benign) and no pineal gland cases. About 12 pituitary gland tumors would be expected over this time period. These 12 cases were distributed evenly throughout the area and no block groups had statistically elevated case counts.

C. <u>Calculation of observed/expected ratios of cancer cases and tests of statistical significance</u>

The expected number of individual types of cancer was calculated by multiplying the comparison area's age- and gender-specific incidence rates by the age- and gender-specific population estimates for census tract 98.10 (and its seven block groups for the brain and CNS tumors). Risk ratios termed Observed/Expected, or O/E, ratios were calculated by dividing the number of diagnosed cases by the expected number of cases for the geographic area for a particular time period. The ratio of the observed number of tumor cases to the expected number may be considered a standardized incidence ratio (SIR).

For brain and CNS tumors, two types of analyses were performed: (1) an O/E ratio for all brain and CNS tumors (combining benign and malignant) and (2) an O/E ratio for malignant tumors alone. Previously published epidemiologic studies of general population exposure to RF sources have been inconsistent regarding the type of tumors included in the investigations, with some studies looking only at the occurrence of malignant tumors, while others have investigated both benign and malignant tumor outcomes.

In this study, the O/E ratios are reported with 95% confidence intervals. Observed/Expected ratios that have a 95% confidence interval that includes the value of 1 are not considered statistically high or low. For example, an O/E ratio of 1.50 with a 95% confidence interval of 0.2 to 3.6 includes the value 1 in the confidence interval, i.e., 1 is within the interval from 0.2 to 3.6. Therefore, the O/E ratio is considered to be within expected statistical variation and not a "statistically significant" outcome.

The statistical significance of the O/E ratio, or SIR, was tested by treating the observed number as a Poisson variate in respect to its expected frequency.[8] A two-tailed test was used to test the null hypothesis that there was no difference between observed and expected numbers of cancer cases. The probability level of 0.05 was used as a cutoff with the one-tail bound at the 0.025 level. We did not perform statistical testing on O/E ratios with less than three observed cases due to the high statistical variability that is inherent with such frequencies.

D. Adjusting for income

All observed/expected statistics for the present study were calculated using a standard area for comparison that included census tracts in the Denver metropolitan area with similar incomes as the Lookout Mountain study area, defined as census tract 98.10. As reported previously, there is a well-recognized association in the epidemiological literature between socioeconomic status (SES) and brain tumor occurrence, with risk increasing with higher SES. As in the past studies, an attempt was made in this update to control for potential bias from differences in SES by limiting the comparison population used to estimate expected case counts to only those census tracts in the Denver metropolitan area that were within $5,000 of the median household income of census tract 98.10.

For the 1979-84 time period, 35 census tracts with a 1980 median household income between $22,286 and $25,286 (within plus or minus $1,500 of the median household income of $23,786 in census tract 98.10) were selected from Adams, Arapahoe, Douglas, Denver and Jefferson counties to use as the standard. Median household incomes were obtained from the report, *1980 Census of Population and Housing, Census Tracts, Denver-Boulder, Colorado Standard Metropolitan Statistical Areas, PHC80-2-138,* published by the U.S. Dept. of Commerce, Bureau of the Census in June 1983.

For the 1985-95 time period, 30 census tracts with a 1990 median household income between $43,875 and $53,875 (within plus or minus $5000 of the 1990 median household income of $48,875 in census tract 98.10) were selected from Adams, Arapahoe, Douglas, Denver and Jefferson counties to use as the standard. Median household incomes were obtained from a December 1993, Denver Regional Council of Government's publication, *The New Audience: a demographic report about older adults in the region: Census Tracts by County.*

For the 1996-2004 time period, 17 census tracts with a 2000 median household income between $75,500 and $85,500 (within plus or minus $5000 of the 2000 median household income of $80,000 in the area covered by census tract 98.10, or census tracts 98.44 and 98.45 in 2000) were selected to use as the standard. Median household incomes were obtained from table P53, Census 2000 Summary File 3 (SF 3) on the U.S. Census Bureau website, http://factfinder.census.gov.

For the 2005-2012 time period, 38 census tracts with a 2005-09 median household income between $82,500 and $92,500 (within plus or minus $5000 of the 2005-09 median household income of $87,500 in the area covered by census tract 98.10, or census tracts 98.44 and 98.45 in 2000) were selected to use as the standard. Median household incomes were obtained from table B19013, American Community Survey for 2005-09 on the U.S. Census Bureau website, http://factfinder2.census.gov.

It had been determined previously, using 1990 census data, that there was variation in the median household income among the seven block groups of census tract 98.10. However, because the number of Denver metropolitan area comparison census tracts (and corresponding population size) would be small for several of the seven block group income categories, we selected comparison census tracts using the median household income for the entire 98.10 census tract and used the same tracts for comparisons with all seven block groups.

The 35 census tracts used for the 1979-84 portion of the analysis totaled nearly 154,000 persons in 1980, the 30 census tracts used for the 1985-95 calculations totaled nearly 121,000 persons in 1990, the 17 census tracts used for the 1996-2004 calculations totaled about 75,000 persons in 2000, and the 38 census tracts used for the 2005-12 calculations totaled about 172,400 persons estimated during this time period. For all time periods combined, the race/ethnicity composition of census tract 98.10 (about 93% white, non-Hispanic) was similar to the comparison areas (about 88% white, non-Hispanic). Cancer cases diagnosed in the comparison population were about 95% white, non-Hispanic compared to 98% white, non-Hispanic in census tract 98.10.

E. Case interviews

As was done for the 1999 and 2004 studies, follow-up telephone interviews were conducted with individuals diagnosed with a brain/CNS tumor, or surviving family member, for cases reported as residing in block groups where statistical elevations were observed, i.e., block groups 2, 3, and 4 and 5 combined. No statistical testing was performed on the results of the interviews. The interviews were intended to provide descriptive epidemiologic information for the purpose of exploring whether it was plausible that disease was associated with RF radiation from the antennas.

Case interviews were conducted by telephone to gather data on length of residence near the antennas, approximate distance of the home from the antenna towers, the person's occupation (a potential confounder), whether there were close blood relatives who had a brain tumor, and whether there was an unobstructed view of the antenna towers from the residence. RF radiation can be effectively blocked by hillsides, trees, or other structures. Therefore, an unobstructed view of the towers would indicate the potential for exposure from the antennas. RF intensity has also been shown to decrease rapidly with distance from the source, and questions about distance from the towers were intended as an estimate of the potential for significant RF exposure. Information was gathered on length of residence in the Lookout Mountain area prior to diagnosis. Cases or individuals responding to the interviews were asked whether past occupational exposure to electromagnetic radiation may have occurred prior to diagnosis, however there was no attempt to gather detailed information about the length of exposure or precise nature of job duties.

F. Evaluation of residential location of brain tumor cases in block group 3 compared to radiofrequency measurements

In the 2004 study the scientific advisory panel members strongly recommended further review of any well-designed RF exposure surveys for the Lookout Mountain area, should such data become available, and consideration of linkage of RF exposure data with available Cancer Registry statistics. Individual level exposure data would allow further testing of the hypothesis of an association between RF exposure and increased risk of developing a brain/CNS tumor, which had been suggested by block group 2 and 3 findings in the 1998, 1999 and 2004 studies.

During 2002, as part of a larger study[6], CSU scientists conducted a curbside RF survey of residences along publicly-accessible streets in the vicinity of the Lookout Mountain radio transmitters. This survey resulted in the selection of a sample of 441 residences with a variety of RF levels. Measurements were not collected in block group 2, block groups 4 and 5 combined, nor in the portion of block group 3 that is at the eastern base of Lookout Mountain just west of Heritage Road (Highway 93).

With the goal of evaluating whether brain tumors tended to occur more often at residences with higher RF measurements in block group 3, the 12 residence addresses of brain tumor cases were compared to the addresses of block 3 residences (n=271) that were part of the CSU sample. Seven additional residences of brain tumor cases in block group 3 were located at the eastern base of the mountain where RF measurements were not done. The distribution of RF measurements for the 259 residences that were not home to any brain tumor cases was used as a "standard" to calculate expected counts of residences of brain tumors by different levels of RF. The percent of "standard" residences in a particular range of RF values was used to estimate the expected count of brain tumor case residences. For example, from Table 8, 62.5% of non-brain cancer residences measured in the 0.00-1.99 RF range. Multiplying 62.5% times the total of 12 brain cancer residences in block group 3 that had RF measurements leads to an expected count of residences of 7.50 for the 0.00-1.99 RF range. There were eight brain cancer residences found in that RF range and comparing that count to the 7.50 expected yields an observed/expected ratio of 1.07, which can then be tested statistically (ref. 8). Similarly, again from Table 8, 37.5% of non-brain cancer residences measured in the 2.00+ RF range. Multiplying 37.5% times the total of 12 brain cancer residences in block group 3 that had RF measurements leads to an expected count of residences of 4.50 for the 2.00+ RF range. There were four brain cancer residences found in that RF range and comparing that count to the 4.50 expected yields an observe/expected ration of 0.89, which can then be test statistically (ref. 8). This approach was used for each range of RF values that are displayed in Tables 8-11.

Because seven of the 20 brain tumor cases (from19 individual residences) in block group 3 had residences located at the eastern base of Lookout Mountain where RF measurements were not done, an attempt was made to estimate the effect of including these cases in the analysis of RF data by statistically testing all the possible ways those seven case residences might have been categorized into the various RF ranges. For example, using Table 8 again, with the two RF ranges of 0.00-1.99 and 2.00+, if the seven residences that were not measured could have been measured, all seven could have actually been in the first range and none in the second range. Or six residences could have been in the first range and one in the second range. Or five could have been in the first range and two in the second range. Considering all these scenarios, there are eight possible ways the table could change (see paragraph below) depending on how many of the seven case residences would have been added to the two RF ranges. By statistically testing each of these eight possible scenarios now using a new total of 19 case residences and recalculating the O/E ratios for each of these eight possible combinations, it is noted that none of these combinations would result in statistically high ratios for either RF range category. This approach was used for Tables 8-11.

The analytical method described in the paragraph above uses a combinatorial composition approach (ref 9). The number $C_k(n)$ of compositions of a number n of length k (where 0 is allowed) is given by the formula

$$C'_k(n) = \binom{n+k-1}{k-1} = \frac{(n+k-1)!}{n!\,(k-1)!},$$

So, from the paragraph above, with the seven case residences postulated as being categorized into two RF ranges, the equation values are n=7 and k=2, so (7+2-1)!/7!(2-1)! = 8!/7!=8. The conclusion is that there are eight possible ways that seven case residences could have been categorized into two RF ranges.

III. RESULTS

The purpose of this report is to update tumor incidence statistics reported in the previous 1998, 1999 and 2004 CDPHE reports[1,4,5] and to evaluate available RF exposure data through linkage of address-level RF data with available Cancer Registry statistics. Results displayed in Tables 1a-4b show updated O/E ratios calculated using Census 2010 population data, as well as additional cases of brain/CNS tumors reported to the state Cancer Registry for the 2003-12 time period. Table 5 displays the number of brain and CNS cases diagnosed by year in the entire census tract and in individual block groups, for the period

1979-2012.

Tables 1a, 1b, and 1c display the number of cancer cases diagnosed compared to the expected number of cases in census tract 98.10 during 1979-2012 for each of the different cancer types evaluated. Nearly all comparisons were within expected statistical variation or statistically lower than expected, based on the age and sex of the residents and using the comparison areas of census tracts socioeconomically similar to census tract 98.10. A total of 1,559 cancers were diagnosed among males and females compared to about 1,673 cases expected for a ratio of 0.93, which was statistically lower than expected. The male ratio for all cancers of 0.98 (829 cancers compared to about 849 cases expected) was within expected statistical variation, while the female O/E ratio for all cancers combined of 0.89 (730 cancers compared to about 824 cases expected) was statistically lower than expected.

The O/E ratio for all cancer types for cases stratified as aged 0-14 and aged 15 and over were also mostly within expected statistical variation. The exceptions were: (1) statistically lower than expected ratios for all cancers combined for both genders combined aged 15 and over and for females aged 15 and over; and (2) statistically lower than expected ratios for leukemias for males aged 15 and over.

Tables 2a, 3a, and 4a, show the number of brain and CNS tumors (combining benign and malignant tumors) diagnosed in census tract 98.10 during 1979-2012, while Tables 2b, 3b, and 4b are restricted to persons with malignant brain tumors.

For tables 2a, 3a, and 4a, the observed number of cases in the entire census tract was close to the expected number based on the age and sex of the residents and using comparison areas of census tracts socioeconomically similar to census tract 98.10. A total of 78 brain and CNS tumors were diagnosed during 1979-2012 in the entire census tract among males and females compared to about 71 tumors expected for an O/E ratio of 1.10. This is within expected statistical limits. The O/E ratio for males of 1.02 (32 tumors compared to about 31 expected) and the O/E ratio for females of 1.17 (46 tumors compared to about 39 expected) were both within expected statistical limits. Individual block group O/E ratios for benign and malignant brain tumors combined are also displayed in Tables 2a, 3a, and 4a. Ratios for most block groups were within expected statistical variation. The exceptions were females in block group 2, males in block group 3 and both genders combined for block group 3. In block group 2 the ratio for females of 2.76 (six tumors compared to about two expected) during 1985-2012 was statistically high. The histology for the tumors of the six cases diagnosed in women in block group 2 during 1985-2012 was the same: benign meningioma. In block group 3 the ratio for benign and malignant tumors combined for males and females combined was 1.65 (20 tumors compared to about 12 expected) which was statistically higher than expected. The ratio for females alone was not higher than expected, but the ratio for males of 2.21 (12 tumors compared to about five expected) was statistically high. Eight of these 12 male tumors were malignant and are described in more detail below.

Individual block group O/E ratios for malignant brain tumors only are displayed in Tables 2b, 3b, and 4b. Risk ratios were all within expected statistical variation except for males and both genders combined in block group 3 and females in block group 4 and 5 combined. The ratio for males and females combined in block group 3 of 2.17 (10 tumors compared to about four or five expected) was statistically higher than expected. The two cases in females were too few to evaluate statistically, but there were eight brain malignancies diagnosed in males in block group 3 during the time period 1985-2012, compared to approximately three cases expected–an O/E ratio of 2.96 (95% CI: 1.27-5.82, $p<0.05$). The histologic types for the eight cancers diagnosed in males were listed as 1 oligodengroglioma, 1 astrocytoma, 1 medulloblastoma, 4 glioblastomas and 1 olfactory neuroblastoma. The ratio for females in combined block group 4 and 5 was statistically high at 2.75 with seven brain malignancies diagnosed compared to two or three cases expected. The histologic types for the seven cancers diagnosed in females were listed as 1 oligodendroglioma, 1 astrocytoma, 3 glioblastomas, 1 ependymoma and 1 mixed glioma.

Table 6 summarizes all data collected by telephone interview for 1985-2012 brain/CNS cases in block groups 2 and 3, and for cases diagnosed from 1979-2012 in combined block group 4/5. Interviews have indicated that all seven cases in block group 2 lived in residences that had direct line of sight to the antenna towers, with 4 of 7 cases living less than a mile from the towers. One had worked in an occupation associated with increased incidence of brain tumors. The length of time reported by interview that the seven cases had lived in block group 2 prior to diagnosis was as follows: 22 years, 18 years, 18 years, 33 years, 11 years, 15 years and 17 years (average residence of approximately 19 years). In block group 3, eleven of 19 diagnosed individuals, or a surviving family member, were successfully contacted. Interviews indicated all but one case had direct line of sight to the towers with seven of 11 cases living less than a mile from the towers at the time of their diagnosis. Interviews indicated that six of 11 individuals diagnosed with a brain or CNS tumor in block group 3 had worked in an occupation associated with an increased risk of developing a brain tumor. The length of time persons with a brain tumor had lived in block group 3 prior to diagnosis was calculated based on information from the 11 interviews (eight male cases and three female cases) and varied as follows: 3 years, 26 years, 26 years, less than 3 years, 2 years, 27 years, 15 years, 11 years, 5 years, 19 years and 30 years (average residence of approximately 15 years). Interviews were obtained for two of seven female cases in combined block group 4/5 where a statistically high number of brain tumors occurred. Interviews indicated both cases had direct line of sight to the towers from their residence and both lived more than a mile from the towers. One individual had lived at their residence for eight years and one for 12 years prior to their diagnosis. One case reported a history of work in an occupation associated with an increased risk of developing a brain tumor. No one interviewed from any of the three block groups with a statistically high number of brain tumors reported a history of serious head injury (resulting in concussion or requiring hospitalization) or radiation therapy for medical conditions prior to diagnosis.

Table 7 displays the various distributions of RF measurements for the 259 residences that served as standards to calculate expected residence counts of brain cancer cases by RF ranges, which are displayed in Tables 8-11. Because so few residences were found to have RF measurements in the higher ranges, grouped ranges of RF were established to achieve more stable estimates of expected counts. Tables 8 and 9 use two RF ranges: 0.00-1.99 and 2.00+, while Tables 10 and 11 use RF ranges that approximate quintiles: 0.00-0.49, 0.50-0.99, 1.00-1.99, 2.00-2.99, and 3.00+.

Table 8 shows that the expected number of residences of cases of benign and malignant brain tumors combined in block group 3 for the two RF ranges, 0.00-1.99 and 2.00+, were both within expected statistical variation. The O/E ratios were 1.07 and 0.89, respectively. If one assumes that the seven brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are eight possible ways that Table 8 would change depending on how many of the seven case residences would have been added to each of the two RF ranges. Based on a new total of 19 case residences and recalculating the O/E ratios for each of these eight possible combinations, none would result in statistically high ratios for either RF range category. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Table 9 displays a similar format to Table 8, but includes only malignant brain tumor information. The O/E ratios were 1.14 and 0.76, respectively, for the 0.00-1.99 and 2.00+ RF ranges. The first ratio was not statistically high and the second ratio had too few cases to test statistically. If one assumes that the three malignant brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are four possible ways that Table 9 would change depending on how many of the three case residences would have been added to each of the two RF ranges. Based on a new total of 10 cases and recalculating the O/E ratios for each of these four possible combinations, none would result in statistically high ratios for either RF range category. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Table 10 shows that the observed number of residences of cases of benign and malignant brain tumors combined in block group 3 for the five RF ranges, 0.00-0.49, 0.50-0.99, 1.00-1.99, 2.00-2.99 and 3.00+ were all within expected statistical variation or had too few cases to test statistically. The ratios were 1.03, 1.31, 0.80, 0.00 and 1.41, respectively. If one assumes that the seven brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are 330 possible ways that Table 10 would change depending on how many of the seven case residences would have been added to each of the five RF ranges. Based on a new total of 19 case residences and recalculating the O/E ratios for each of these 330 possible combinations, there is a 2.1% chance (7 of the 330 possible combinations) that the resulting findings would have been statistically high for any particular RF range category. The possible combinations that would have resulted in statistically high ratios would be if 6 or 7 case residences had been measured as being in either the lowest or highest range value or if all 7 case residences had been added to one of the three middle RF range values. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Table 11 displays a similar format to Table 10, but includes only malignant brain tumor information. The O/E ratios were 0.88, 1.68, 0.69, 0.00 and 1.21, respectively, for the 0.00-0.49, 0.50-0.99, 1.00-1.99, 2.00-2.99 and 3.00+ RF ranges. The one RF range (0.50-0.99) that had sufficient counts to test statistically was not higher than expected. The other RF ranges all had too few cases to test statistically. If one assumes that the three malignant brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are 35 possible ways that Table 11 would change depending on how many of the three case residences would have been added to each of the five RF ranges. Based on the new total of 10 cases and recalculating the O/E ratios for each of these 35 possible combinations, none would result in statistically high ratios for any of the RF range categories. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

The results of the current analysis are similar to the findings of the 2004 study. Statistically significant SIRs persist in women in block group 2 and in men in block group 3. There have been two new cases diagnosed in women in block group 2 and five additional cases reported in men in block group 3. The histologic pattern of the new cases resembles that of the original cases diagnosed from 1985-2002 reported in the 2004 study. Two new cases of benign meningioma were diagnosed in females in block group 2, and of the five new cases in males in block group 3, two were benign and three were malignant (one oligodengroglioma, one glioblastoma and one olfactory neuroblastoma). Consequently, SIRs for women in block group 2 and men in block group 3 remain statistically significant and the confidence intervals have become narrower (indicating greater precision of the risk estimate) with the larger study sample. The finding of higher than expected female brain malignancies in block group 4 and 5 combined for 1979-2012 is new since the previous study. Four female cases were added from this area since the 2004 study making a total of seven cases compared to an expected count of two or three and an O/E ratio of 2.75, which is statistically high. (Six cases would have been within expected statistical variation.) This area is just east of Heritage Rd. and south of U.S. Highway 6 about two miles southeast of the Lookout Mountain antenna farm.

New results from the current analysis include an evaluation of residential location of brain tumor cases in block group 3 compared to residential RF measurements collected in block group 3. The observed/expected calculation approach suggests that residences of brain tumor cases in block group 3 (whether benign and malignant combined or malignant only) had RF values similar to what would be expected from the distribution of RF measurements among the 259 residences not home to any brain tumor cases.

IV. DISCUSSION

Findings from the 2015 study continue to be consistent with previous CDPHE reviews of cancer outcomes in residents near the LOM broadcast antennas with a reported persistent elevation in incidence of brain tumors in some block groups but with several inconsistencies reported in gender affected and histologic tumor type.

The study design used in this update is essentially the same as the design used in the 1998 tract-level analysis and the 1999 and 2004 block group-level analyses of cancer incidence.[1,4,5] As discussed in those previous reports, this type of health statistics review, designed to investigate an apparent excess number of people with a particular disease outcome, does not allow definitive conclusions to be made about a cause and effect relationship with any particular potential exposure, such as electromagnetic radiation from broadcast antennas. Studies of this type are frequently conducted around communities adjacent to suspected environmental exposures since they can readily use data routinely reported to cancer registries and allow citizens to compare cancer incidence in their community to the expected incidence based on rates in a similar comparison population not affected by the environmental exposure of concern.[10] Observed differences between communities, however, are not necessarily attributable to the hypothesized exposure. Lack of reliable data for critical exposure variables such as a measurement of individual exposure, in- and out-migration, other exposures inside or outside the home, or length of residence may result in misclassification bias in studies of this nature. Inherent in this study design is that information on potential confounders may be lacking and cannot be easily controlled for. This study was able to control for potential confounding due to population differences in age and sex, by calculating age- and sex-adjusted tumor rates. It also took into account socioeconomic status, since the comparison areas were roughly matched on income. SES has been shown to be an important risk factor for brain/CNS cancer with higher rates typical in higher SES populations.

Data on individual-level exposures to electromagnetic radiation were not collected in this study, and geographic area (assigning cases to block group area) was used as a surrogate for exposure, similar to the 1998, 1999 and 2004 studies. Residence-level RF measurements from the Lookout Mountain area collected by CSU researchers in 2002 confirmed an association between RF exposure levels and (a) distance of a residence to the towers; (b) elevation of the home; and (c) unobstructed line-of sight (percent of towers visible).[6] Because of the complex topography in the census tract studied, RF exposure within some block group boundaries is not uniform, and therefore, block group is at best a crude measure of exposure.

For the current study, RF measurements collected by CSU scientists during 2002 were evaluated by address in block group 3. It was determined that residences of brain tumor cases (whether benign and malignant combined or malignant only) measured no higher RF values in general than would be expected from the distribution of RF measurements among the 259 residences not home to any brain tumor cases. One critique of these RF measurements is that no data were collected in the part of block group 3 at the eastern base of Lookout Mountain where a large number of homes exist, including the homes of seven brain cancer cases. An attempt was made in the current study to test the effect of adding these seven residences into each of the various RF ranges that were evaluated, assuming that, if measured, they could have been categorized into any of the RF ranges assessed. For Tables 8, 9 and 11, all of the assumed O/E ratios based on this approach were within expected statistical variation. For Table 10, there was a low chance (2.1%) of any particular RF range value being statistically high. The possible combinations that would have resulted in statistically high ratios would have been if 6 or 7 case residences had been measured as being in either the lowest or highest range value of the five RF categories (0.00-0.49, 0.50-0.99, 1.00-1.99, 2.00-2.99 and 3.00+) or if all 7 case residences had been added to one of the three middle RF range values. Given that six of the seven case residences that were not measured were a mile or more from the tower complex, it is unlikely that they would have been measured in the highest RF range. These RF measurement data were not intended to capture the full range of historical exposures to RF on Lookout Mountain nor do they represent individual person-level exposure. However, they did offer the first opportunity to link a measure of potential RF exposure at the residence level to Cancer Registry data. Results of this linkage tend to support the finding that RF intensity in block group 3 has a very low probability of an association with the residential locations of brain tumor cases and, thus, may not explain the increased incidence of brain cancers in that block group.

The histology or cell type of a cancer may offer clues to whether an elevated observed/expected cancer ratio is indicative of a possible association with a particular environmental exposure or possibly a chance occurrence. Differences were noted in the histologic type for cases residing in block group 2 compared to those in block group 3 and combined block group 4/5. All seven of the women diagnosed with tumors between 1985 and 2012 in block group 2 had benign meningiomas. One benign case was diagnosed in a male in block group 2. This individual was diagnosed with a benign neurilemoma (schwannoma). In block group 3, all but one of the malignant brain cases diagnosed were glioma type (either astrocytomas, medulloblastomas, oligodengrogliomas or glioblastomas). Eight of 10 malignant cases from block group 3 occurred in males. In block group 4 and 5 combined, all of the malignant brain cases diagnosed were glioma type (either astrocytoma, oligodengroglioma, glioblastoma, ependymoma or mixed glioma), but seven of eight malignant cases in this area were females.

In addition to differences in cell type, the gender of cases contributing to statistically significant O/E ratios was different between block groups 2 (female, benign tumors), 3 (male, malignant tumors) and 4/5 combined (female, malignant tumors)–although there are cases of both genders in all three block group areas. Associations are generally strengthened when both genders show a similar pattern of excess numbers of a particular type of cancer, because exposures found in or around the home would be expected to affect both genders. Therefore these findings tend to weaken the hypothesis of a common etiology of elevated brain/CNS tumors in these three block groups, although the importance of other factors in the development of brain/CNS tumors, and what, if any additive or synergistic effect with RF exposure they may have, is unknown.

Several large expert reviews of the available scientific literature on RF exposure and cancer have been released since 2004.[11, 13-18, 24] Overall, study outcomes still exhibit enough inconsistency and acknowledged methodological difficulties that recent reviews by expert panels have reached somewhat different conclusions about the likelihood of an association between RF exposure and cancer and how uncertainty or bias in study design should be interpreted.

In 2011, the International Agency for Research on Cancer (IARC) evaluated carcinogenic risks to humans from radiofrequency electromagnetic radiation and classified RF fields as possibly carcinogenic (IARC Group 2B) based on limited epidemiologic evidence in humans of increased risk of glioma (malignant brain cancer) and acoustic neuroma associated with cell phone use.[19] A detailed review and summary was published in 2013 as IARC Monograph Vol. 102.[11] The IARC Working Group (WG) reviewed available epidemiologic evidence for an association of RF-EMF exposure and cancer for several populations: those exposed in occupational settings, general population exposure to sources in the environment (broadcast antennas, mobile phone base stations), and personal exposure to mobile phones, cordless phones and other devices. Evidence from available studies of occupational and environmental exposures was judged by the WG to be inadequate. Therefore the WG primarily based it's classification for RF fields on studies of cell phone users. Two retrospective case-control studies were selected by the WG as the most informative for the evaluation, namely the INTERPHONE study and a pooled analysis of studies by the Hardell group of Swedish cell phone subscribers.[21-23]

In the INTERPHONE study, a large multi-national case-control study, an elevated risk of glioma and acoustic neuroma was observed among the 10 percent of study participants who reported the longest cumulative call time (heaviest regular cell phone users defined as those using a cell phone for 1,640 hours or more). Odds ratios (ORs) were uniformly below or close to unity for the other nine deciles of exposure, with the ninth decile showing the lowest risk. Data suggested increased risk for ipsilateral exposure (on the same side of the head as the tumor) and for tumors in the temporal lobe (where RF exposure to the brain is highest). A reduced OR related to ever having been a regular mobile phone user was seen for glioma [OR 0.81; 95% confidence interval (CI) 0.70-0.94] and meningioma (OR 0.79; 95% CI 0.68-0.91), which the WG concluded could possibly reflect participation bias or other methodological limitations. The Swedish pooled analysis reported an OR for glioma of 1.3 (95% CI 1.1-1.6) for participants who had used a mobile phone for more than 1 year with increased ORs reported for increasing time since first use of a cell phone and for total call time (OR 3.2; 95% CI 2.0-5.1 reported for the heaviest users with more than 2,000 hours of use). Similar findings were reported for use of cordless phones. The IARC WG determined that evidence in the available studies was *limited*[3] for glioma and acoustic neuroma and *inadequate*[4] to draw conclusions for other types of cancer including meningioma.

The IARC WG noted that both the INTERPHONE study and the Swedish pooled analysis were susceptible to recall and participation bias with an uncertain effect on study outcomes, however a majority of the review panel concluded that the findings could not be dismissed as attributable to bias alone, and that a causal interpretation between mobile phone RF-EMF exposure and brain cancer was possible.[19] Some members of the IARC WG, however, considered the evidence in humans to be inadequate due to inconsistencies between the INTERPHONE and Swedish studies, lack of exposure-response in the INTERPHONE data, and no corroborating evidence of an increase in brain cancer incidence rates in time-trend data.

To address some of the uncertainties, additional analyses were undertaken by the INTERPHONE researchers and findings were published as Appendix 2 to the study. In the original paper, those who *never* used mobile phones had been used as the reference group. For the analysis in the appendix, the category *lightest users* (those who used cell phones for less than two years) were used as the reference group. The reanalysis showed a doubling of risk of glioma for those who used a mobile phone for ten or more years and a dose-response relationship was observed, with the highest risk among the heaviest users. There was no statistical elevation reported for meningioma even among those with highest exposure.

Since the release of the INTERPHONE study, population-based cancer registries in several countries have been used to look at trends in brain tumor incidence since the time cell phone use became widespread.[12, 20] Results show incidence rates of glioma have remained stable and do not appear to be compatible with projected rates that would be expected from the Swedish studies or INTEREPHONE. As others have pointed out, many of the these time-trend studies have substantial limitations. However, because most of the analyses examined trends until the early 2000s only, trend analysis may not yet be of sufficient duration if excess risk only manifests more than a decade after phone use begins, or if phone use only affects a small proportion of brain tumor cases, e.g., the most heavily exposed.[26, 12]

Additional studies published since the IARC review in 2011 have not lent strength to the finding of increased risk of glioma from RF exposure in cell phone users. The UK

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[3] ***'Limited evidence of carcinogenicity'***: A positive association has been observed between exposure to the agent and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence.

[4] ***'Inadequate evidence of carcinogenicity'***: The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available.

Million Women study was a prospective cohort that investigated risk in relation to duration and level of cell phone use. Use of mobile phones was not associated with an increased risk of glioma or meningioma. An increased risk of acoustic neuroma in women who had used a mobile phone for 5 years or longer was reported, with risk increasing with increasing duration of exposure.[27] An increased risk of acoustic neuroma in cell phone users has also been reported in a study conducted in Japan.[25]

Several other expert reviews of RF exposure and cancer outcomes have concluded the weight of evidence from the available studies does not suggest an increased risk of cancer from RF exposure. Most reviews are in agreement that the available studies are not of sufficient length to rule out possible effects from long-term continuous RF exposure, with some agencies recommending a precautionary approach until inconsistencies can be resolved and longer-term effects have been more thoroughly evaluated.[13, 14, 16-18, 24]

The IARC cancer review for RF EMFs found the evidence to be insufficient to reach a conclusion as to the potential association of mobile-phone use and either leukemia or lymphoma. For the 2015 study, we retained analysis of these cancer types to maintain consistency with previous reports and to provide information important to the community. However, the absence of increased risk for these tumors types in the Lookout Mountain area is no longer regarded as an inconsistency (as discussed in the 2004 study[5]) based on generally negative findings in recent expert reviews of RF exposure and cancer.

Telephone interviews of brain/CNS cases from block groups 2, 3 and 4/5 combined indicated that all but one residence had direct line of sight to the antennas from their residence at the time of diagnosis. While this information does not confirm or quantify "exposure" or make meaningful comparisons to non-cases, it does indicate the potential for exposure from the towers for most cases. As shown in table 6, some differences were noted between block groups regarding the percent of individuals living within a mile or less of the towers, with the majority of interviewed block group 3 cases responding that they lived less than a mile from the towers and almost half of the interviewed block group 2 cases responding that they lived more than a mile away. Both block group 4/5 case residences for which information was collected reported being more than a mile from the towers, consistent with the fact that all homes in this area are more than a mile away. Spot RF measurements from the Lookout Mountain area taken by CSU scientists confirmed previous data indicating that the intensity of RF exposure is highly dependent on distance from broadcast towers particularly for residences with direct line of sight to the broadcast antennas. In the CSU study, power density levels were 10-20 times higher for residences 1-2 km or less from the towers compared to those greater than 2 km away (approximately one mile). For residences within an average distance of 1-3 km from the towers, exterior RF measurements were 13-30 times greater among homes that had over 50% of the transmitters visible compared with homes with 50% or less visible at those distances.[6]

Differences in residency time were reported in interviews, with all of the cases from block group 2 having lived at the residence listed at the time of their diagnosis for more than 10 years, while 3 of the 11 cases from block group 3 reported living at that residence for less than 5 years. Only two of seven cases or surviving family members were successfully contacted in block group 4/5, both of whom were reported to have lived near the towers for more than 5 years. While latency, or the time between exposure and clinical recognition of a disease, is believed to be at least 5 years and usually more than 10 years for a genotoxic environmental exposure and cancer, tumor promoters may shorten latency periods for disease already initiated. Non-ionizing RF radiation has been suggested to act as a cancer promoter, however uncertainty remains regarding a potential biological mechanism by which RF radiation might act. Therefore, it is not yet possible to assign a scientifically-based estimate of latency for exposure to RF radiation. The latest expert reviews report an association between RF exposure from cell phone use and increased risk of brain tumor after 5-15 years of exposure among the heaviest users. [11, 19, 22, 27]

In this study, no individual-level information was available on personal exposure levels inside or outside of the home, such as use of electrical appliances or electronic equipment, frequency of cell phone use, or exposure to RF electromagnetic radiation from the towers. In block group 3, the majority of those diagnosed with a brain or CNS cancer also reported having worked in a job category associated in the literature with an increased risk of developing a brain or CNS tumor. These exposures could represent an alternative source of exposure to non-ionizing radiation or could be additive with exposures to the towers as a contributory factor. In block group 2, where most cases occurred in women, no occupational exposure associated with an increased risk of brain tumor occurrence was reported. Interview information for the two block group 4/5 cases indicated possible occupational exposure associated with increased risk of brain tumor for one of the cases. Although some occupational history was gathered during interviews for block groups with a statistically high number of brain tumors, it is not possible to establish precise RF exposure levels over a meaningful period of time for any of these individuals from this study. The role of occupation as a potential confounder in this study is uncertain but interviews indicate a potentially more significant effect for block group 3 cases. Similarly, a positive family history of brain/CNS cancer could suggest an alternate etiology for disease outcome (other than exposure from the towers), or could suggest that an inherited cancer susceptibility gene made the case more likely to develop a tumor as a result of exposure to a carcinogen. It is not possible to clearly identify the role of family history and susceptibility in this study but only one of the 20 cases/surviving family members interviewed reported a known family history of brain tumor. The significance of data gathered by interview regarding line of sight, distance to towers, residence time and occupational exposures is limited, particularly for block groups 3 and 4/5 combined, due to the low percentage of cases/surviving family members that could be successfully located and interviewed (58% and 29% interviewed for block group 3 and block group 4/5 combined, respectively).

This study presented an opportunity to assess exposure data available prior to the time a new Supertower (multiple broadcast transmitters consolidated onto one new tower) was constructed on Lookout Mountain to replace multiple existing broadcast antennas. At the time the 2004 study was released, panel members strongly recommended further review of any well-designed RF exposure surveys for the Lookout Mountain area, should such data become available, and consideration of linkage of RF exposure data with available Cancer

Registry statistics. Because of the significant tower configuration changes when the Supertower was built in 2008, data collected by CSU represent the only opportunity to assess exposure during the time period when cancer cases were reported (assuming minimum latency of 5 years or more). As reported by CSU researchers, exposure data for residences tested in the LOM area indicate RF levels were all below current safety limits set for the general public, however approximately 25% of all LOM residences where exposure data were collected had RF measurements above the median RF exposure level estimated for the U.S population at large.[6] Metrics devised to assess available exposure data for the 2015 study did not confirm an association with RF level and increased risk of developing cancer which weakens the hypothesis that the excess number of brain tumors reported are associated with RF exposure from the broadcast towers. However these results should be considered within the context of the relatively small number of cases reported and availability of exposure data for block group 3 cases only.

V. CONCLUSIONS

Results of the 2015 update of cancer incidence for 1979-2012 for residents living in the vicinity of the Lookout Mountain towers are generally consistent with the findings reported in the previous studies, and confirm a persistent elevation of brain/CNS tumors in some of the geographic areas studied. The 1998 study covered the time period from 1985-1995. The 1999 study covered the time period from 1979-1997. The 2004 study covered the time period from 1979-2002. This update analyzed Cancer Registry statistics for an additional ten years of tumor data, and uses more precise population estimates made available with the release of the U. S. Census 2010 data. It also evaluated RF measurements collected in 2002 by scientists at Colorado State University in relationship to the residential location of brain cancers in block group 3.

Cancer incidence for all tumor types investigated for census tract 98.10 as a whole was within the expected statistical range. The only consistently elevated ratios reported in the 2015 update (although still within expected statistical variation) were for brain and other central nervous system (CNS) tumors, which is consistent with the findings in the 1999 and 2004 studies. Findings for brain/CNS tumor statistics by individual block groups can be summarized as follows:

1. The O/E ratios for benign brain/CNS tumors in women in block group 2 and malignant brain/CNS tumors in men in block group 3 remain statistically elevated. The O/E ratio for malignant brain/CNS tumors in block group 4/5 combined is statistically elevated in women only.

2. O/E ratios were within expected statistical variation for brain/CNS tumors in all other block group areas for both men and women.

3. Two additional new benign brain/CNS tumors were diagnosed in women in block group 2, during the extended years of observation of 2003-2012, and three additional malignant brain/CNS cancers were diagnosed in men in block group 3. These additional cases do not meaningfully alter the O/E ratio or confidence interval reported for these block groups in the 2004 study and do not alter the strength of association reported in 2004 for either block group. One new finding not previously reported was a statistically elevated number of brain cancers in block group 4 and 5 combined. Four new cases of malignant brain/CNS cancers were diagnosed in females in block group 4/5 since the 2004 study, resulting in a statistically high number of malignant cancers in this block group for females only.

4. Block groups 2 and 3 are the block groups in closest proximity to the towers. Combined block group 4/5 is located approximately 2 miles southeast of the transmitters.

5. 100% of cases (or their survivors) diagnosed during 1979-2012 in block group 2 and all but one case in block group 3 indicated by telephone interview that there was direct line of sight or an unobstructed view of the towers from the case's residence, indicating the potential for RF exposure at these residences. One of two cases/surviving family members interviewed from block group 4/5 indicated direct line of sight to the towers at the time of their diagnosis.

6. In block group 2, for the period 1985-2012, the majority of the cases (6 of 7 cases) were diagnosed in females, all with similar histology -benign meningioma. One case reported a history of brain tumor in a close relative (maternal aunt) and one reported work in an occupation with an increased risk of developing a brain tumor. The importance of these factors in the development of brain/CNS tumors, and what if any additive or synergistic effect with RF exposure they may have, is unknown. The duration of residence in case homes prior to diagnosis of disease was > 10 years in all block group 2 cases.

7. In block group 3, the majority of cases for the period 1985-2012 were diagnosed in males (12 of 20 cases), eight of the 12 with malignant glioma. The occupational history, i.e. an alternate exposure source, was positive in six of the eleven block group 3 cases for whom an interview was completed, although the precise length of occupational exposure associated with increased risk of brain/CNS tumor is unknown, as is the potential for interactive effects with RF exposure in the home. The duration of residence in the case's home prior to diagnosis of disease was <5 years for 3 of the 11 cases. The latency, or time between exposure and clinical recognition of a disease, is believed to be at least 5 years and usually more than 10 years for a

genotoxic environmental exposure and cancer. In light of the uncertainties related to potential biological mechanisms by which RF might act, however, it is not yet possible to assign a scientifically based estimate of latency for RF exposure and tumor growth, but recent reviews of the association of RF exposure from cell phone use and brain cancer have not generally detected an association with exposure of less than 5-15 years.

8. In block group 4/5 combined, the majority of cases of malignant brain/CNS cancer occurred in women (7 of 8 cases diagnosed for the period 1979-2012), which was the only statistically significant finding for that block group. Contacting cases or surviving family members for interview was less successful for this block group with only 2 of 7 contacted. Block group 4/5 is located distant to the broadcast towers (> 2 miles) compared to block groups 2 and 3, which indicates likely lower exposure levels for this geographic area as a whole.

9. Inconsistencies in gender and cell type persist in the 2015 study. Cell types were not the same across block groups with a statistically high incidence of brain/CNS tumors. Differences were noted in the histologic type for cases residing in block group 2 (benign meningioma) compared to those in block group 3 and combined block group 4/5 (malignant tumors). For the two block groups with elevated numbers of malignant brain tumors (block group 3 and 4/5 combined) men and women were not similarly affected. There is no indication in the scientific literature that residential exposure to RF would selectively affect one gender differently than another, therefore these findings tend to weaken the hypothesis of a common etiology of elevated brain/CNS tumors across all block groups. However the scientific knowledge of RF exposure and the potential for interactive effects with other individual exposures is not adequate to draw firm conclusions about this disparity between genders and cell type particularly for longer-term exposures. Recent expert reviews of RF exposure in cell phone users somewhat strengthens the possibility of an association between RF exposure and glioma (malignant brain cancer), but weakens the likelihood of an association with meningioma (benign brain tumors).

10. The 2015 study provides the first linkage of RF exposure data with available Cancer Registry statistics and provides an evaluation of residential location of brain tumor cases in block group 3 compared to residential RF measurements collected by CSU researchers for that block group. Metrics devised to assess available exposure data for the 2015 study did not confirm an association with RF level and increased risk of developing brain cancer which weakens the hypothesis that the excess number of brain tumors reported are associated with RF exposure from the broadcast towers. However these results should be considered within the context of the relatively small number of cases reported and availability of exposure data for block group 3 cases only.

As discussed in the three previous CDPHE studies[1, 4, 5] the results of this type of study cannot produce conclusive information about cancer causation. Rather, the goal was to determine if there are data that support an association between the observed elevated risk ratios for brain and CNS tumors and RF exposure from the broadcast towers. This study confirmed a persistent elevation in brain/CNS tumor incidence in two block groups (2 and 3) and reports a new finding of a statistically elevated number of brain cancers in one additional block group (4/5 combined). Study conclusions also note inconsistencies in gender, cell type (benign versus malignant brain tumors) and RF exposure level between these block groups which weakens the hypothesis of a common etiology or one underlying cause for the statistically significant elevations reported. In addition, linkage of RF exposure data (external spot measurements) with Cancer Registry data indicate a very low probability of an association between residential RF exposure and brain tumor incidence for the data available. As with past cancer incidence reviews, it is difficult to draw definitive conclusions because brain cancer is a relatively rare disease and case numbers are few in the Lookout Mountain area.

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Table 1a - Number of **Males** with Cancer Compared to the Expected Number in Census Tract 98.10 by Cancer Site, 1979-2012

Cancer Site	Observed	Expected	O/E Ratio	P value	95% C.I.
All Cancers	829	848.852	0.98	NS	0.91-1.05
- Age 0-14	8	5.570	1.44	NS	0.62-2.83
- Age 15+	821	843.282	0.97	NS	0.91-1.04
Brain and CNS	18	16.052	1.12	NS	0.66-1.77
- Age 0-14	2	1.111	1.80	NC	NC
- Age 15+	16	14.940	1.07	NS	0.61-1.74
Leukemias	18	27.661	0.65	NS	0.39-1.03
- Age 0-14	3	2.168	1.38	NS	0.29-4.05
- Age 15+	15	25.493	0.59	<0.05	0.33-0.97
Non-Hodgkin Lymphoma	27	34.691	0.78	NS	0.51-1.13
Male Breast	0	NC	NC	NC	NC
Eye Melanoma	1	NC	NC	NC	NC

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 1b - Number of **Females** with Cancer Compared to the Expected Number in Census Tract 98.10 by Cancer Site, 1979-2012

Cancer Site	Observed	Expected	O/E Ratio	P value	95% C.I.
All Cancers	730	823.697	0.89	<0.05	0.82-0.95
- Age 0-14	5	4.752	1.05	NS	0.34-2.46
- Age 15+	725	818.945	0.89	<0.05	0.82-0.95
Brain and CNS	18	10.702	1.68	NS	1.00-2.66
- Age 0-14	2	1.310	1.53	NC	NC
- Age 15+	16	9.391	1.70	NS	0.97-2.77
Leukemias	16	16.344	0.98	NS	0.56-1.59
- Age 0-14	1	1.224	0.82	NC	NC
- Age 15+	15	15.120	0.99	NS	0.55-1.64
Non-Hodgkin Lymphoma	21	26.299	0.80	NS	0.49-1.22
Female Breast	294	315.655	0.93	NS	0.83-1.04
Eye Melanoma	0	NC	NC	NC	NC

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 1c - Number of **Males and Females** with Cancer Compared to the Expected Number in Census Tract 98.10 by Cancer Site, 1979-2012

Cancer Site	Observed	Expected	O/E Ratio	P value	95% C.I.
All Cancers	1559	1672.549	0.93	<0.05	0.89-0.98
- Age 0-14	13	10.322	1.26	NS	0.67-2.15
- Age 15+	1546	1662.227	0.93	<0.05	0.88-0.98
Brain and CNS	36	26.754	1.35	NS	0.94-1.86
- Age 0-14	4	2.421	1.65	NS	0.45-4.23
- Age 15+	32	24.331	1.32	NS	0.90-1.86
Leukemias	34	44.005	0.77	NS	0.53-1.08
- Age 0-14	4	3.392	1.18	NS	0.32-3.02
- Age 15+	30	40.613	0.74	NS	0.50-1.06
Non-Hodgkin Lymphoma	48	60.990	0.79	NS	0.58-1.04
Female Breast	294	315.655	0.93	NS	0.83-1.04
Eye Melanoma	1	NC	NC	NC	NC

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 2a - Number of **Males** with Brain and CNS Tumors **(Benign + Malignant)**[1] Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-2012	32	31.454	1.02	NS	0.70-1.44
Block Group 1	1979-2012	3	5.759	0.52	NS	0.11-1.52
Block Group 2	1985-2012	1	1.498	0.67	NC	NC
Block Group 3	1985-2012	12	5.420	2.21	<0.05	1.14-3.86
Block Group 4&5	1979-2012	6	6.549	0.92	NS	0.34-2.00
Block Group 6	1979-2012	0	0.895	0.00	NC	NC
Block Group 7	1979-2012	10	10.234	0.98	NS	0.47-1.80

[1]--"Benign + malignant" includes all tumors, i.e., benign, in-situ, malignant, and uncertain.
NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 2b - Number of **Males** with Brain and CNS Tumors **(Malignant only)** Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-2012	18	16.052	1.12	NS	0.66-1.77
Block Group 1	1979-2012	2	2.883	0.69	NC	NC
Block Group 2	1985-2012	0	0.698	0.00	NC	NC
Block Group 3	1985-2012	8	2.707	2.96	<0.05	1.27-5.82
Block Group 4&5	1979-2012	1	3.353	0.30	NC	NC
Block Group 6	1979-2012	0	0.449	0.00	NC	NC
Block Group 7	1979-2012	6	5.186	1.16	NS	0.42-2.52

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 3a - Number of **Females** with Brain and CNS Tumors **(Benign + Malignant)**[1] Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-2012	46	39.322	1.17	NS	0.86-1.56
Block Group 1	1979-2012	4	6.982	0.57	NS	0.16-1.47
Block Group 2	1985-2012	6	2.171	2.76	<0.05	1.01-6.02
Block Group 3	1985-2012	8	6.694	1.20	NS	0.52-2.35
Block Group 4&5	1979-2012	14	9.928	1.41	NS	0.77-2.37
Block Group 6	1979-2012	1	1.063	0.94	NC	NC
Block Group 7	1979-2012	13	11.753	1.11	NS	0.59-1.89

[1]--"Benign + malignant" includes all tumors, i.e., benign, in-situ, malignant, and uncertain.
NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 3b - Number of **Females** with Brain and CNS Tumors **(Malignant only)** Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-2012	18	10.702	1.68	NS	1.00-2.66
Block Group 1	1979-2012	2	1.862	1.07	NC	NC
Block Group 2	1985-2012	0	0.516	0.00	NC	NC
Block Group 3	1985-2012	2	1.904	1.05	NC	NC
Block Group 4&5	1979-2012	7	2.543	2.75	<0.05	1.11-5.68
Block Group 6	1979-2012	0	0.284	0.00	NC	NC
Block Group 7	1979-2012	7	3.289	2.13	NS	0.86-4.39

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 4a - Number of **Males and Females Combined** with Brain and CNS Tumors **(Benign + Malignant)**[1] Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-2012	78	70.776	1.10	NS	0.87-1.38
Block Group 1	1979-2012	7	12.741	0.55	NS	0.22-1.13
Block Group 2	1985-2012	7	3.669	1.91	NS	0.77-3.93
Block Group 3	1985-2012	20	12.114	1.65	<0.05	1.01-2.55
Block Group 4&5	1979-2012	20	16.477	1.21	NS	0.74-1.88
Block Group 6	1979-2012	1	1.958	0.51	NC	NC
Block Group 7	1979-2012	23	21.987	1.05	NS	0.66-1.57

[1]--"Benign + malignant" includes all tumors, i.e., benign, in-situ, malignant, and uncertain.
NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 4b - Number of **Males and Females Combined** with Brain and CNS Tumors **(Malignant only)** Compared to the Expected Number in Census Tract 98.10, by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-2012	36	26.754	1.35	NS	0.94-1.86
Block Group 1	1979-2012	4	4.745	0.84	NS	0.23-2.16
Block Group 2	1985-2012	0	1.214	0.00	NC	NC
Block Group 3	1985-2012	10	4.611	2.17	<0.05	1.04-3.99
Block Group 4&5	1979-2012	8	5.896	1.36	NS	0.59-2.67
Block Group 6	1979-2012	0	0.733	0.00	NC	NC
Block Group 7	1979-2012	13	8.475	1.53	NS	0.82-2.62

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 5. Number of Malignant or Benign Brain and Central Nervous System Tumor Cases in Census Tract 98.10, by Year and Block Group at Diagnosis.

Year	Malignant					
	Block Group					Total
	1	2	3	4/5	7	
1979					1	1
1980		1			1	2
1981						
1982	1					1
1983						
1984				2	1	3
1985			1			1
1986						
1987						
1988						
1989						
1990			1			1
1991						
1992					1	1
1993						
1994	1		1			2
1995	1		1	2	1	5
1996					1	1
1997			1		1	2
1998						
1999			1			1
2000						
2001	1				1	2
2002						
2003				1	2	3
2004						
2005			2		1	3
2006						
2007			1	1		2
2008				1		1
2009				1	1	2
2010						
2011			1		1	2
2012						
Total	4	1	10	8	13	36

Year	Benign					
	Block Group					Total
	1	2	3	4/5	7	
1979						
1980						
1981						
1982						
1983						
1984						
1985		1				1
1986				1		1
1987						
1988						
1989						
1990						
1991						
1992						
1993		1				1
1994				1		1
1995		1				1
1996					1	1
1997						
1998	1			3		4
1999				1		1
2000		1		1		2
2001						
2002		1				1
2003		1	3	1		5
2004			1	1	1	4
2005		1	1		1	3
2006	1					1
2007	1		2	2		5
2008			1		4	5
2009				1	1	2
2010						
2011					1	1
2012			2			2
Total	3	7	10	12	9	42

Empty cells indicate no diagnoses reported for the year in the block group.
Block group 6 is not included in Table 5 because only one case was reported from 1979-2012 (a benign case in 2004).

Table 6 - Summary of telephone interviews for brain/CNS tumor patients living in block group 2, block group 3, and combined block group 4&5.

Interview Question	Block Group 2[1] (n=7) [% answering *yes*]	Block Group 3[2] (n=11) [% answering *yes*]	Block Groups 4&5[3] Combined (n=2) [% answering *yes*]
Lived in area less than 5 years	0	27.3	0
Lived in area 5 years or more	100	72.7	100
Lived in area 10 years or more	100	63.6	50
Close blood relative with brain tumor	14.3	0	0
Can see antenna from home	100	90.1	100
Worked in occupation associated with increased risk of brain tumor[4]	14.3	54.5	50
Lived 1 mile or less from antennas	57.1	63.6	0
Lived more than 1 mile from antennas	42.9	36.4	100

[1] Interviews obtained for 7 of 7 cases diagnosed in block group 2 from 1985-2012.

[2] Interviews obtained for 11 of 19 individuals diagnosed in block group 3 from 1985-2012. These 19 individuals represent 20 cases with one person diagnosed with a double primary.

[3] Interviews obtained for 2 of 7 cases diagnosed in females in block group 4/5 combined from 1979-2012.

[4] Occupations associated in the scientific literature with an increased risk of brain tumor include: electronics and electrical workers (i.e., lineman, electrical engineer, technician/assembler); work in telecommunications industry; radio/TV repairman; pilot/aircraft worker; farm/agricultural worker; work with solvents or paints; work in rubber or petrochemical industry. Occupations of persons in block groups 2, 3 and 4/5combined included: pilot/aircraft worker (commercial or military); electrical work (computer software testing and geophysics); work with radar (meteorological research); work in energy sector (nuclear plant); and work with solvents (painting, printing and oil industry).

Table 7 –Distributions of RF measurements among 259 residences that were not home to any cases of brain tumors diagnosed 1979-2012 from block group 3.

RF Range	Count of Residences	Percent
0.00-0.99	108	41.7
1.00-1.99	54	20.8
2.00-2.99	36	13.9
3.00-3.99	26	10.0
4.00-4.99	7	2.7
5.00-5.99	11	4.2
6.00-6.99	3	1.2
7.00-7.99	5	1.9
8.00-8.99	0	0.0
9.00+	9	3.5
Total	259	100.0
0.00-1.99	162	62.5
2.00+	97	37.5
Total	259	100.0
0.00-0.49	42	16.2
0.50-0.99	66	25.5
1.00-1.99	54	20.8
2.00-2.99	36	13.9
3.00+	61	23.6
Total	259	100.0

Table 8 – Count of **Residences** of Cases with Brain and CNS Tumors **(Benign and Malignant)** in Block Group 3 by RF Ranges Compared to the Expected Count Based on the RF Distribution of Residences Not Home to Any Brain Tumor Cases

RF Range	Count of Residences	Expected Count	O/E Ratio	P Value
0.00-1.99	8	7.50 = (62.5% of 12)	1.07	NS
2.00+	4	4.50 = (37.5% of 12)	0.89	NS
Total	12	12.00	NA	NA

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05
NA=not applicable

Note: Residences in the most eastern subdivisions of block group 3 located just west of Heritage Rd. were not measured for RF. If one assumes that the 7 brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are eight possible ways the table above would change depending on how many of the 7 case residences would have been added to each of the two RF ranges. Based on a new total of 19 case residences and recalculating the O/E ratios for each of these eight possible combinations, none would result in statistically high ratios for either RF range category. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Table 9 – Count of **Residences** of Cases with Brain and CNS Tumors **(Malignant Only)** in Block Group 3 by RF Ranges Compared to the Expected Count Based on the RF Distribution of Residences Not Home to Any Brain Tumor Cases

RF Range	Count of Residences	Expected Count	O/E Ratio	P Value
0.00-1.99	5	4.375 = (62.5% of 7)	1.14	NS
2.00+	2	2.625 = (37.5% of 7)	0.76	NC
Total	7	7.00	NA	NA

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05
NA=not applicable

Note: Residences in the most eastern subdivisions of block group 3 located just west of Heritage Road were not measured for RF. If one assumes that the 3 malignant brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are four possible ways the table above would change depending on how many of the 3 case residences would have been added to each of the two RF ranges. Based on a new total of 10 case residences and recalculating the O/E ratios for each of these four possible combinations, none would result in statistically high ratios for either RF range category. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Table 10 – Count of **Residences** of Cases with Brain and CNS Tumors **(Benign and Malignant)** in Block Group 3 by RF Ranges Compared to the Expected Count Based on the RF Distribution of Residences Not Home to Any Brain Tumor Cases

RF Range	Count of Residences	Expected Count	O/E Ratio	P Value
0.00-0.49	2	1.944 = (16.2% of 12)	1.03	NC
0.50-0.99	4	3.06 = (25.5 of 12)	1.31	NS
1.00-1.99	2	2.496 = (20.8% of 12)	0.80	NC
2.00-2.99	0	1.668 = (13.9% of 12)	0.00	NC
3.00+	4	2.832 = (23.6% of 12)	1.41	NS
Total	12	12.00	NA	NA

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05
NA=not applicable

Note: Residences in the most eastern subdivisions of block group 3 located just west of Heritage Rd. were not measured for RF. If one assumes that the 7 brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are 330 possible ways the table above would change depending on how many of the 7 case residences would have been added to each of the five RF ranges. Based on a new total of 19 case residences and recalculating the O/E ratios for each of these 330 possible combinations, there is a 2.1% chance (7 of the 330 possible combinations) that the resulting findings would be statistically high for any particular RF range category. The possible combinations that would have resulted in statistically high ratios would be if 6 or 7 case residences had been measured as being in either the lowest or highest range value or if all 7 case residences had been added to one of the three middle RF range values. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Table 11 – Count of **Residences** of Cases with Brain and CNS Tumors **(Malignant Only)** in Block Group 3 by RF Ranges Compared to the Expected Count Based on the RF Distribution of Residences Not Home to Any Brain Tumor Cases

RF Range	Count of Residences	Expected Count	O/E Ratio	P Value
0.00-0.49	1	1.134 = (16.2% of 7)	0.88	NC
0.50-0.99	3	1.785 = (25.5% of 7)	1.68	NS
1.00-1.99	1	1.456 = (20.8% of 7)	0.69	NC
2.00-2.99	0	0.973 = (13.9% of 7)	0.00	NC
3.00+	2	1.652 = (23.6% of 7)	1.21	NC
Total	7	7.00	NA	NA

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05
NA=not applicable

Note: Residences in the most eastern subdivisions of block group 3 located just west of Heritage Rd. were not measured for RF. If one assumes that the 3 malignant brain tumor case residences located in the area of block group 3 that was not measured for RF could have been measured, there are 35 possible ways the table above would change depending on how many of the 3 case residences would have been added to each of the five RF ranges. Based on the new total of 10 case residences and recalculating the O/E ratios for each of these 35 possible combinations, none would result in statistically high ratios for any of the RF range categories. Source used for number of possible compositions: http://mathworld.wolfram.com/Composition.html

Figure 1. Map of Block Group Areas within Census Tract 98.10