

Nitrate in ground water from private, public-supply, and monitoring wells open to the glacial aquifer system, United States

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Introduction

The glacial aquifer system includes all unconsolidated aquifers above bedrock north of the line of continental glaciation throughout the United States. Total withdrawals from the glacial aquifer system were 3,560 million gallons per day in 2000, which constitutes almost 5 percent of total withdrawals from all aquifers in the United States (Maupin and Barber, 2005).

Over 1,700 water-quality samples have been collected by the National Water-Quality Assessment Program (NAWQA) from 1991 to 2003 to assess the water quality of the glacial aquifer system. This includes 471 private, 99 public-supply, and 1116 monitoring well samples. This large data set is unique in that the samples have been collected using a consistent sampling protocol, and multiple nested samples.

The purpose of this study is to determine distribution and occurrence of nitrate in ground water from private supplies, and assess the relation between nitrate concentration and the factors that most affect the concentrations in the glacial aquifer system. Data collected between 1991 and 2005 from the nested monitoring, private, and public supply wells are used. First, the problem of differences in nitrate concentration by well type needs to be addressed to see if the data should be grouped or if the differences in nitrate concentration by well type (private, public, or monitoring) are related to well construction, differences in depth, or the purpose of the well.

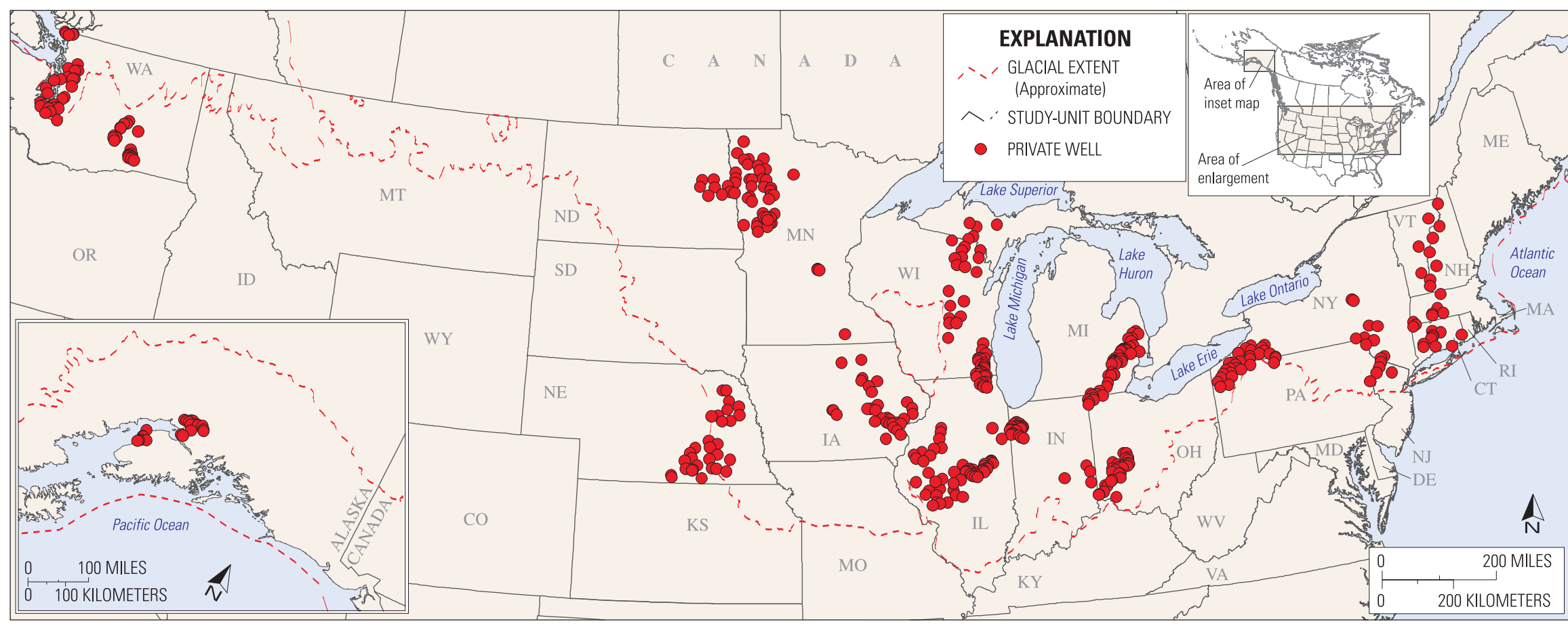
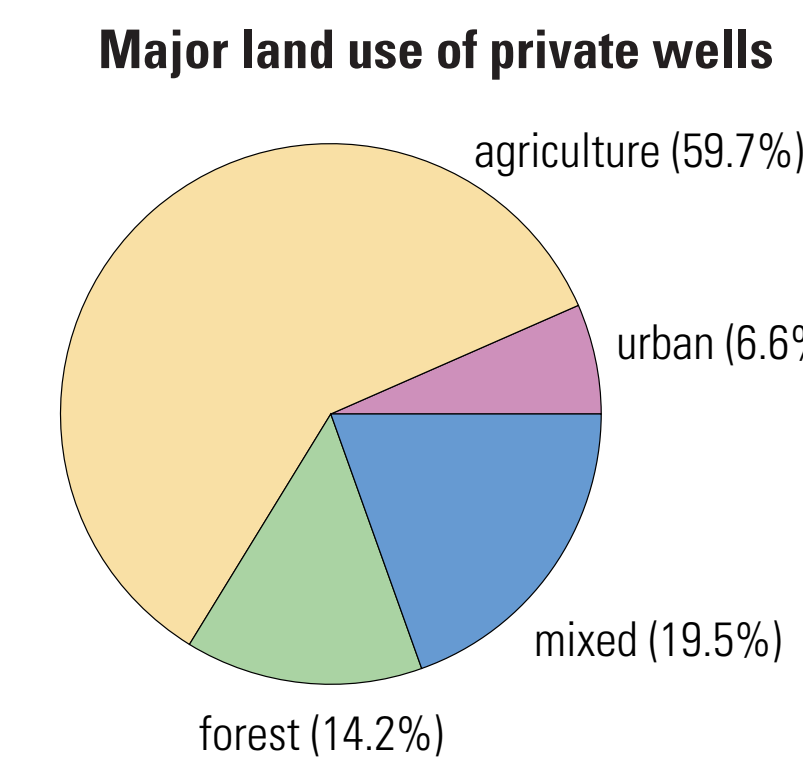
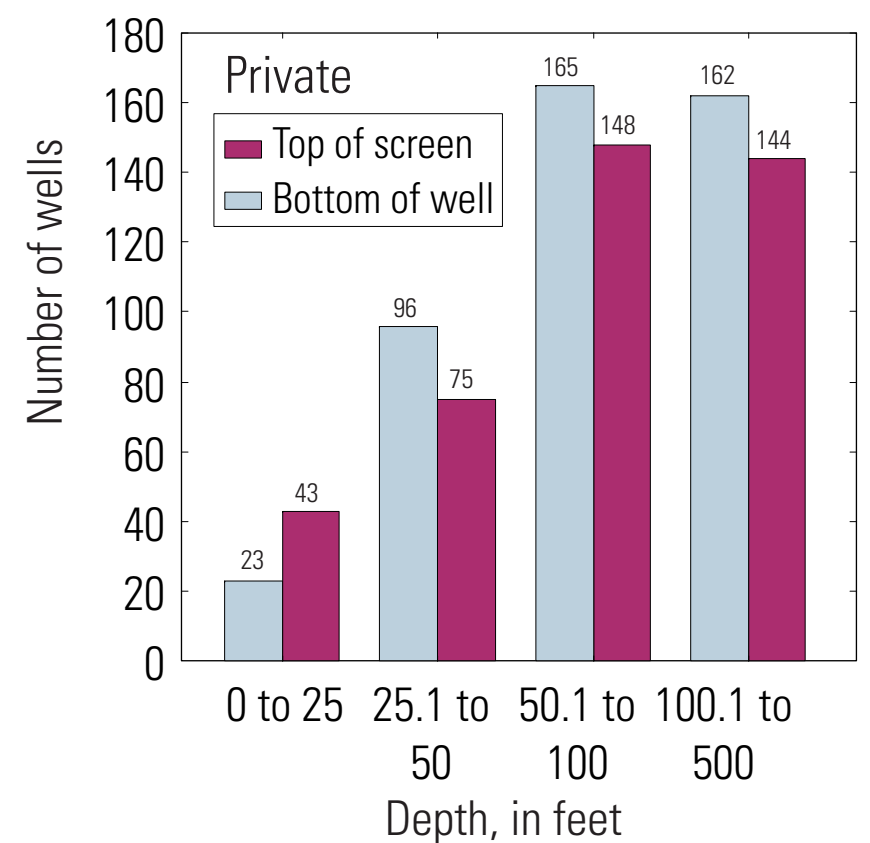
Secondly, a national model of probability of nitrate contamination in shallow aquifers (typically 5 meters deep or less depth to water) was developed by Nolan and others (2002) for the entire United States based on nitrate data from all aquifers. Does this model adequately define the probability of nitrate contamination in private wells in the unconsolidated glacial deposits, which have a median depth to water of 7.6 meters? Are there other variables that should be considered for nitrate contamination in this aquifer system?



For more information, contact:

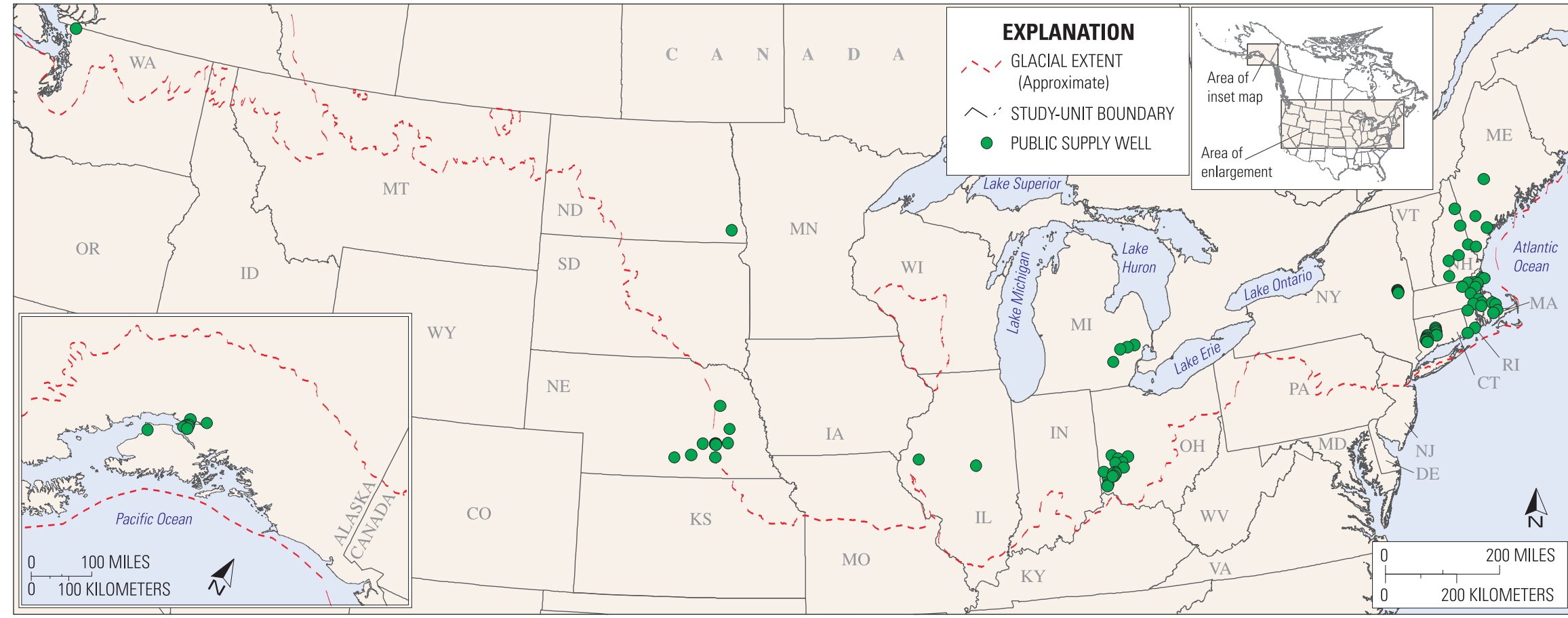
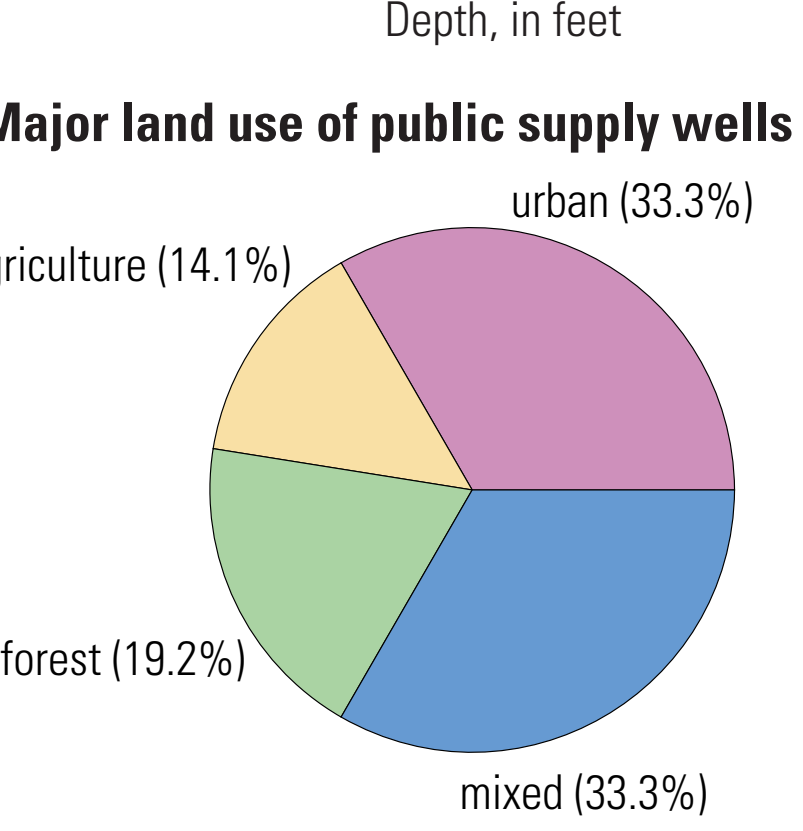
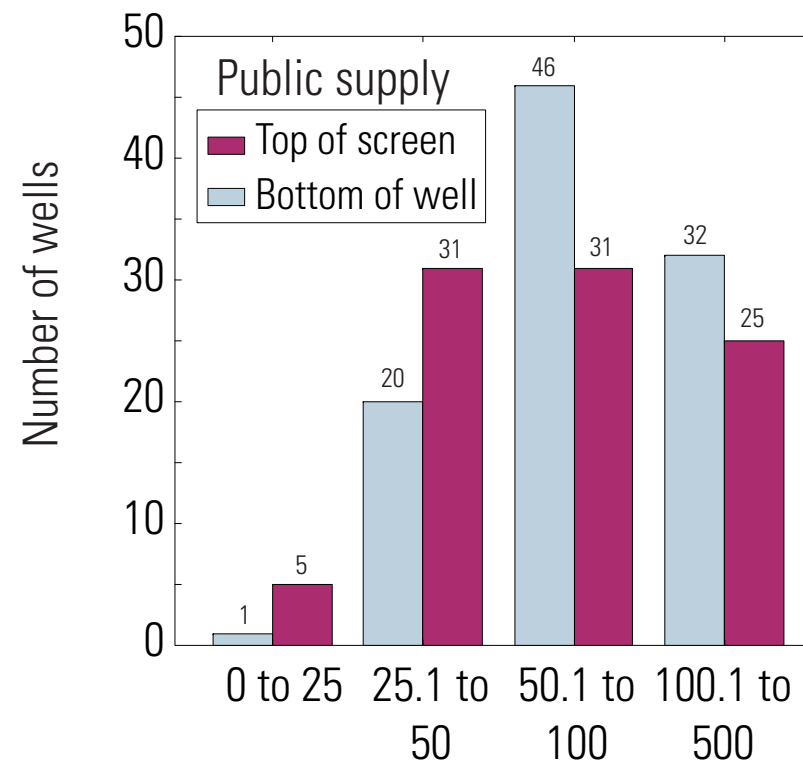
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Private wells



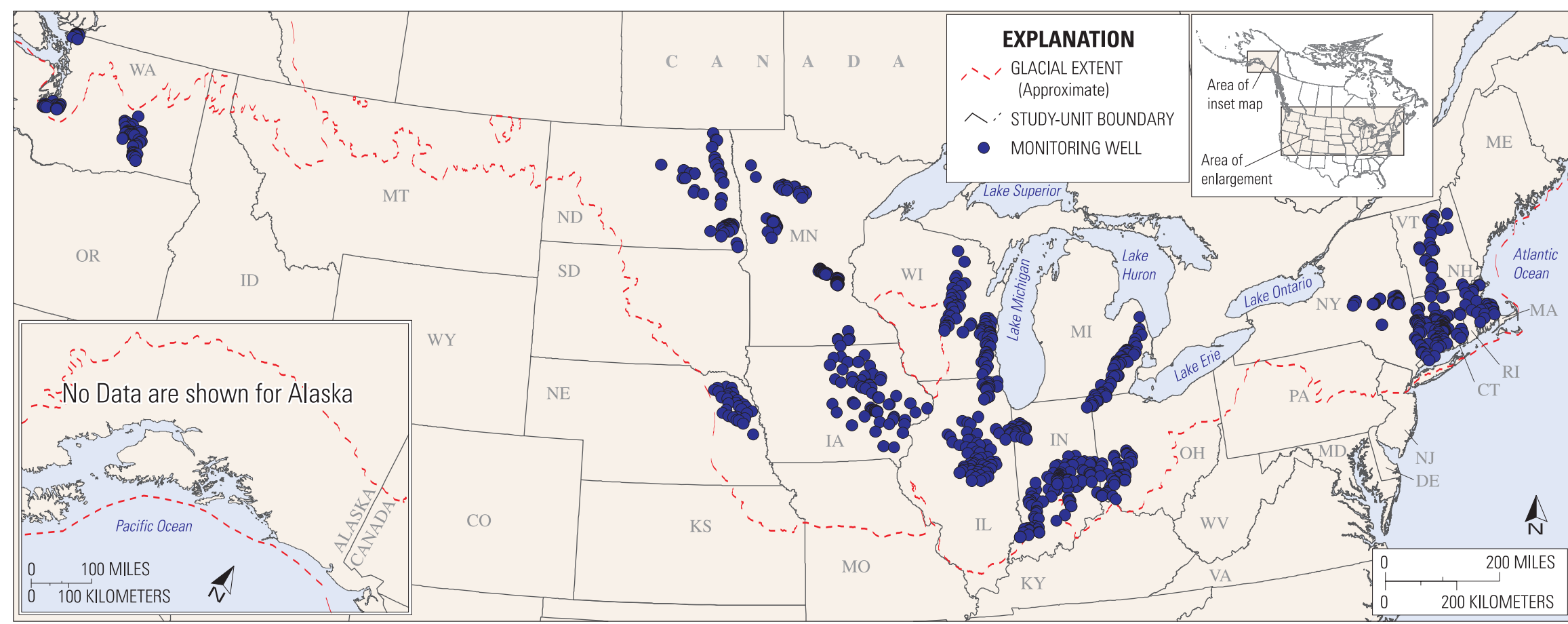
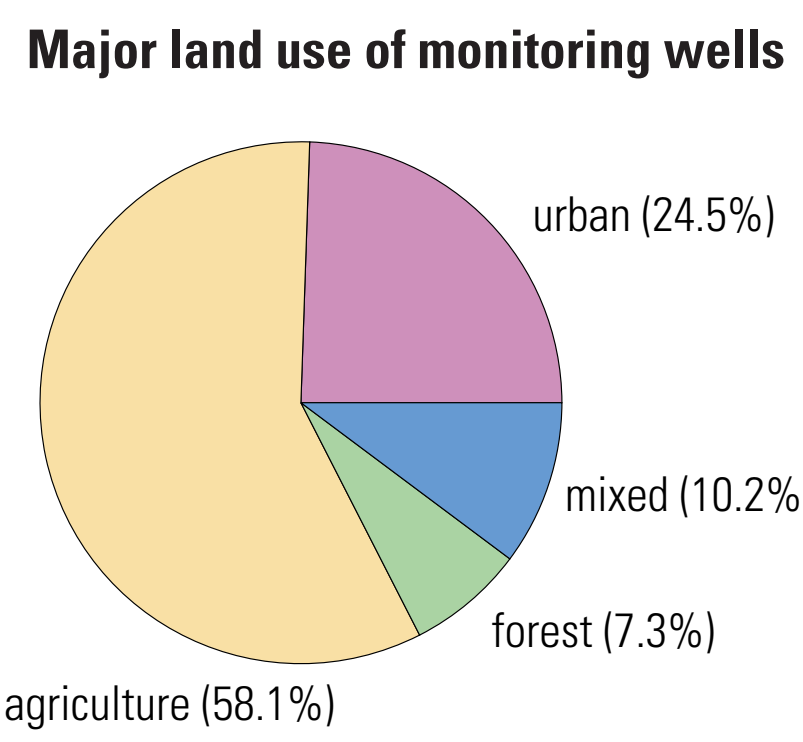
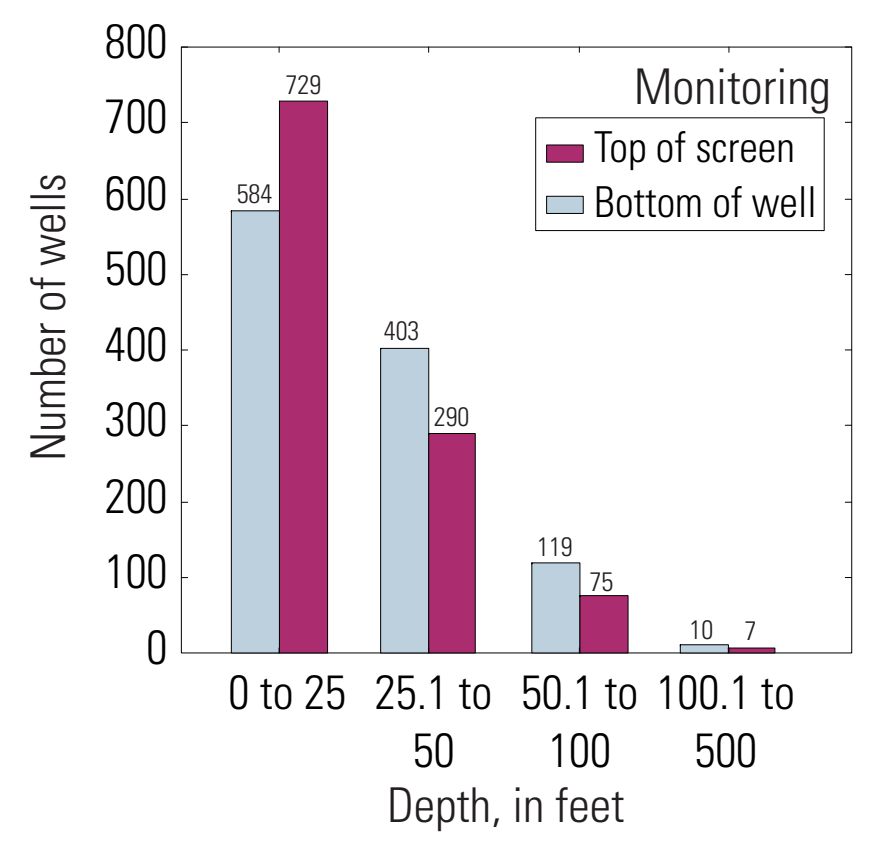
- The purpose of the samples is to assess major drinking water aquifers.
- 471 wells were sampled.
- Median nitrate concentration is 0.13 milligrams per liter (mg/L)
- More than 60% of the wells are screened greater than 50 feet deep.
- Median well depth is 80 feet.
- Almost 60% of the wells are in agricultural land use settings.

Public-supply wells



- The purpose of the samples is to assess major drinking water aquifers.
- 99 wells were sampled.
- Median nitrate concentration is 0.71 milligrams per liter (mg/L).
- Most wells are screened greater than 25 feet deep. The difference between the top of screen and bottom of the well indicates a longer well screen for public supply wells than other well types.
- Median well depth is 76.5 feet.
- Most of the wells are in urban (33%) or mixed land use (33%) settings.

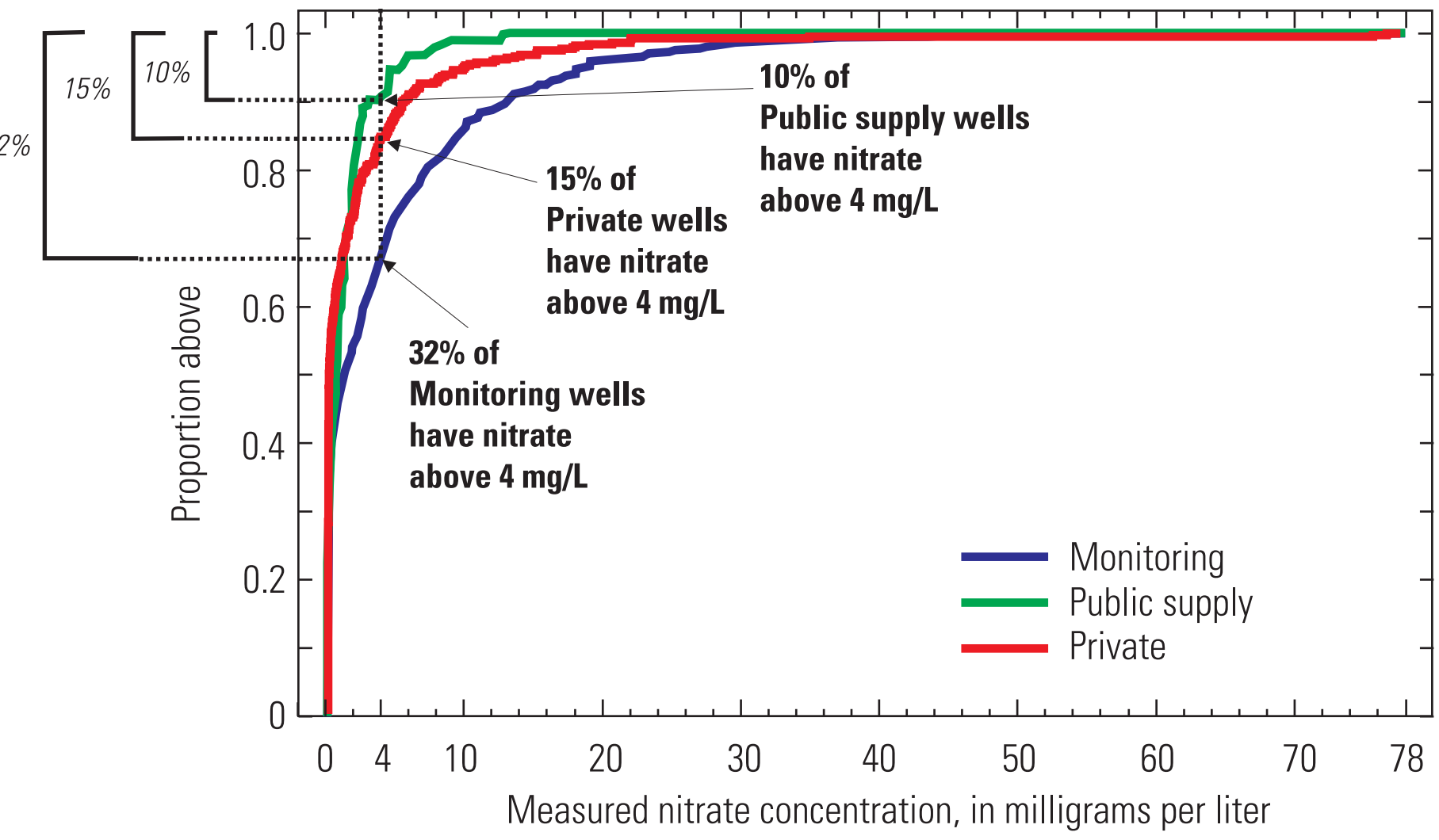
Monitoring wells



- The purpose of the samples is to assess recently recharged ground water, which is why the distribution is skewed to the left.
- 1116 monitoring wells were sampled.
- Median nitrate concentration is 1.2 milligrams per liter (mg/L).
- Most wells are screened less than 25 feet deep.
- Median well depth is 24.5 feet.
- Almost 60% of the wells are in agricultural land use settings.

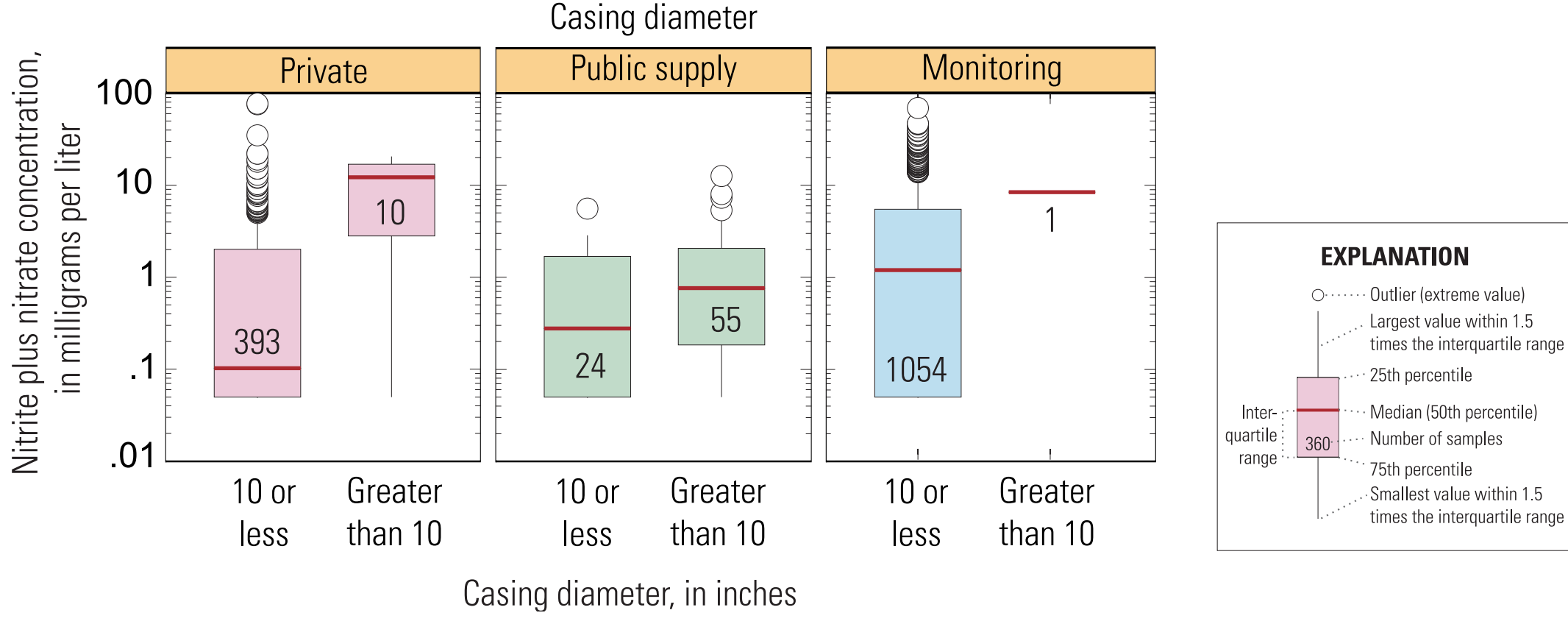
Are there differences in nitrate concentration by well type?

Yes. Overall, there is a difference in nitrate concentrations between private, public supply, and monitoring wells in the glacial aquifer system as can be seen with these survival curves. More monitoring wells have nitrate concentrations above 4 mg/L compared to private and public supply wells. *Why are there differences in nitrate concentration by well type? Are these differences because of the well type or is it because of differences in the construction or location?*

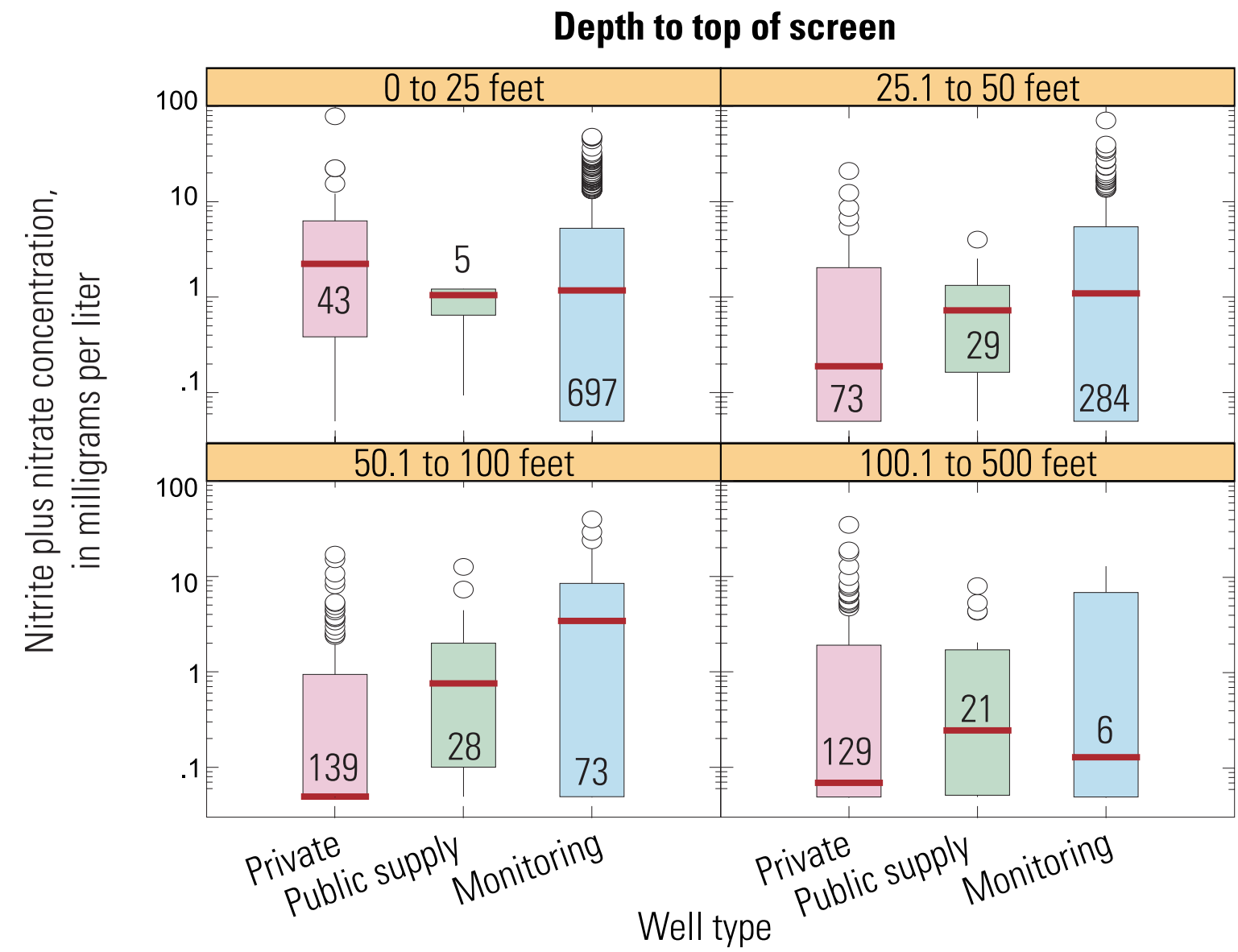


Are there differences in nitrate concentration due to well construction?

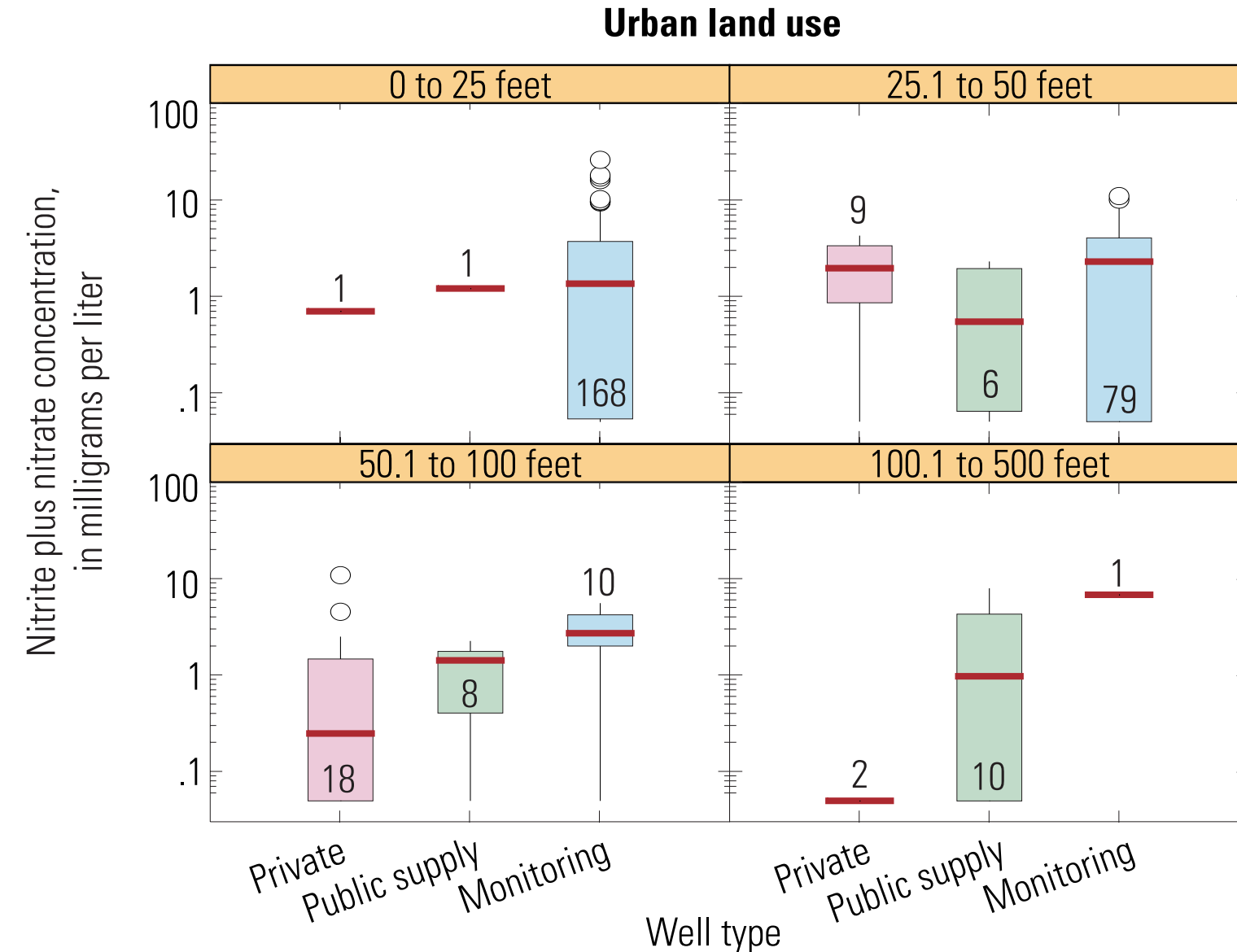
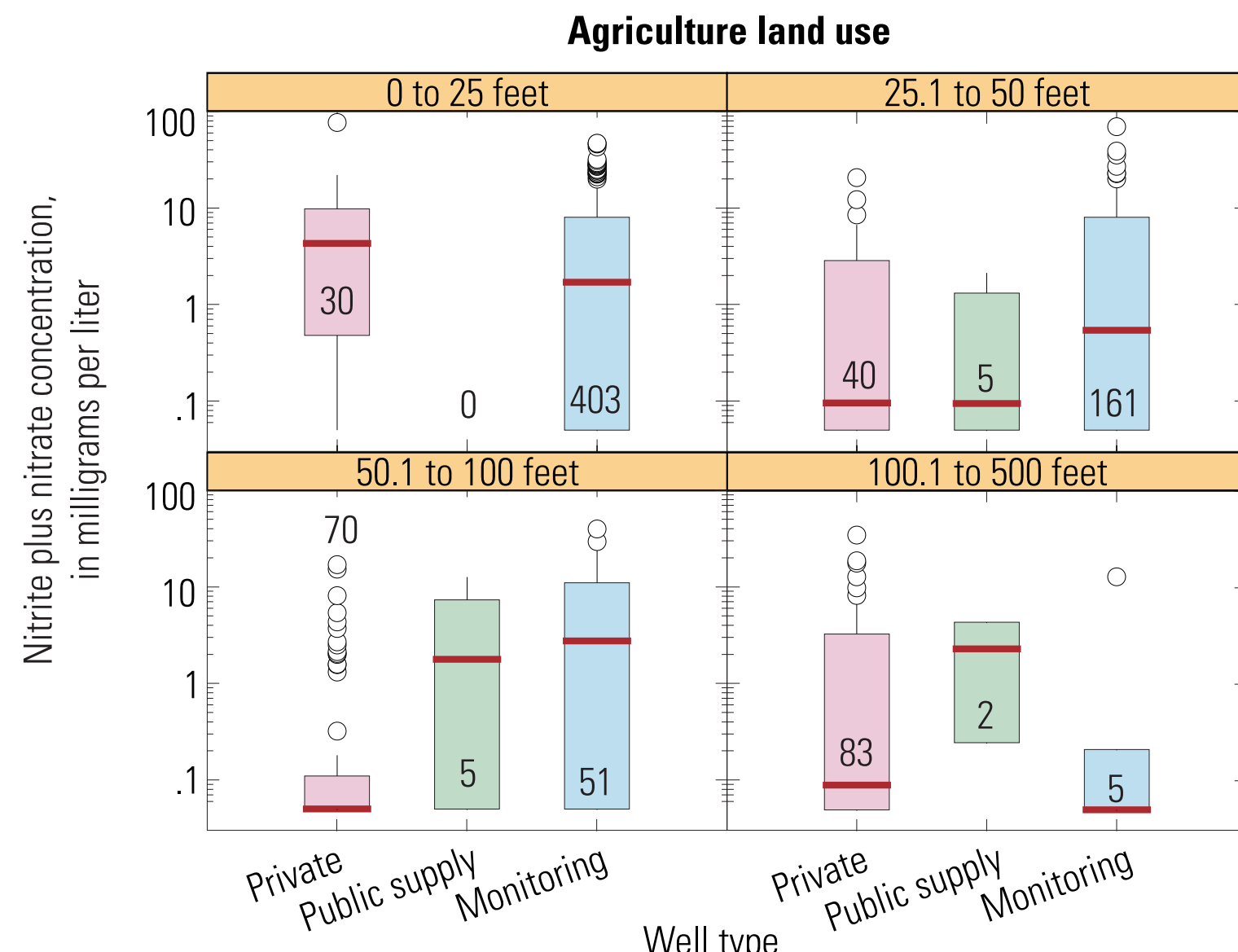
Yes. Private wells show a difference in nitrate concentration by casing diameter, which indicates that well construction can have an influence on nitrate concentrations in private wells. This is a concern because many private well owners have large diameter dug wells. A Kruskal-Wallis rank test shows the difference to be significant for private wells, but not for public supply or monitoring wells.



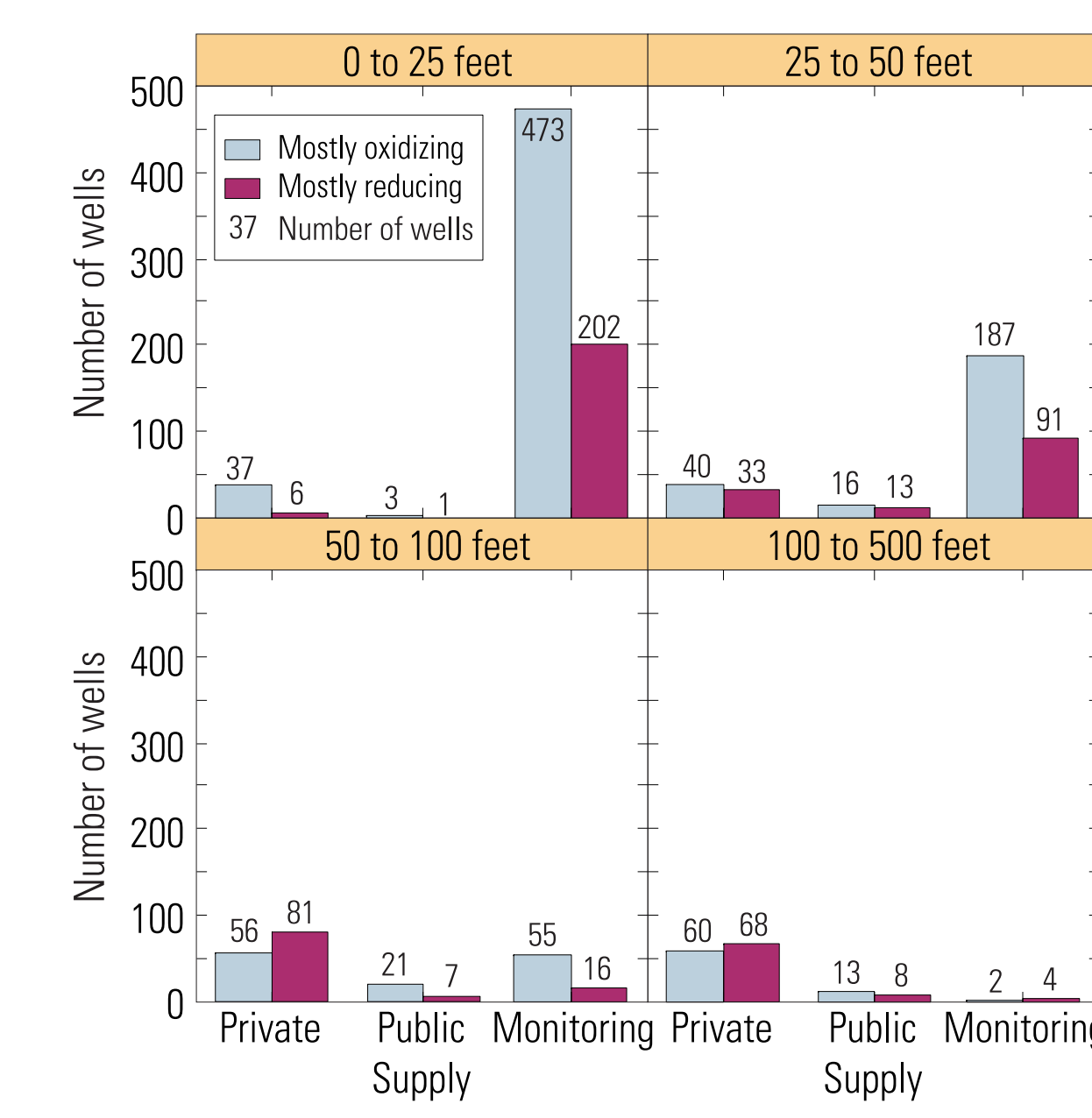
Regardless of well type, median nitrate concentrations are similar from 0 to 25 feet deep. Private wells have the lowest median nitrate concentration in depths from 25 to 100 feet; in this depth range there is a significant difference between private, public supply, and monitoring wells. This may be influenced by a difference in distribution of private (54%), public supply (67%), and monitoring (33%) wells in the 25 to 100 feet depth range. Well construction, as indicated by depth to top of screen, can influence nitrate concentrations by well type from 25 to 100 feet.



Are there differences in nitrate concentration by location?



Why is nitrate concentration different in well types in the 50-100 feet depth range?

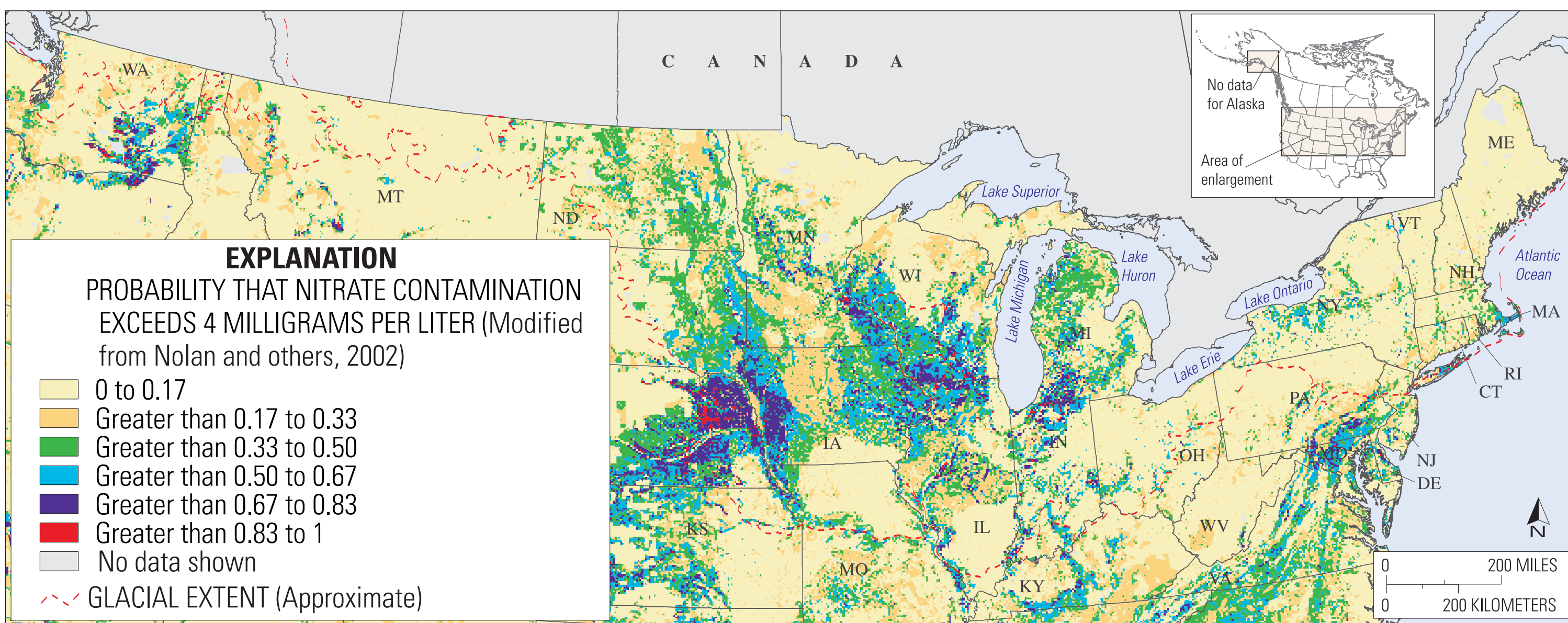


ratio of reducing to oxidizing may account for the difference in nitrate concentrations between 50-100 feet for the well types.

Why are there more reducing than oxidizing wells for domestic supplies between 50-100 feet compared to public supply and monitoring wells?

The determination of location for domestic supply wells is less flexible than for public supply and monitoring wells. Private well owners need to install their wells in the immediate area where they need water, which can be lower-yielding clay-rich aquifer material. Whereas, public supplies are located in areas known to have high yielding aquifer material and monitoring wells are located in areas with good accessibility to recently recharged ground water.

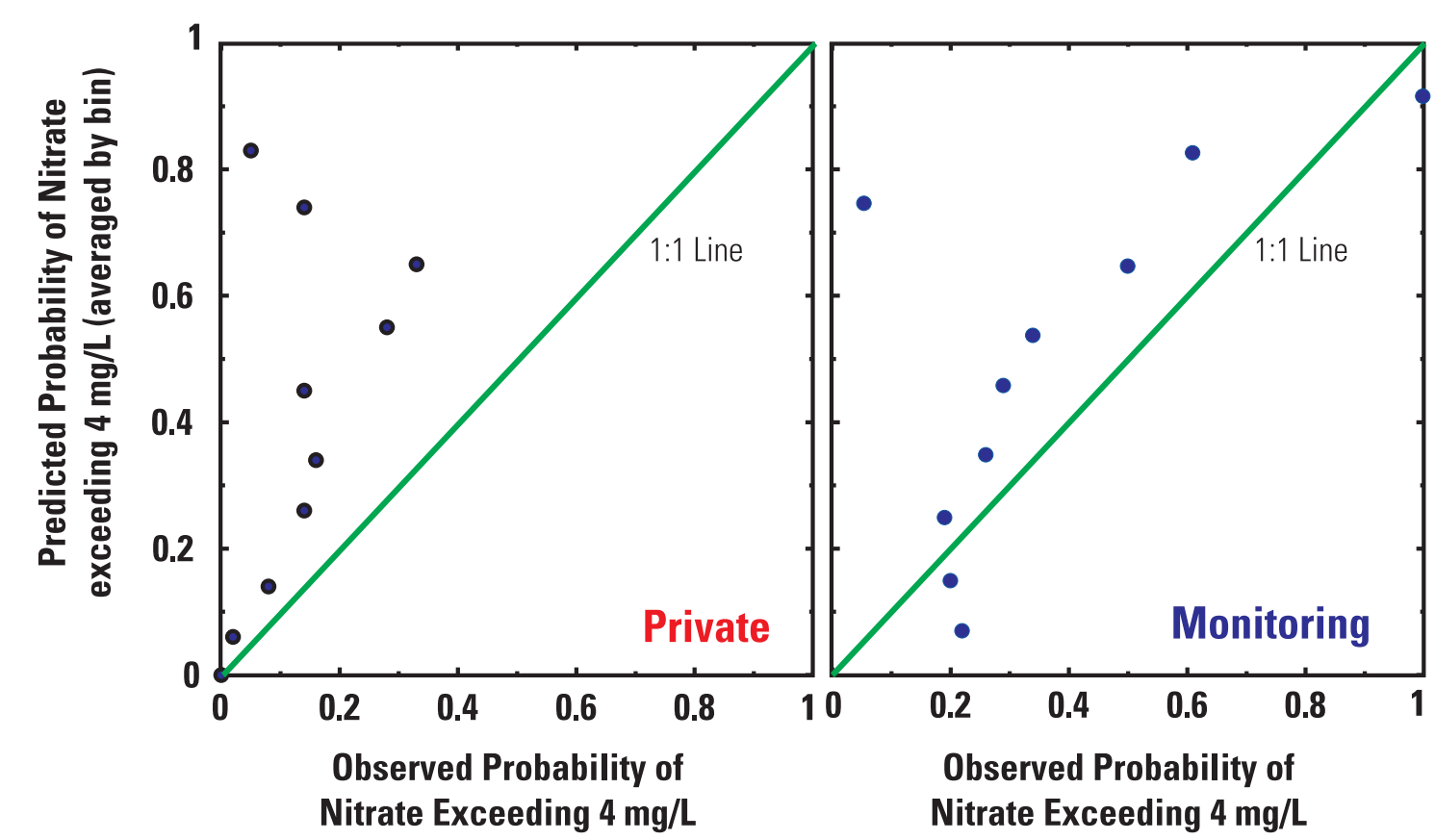
Nitrate in private wells -- from monitoring to prediction



A map showing the probability of nitrate contamination of shallow ground water was developed by Nolan and others (2002). Key factors in this logistic regression model include: agricultural land use, population density, soil drainage characteristics, depth to water table, and presence of sand and gravel aquifers. The national model looks at monitoring wells in many different aquifer systems.

This model was used to test the probability of nitrate concentrations exceeding 4 mg/L in the glacial aquifer system. The graph shows how closely the Nolan and others (2002) model matches the observed nitrate concentrations in the glacial aquifer system for private (median depth 80 feet) and monitoring wells (median depth 25 feet). In general, the Nolan model predicts a higher probability for nitrate concentrations greater than 4 mg/L than were observed in private wells in the glacial aquifer. The model fits observed nitrate concentrations from monitoring wells in the glacial aquifer system better than it does nitrate concentrations from private wells. The Nolan model needs to be refined to account for the different nitrate concentrations in deeper private wells from the glacial aquifer system.

The difference between construction and location characteristics of private and monitoring wells imply there are other variables that will help predict probabilities of nitrate concentrations greater than 4 mg/L in private wells. Statistical analysis of over 30 additional variables indicate that redox, geologic material, and well construction attributes need to be included in refining the model for private wells in the glacial aquifer system.



Comparison of Nolan and others (2002) logistic regression model based on monitoring well data from all aquifers to domestic wells in the glacial aquifer system.			
	Number of wells with predicted probability less than or equal to 50% that nitrate is greater than 4 mg/L	Number of wells with predicted probability greater than 50% that nitrate is greater than 4 mg/L	TOTAL
Number of wells with measured nitrate less than or equal to 4 mg/L	266 (354 would be ideal)	88	354
Number of wells with measured nitrate greater than 4 mg/L	33	34 (67 would be ideal)	67
TOTAL	299	122	421

Summary

- Monitoring wells have more detections of nitrate concentrations above 4 mg/L compared to private and public supply wells in the glacial aquifer system.
- Private wells show a difference in nitrate concentration by casing diameter, which indicates that well construction can influence nitrate concentrations in private wells.
- Median nitrate concentrations differ among private, public supply, and monitoring wells when equalized by depth. The most notable difference is for the 50-100 feet depth interval.
- Well construction, as indicated by depth to top of screen, does not affect nitrate concentration among well types for depths less than 25 feet. Depth is a factor for wells with screens from 25 to 100 feet.
- The controlling factors on nitrate in deeper wells may be related to oxidation-reduction (redox) potential and biochemical processes. In the depth range (50-100 feet) with the most notable difference in nitrate concentrations, a comparison of redox potential by well type reveals that more private wells are reducing; whereas, more public and monitoring wells are oxidizing. This may be the result of the decreased flexibility in locating private wells.
- A logistic regression model predicting the probability of nitrate concentration greater than a background level is being developed for private wells in the glacial aquifer system. In addition to the factors utilized in the Nolan and others (2002) model, this new model will include information relating to redox potential.

References

Nolan, B.T., Hitt, K.J., and Ruddy, B.C., 2002, Probability of nitrate contamination of recently recharged ground waters in the conterminous United States: Environmental Science and Technology, v. 36, no. 10, p. 2138-2145.

Maupin, M.A. and Barber, N.L., 2005, Estimated withdrawals from principal aquifers in the United States-2000: U.S. Geological Survey Circular 1279, 46 p.