Radionuclides in Northern New Jersey Fractured-Rock Aquifers, Geological and Geochemical Indicators of Variability, and Regional Implications

U.S. Geological Survey

in cooperation with

N.J. Dept. Environmental Protection

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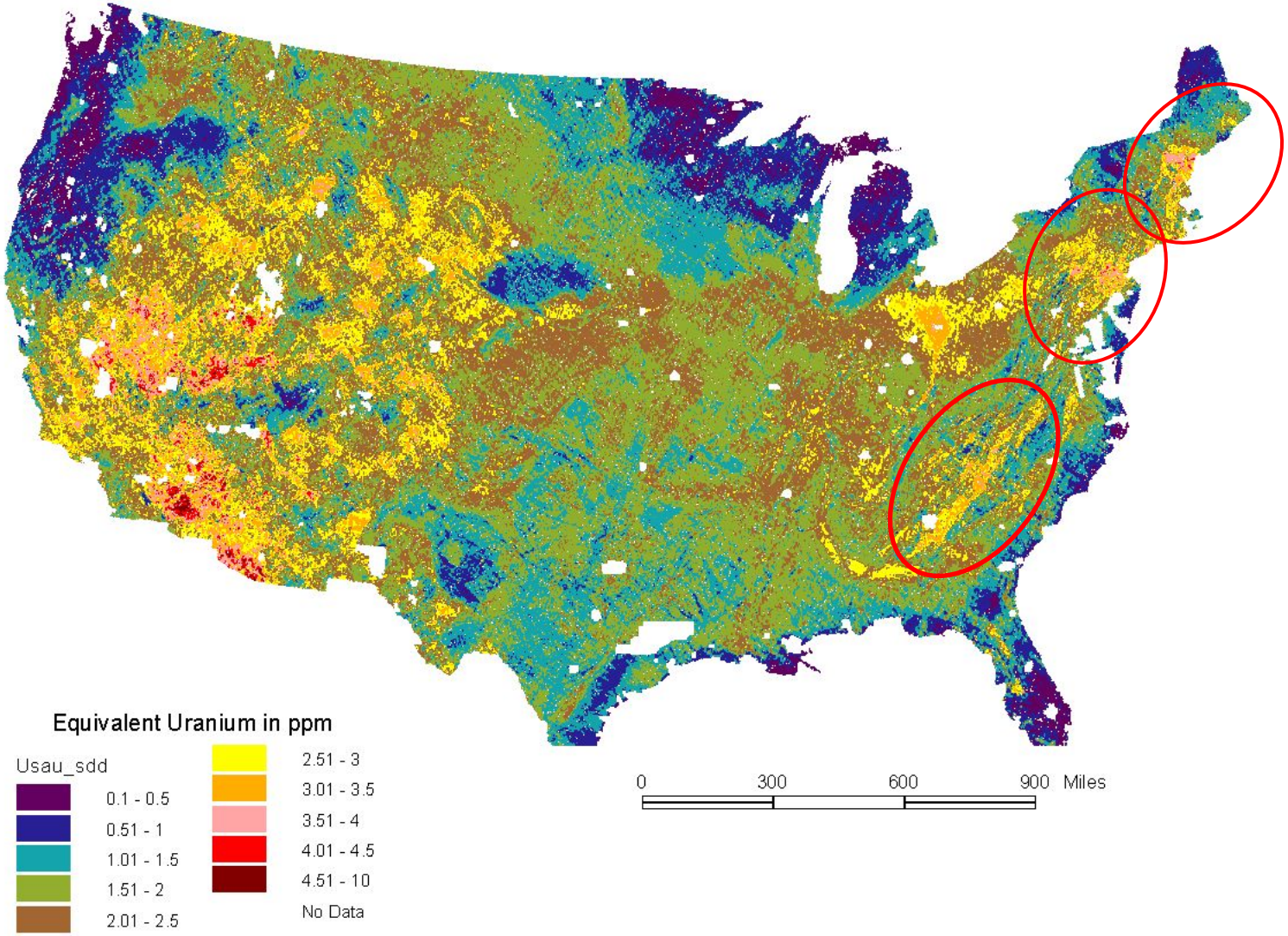
Presentation Summary

- *Occurrence of Radium (Ra), parent Uranium (U), and progeny Radon (Rn), are different because of differences in geology and geochemistry.*
- Update of ongoing northern New Jersey fractured crystalline and sedimentary bedrock studies
- Comparison among radionuclides
- Comparison with gross alpha
- Regional Implications: NAWQA national occurrence study findings specific to the Northeastern USA

•Equivalent Uranium in surficial materials



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Radionuclide Decay Series

•Uranium 238

•Thorium 232

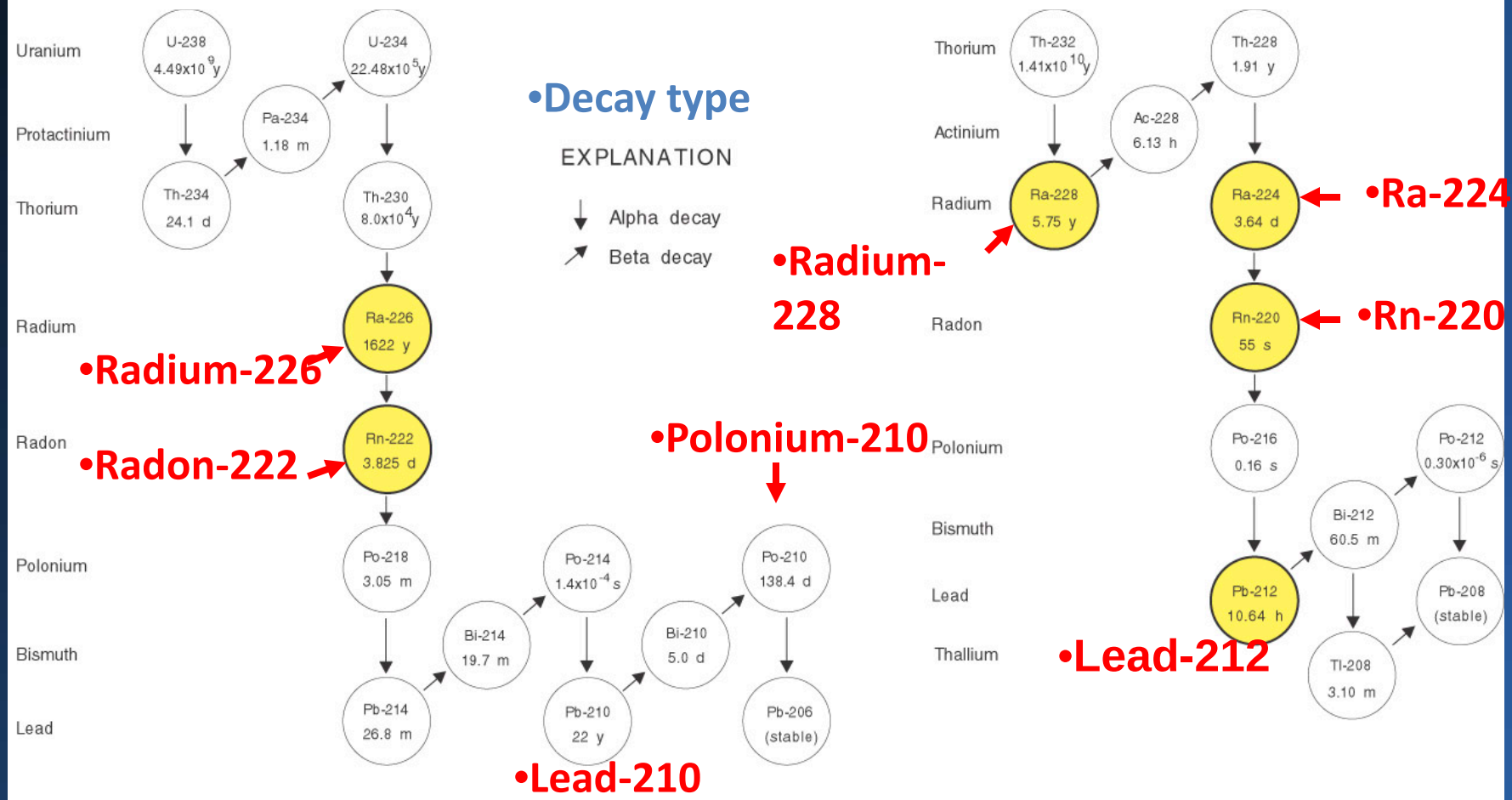


Figure 1. Diagram showing uranium-238 and thorium-232 radioactive decay series. (Radionuclides of interest in this study are shaded). [Times shown are half-lives: y, years; d, days; h, hours; m, minutes; s, seconds] (From Hall and others, 1985)

•Gross alpha = many individual isotope contributions!

USGS

NJ PWTA Gross Alpha Exceedances (data up to 4/19/2010)

Province	Exceedance
Coastal Plain	10.7%
Piedmont*	3.8%
Highland*	2.5%

- *potential exceedance

- Range – ND to 481 pCi/l

USGS

Private Well Test Program's Gross Alpha Requirement – Additional Counties in Northern New Jersey for Testing

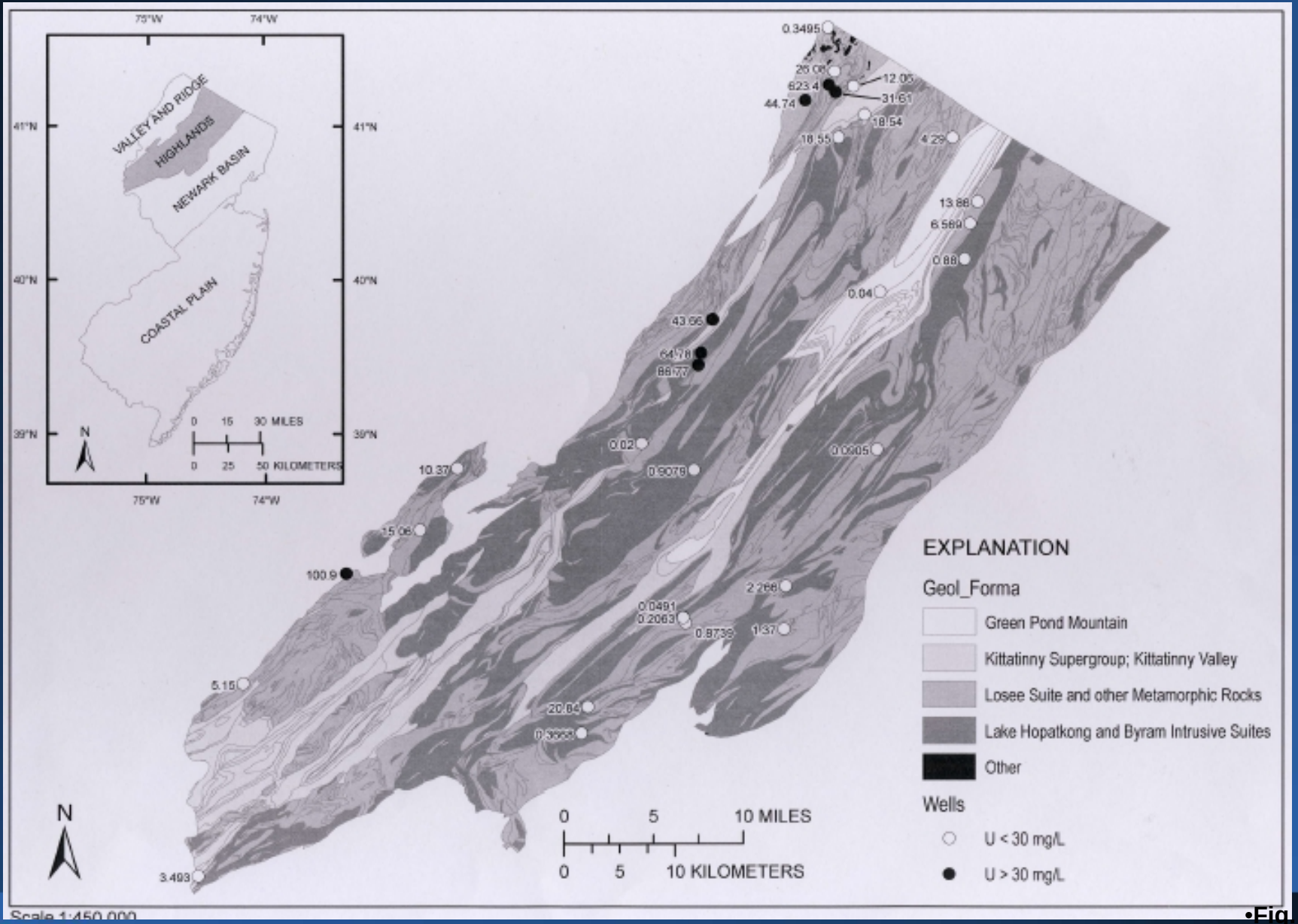
C.58:12A-28 Water test parameters.

3. Every water test conducted in accordance with this act shall include a test for at least the following parameters: bacteria (total coliform); nitrates; iron; manganese; pH; all volatile organic compounds for which maximum contaminant levels have been established pursuant to P.L.1977, c.224 (C.58:12A-1 et seq.); and lead.

In addition, the water test shall include a short term 48-hour gross alpha test to screen for the presence of radium, provided that the Department of Environmental Protection has made a finding pursuant to subsection b. of section 4 of this act that there are a sufficient number of laboratories certified to perform the test.

- **What if anything can be recommended to homeowners in Northern New Jersey who have high gross alpha activity in their well water?**

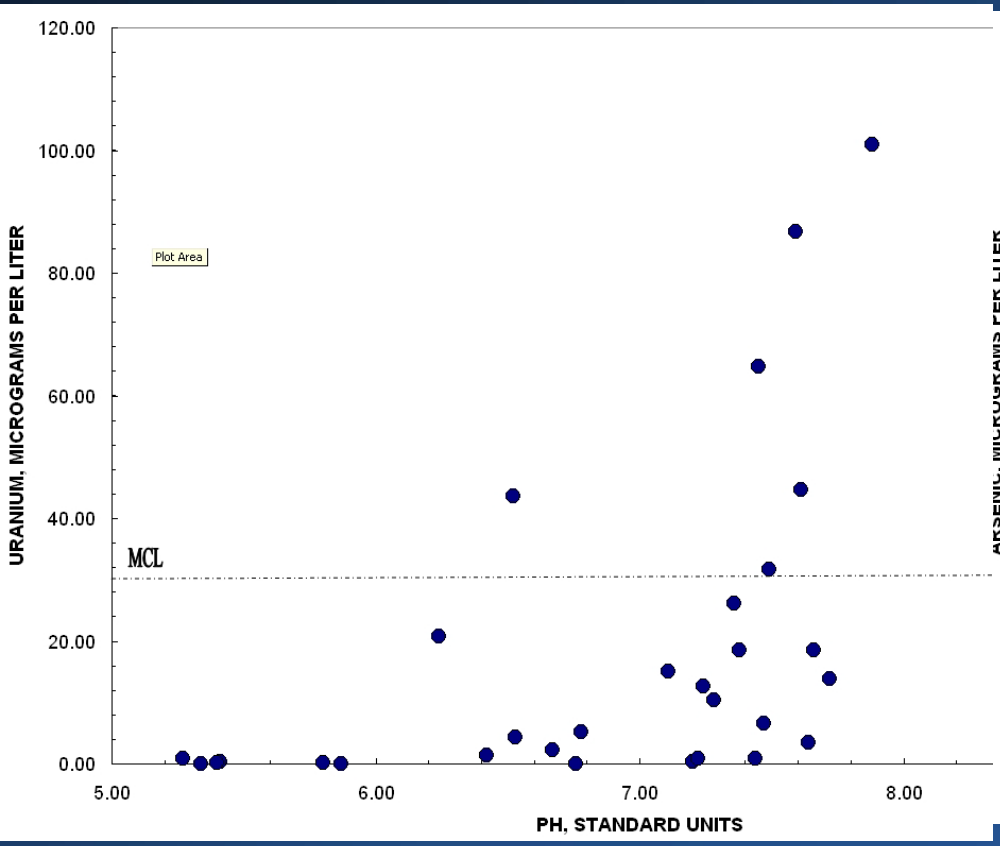
•Highest U is found in western part of NJ Highlands (more alkaline)

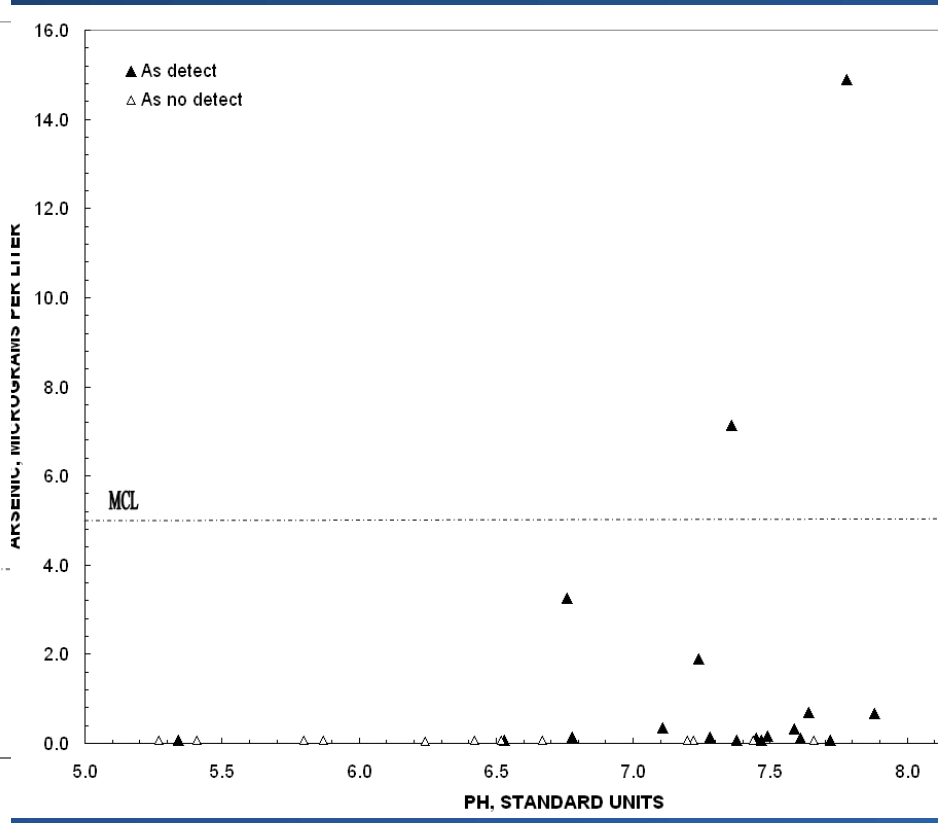


•Fig. 1

USGS

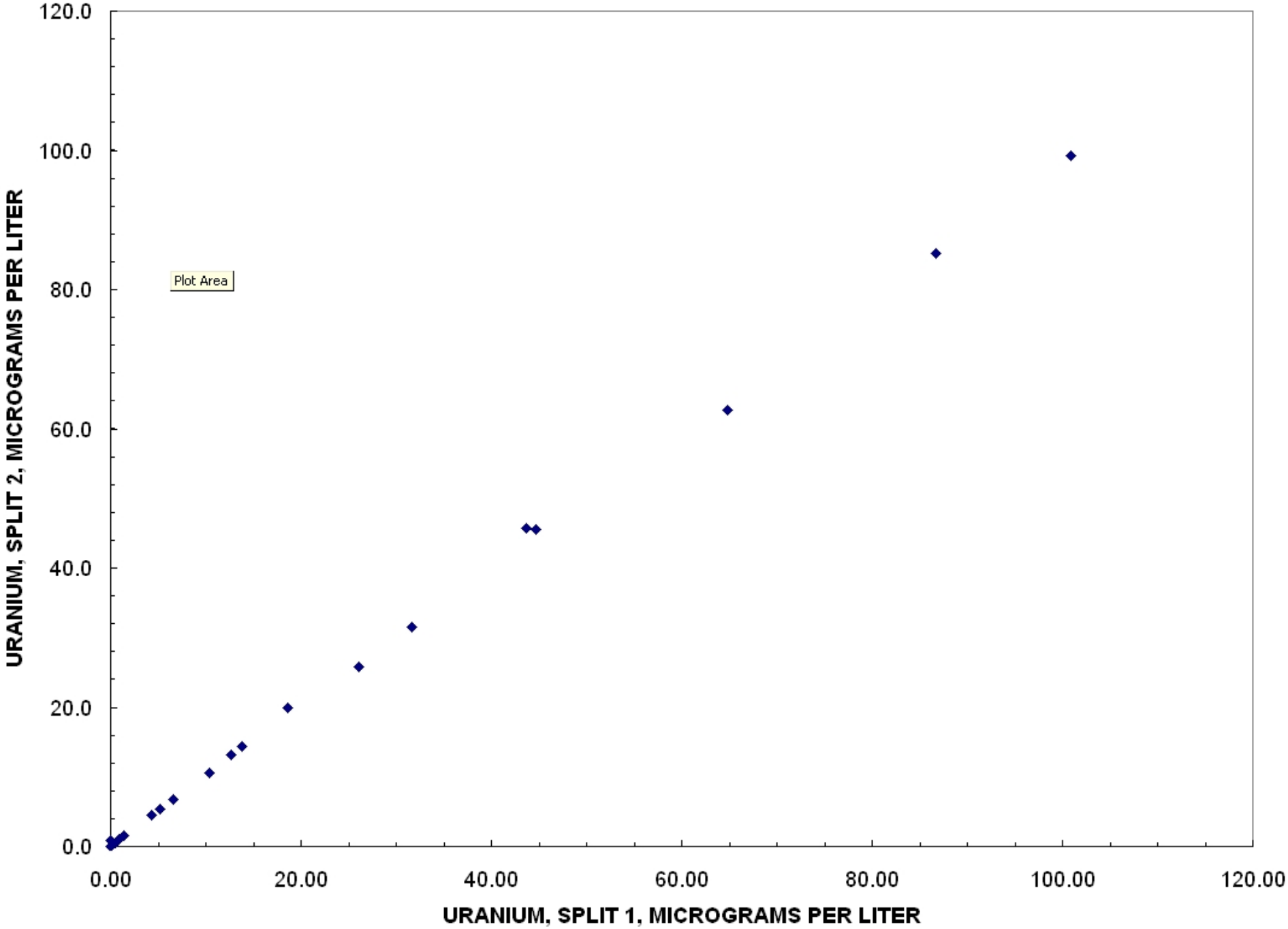
Both Uranium and Arsenic highest in the most alkaline waters in the NJ Highlands



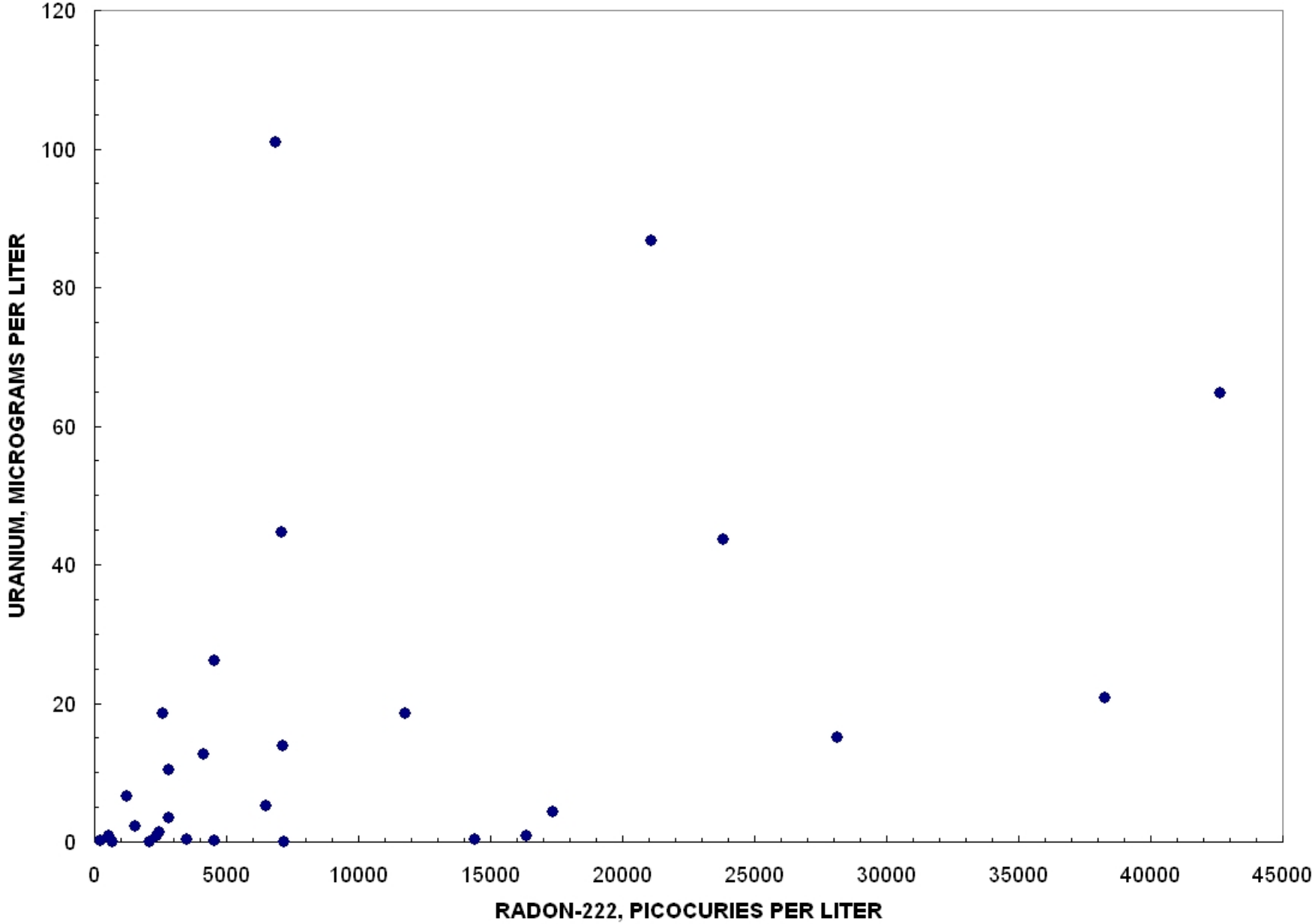


•Fig. 6

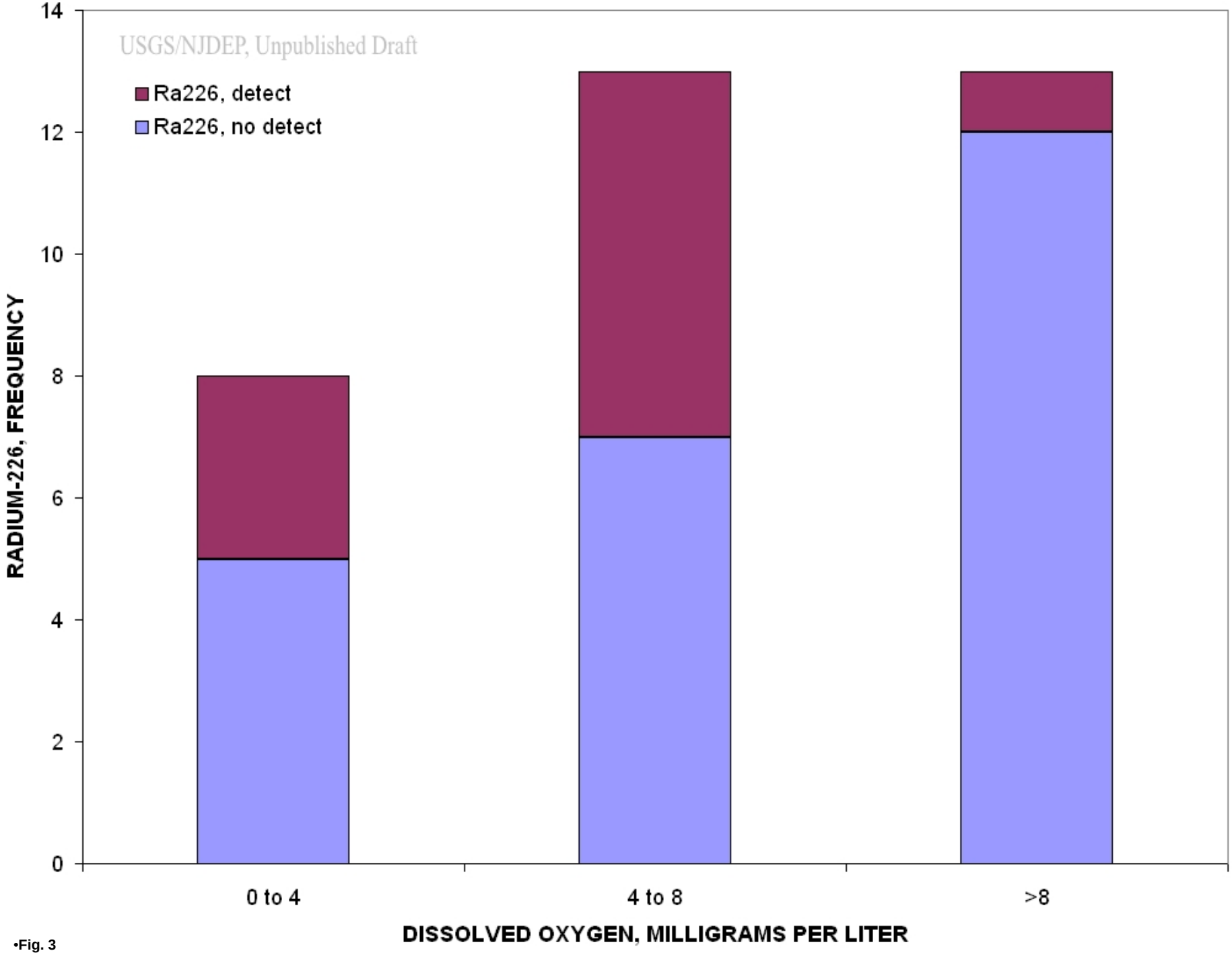
USGS


120.0
100.0
80.0
60.0
40.0
20.0
0.0
URANIUM, SPLIT 2, MICROGRAMS PER LITER
Plot Area
0.00
20.00
40.00
60.00
80.00
100.00
120.00
URANIUM, SPLIT 1, MICROGRAMS PER LITER

•NJ Crystalline rock: weak correlation

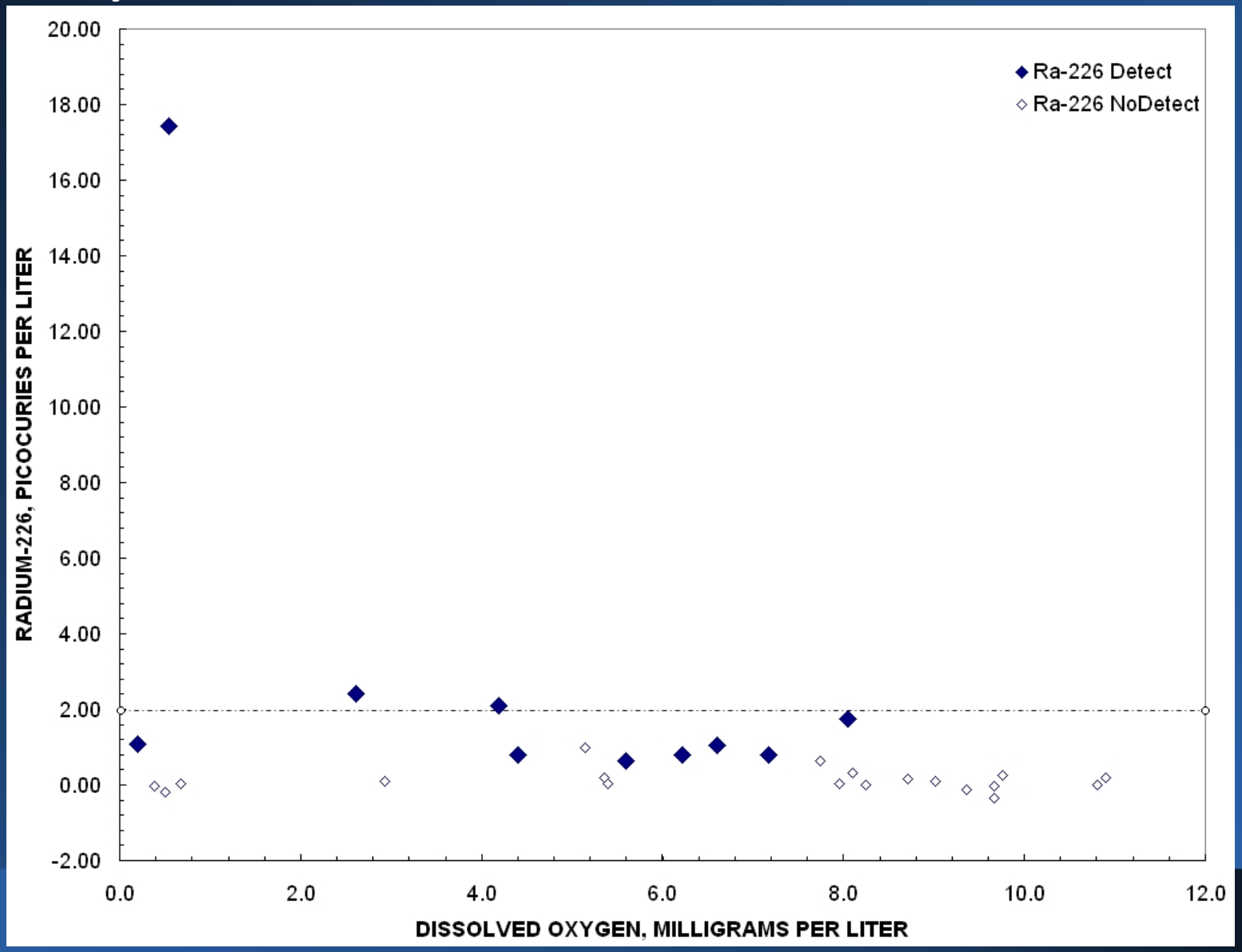


•Fig. 8


USGS/NJDEP, Unpublished Draft
Ra226, detect
Ra226, no detect
RADIUM-226, FREQUENCY
0
2
4
6
8
10
12
14
0 to 4
4 to 8
>8
DISSOLVED OXYGEN, MILLIGRAMS PER LITER

•Fig. 3

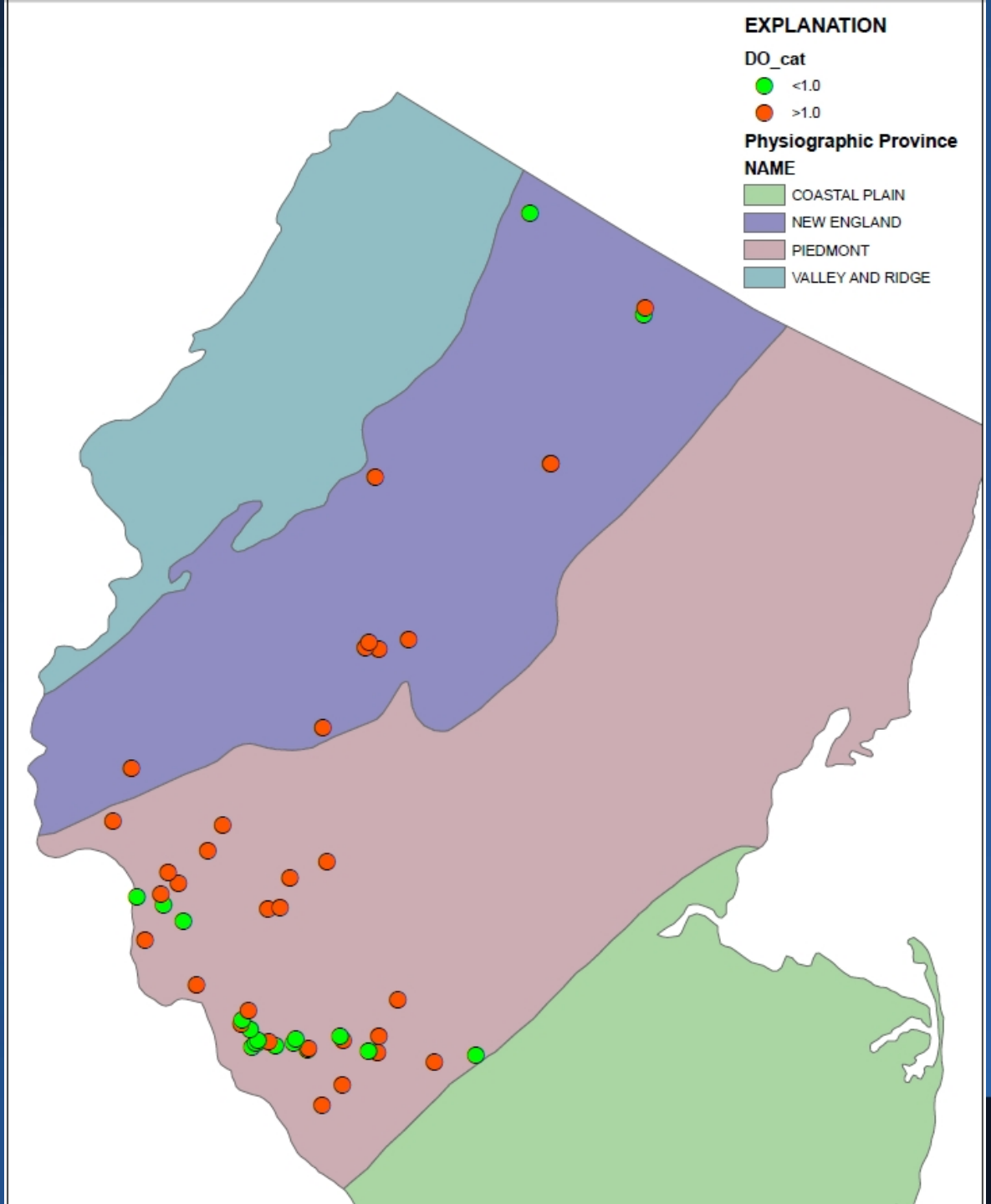
NJ Crystalline rocks: Ra in anoxic water



•Fig. 4

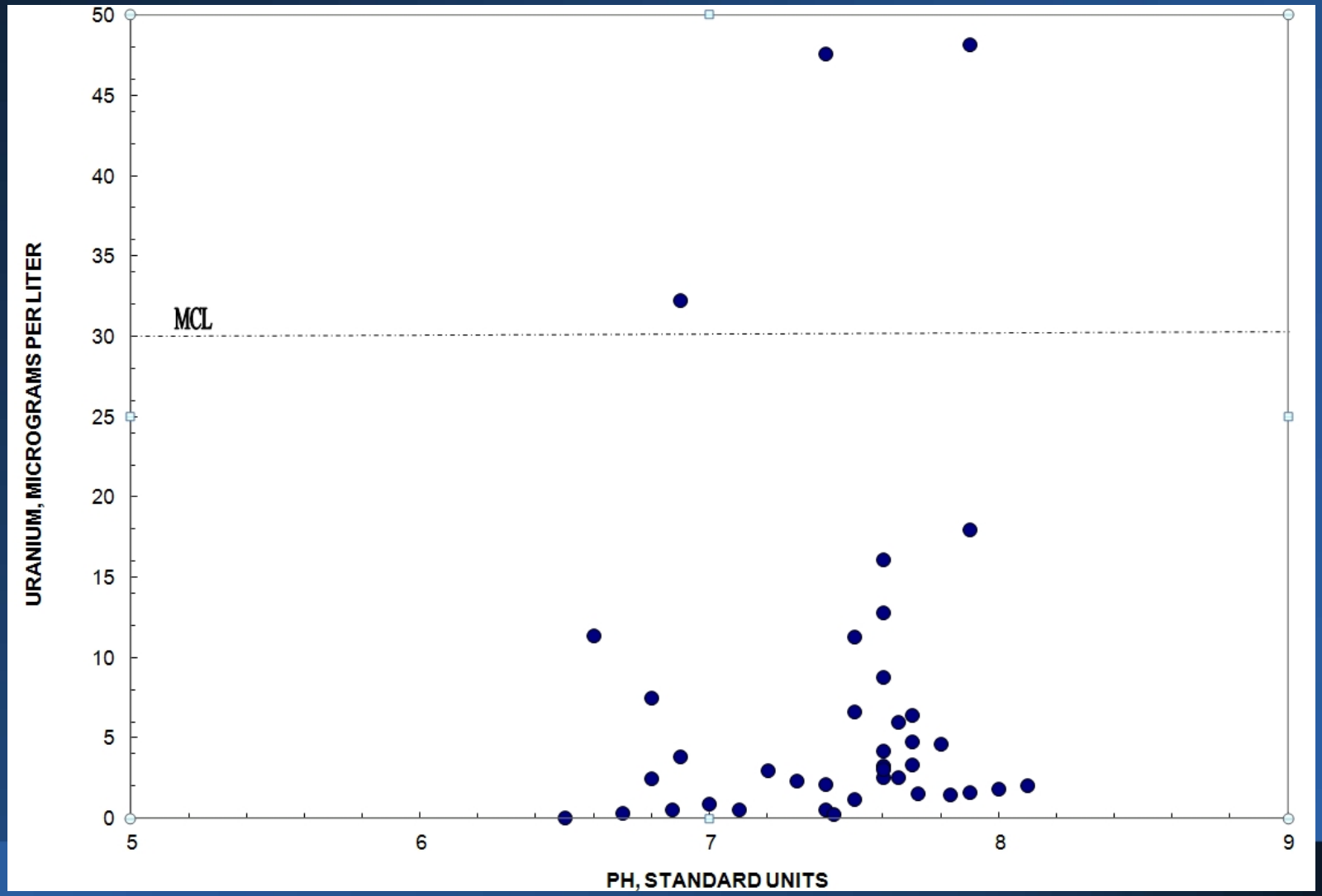
Follow-up

- To better characterize U & Ra mixtures in lower DO waters
- Compare results among New Jersey Piedmont (black shale) and Highlands Provinces (gneiss, granite)



USGS

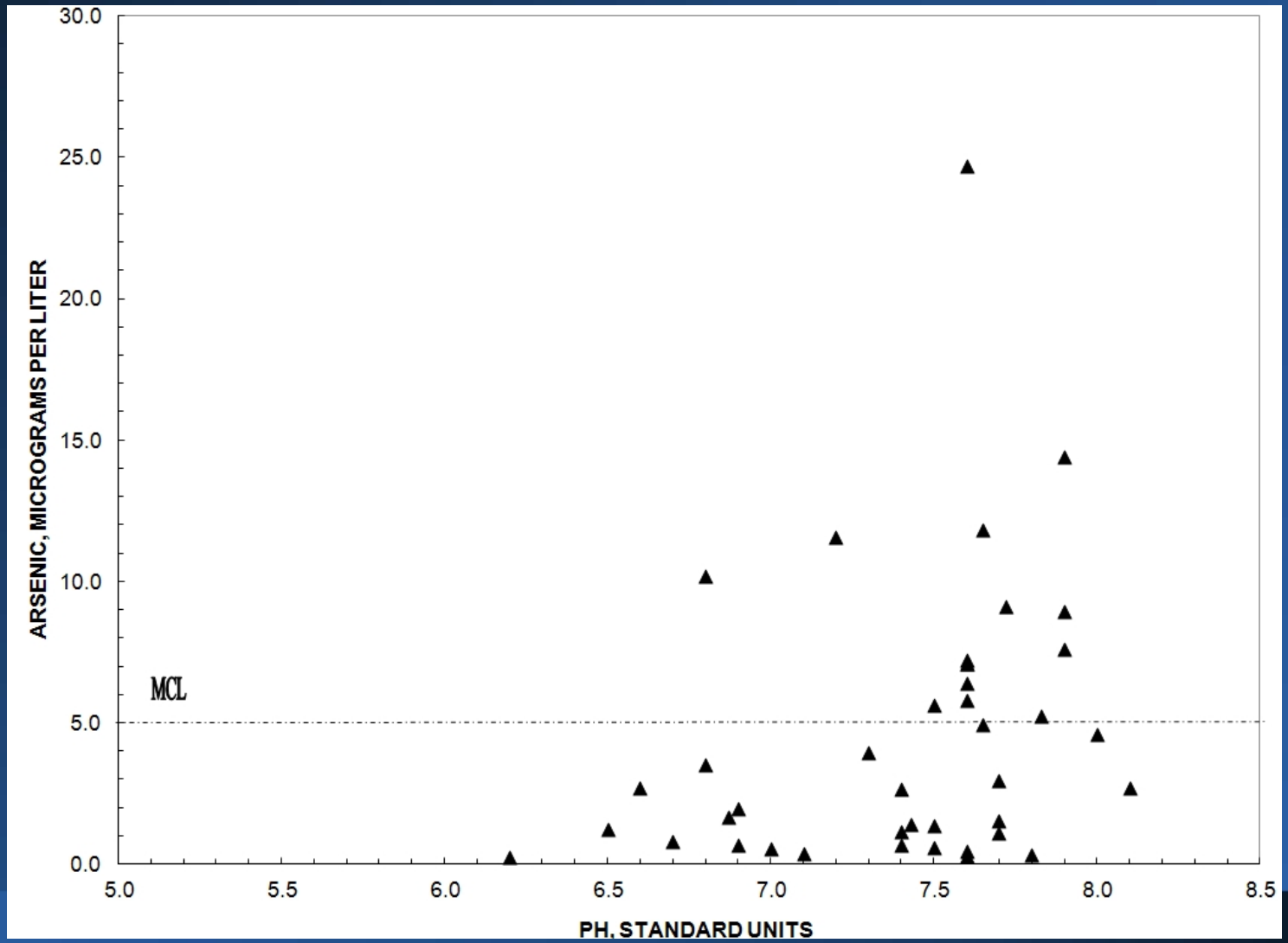
Both Uranium and Arsenic highest in the most alkaline waters in the NJ Piedmont



•Fig. 6

USGS

Both Uranium and Arsenic highest in the most alkaline waters in the NJ Piedmont



•Fig. 6

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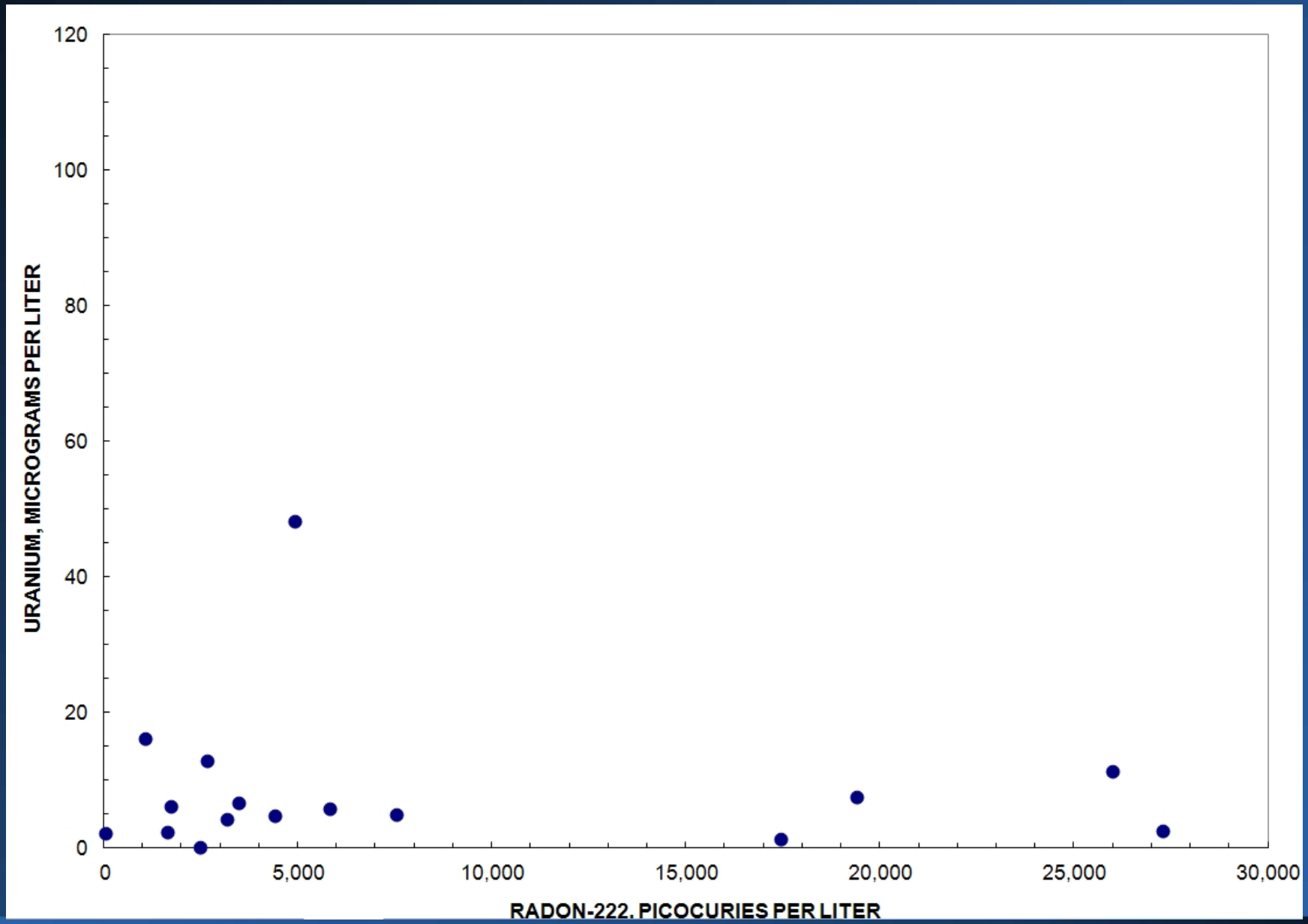
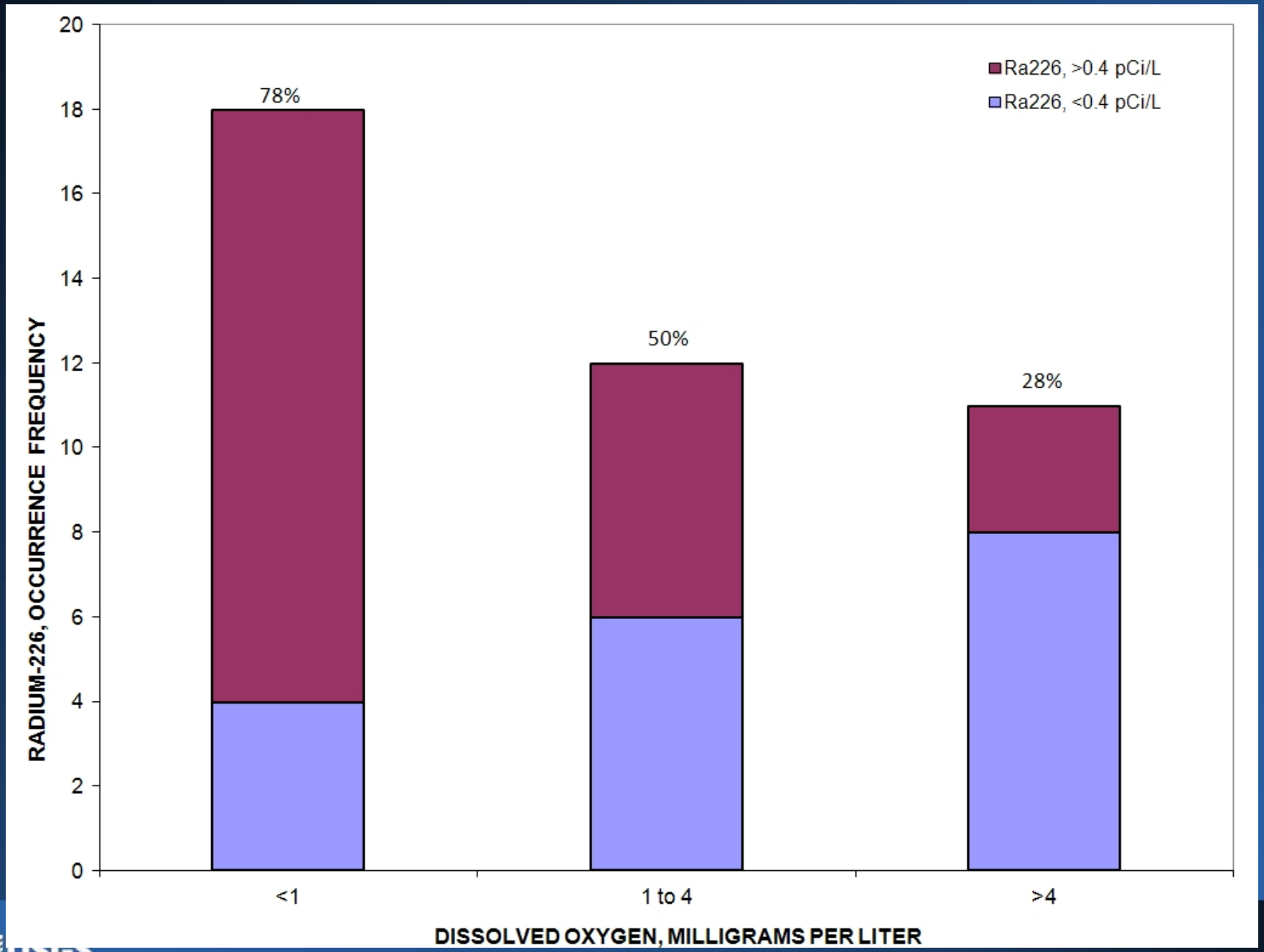
•NJ Piedmont rock: no correlation

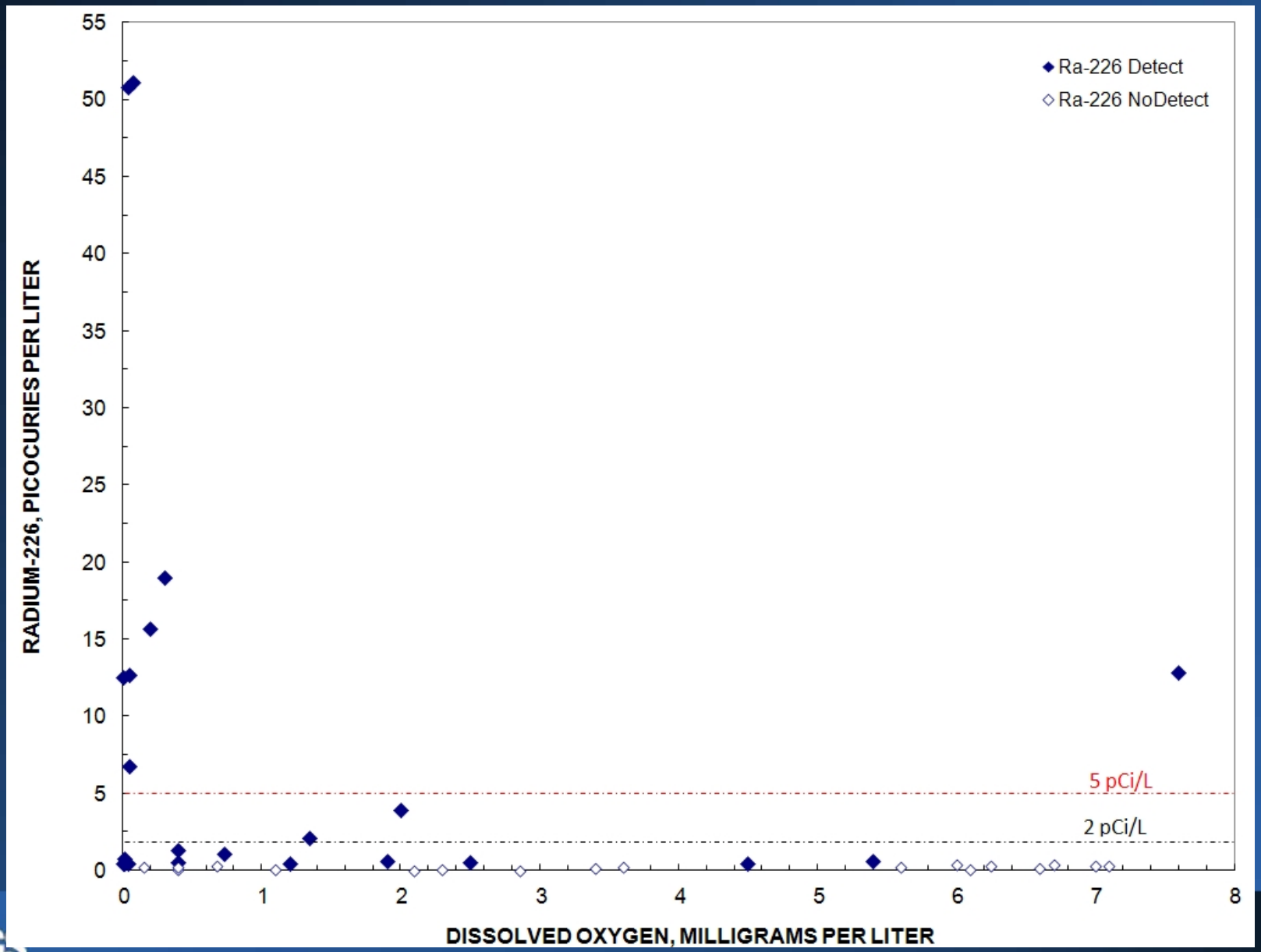


•Fig. 8


Ra226, >0.4 pCi/L
Ra226, <0.4 pCi/L
78%
50%
28%
RADIUM-226, OCCURRENCE FREQUENCY
0
2
4
6
8
10
12
14
16
18
20
<1
1 to 4
>4
DISSOLVED OXYGEN, MILLIGRAMS PER LITER

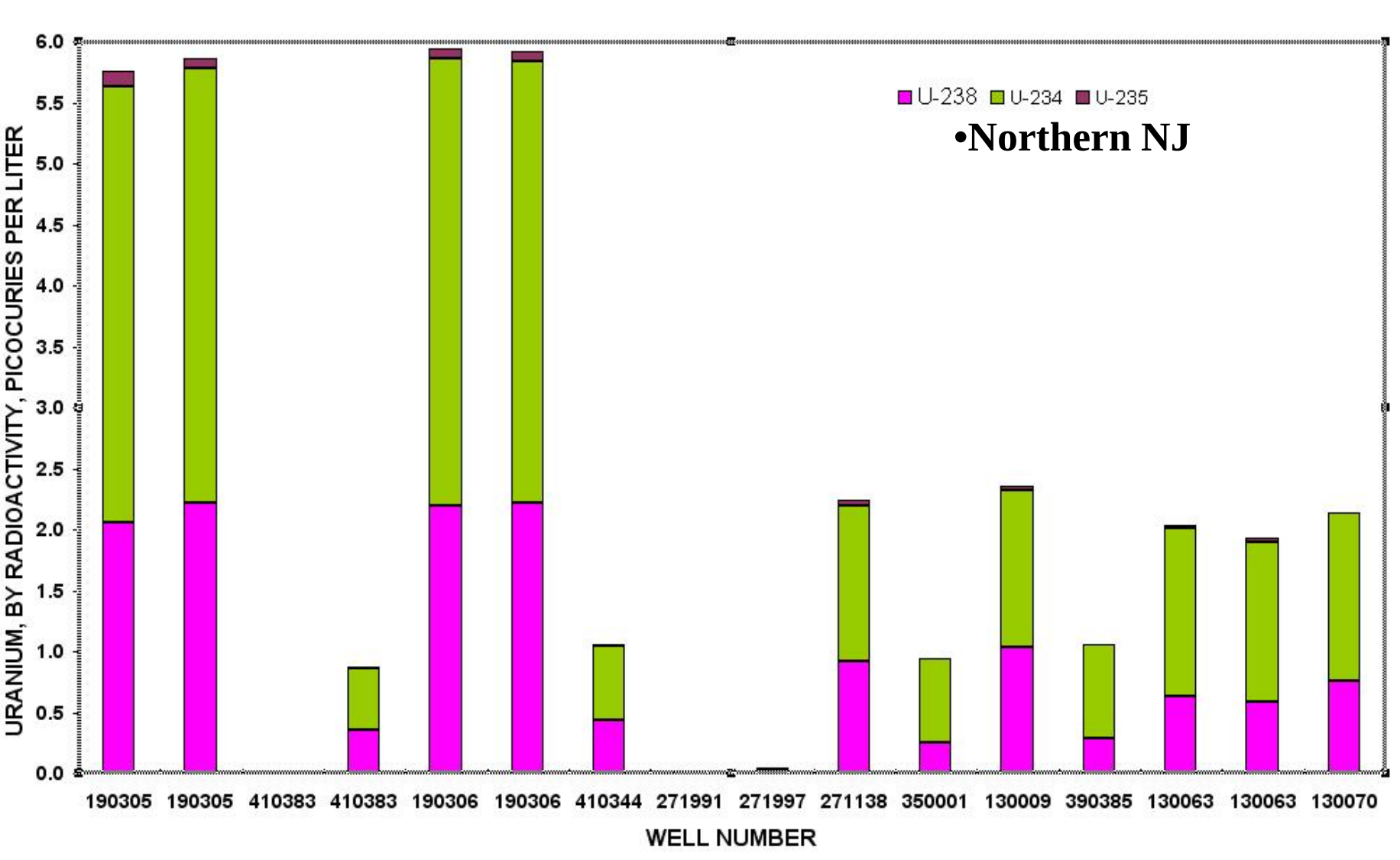
•Fig. 3

NJ Piedmont rocks: Ra in anoxic water

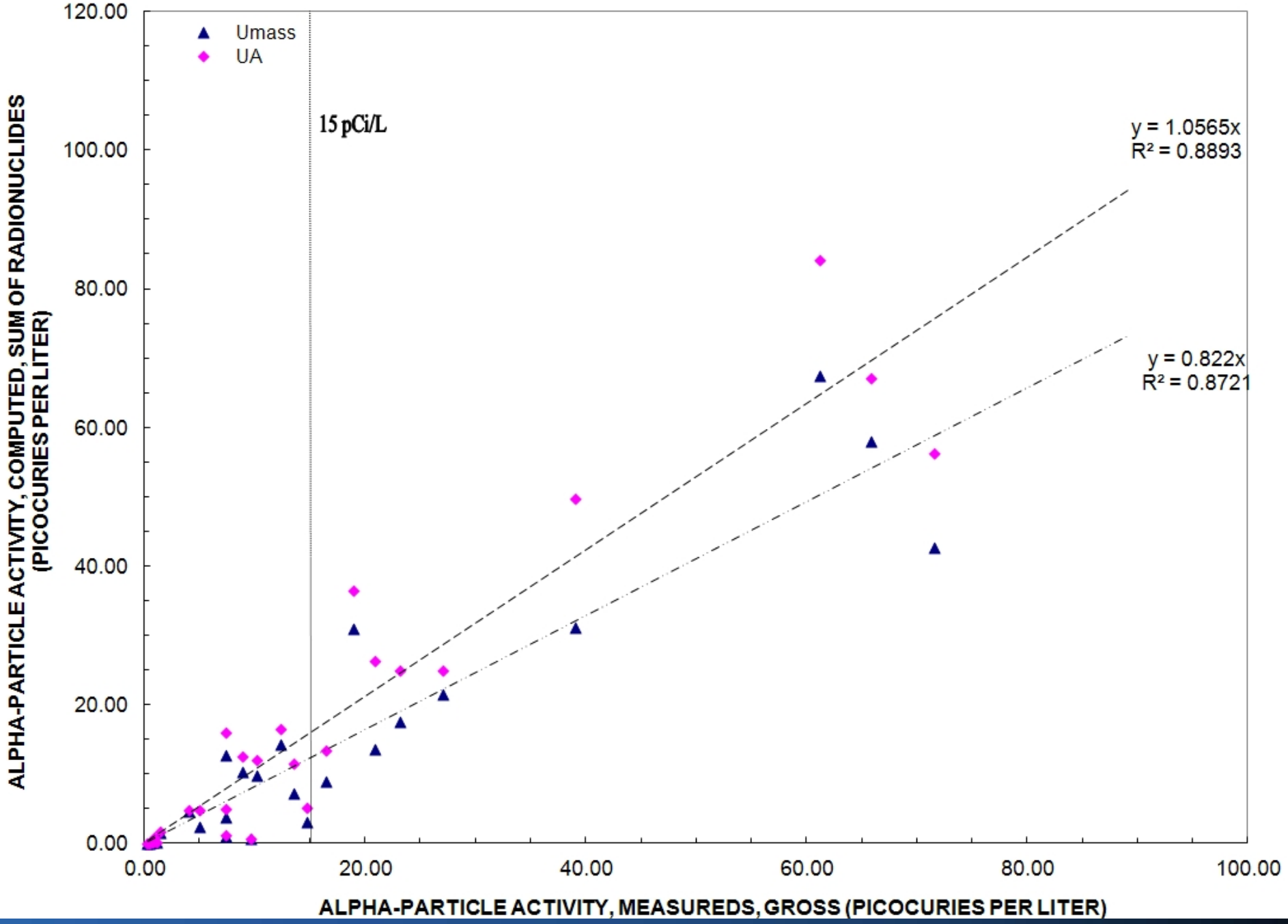


•Fig. 4

•U-234 isotope always in excess increasing gross alpha activity



USGS


Umass
UA
15 pCi/L
y = 1.0565x
R² = 0.8893
y = 0.822x
R² = 0.8721
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
ALPHA-PARTICLE ACTIVITY, COMPUTED, SUM OF RADIONUCLIDES (PICOCURIES PER LITER)
ALPHA-PARTICLE ACTIVITY, MEASUREDS, GROSS (PICOCURIES PER LITER)

Excess U-234 accounts for GrossAlpha where U is dominant. Ra is locally an important issue in anoxic waters. It is difficult to accounting for Ra-226 and U-234 in those waters without detailed testing.

alpha_th, 48 hr (pCi/L)	U (ug/L)	alpha_from_Umass (pCi/L)	alpha_minus_Umass (pCi/L)	UAR	alpha_from_UAR (pCi/L)	alpha_minus_UAR (pCi/L)	Ra-226 (pCi/L)	Ra-224 (pCi/L)
65.9	86.77	57.94	7.96	1.32	67.09	-1.19		
27.02	31.61	21.49	5.53	1.31	24.86	2.16		1.58
71.6	64.78	42.64	28.96	1.64	56.28	15.32	2.10	2.34
14.74	4.29	3.06	11.68	2.32	5.08	9.66	2.41	

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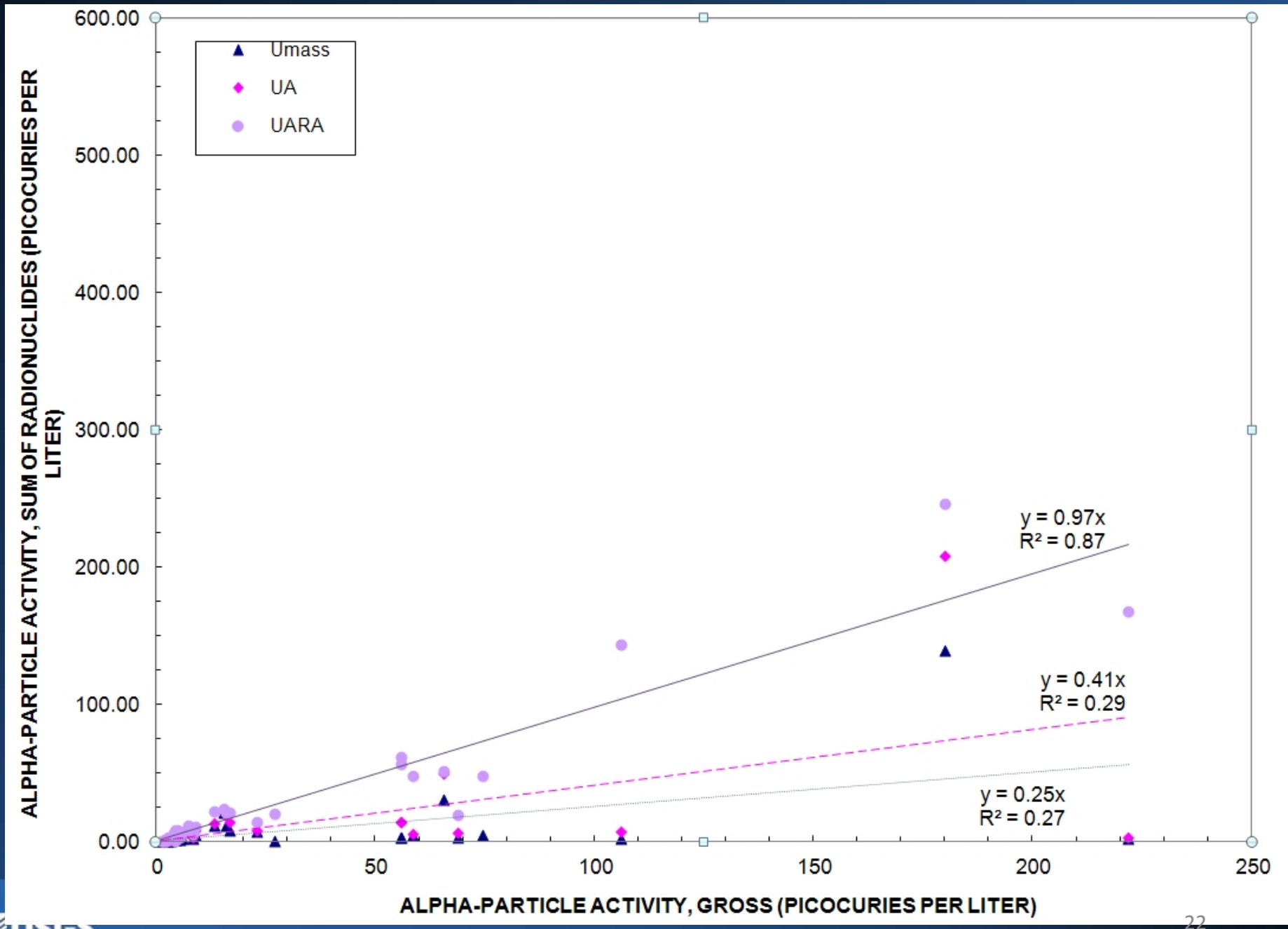

Umass
UA
UARA
y = 0.97x
R² = 0.87
y = 0.41x
R² = 0.29
y = 0.25x
R² = 0.27
ALPHA-PARTICLE ACTIVITY, SUM OF RADIONUCLIDES (PICOCURIES PER LITER)
ALPHA-PARTICLE ACTIVITY, GROSS (PICOCURIES PER LITER)
600.00
500.00
400.00
300.00
200.00
100.00
0.00
0
50
100
150
200
250

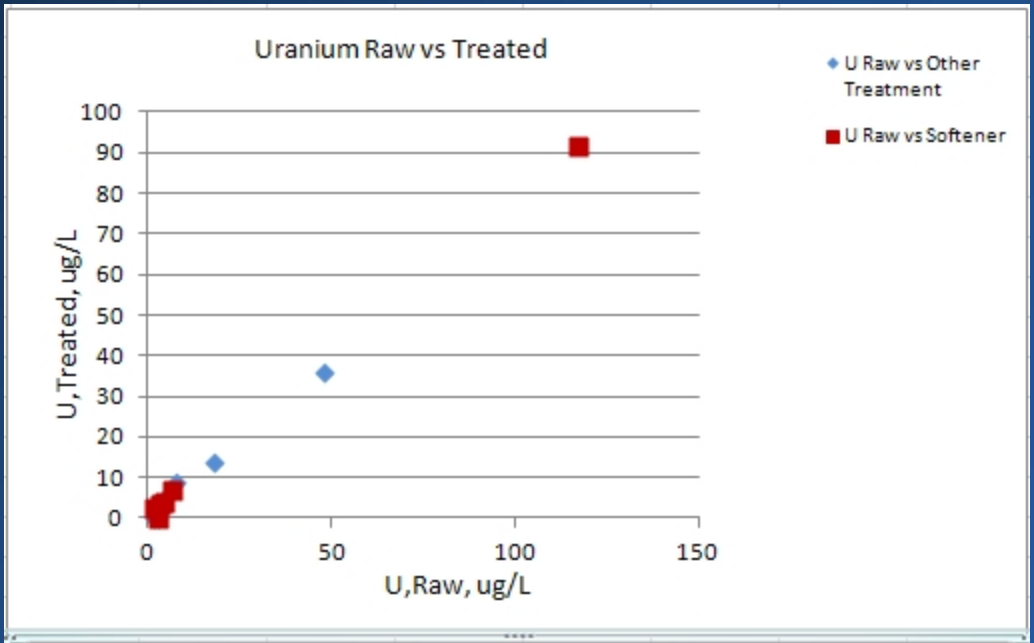
Treatment Options

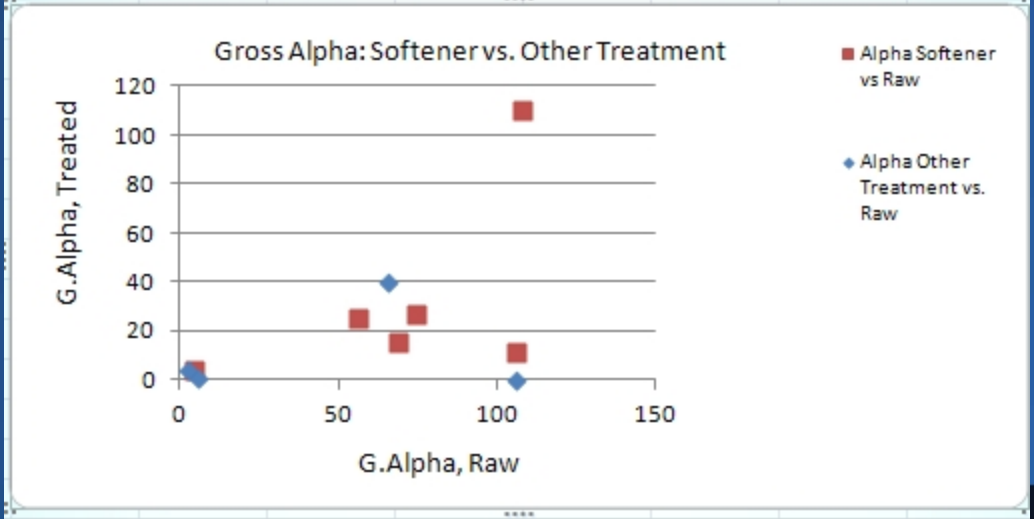
- Radium – Cation Exchange Resin (Water Softener, whole house) or Reverse Osmosis (RO, kitchen tap only)

- Uranium – Anionic Exchange Resin or Reverse Osmosis (RO)
- Arsenic – Granular Ferric Oxide (GFO) most preferred

- Uranium was generally not removed by “typical” home owner treatment systems.
- Radium was decreased or removed by softeners
- If uranium contributed to alpha as well, gross alpha was not Minimized

If excess U-234 was high, even the U mass test could not provide a readily apparent treatment plan





USGS

NAWQA National Exceedances (data up to 2005)

Compound	Exceedance
Uranium	1.7%
Radium	3.2%
Radon*	60 or 6%

- *potential exceedance: proposed standards:
- 300 or 4000 pCi/L

- All organics < 1 %

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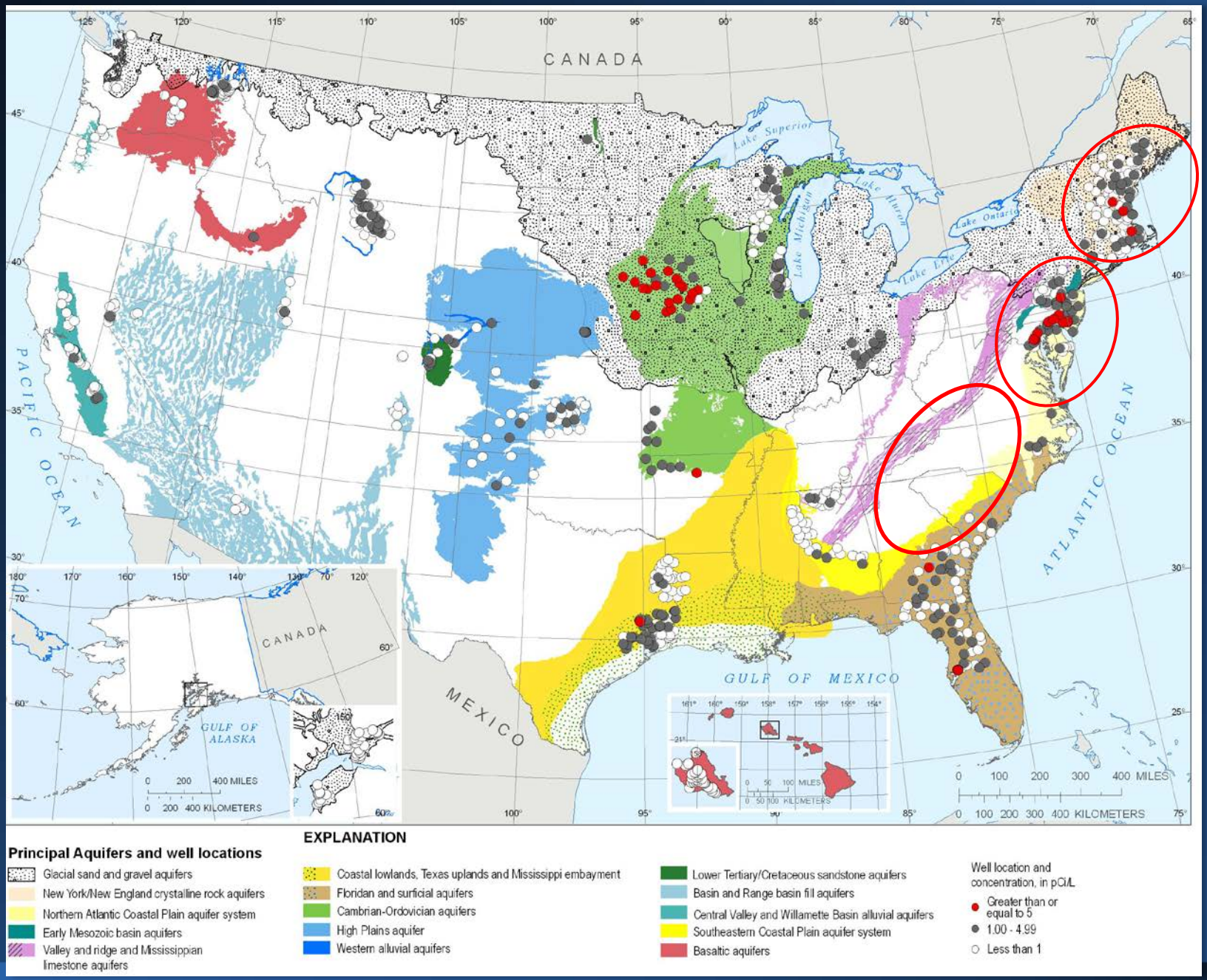
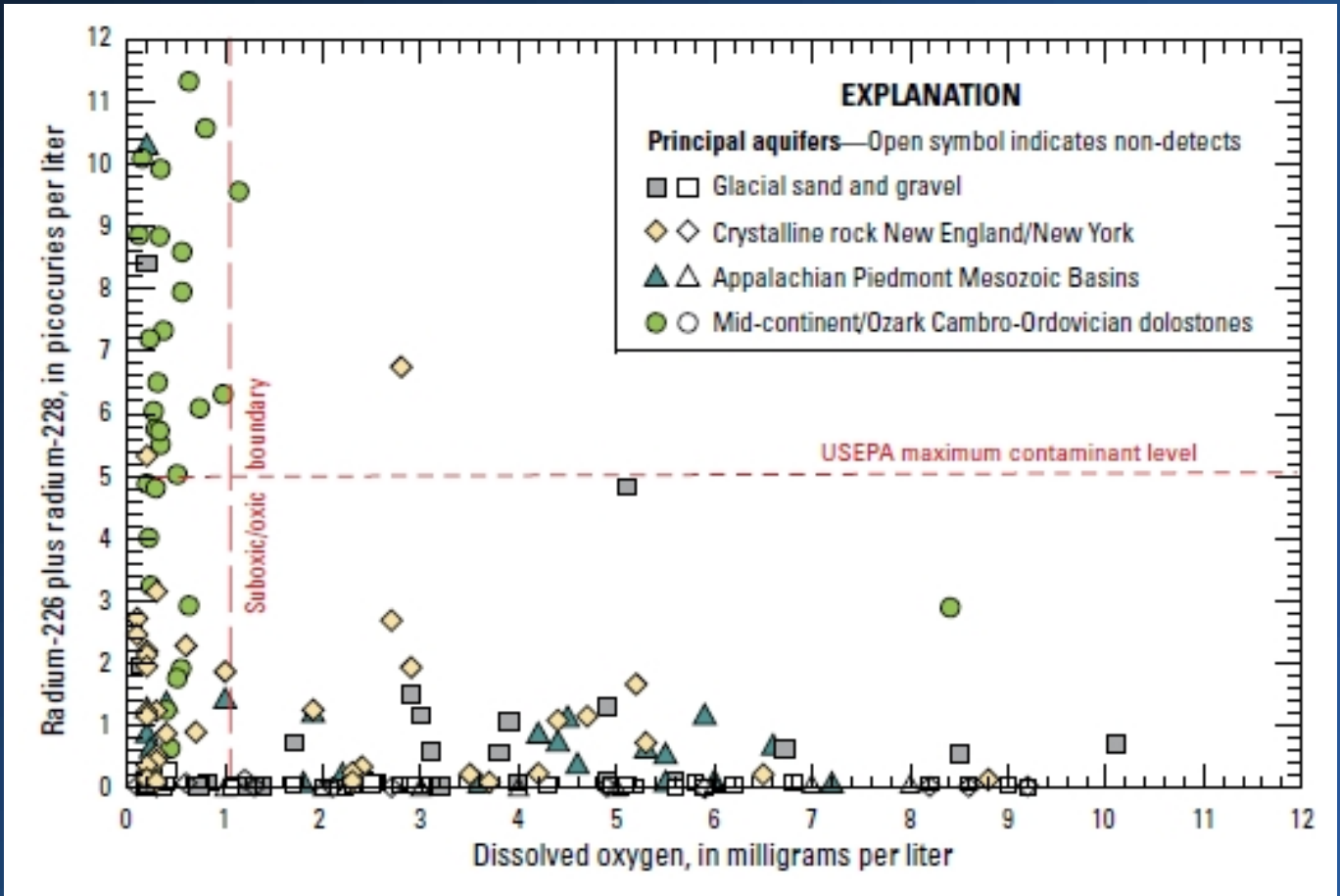


Highest Ra concentrations are east of the High Plains

Ra and Dissolved Oxygen (National)



Near hyperbolic relation of combined Ra with Dissolved Oxygen

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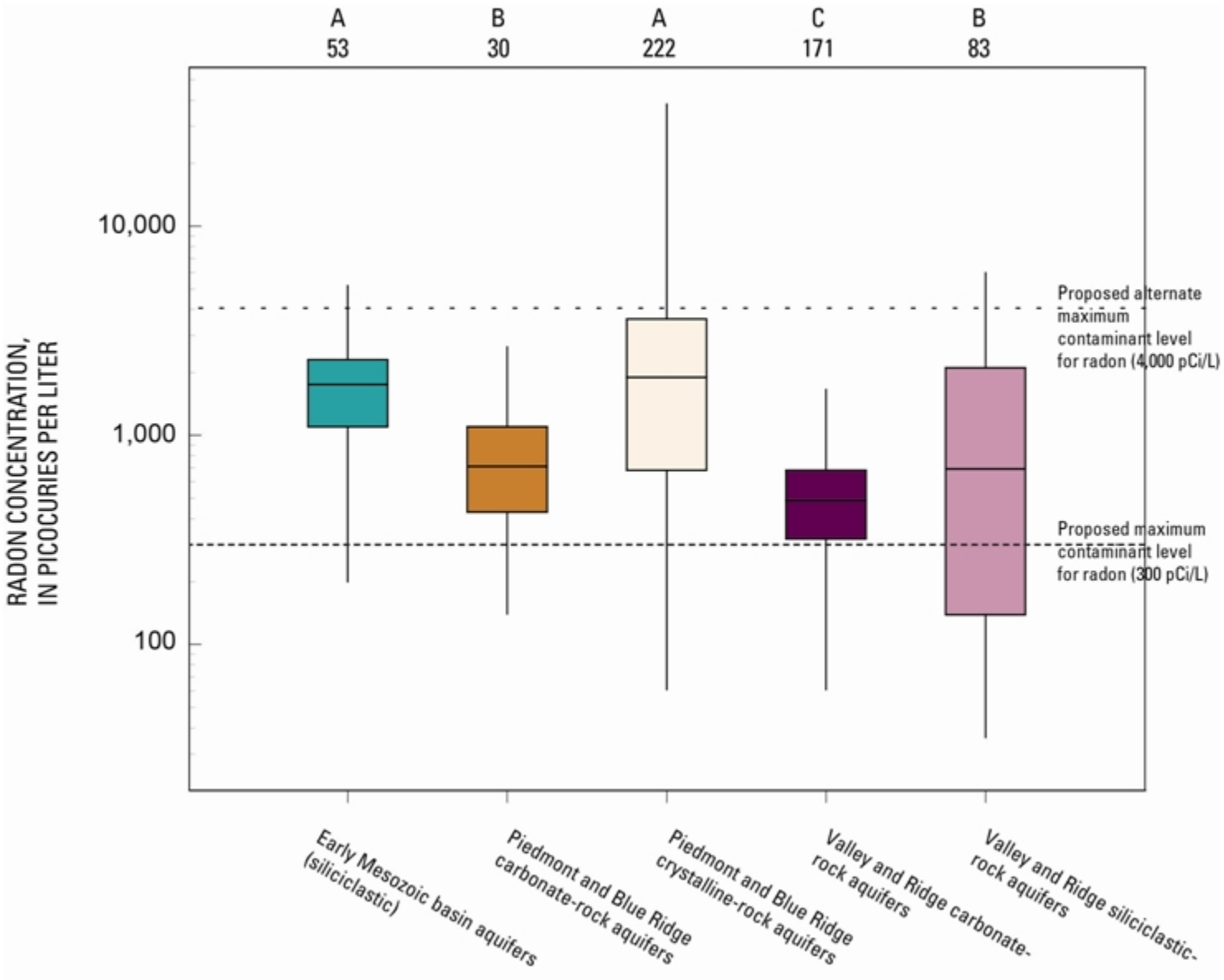
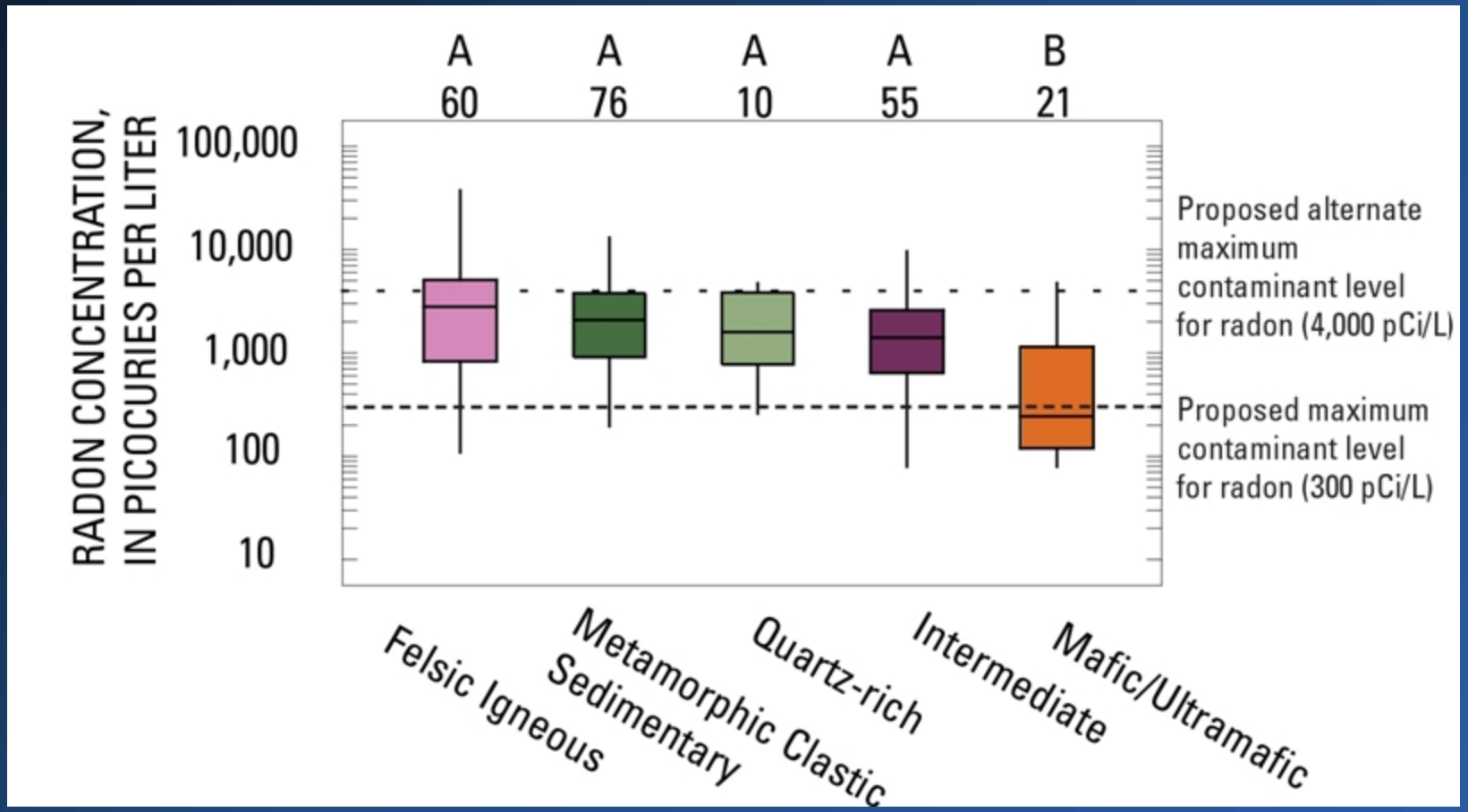
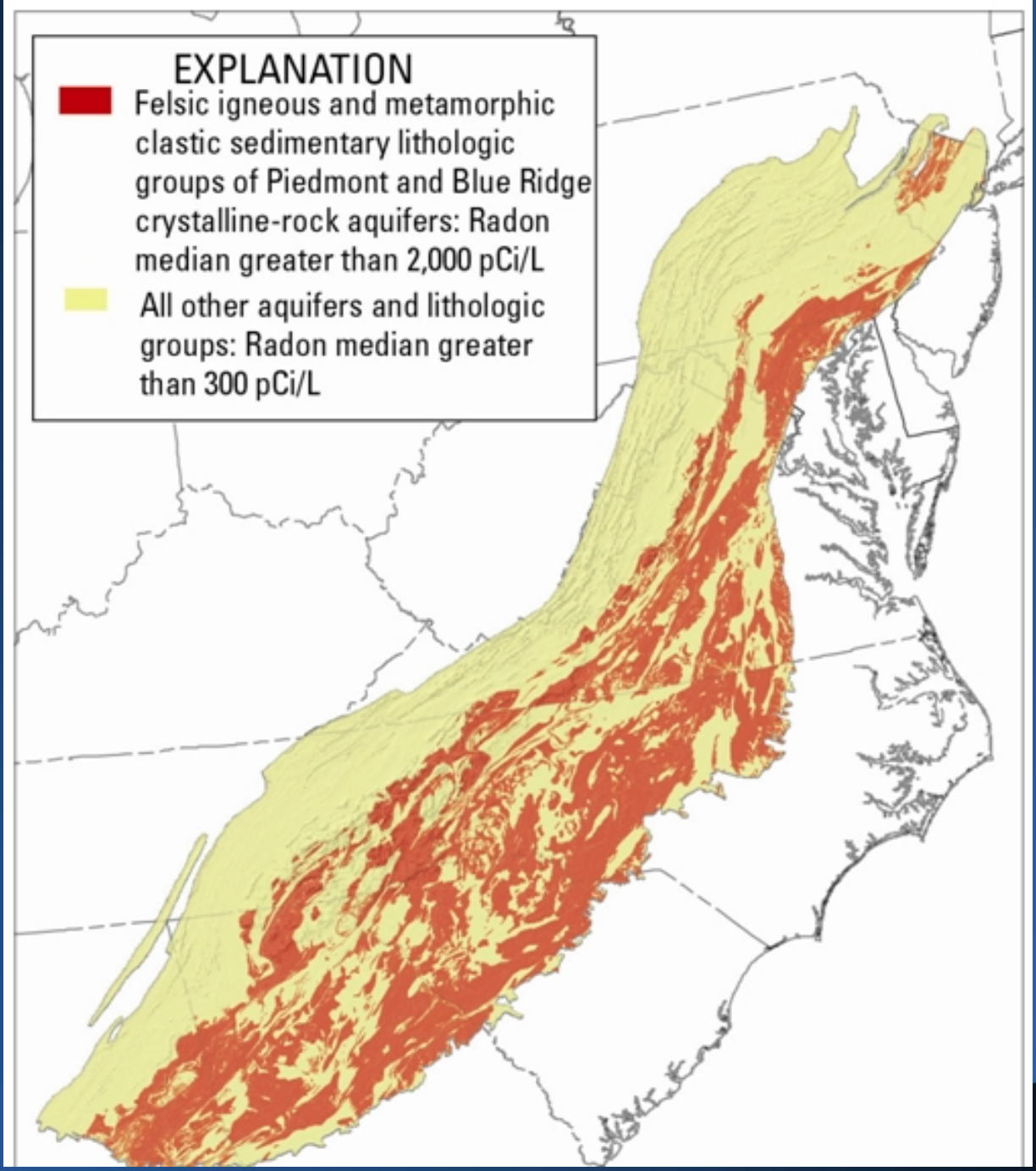
•Crystalline rocks in Piedmont have highest radon



•Felsic igneous rocks in Piedmont have highest radon among Crystalline rocks



•Geologic potential useful for highlighting regions most likely to have highest radon



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North NJ: Occurrence, Implications

- Sites where water was at or near saturation with DO (> 8 mg/L), U was nearly all the gross alpha-particle activity
- Sites where water was not near saturation with DO (< 8 mg/L), U were still abundant, but concentrations of Ra-226 were also detected . Where DO < 1 mg/L, Ra is occasionally present in high concentrations.
- Implications for gross alpha – must know isotopic composition and sample geochemistry!
- U and As were higher more frequently in alkaline water with pH $\geq$ about 7.4 than in less alkaline water – these were more common in metamorphic than granitic rock and in mudstone
- Anion exchange removed U/ Cation exchange removed Ra
- Limited guidance is possible for home owners on the basis of DO and to lesser extent pH and rock type

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REGIONAL CONCLUSIONS

1. Occurrence of Radon > 4000 pCi/L in water from bedrock aquifers in New England, New Jersey,and Appalachians is among the highest in the Nation.
2. The highest concentrations of uranium in New England, New Jersey,and Appalachians aquifers were associated with oxic alkaline water from crystalline bedrock, and the occurrence frequency above the MCL is among the higher frequencies for any region in the United States.
3. Despite high uranium content in bedrock elsewhere in the Eastern USA, Uranium concentration in water correlates with that of radon in water strongly only in New England, only weakly in Piedmont, and in NJ crystalline rock aquifers.
4. Ra occurrence in New England greater than 2 pCi/L is more likely in acidic conditions in glacial aquifers and in reducing conditions in bedrock aquifers.

Most Important!

- Effectiveness of sampling: Inexpensive uranium mass analysis along with gross alpha-particle activity and pH would provide useful information for many, but not all, homeowners with regards to drinking-water radionuclide concerns.
- Piedmont treatment issues: Elevated radium-226 and excess uranium-234 and gross alpha-particle activity may need multiple types of remediation treatment, including combined cation exchange and anion exchange treatment.

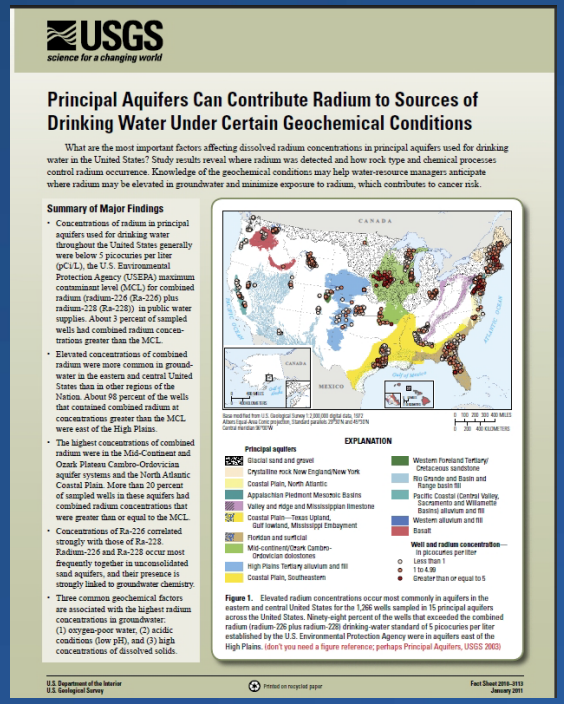
References and Acknowledgments

OCCURRENCE AND GEOCHEMISTRY OF RADIUM IN WATER FROM PRINCIPAL DRINKING-WATER AQUIFER SYSTEMS OF THE UNITED STATES, *APPLIED GEOCHEMISTRY 2012, V. 27, P. 729*

NAWQA Radium Fact Sheet FS 2010-3113

http://water.usgs.gov/nawqa/trace/radium/

----please visit----



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science for a changing world

Principal Aquifers Can Contribute Radium to Sources of Drinking Water Under Certain Geochemical Conditions

What are the most important factors affecting dissolved radium concentrations in principal aquifers used for drinking water in the United States? Study results reveal where radium was detected and how rock type and chemical processes control radium occurrence. Knowledge of the geochemical conditions may help water-resource managers anticipate where radium may be elevated in groundwater and minimize exposure to radium, which contributes to cancer risk.

Summary of Major Findings

- Concentrations of radium in principal aquifers used for drinking water throughout the United States generally were below 5 picocuries per liter (pCi/L), the U.S. Environmental Protection Agency (USEPA) maximum contaminant level (MCL) for combined radium (radium-226 (Ra-226) plus radium-228 (Ra-228)) in public water supplies. About 3 percent of sampled wells had combined radium concentrations greater than the MCL.
- Elevated concentrations of combined radium were more common in groundwater in the eastern and central United States than in other regions of the Nation. About 98 percent of the wells that contained combined radium at concentrations greater than the MCL were east of the High Plains.
- The highest concentrations of combined radium were in the Mid-Continent and Ozark Plateau Cambro-Ordovician aquifer systems and the North Atlantic Coastal Plain. More than 20 percent of sampled wells in these aquifers had combined radium concentrations that were greater than or equal to the MCL.
- Concentrations of Ra-226 correlated strongly with those of Ra-228. Radium-226 and Ra-228 occur most frequently together in unconsolidated sand aquifers, and their presence is strongly linked to groundwater chemistry.
- Three common geochemical factors are associated with the highest radium concentrations in groundwater: (1) oxygen-poor water, (2) acidic conditions (low pH), and (3) high concentrations of dissolved solids.

EXPLANATION

Principal aquifers
- Glacial sand and gravel
- Crystalline rock New England/New York
- Coastal Plain, North Atlantic
- Appalachian Piedmont Mesozoic Basins
- Valley and ridge and Mississippian limestone
- Coastal Plain—Texas Upland, Gulf lowland, Mississippi Embayment
- Floridan and surficial
- Mid-continent/Ozark Cambro-Ordovician dolostones
- High Plains Tertiary alluvium and fill
- Coastal Plain, Southeastern
- Western Foreland Tertiary/Cretaceous sandstone
- Rio Grande and Basin and Range basin fill
- Pacific Coastal (Central Valley, Sacramento and Willamette Basins) alluvium and fill
- Western alluvium and fill
- Basalt

Well and radium concentration—in picocuries per liter
- Less than 1
- 1 to 4.99
- Greater than or equal to 5

Figure 1. Elevated radium concentrations occur most commonly in aquifers in the eastern and central United States for the 1,266 wells sampled in 15 principal aquifers across the United States. Ninety-eight percent of the wells that exceeded the combined radium (radium-226 plus radium-228) drinking-water standard of 5 picocuries per liter established by the U.S. Environmental Protection Agency were in aquifers east of the High Plains. (don't you need a figure reference; perhaps Principal Aquifers, USGS 2003)

U.S. Department of the Interior
U.S. Geological Survey

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State of NJ (Barker Hamill, Judith Louis, Steve Spayd)

OTHER STATE SUPPORT WAS SOLICITED

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