An integrative investigation of the sources and effects of groundwater contamination for local communities and homeowners in North Carolina

USDA project 2006-03956

110.D INTEGRATED RESEARCH, EDUCATION, AND EXTENSION PROJECTS

Participants

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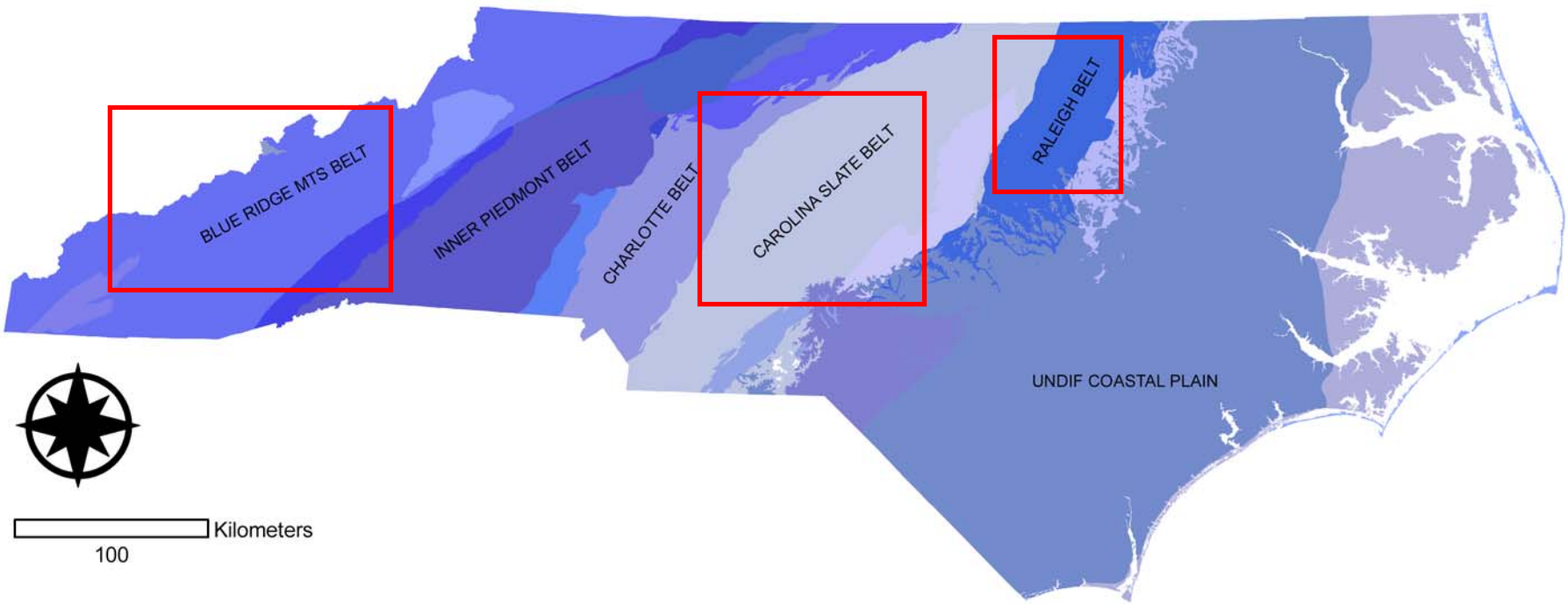
- Hope Taylor-Guevara: *Clean Water for North Carolina*
- Ted Campbell , Rick Bolich, *North Carolina Dept. of Environment and Natural Resources*, *Division of Water Quality - Groundwater Section*

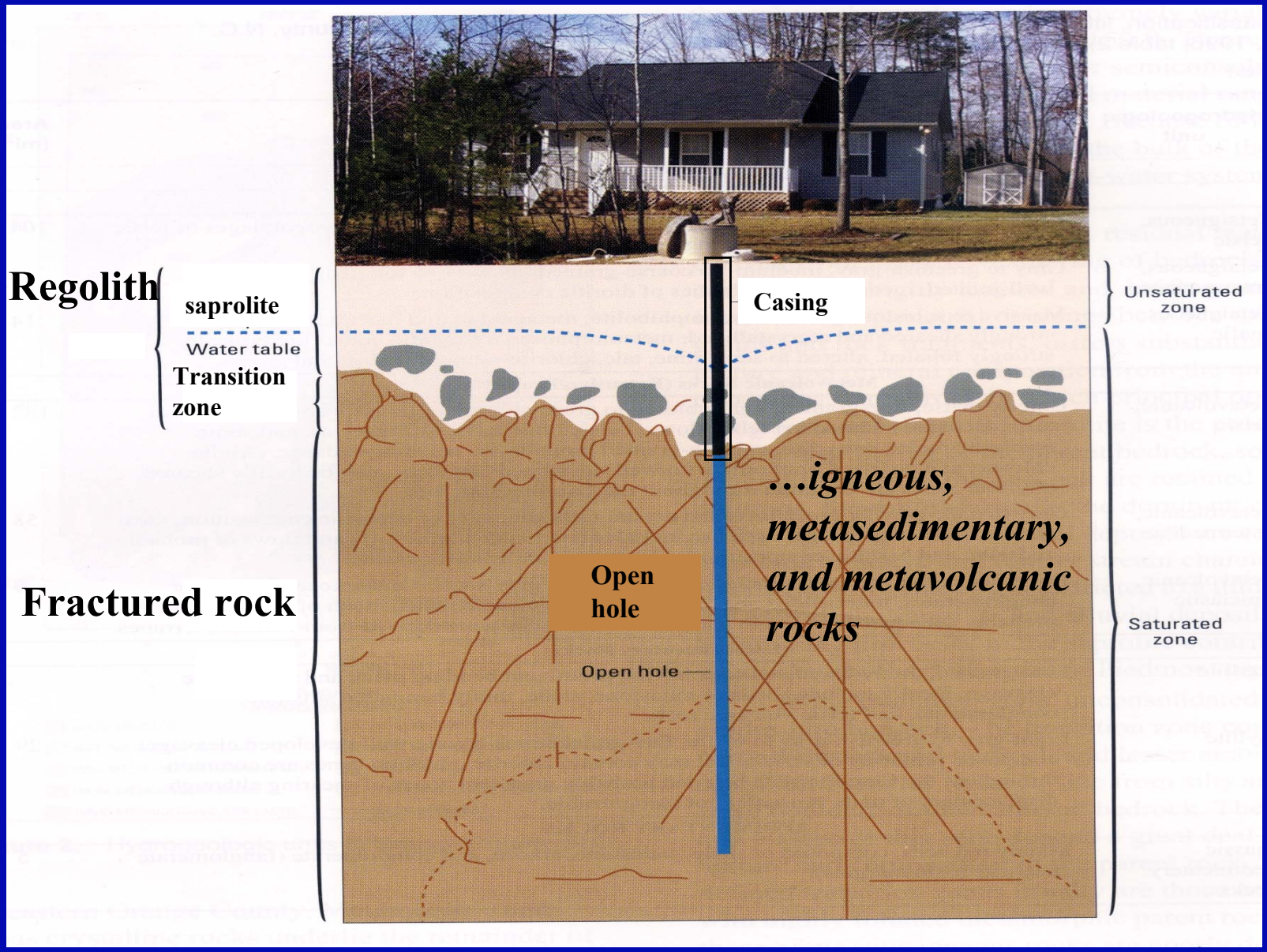
Statement of the Problem

- More than two million residents in North Carolina use groundwater as a sole source for drinking water. Rise in population is associated with drilling new wells (5,000 to 6,000 per year)
- In several areas, the levels of naturally occurring contaminants of arsenic, radon, and radium exceed drinking water regulations.
- Wells of private homeowners are not regulated.

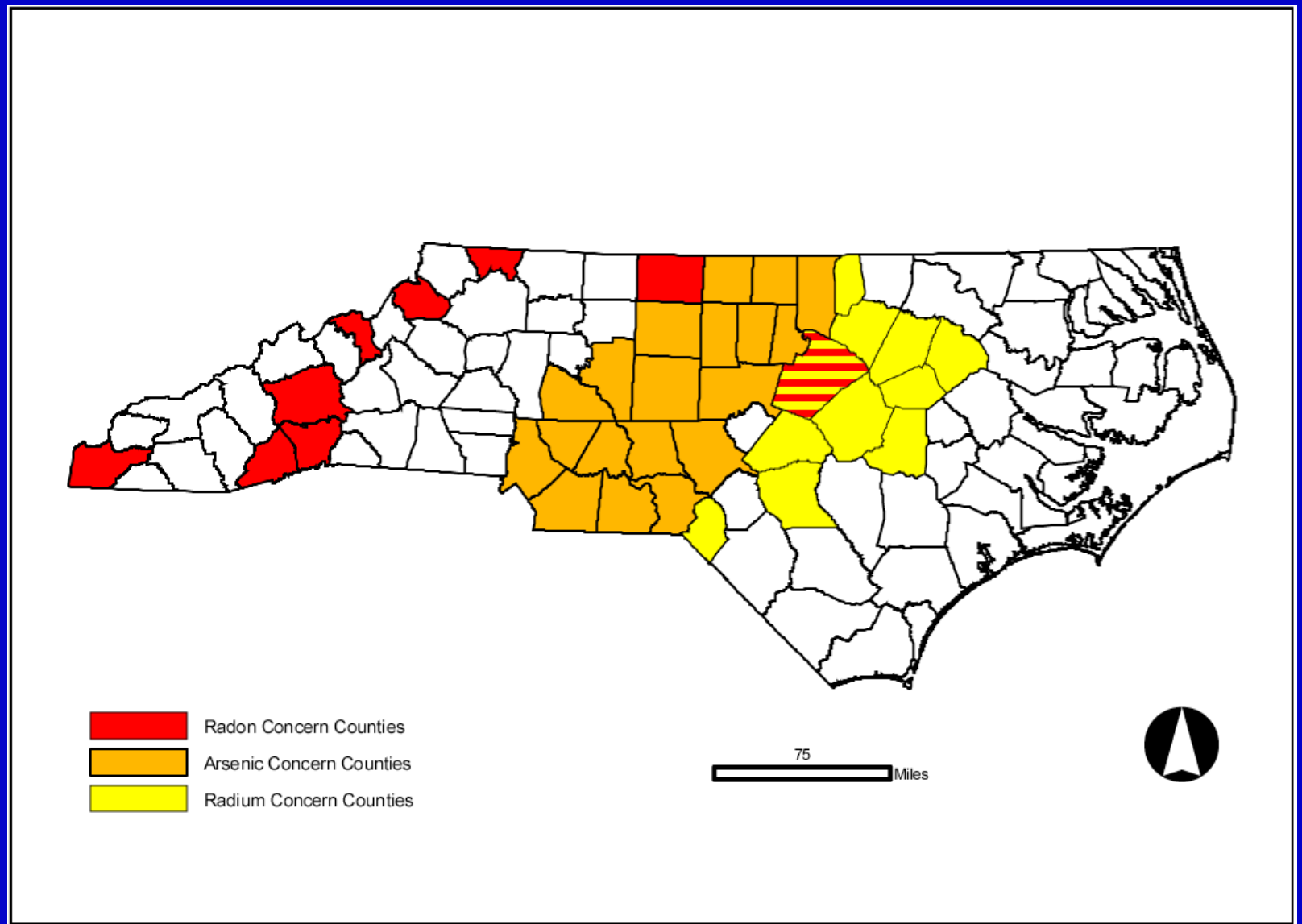
Major geological units of North Carolina



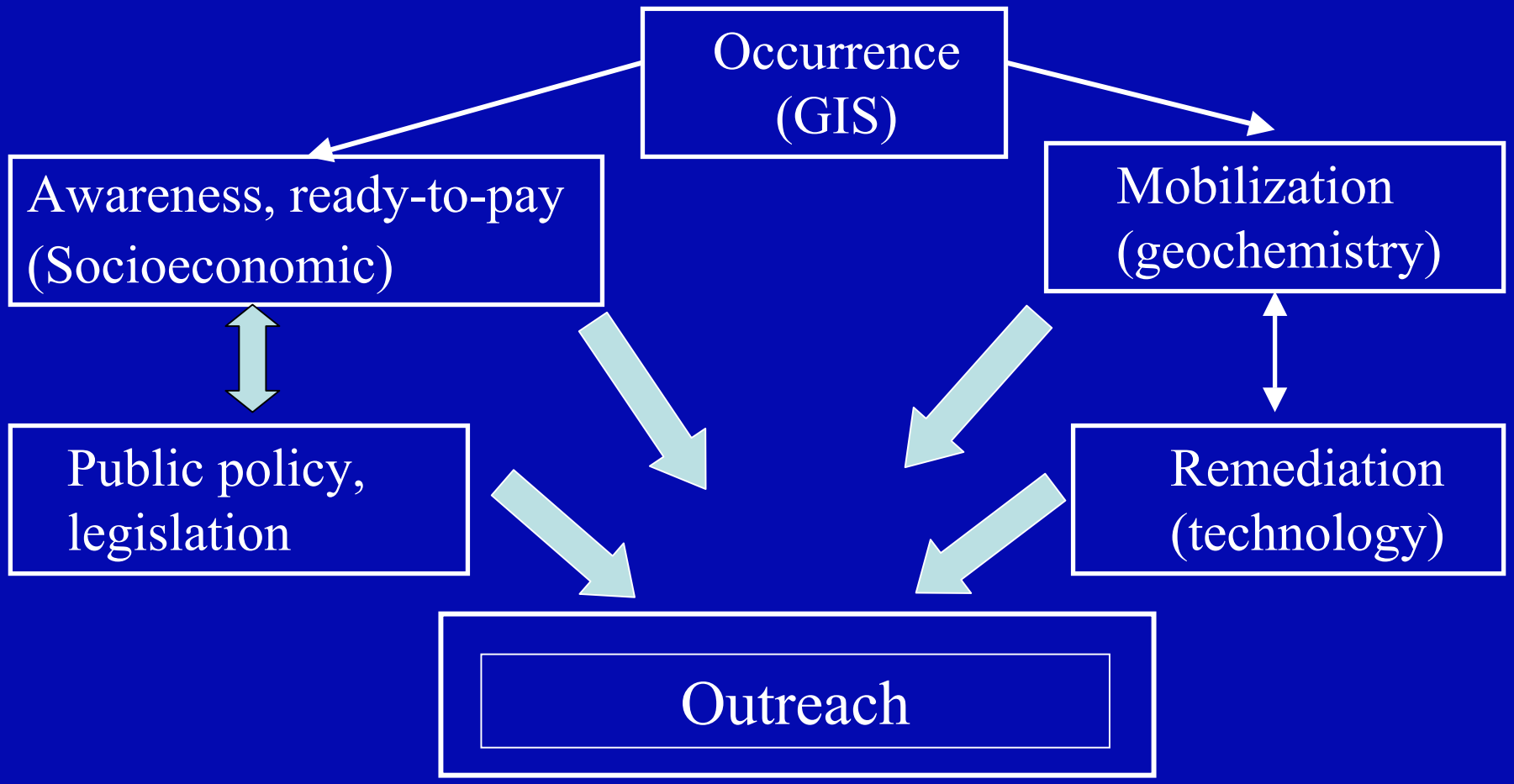
Typical private well and geology in the Piedmont, NC



Distribution of natural contaminants in groundwater of North Carolina



An integrative investigation of the sources and effects of groundwater contamination for local communities and homeowners in North Carolina



The project objectives - distribution and geochemistry

- Assess the levels of arsenic, radon, and radium in private wells in North Carolina across socioeconomic and geological variables.
- Defined zones identified as “hot spots” for these contaminants.
- Develop geochemical models for understanding the mechanisms that enhance the mobilization of natural contaminants in groundwater.
- Establish simple chemical and physical “fingerprinting indicators” as warning tools for occurrence of high contaminants in groundwater.

The project objectives - technology

- Evaluate the available treatment methodologies for removal of arsenic, radon, and radium from well water, their economic cost, and the relationships between removal recovery and contaminant accumulation in the residual effluent and/or separation media.

The project objectives - socioeconomic

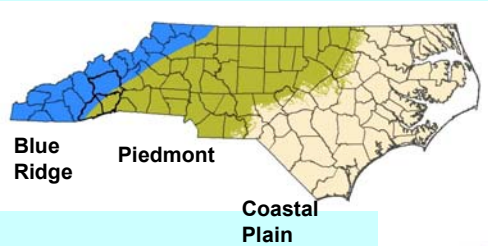
- Assess the relationships between arsenic, radon, and radium levels in private wells in North Carolina and socioeconomic characteristics.
- Assess the baseline level of awareness of inorganic contamination in drinking water among households with private wells.
- Assess how households respond to provision of information on the health effects of inorganic chemical contaminants and specific information on the levels of these contaminants in their drinking water.
- Estimate households' willingness-to-pay to reduce health risk from exposure to arsenic, radon and radium in drinking water.

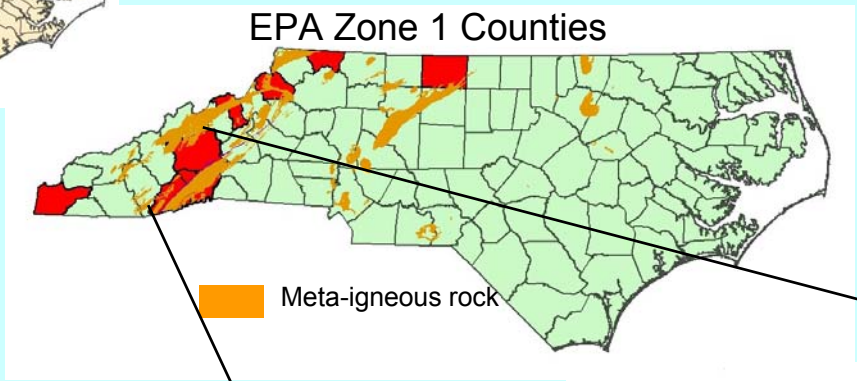
The project objectives - policy and outreach

- Develop natural science and social science based recommendations for changes in current public policy and legislation with respect to the exposure of private homeowners to contaminants in well waters and drawing upon lessons learned in other states.
- Develop and evaluate outreach tools to provide reliable information about the magnitude of water contamination, health implications, economic cost for remediation and policy implication to the stakeholders: the private homeowners, the state and county agencies, and the private sector.

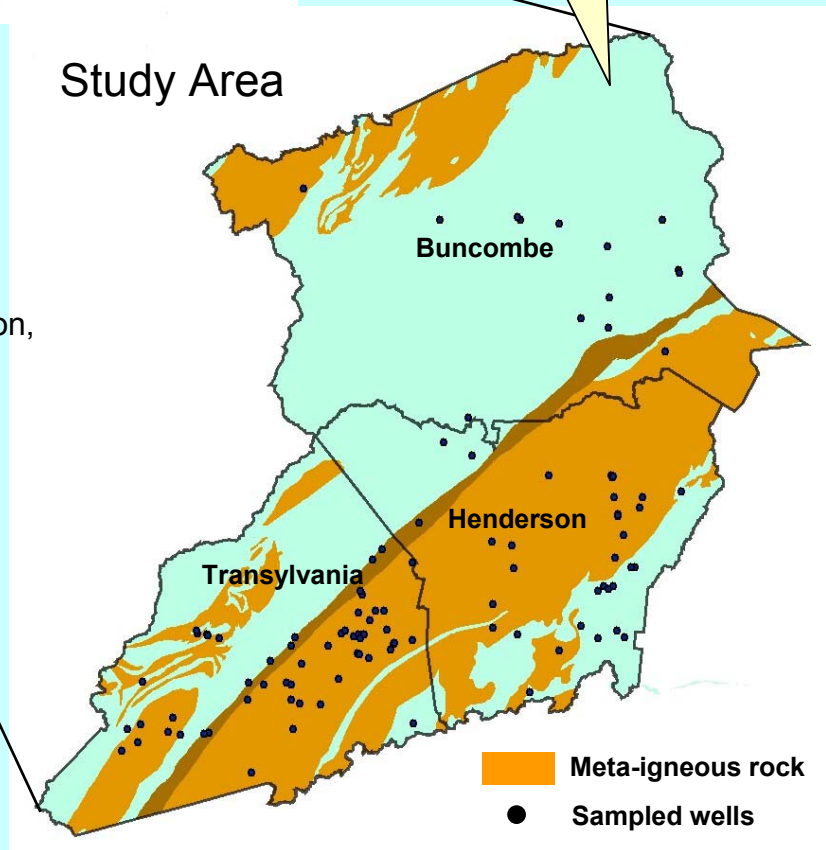
Distribution of naturally occurring contaminants in groundwater in North Carolina

2005





103 private wells



Meta-igneous rocks

Includes granites and granitic gneisses (Henderson, Toxaway, Caesar's Head)

Meta-sedimentary rocks

Includes schists, metagraywackes, and metavolcanics of the Ashe Metamorphic Suite

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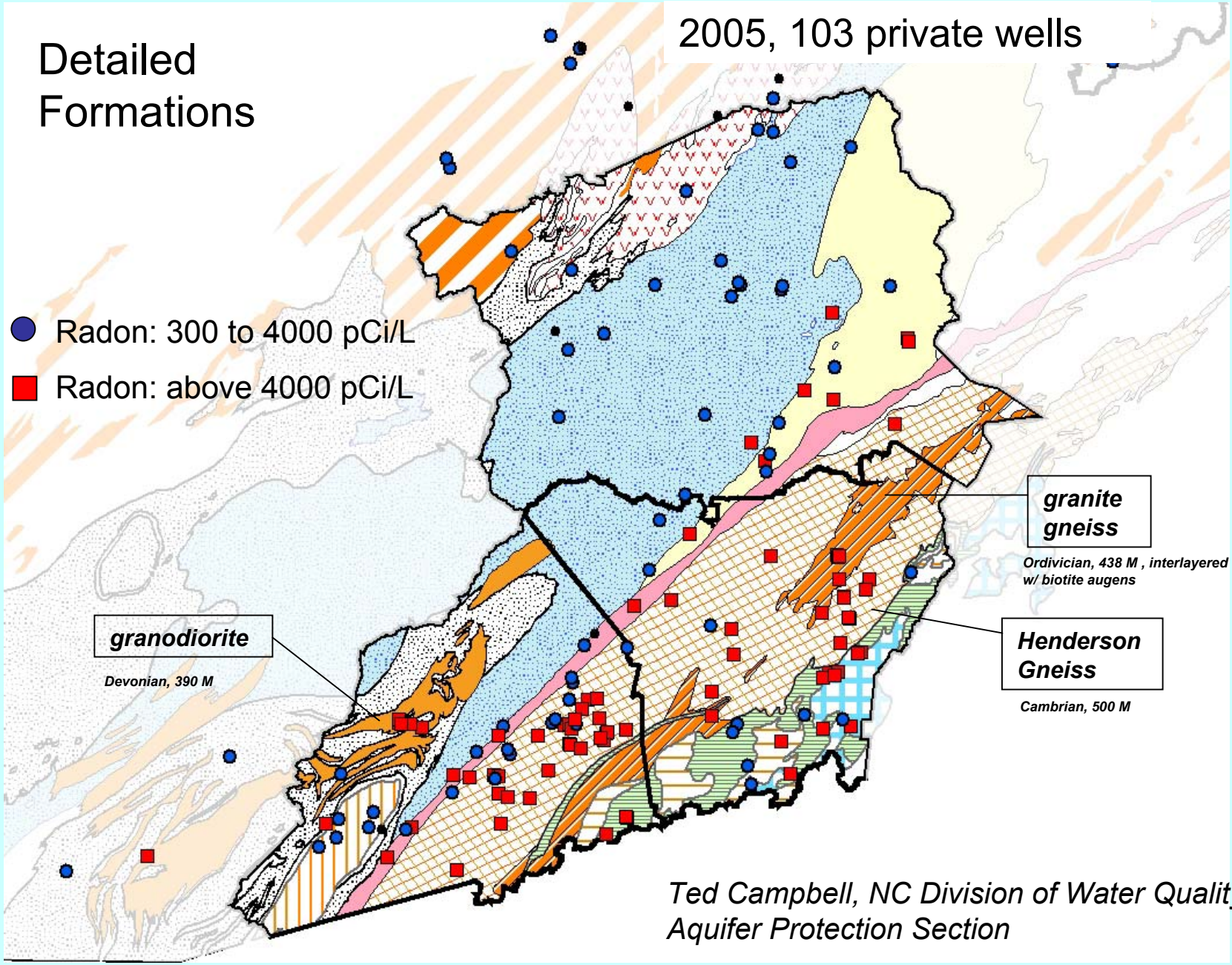
Detailed Formations

2005, 103 private wells



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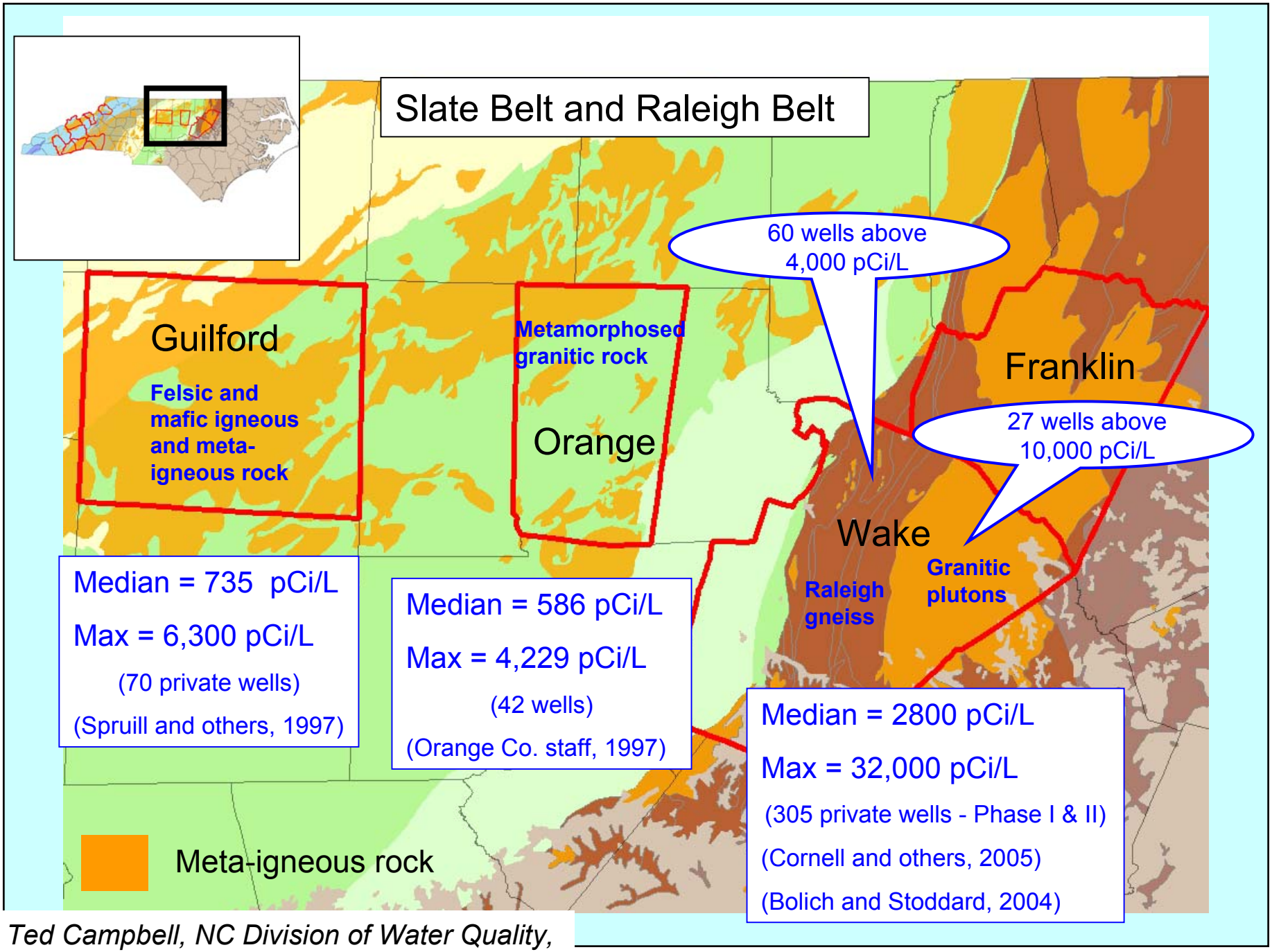

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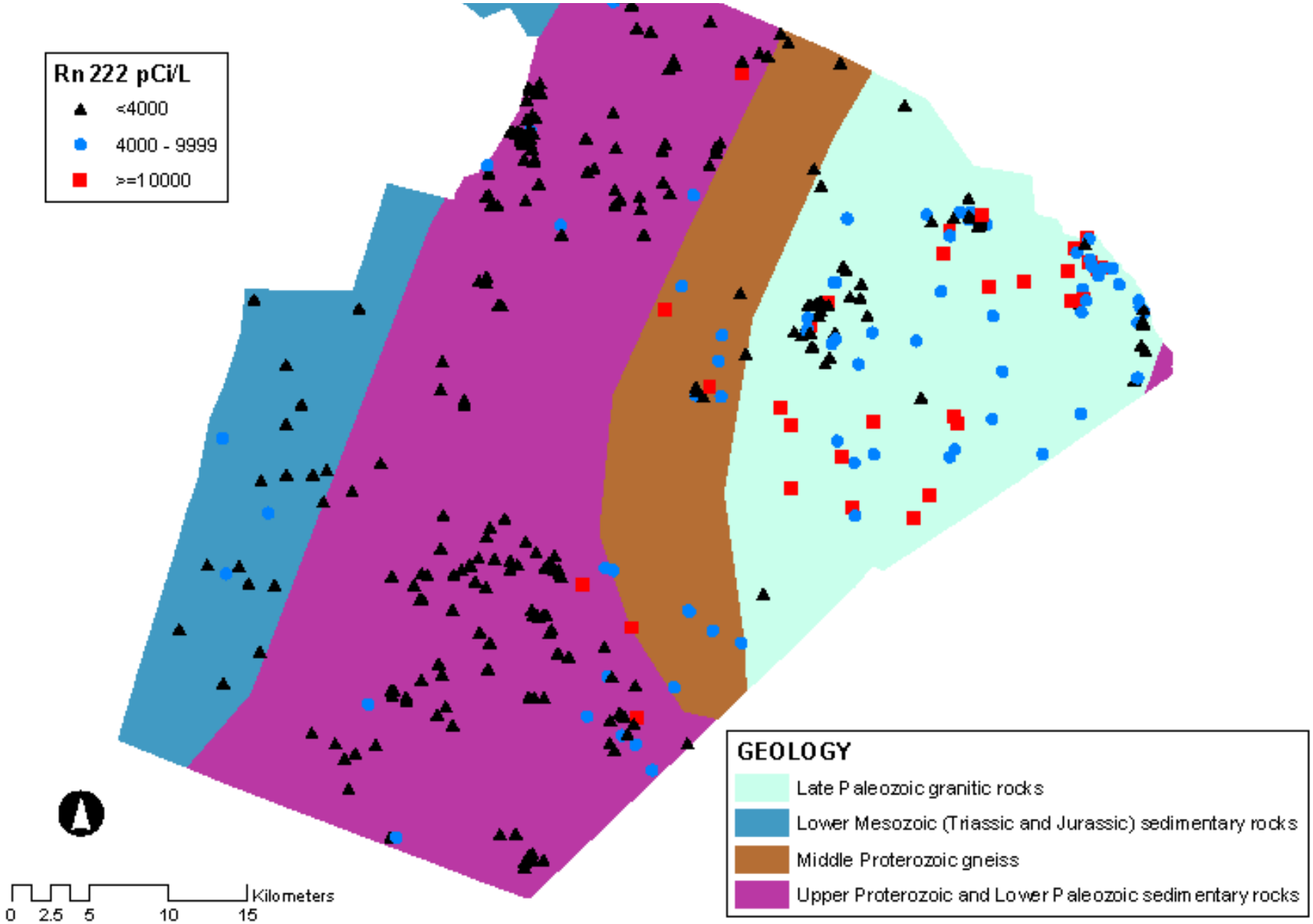
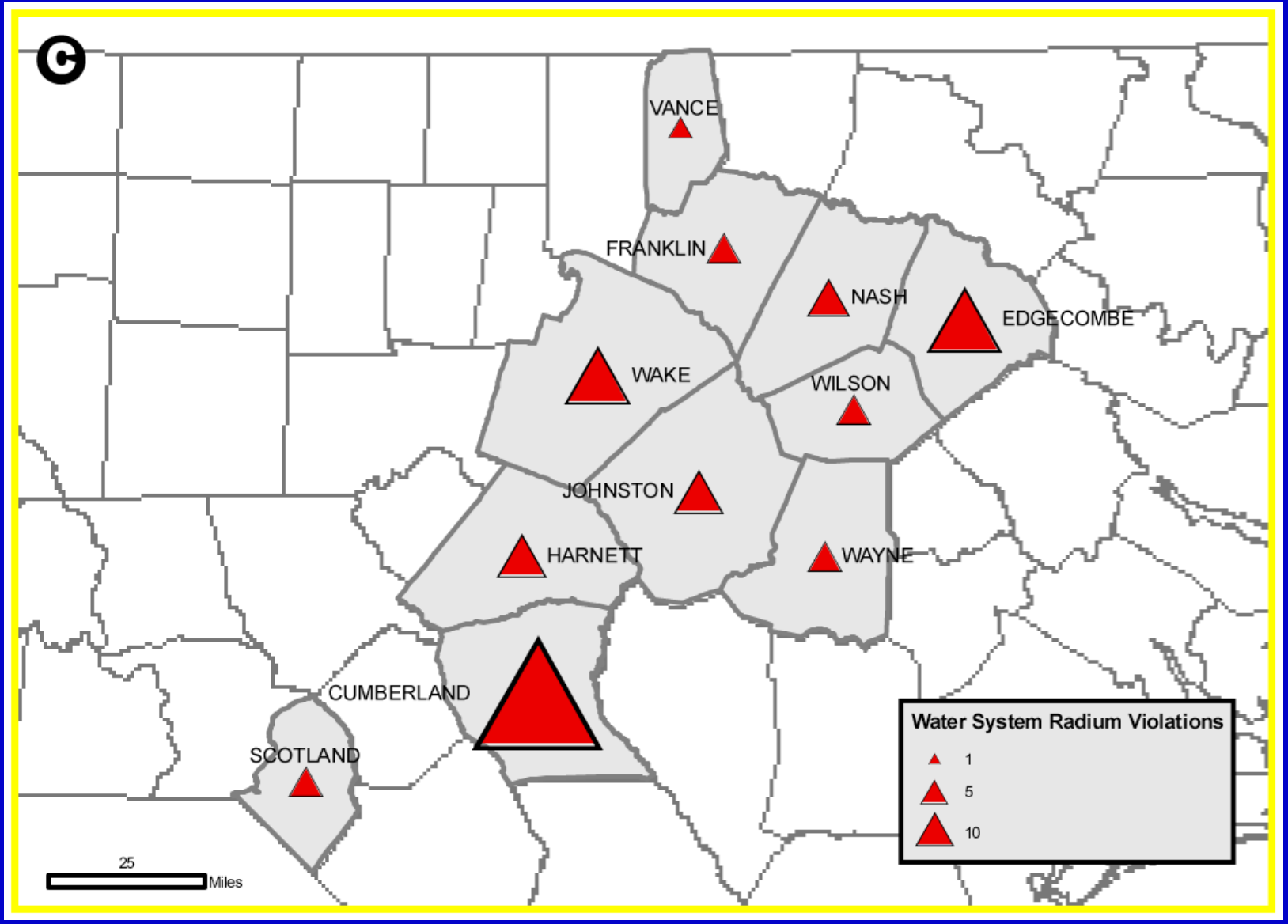
Distribution of radon in groundwater in Wake County

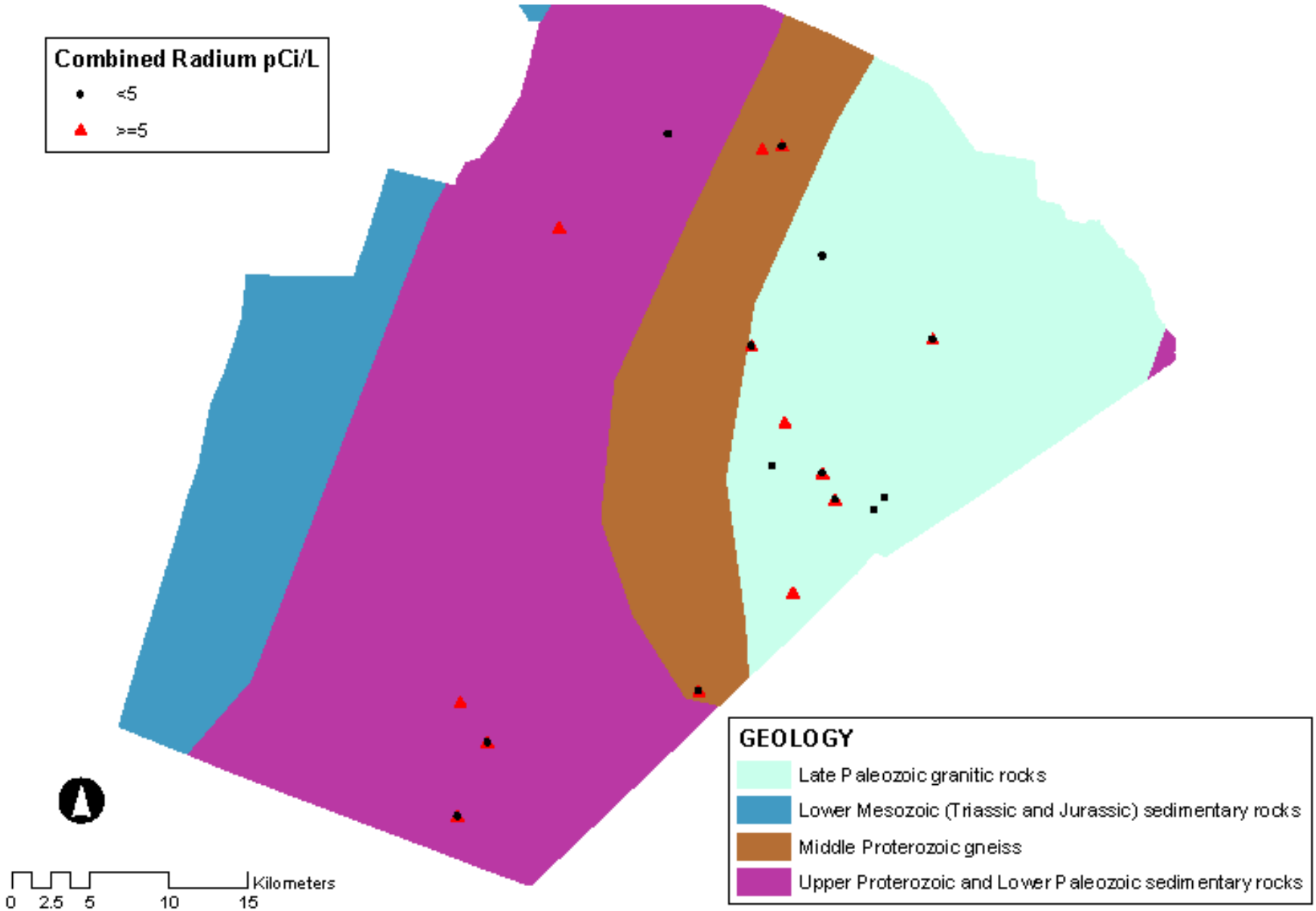


Radium violations (>5 pCi/L) in public water systems

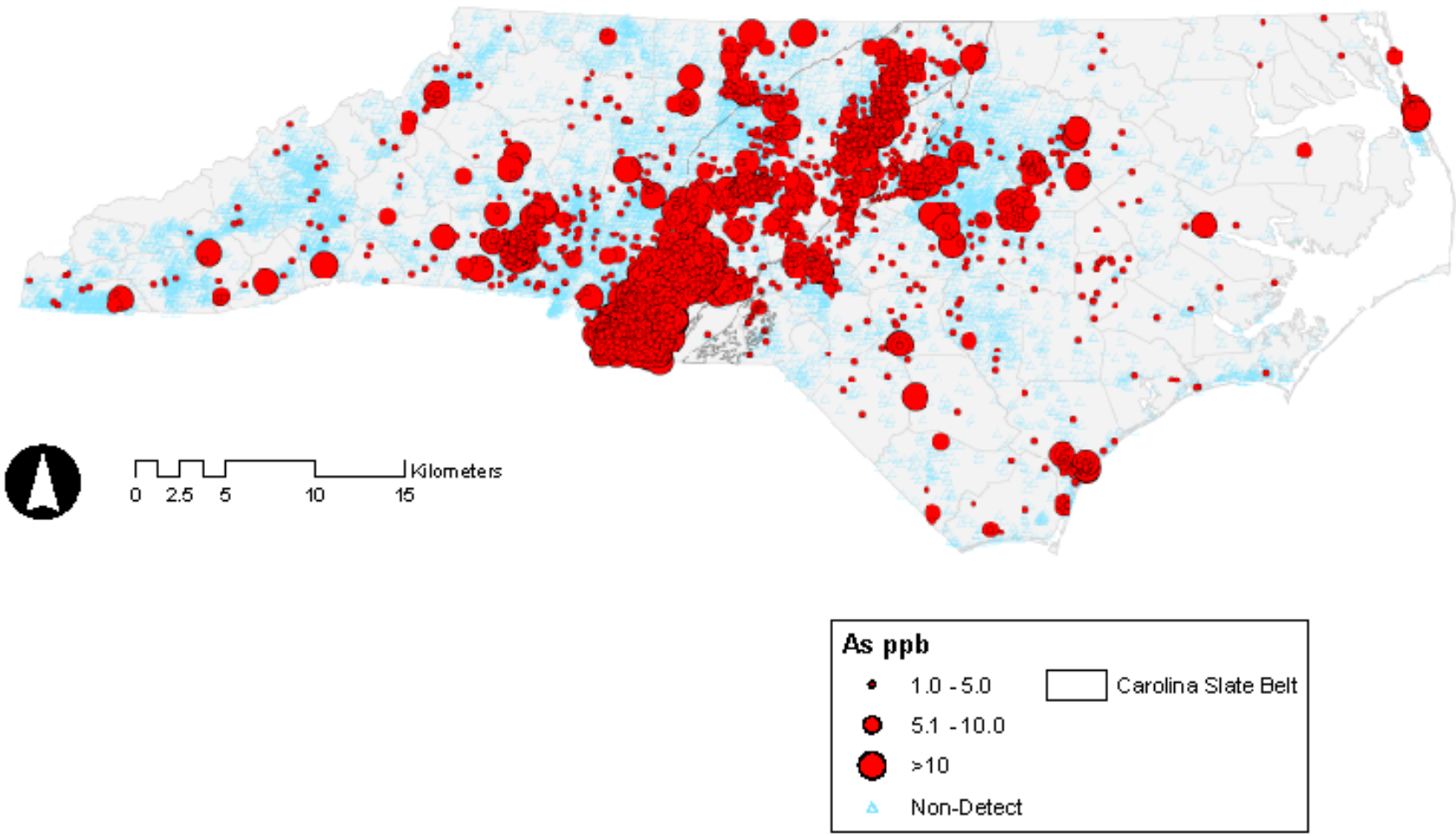


Modified after Menetrez and Watson, 1983. Natural radioactivity in North Carolina groundwater supplies. University of North Carolina, Water Resources Research Institution, Report 208, 30p.

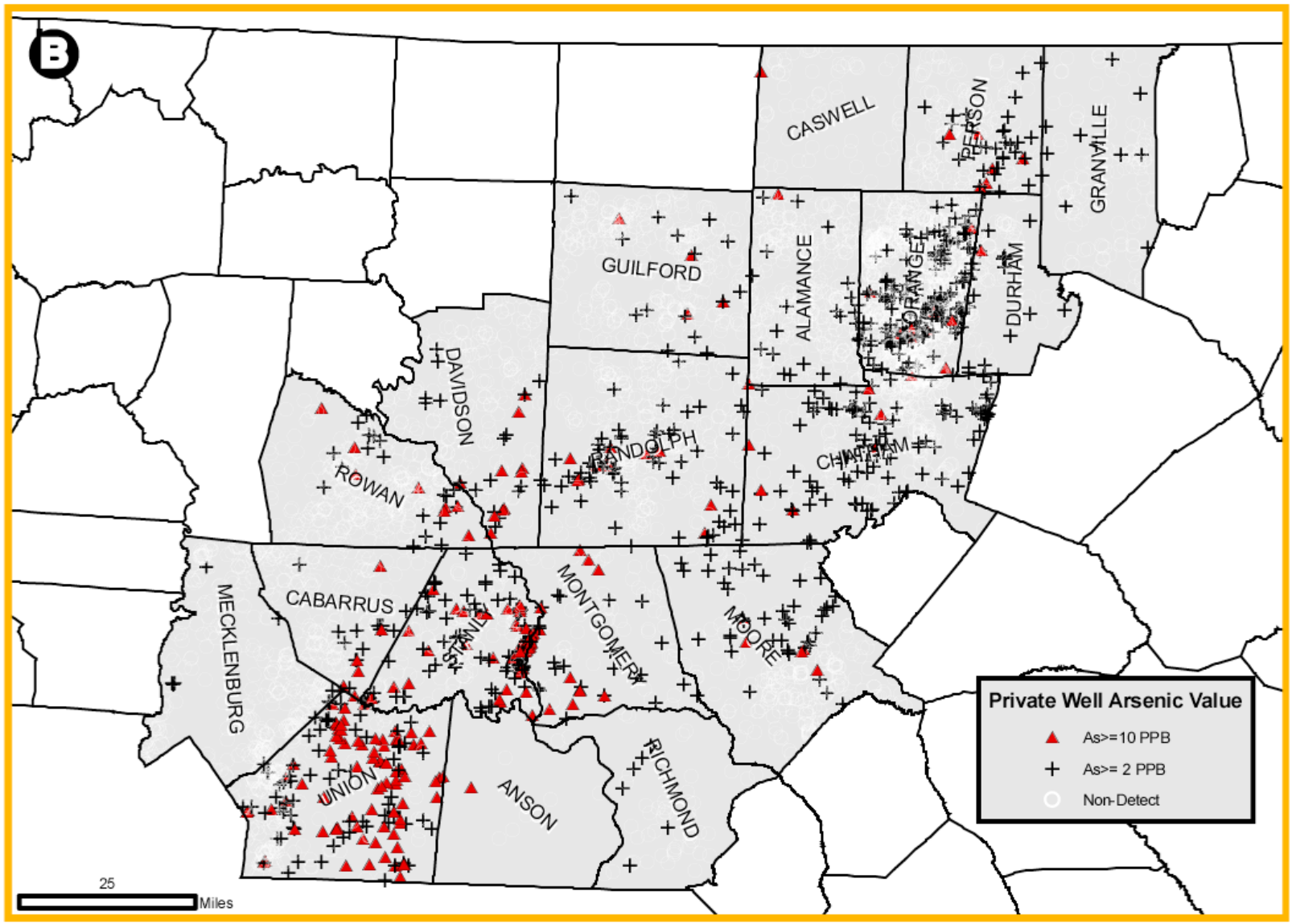
Distribution of radium in groundwater in Wake County



Distribution of Arsenic in groundwater in North Carolina

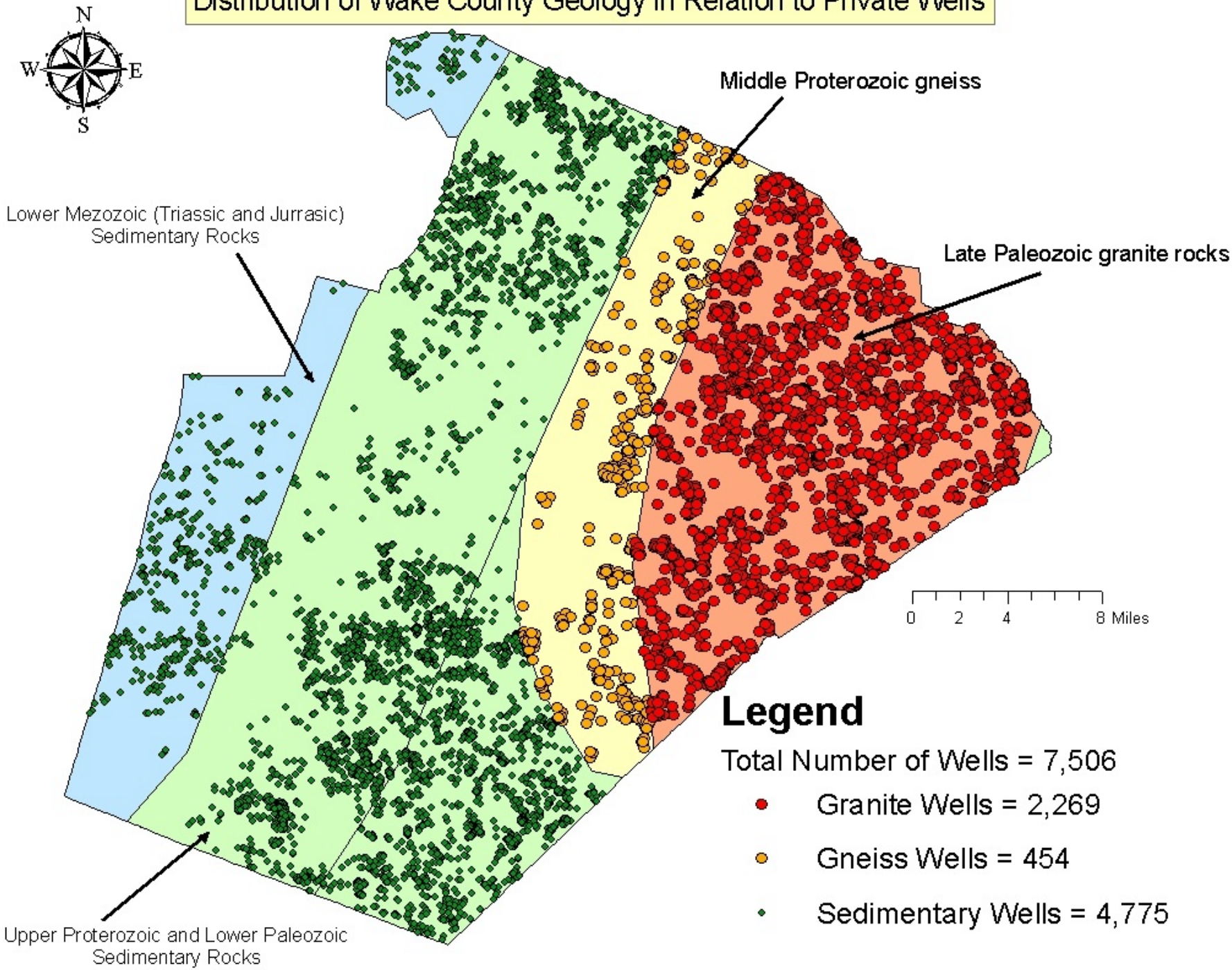


High- arsenic groundwater in the Slate Belt



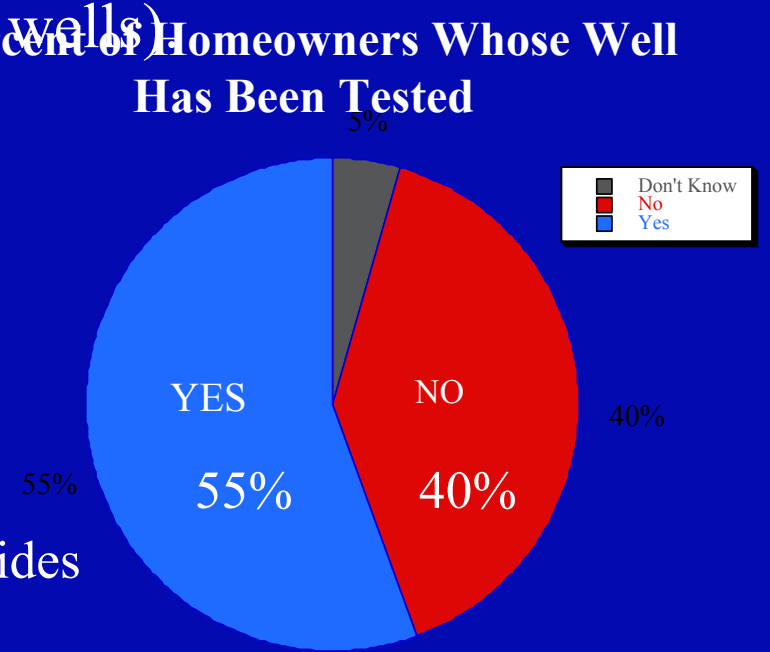
Preliminary Socioeconomic Results:

Distribution of Wake County Geology in Relation to Private Wells

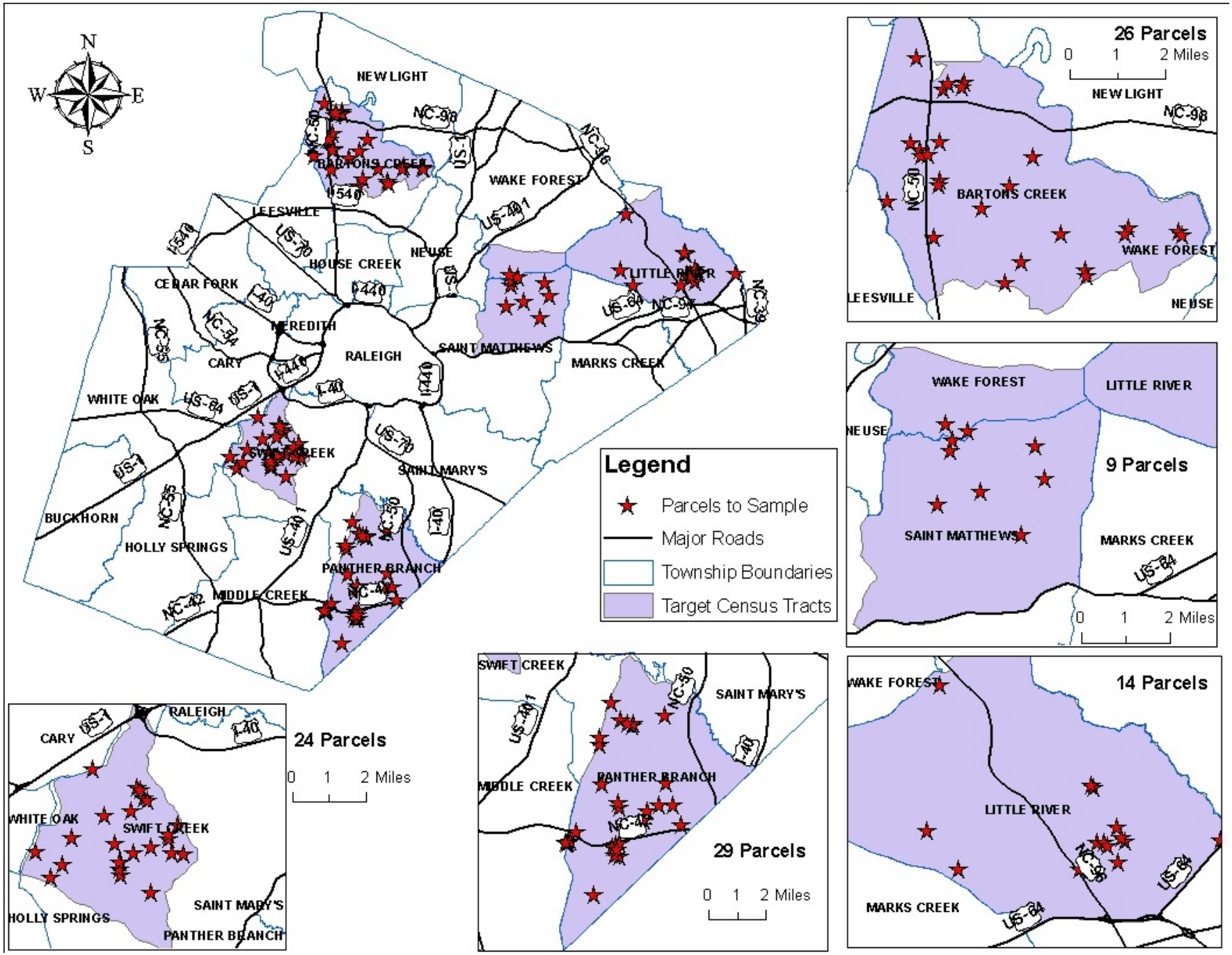


Socioeconomic study: Phase I (Wake County, NC)

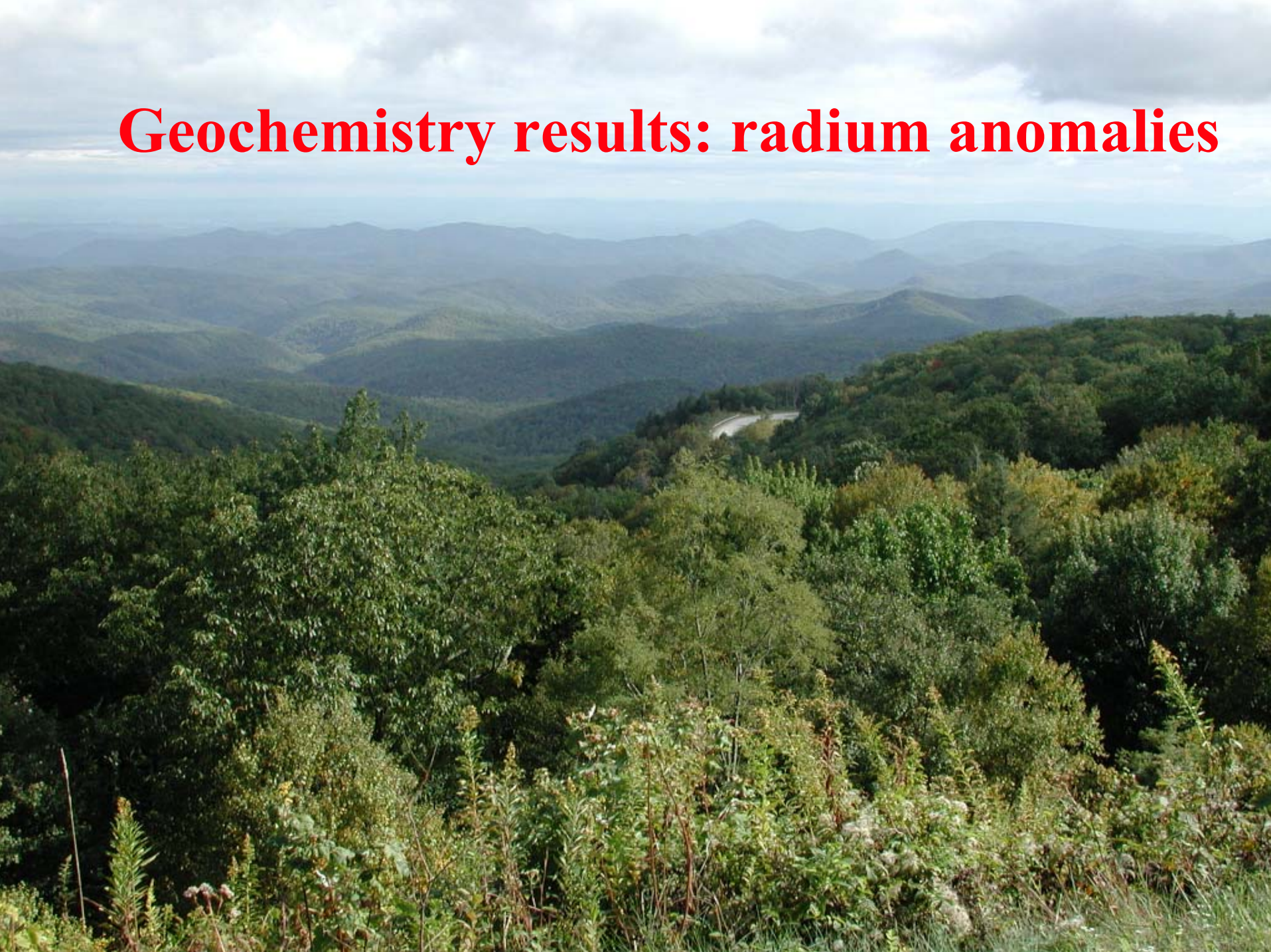
- Sent roughly 1600 letters to homeowners with request to participate in our study.
- Received over 200 phone calls in response.
- Selected 100 as participants in phase I.
- Survey on contaminants awareness in Phase I.
- Begin sampling wells from 100 homeowners in Wake County (since beginning of 2007 ~ 30 wells)



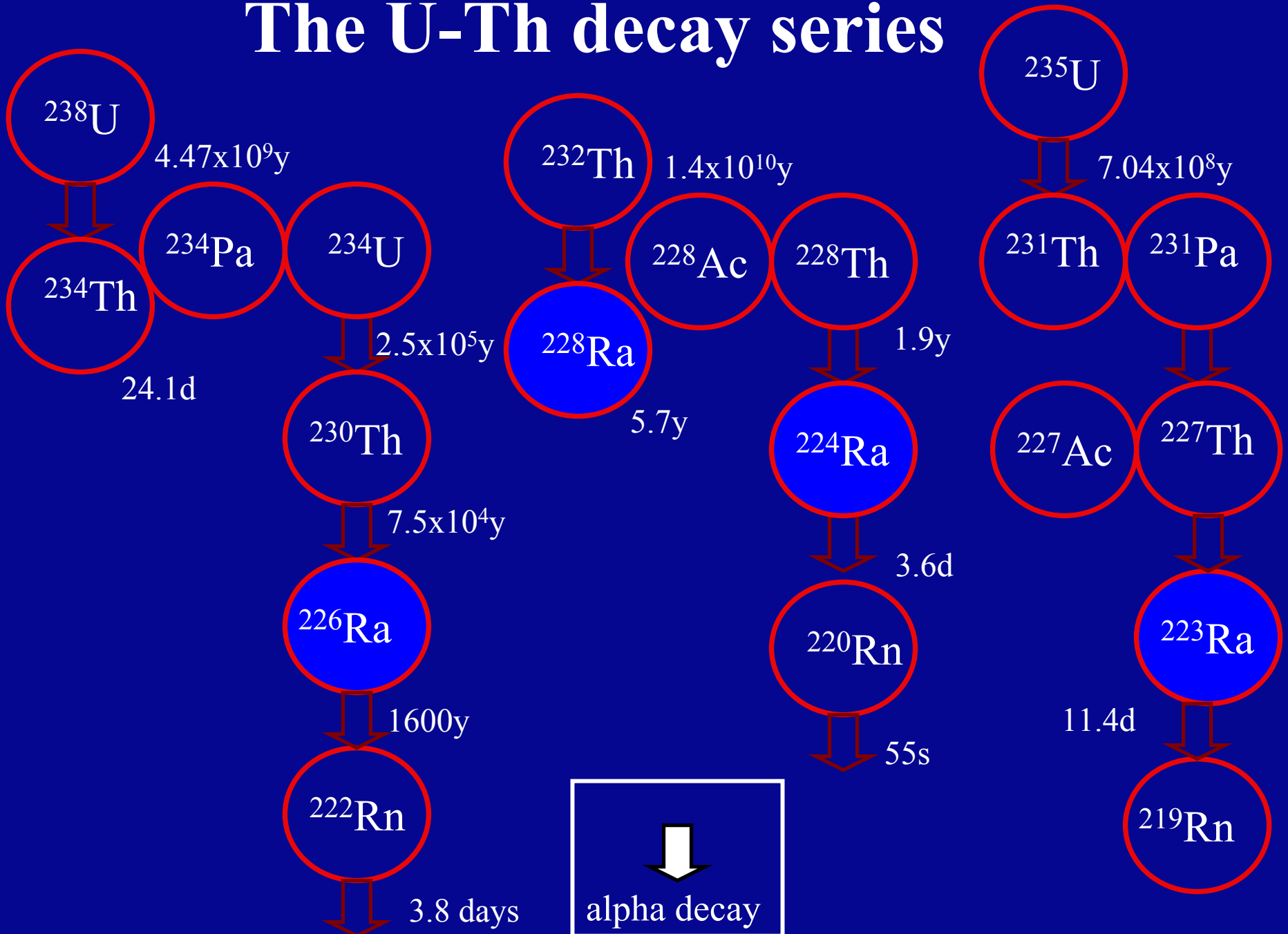
- 49 houses have had well tested
- Only 5 households have tested for arsenic
- Only 1 household have tested for radionuclides

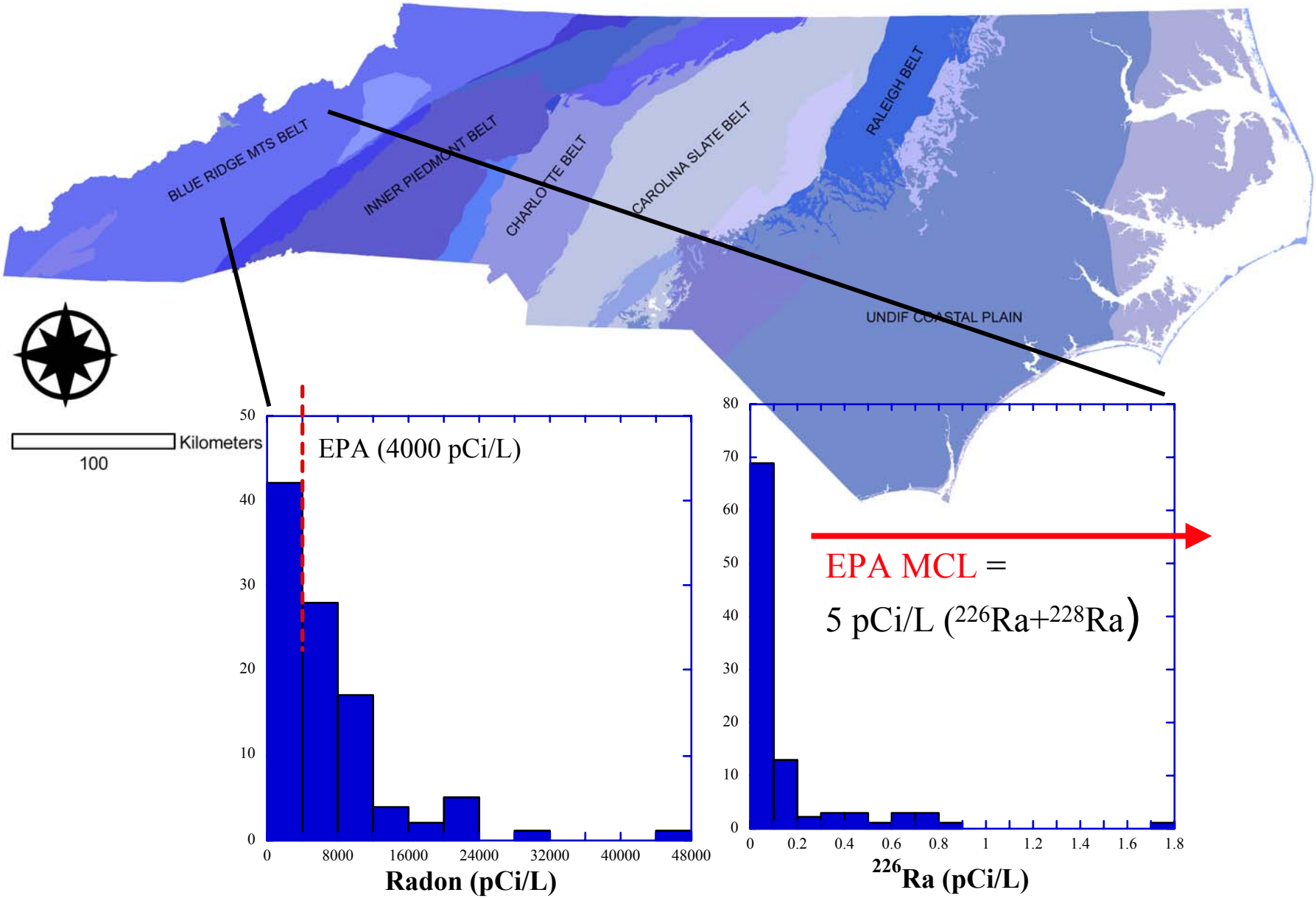

N
W
E
S
NEW LIGHT
BARTONS CREEK
WAKE FOREST
LEESVILLE
HOUSE CREEK
NEUSE
CEDAR FORK
LITTLE RIVER
MEREDITH
CARY
RALEIGH
SAINT MATTHEWS
MARKS CREEK
WHITE OAK
SWIFT CREEK
SAINT MARY'S
BUCKHORN
HOLLY SPRINGS
PANTHER BRANCH
MIDDLE CREEK
Legend
Parcels to Sample
Major Roads
Township Boundaries
Target Census Tracts
26 Parcels
0 1 2 Miles
9 Parcels
0 1 2 Miles
24 Parcels
0 1 2 Miles
29 Parcels
0 1 2 Miles
14 Parcels

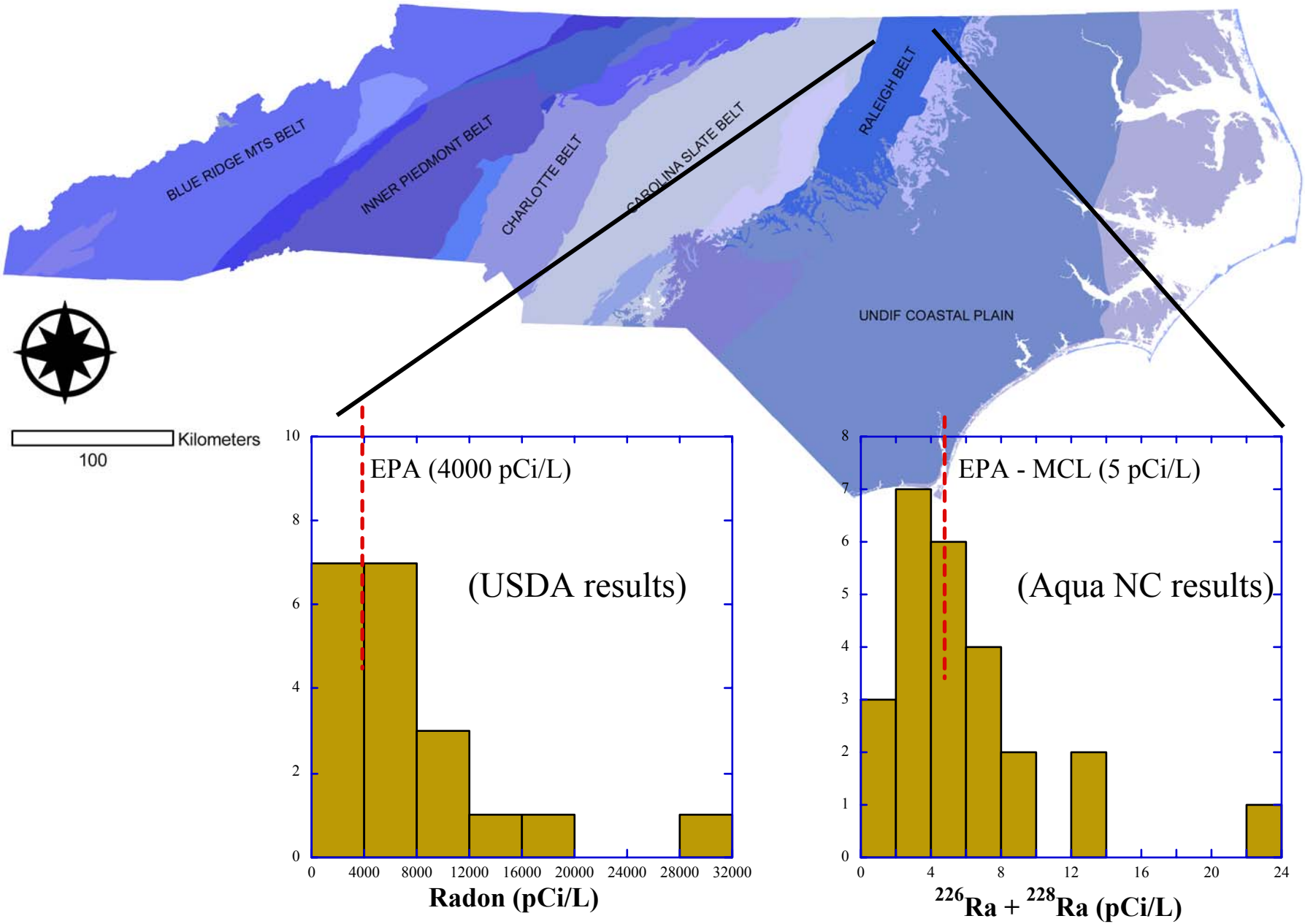
Geochemistry results: radium anomalies



The U-Th decay series



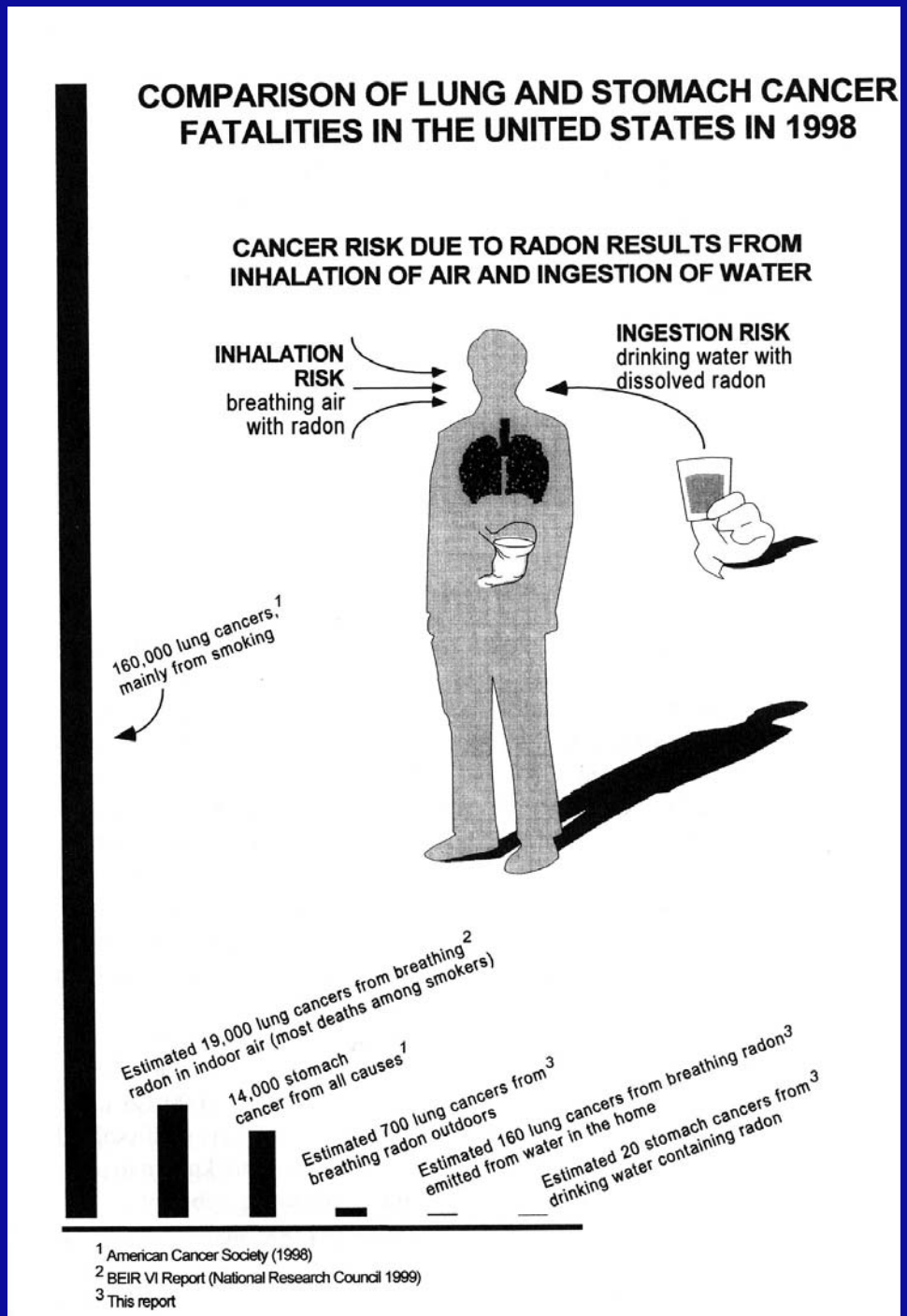

BLUE RIDGE MTS BELT
INNER PIEDMONT BELT
CHARLOTTE BELT
CAROLINA SLATE BELT
RALEIGH BELT
UNDIF COASTAL PLAIN
Kilometers
100
EPA (4000 pCi/L)
Radon (pCi/L)
EPA MCL =
5 pCi/L ($^{226}Ra+^{228}Ra$)
^{226}Ra (pCi/L)


BLUE RIDGE MTS BELT
INNER PIEDMONT BELT
CHARLOTTE BELT
CAROLINA SLATE BELT
RALEIGH BELT
UNDIF COASTAL PLAIN
Kilometers
100
EPA (4000 pCi/L)
(USDA results)
Radon (pCi/L)
EPA - MCL (5 pCi/L)
(Aqua NC results)
226Ra + 228Ra (pCi/L)

Health Implications

Health effects of radium

- Radium is biochemically similar to barium and calcium, when ingested is concentrated in the bone.
- Epidemiological studies revealed that exposure to radium is associated with higher rates of leukemia and bone cancer.
- Drinking water studies in Ontario, Canada, Illinois/Iowa, Wisconsin, and New Jersey (2003) have found association between bone cancer and elevated radium level in drinking water. Males in southern New Jersey, where radium concentration exceeded federal standards, had a three-fold higher risk of developing bone cancer.



Lung cancer has become the leading cause of cancer deaths in the American population. After smoking, environmental radon is considered to be the second leading cause of lung cancer, with an estimate of 3,300 to 38,600 lung cancer deaths per year in the United States .

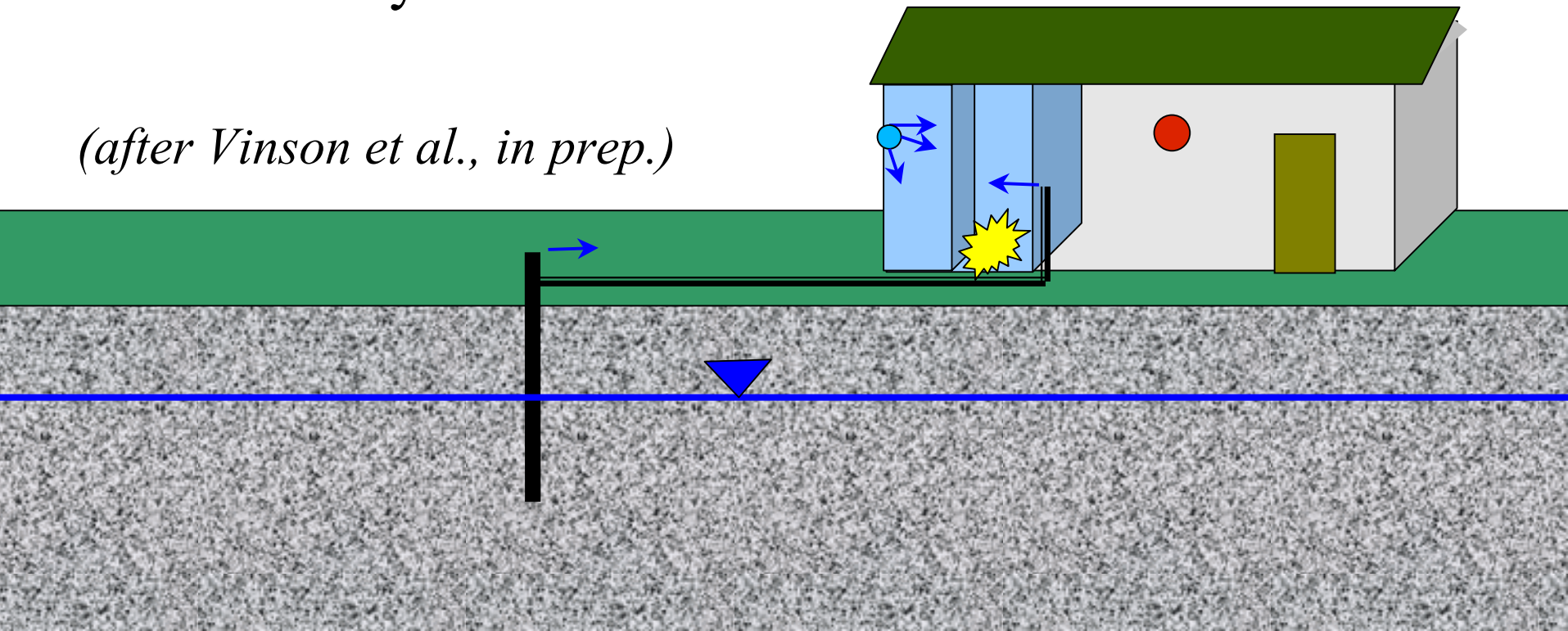
Existing standards and advisories

	Threshold concentration	% exceeding in Blue Ridge Mt.	% exceeding in USA (Focazio *et al.*, 2006)
EPA proposed MCL	300 pCi L^{-1}	98	75
EPA proposed alternative MCL	4000 pCi L^{-1}	68	9
CT, MA, RI, VT, NH, NJ, ME, WI	300-10,000 pCi L^{-1}		

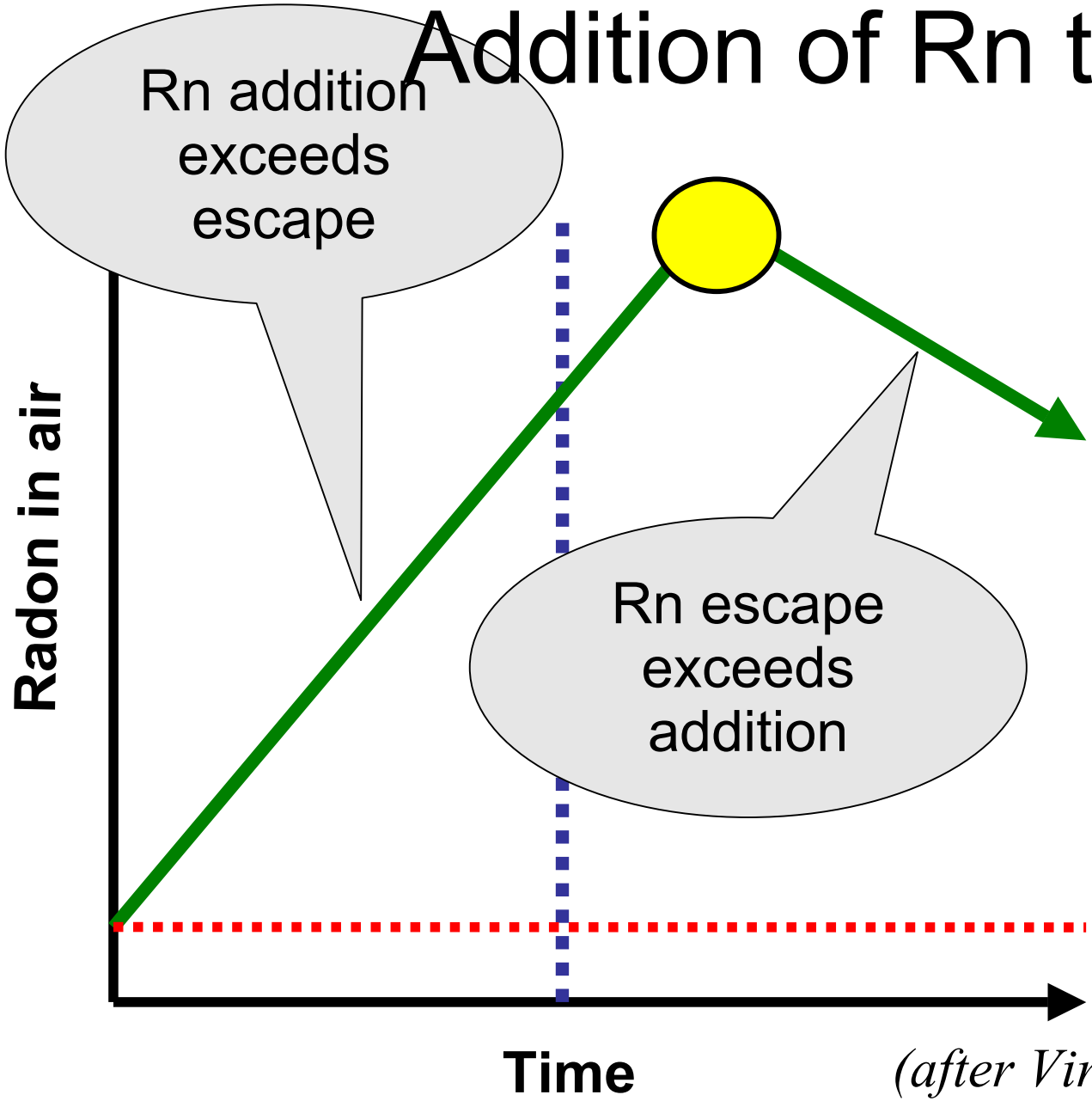
The effect of radon degassing in showers

- Sampling of well water and indoor tap water
- Measurement of Rn in bathroom air before, during, and after a shower
- Multi-day charcoal tests of indoor air Rn

(after Vinson et al., in prep.)

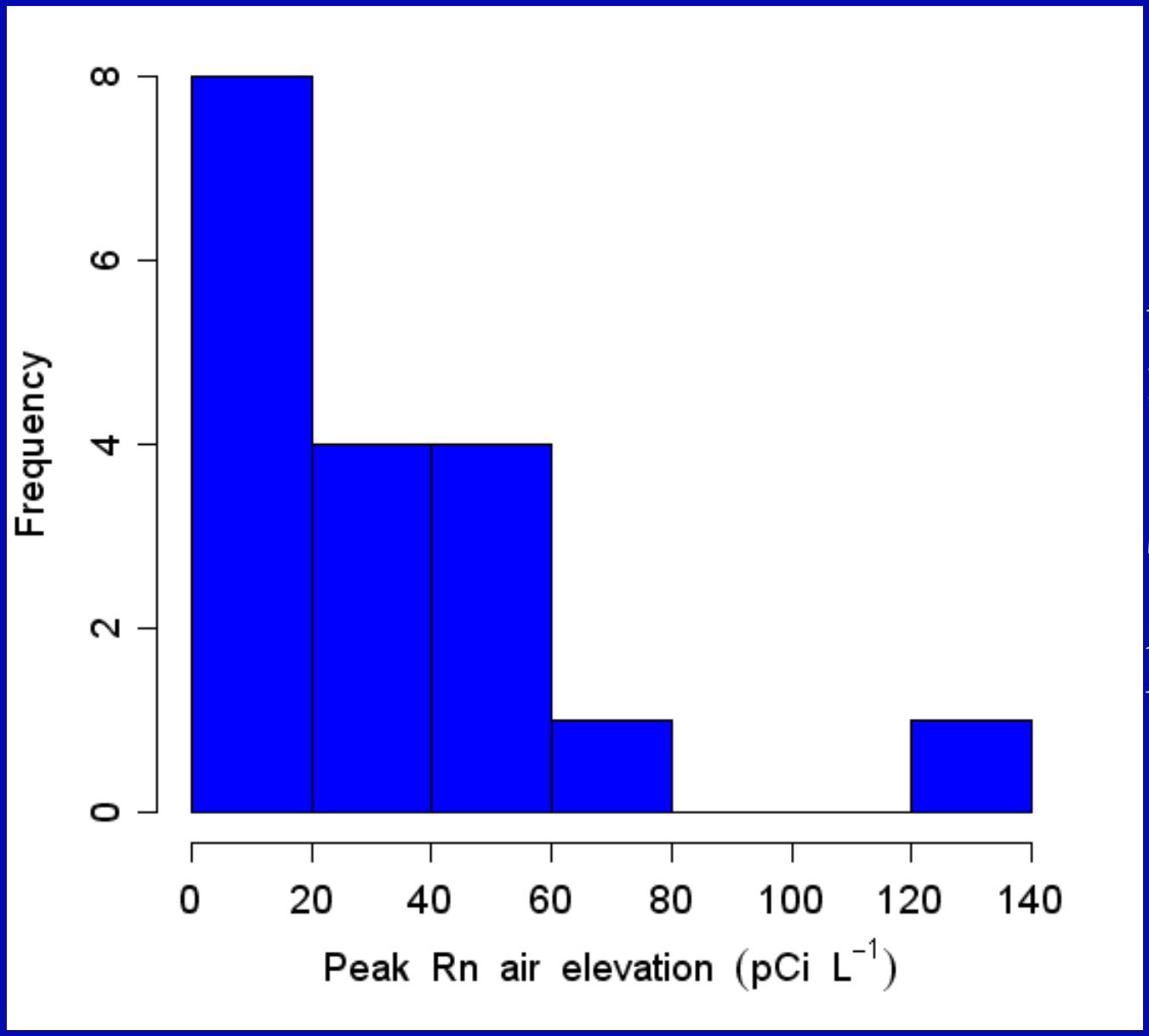


Addition of Rn to room air



(after Vinson et al., in prep.)

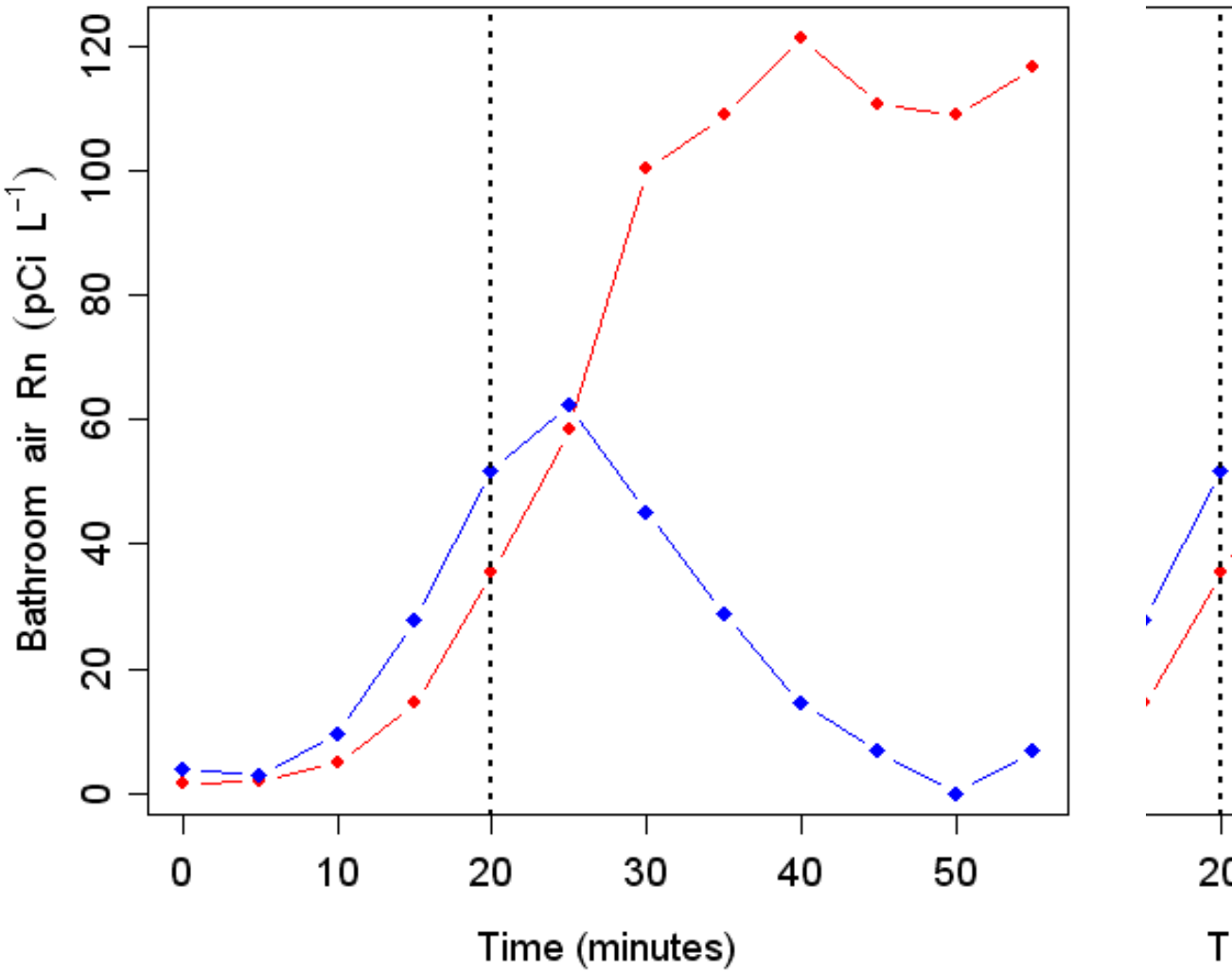
Results: airborne Rn peaks



Airborne Rn increased up to 120 pCi L^{-1}

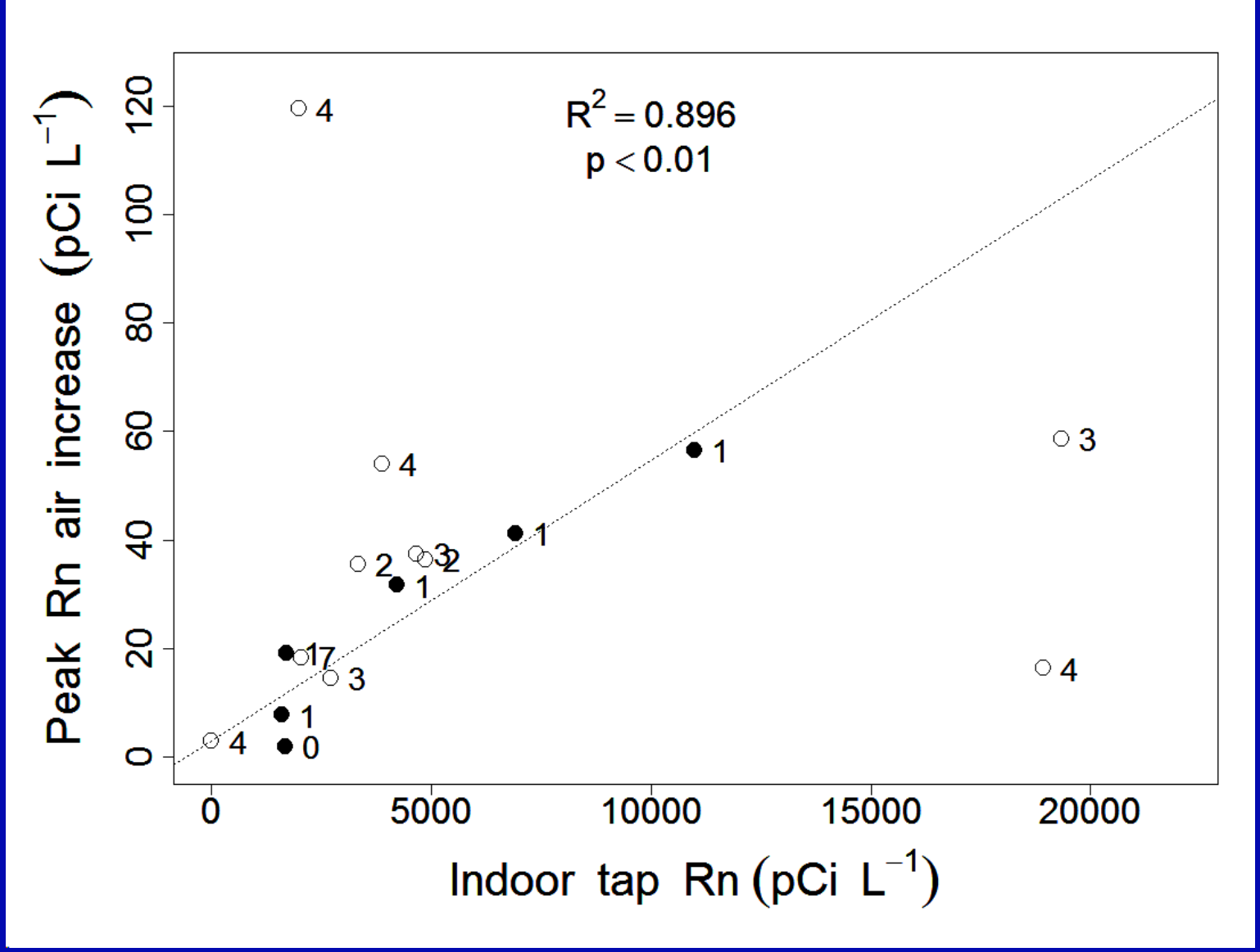
Timing of peak varies

- Rooms with good mixing & escape
  - Earlier peak
  - Smaller peak
- Rooms with poor mixing & escape
  - Later peak
  - Higher peak



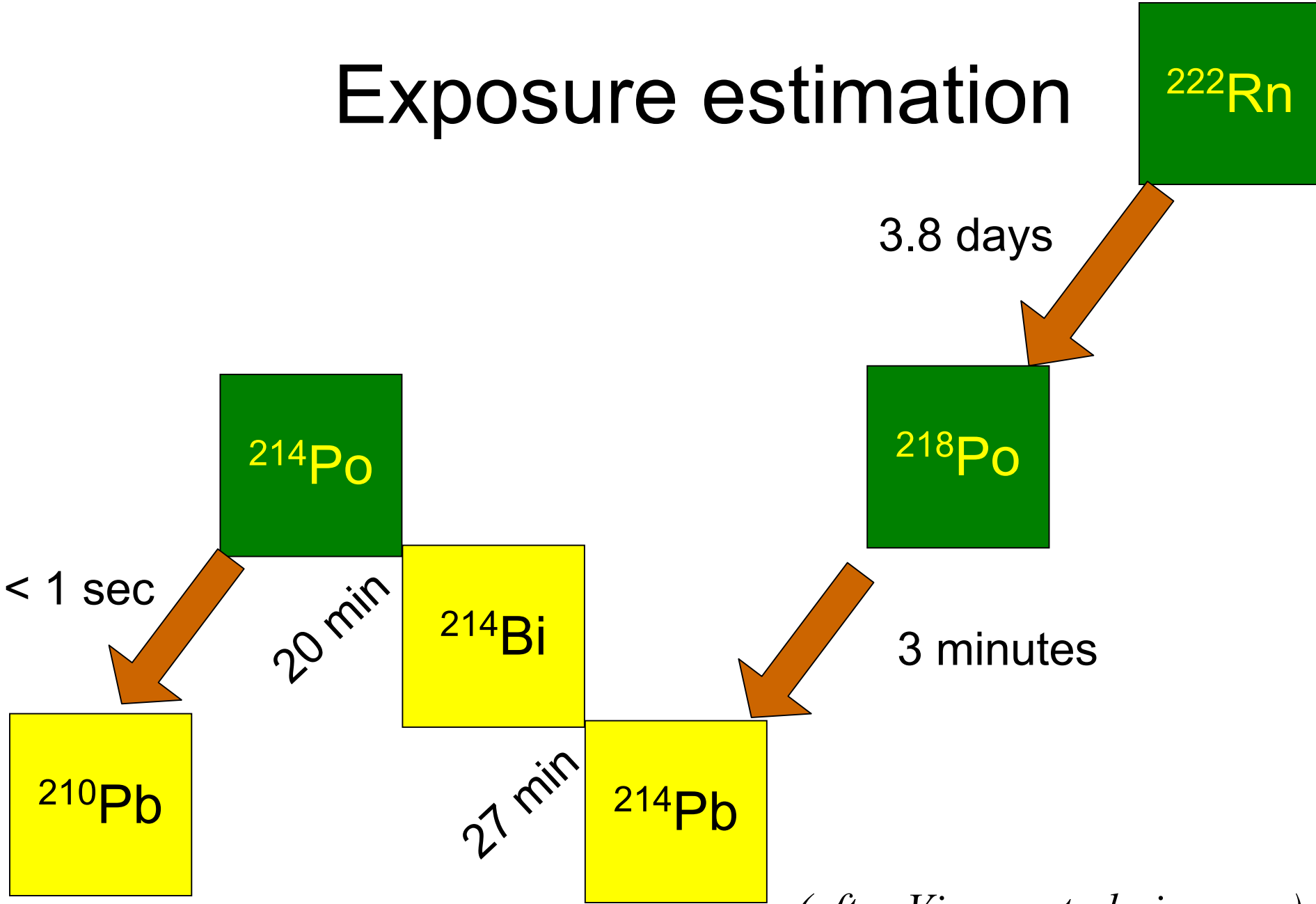
(Fitzgerald *et al.*, 1997)

(after Vinson et al., in prep.)



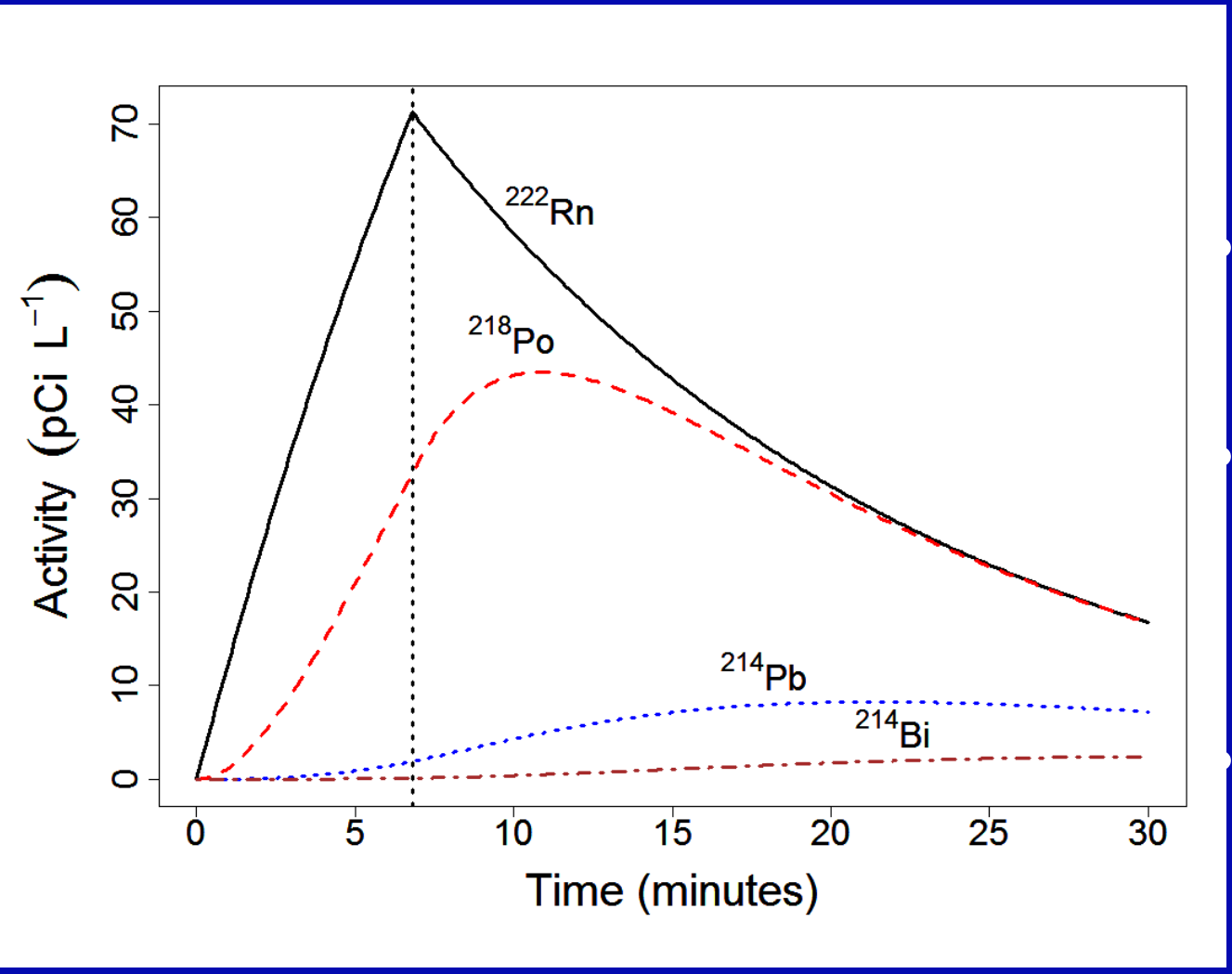
For bathrooms peaking earliest (good mixing and inherent ventilation), a linear relationship exists between Rn added to air and Rn in water

Exposure estimation



(after Vinson et al., in prep.)

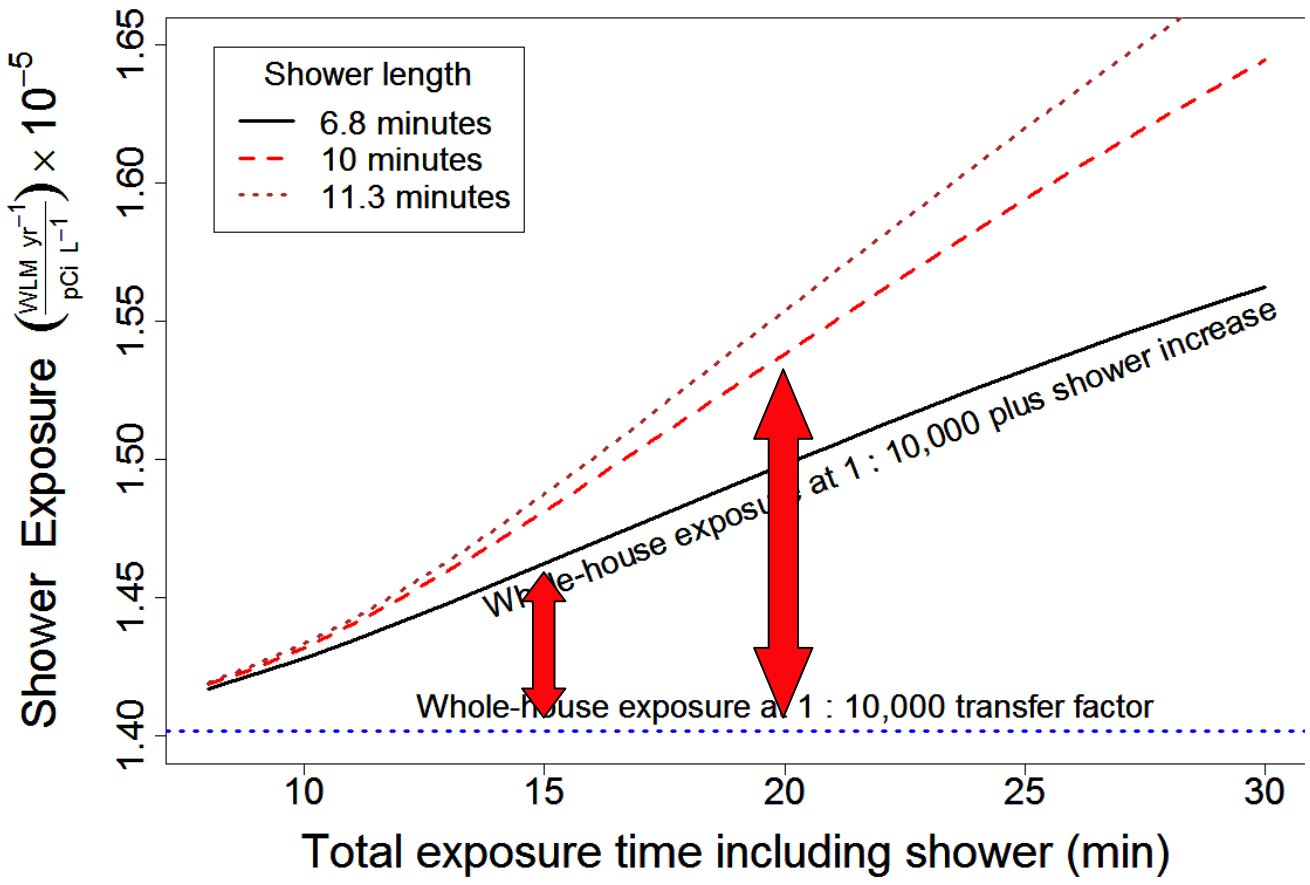
Modelled progeny growth



- Rn in water = 40,000 pCi L^{-1}
- Assumes no progeny in shower water
- Model for 6.8 minute shower

(after Vinson et al., in prep.)

Exposure per unit Rn in water

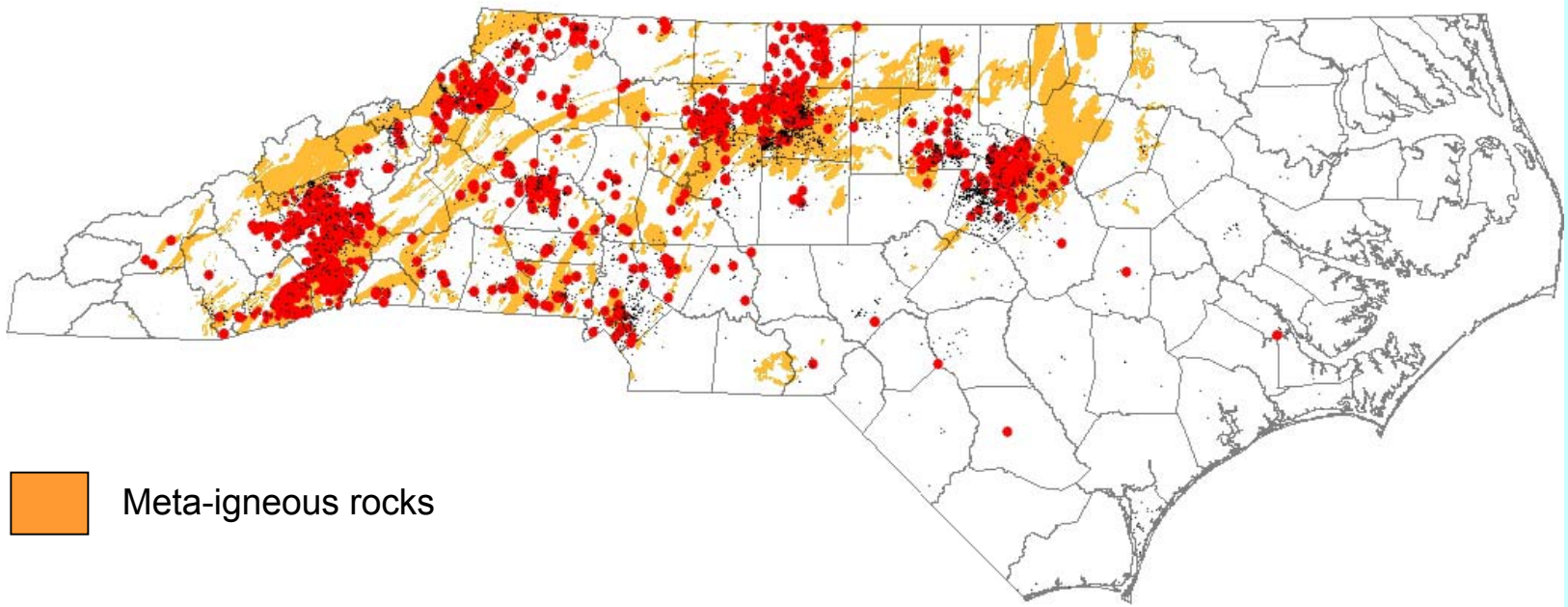


(after Vinson et al., in prep.)

% increase

- Exposure has linear increase with Rn in water
- Exposure has non-linear increase with exposure time

Indoor Air Radon in NC

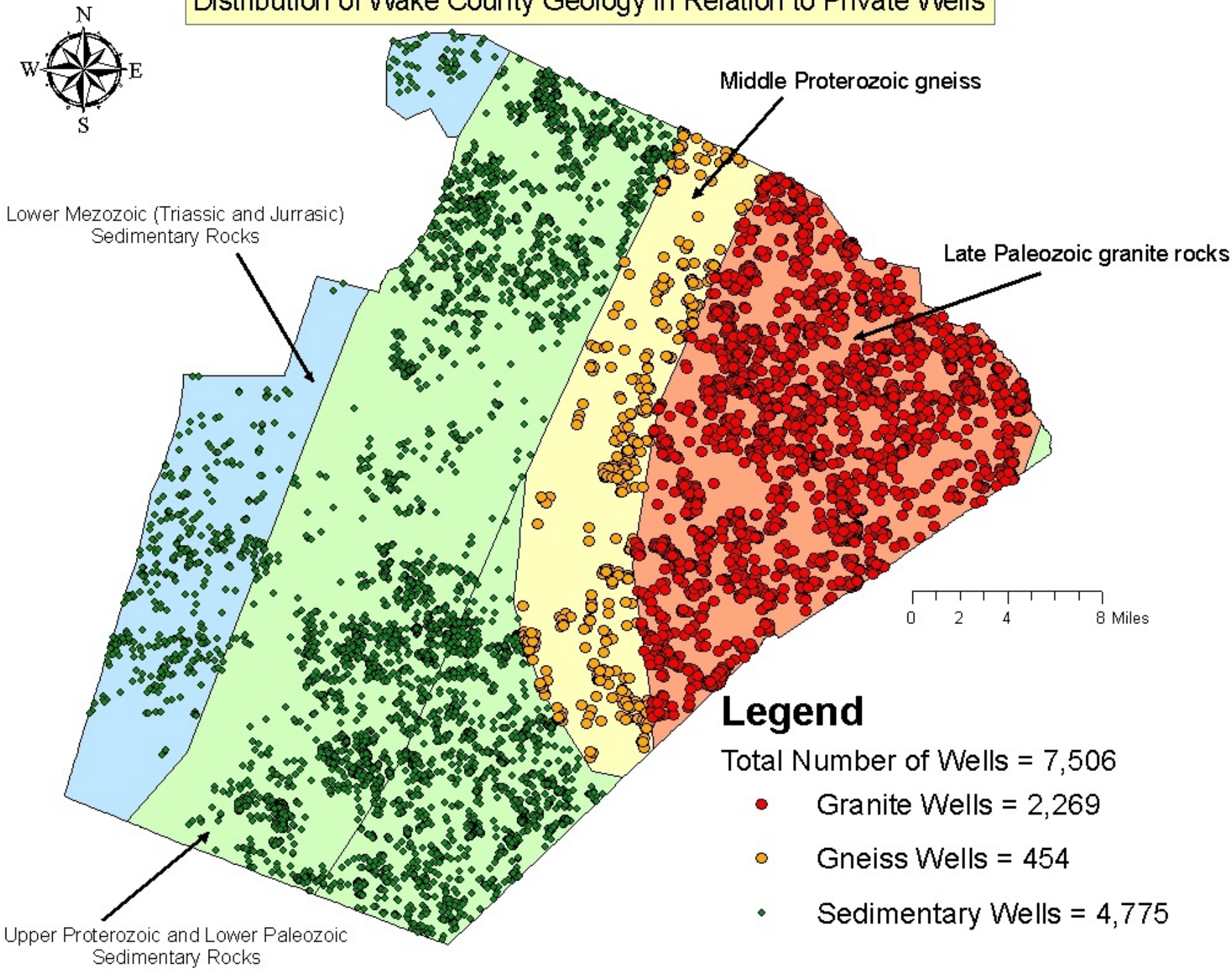


High radon in groundwater : increases risk for radiation exposure

* Data from Airchek, Inc, 2006

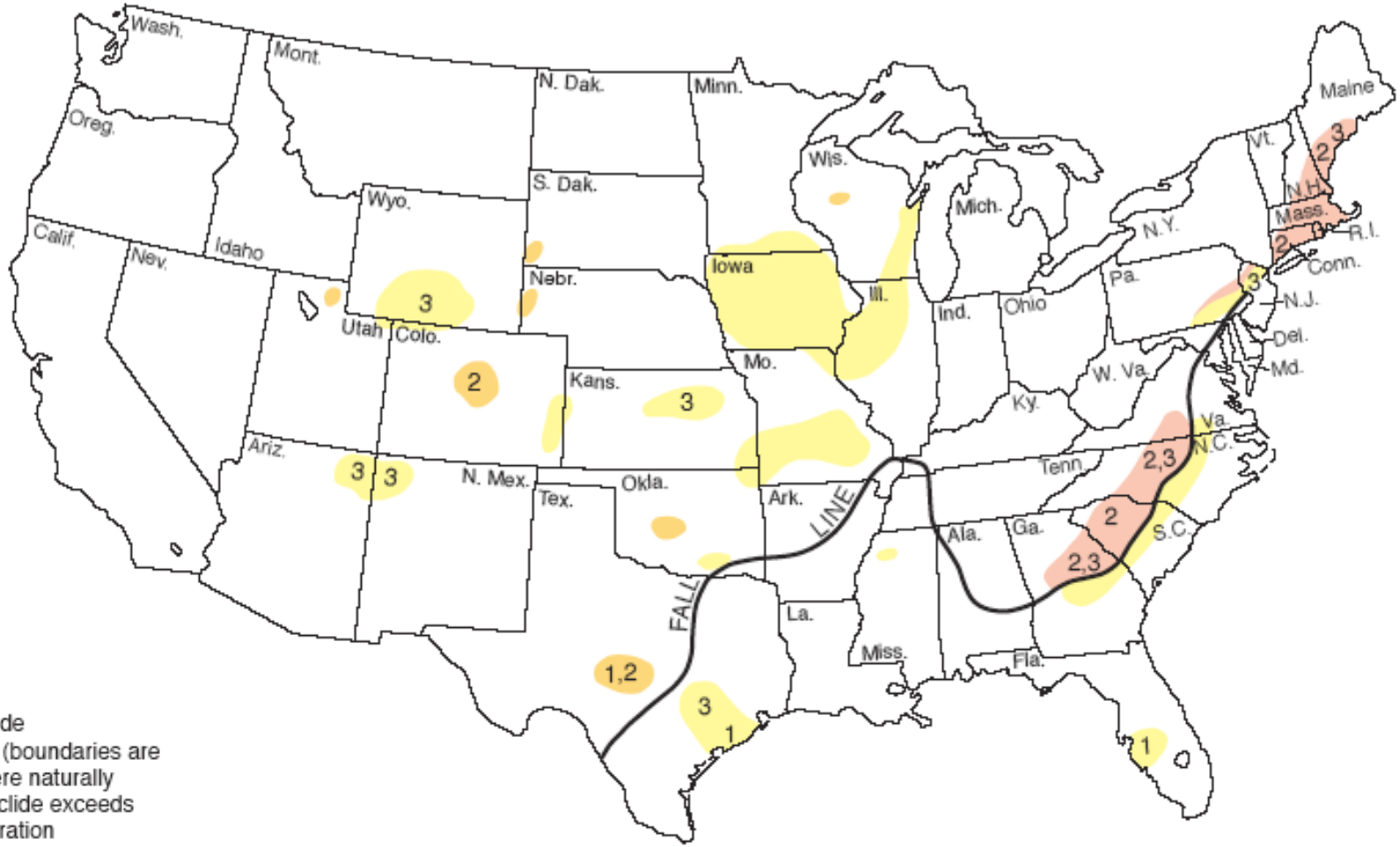
n = 16,384
max = 2146 pCi/L
median = 1.6 pCi/L

Distribution of Wake County Geology in Relation to Private Wells



Conclusions

- We have identified “hot spots” of high levels of naturally occurring contaminants (NORM) in groundwater in NC.
- The hot spots are related to the local geology.
- Preliminary results from Wake County define a zone of high radon and high radium, which might effect ~2,270 private wells.
- Preliminary survey results suggest that the levels of awareness, monitoring, and treatment of naturally occurring contaminants by private homeowners are zero.



EXPLANATION

Dominant radionuclide

Generalized area (boundaries are approximate) where naturally occurring radionuclide exceeds indicated concentration

Radon—10,000 pCi/L (equivalen to about 1 pCi/L in air)

Radium—5 pCi/L

Uranium—10 pCi/L

Other radionuclides also present

1 Radon

2 Radium

3 Uranium

Radionuclides "hot spots" in the USA (USGS report)