Groundwater Quality in Arizona:
A 15-Year Overview of the ADEQ Ambient Monitoring Program (1995-2009)

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Maps by Jason Jones

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Thanks:

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Report Cover: Pumps powered by solar energy, electricity and wind are used to produce water from wells throughout Arizona.

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Abstract - In pursuing its mandated mission to characterize groundwater quality in the state, the Arizona Department of Environmental Quality (ADEQ) has collected samples from 1,477 sites over a 15-year period between 1995 and 2009. The sample sites consisted mainly of domestic, stock, irrigation and municipal wells and, to a lesser extent, springs used predominantly for watering stock and wildlife. Sampling activity was conducted within 35 of the state's 51 officially designated groundwater basins and covered much of Arizona with the exception of Native American tribal lands.

All groundwater samples were analyzed for most inorganic constituents listed in the U.S. Environmental Protection Agency Safe Drinking Water (SDW) Act. Approximately a third of the wells also had samples collected for SDW radionuclide constituents and lesser numbers of samples were collected for Volatile Organic Compounds and pesticide analyses.

Of the 1,477 sites sampled, 31 percent exceeded at least one health-based water quality standard, which provides a rough estimate of the percentage of wells state-wide not meeting SDW standards. Over 97 percent of exceedances were caused by elevated concentrations of four constituents: arsenic (41 percent), fluoride (22 percent), nitrate (18 percent) and gross alpha (16 percent). The data provide comprehensive and reliable information on the occurrence and concentrations of groundwater contaminants. This is critical knowledge for the estimated 100,000 private domestic wells in the state whose owners represent about 5 percent of Arizona's population.

Unlike public water systems, private domestic wells are not subject to SDW regulations. Thus, collecting and analyzing water samples from private wells is not required and only occasionally conducted. One factor in well owner's reluctance to have their domestic water tested is expense; a comprehensive inorganic suite costs over $650. Testing for only the four constituents that constitute 97 percent of the water quality exceedances in this study is an economical ($85) alternative for private well owners in Arizona. Although ADEQ recommends sampling for all the SDW constituents, testing for arsenic, fluoride, nitrate and gross alpha would be an important initial step in evaluating the suitability of water for domestic use.

Introduction

In pursuing its mandated mission to characterize groundwater quality in the state (ADEQ, 2009) the Arizona Department of Environmental Quality (ADEQ) sampled 1,477 wells (including dozens of springs) throughout Arizona with the exception of Native American tribal lands. Sampling occurred over a 15-year period between 1995 and 2009. Groundwater samples were tested for most inorganic constituents listed in the U.S. Environmental Protection Agency (USEPA) Safe Drinking Water (SDW) Act *(see Table 2)*. Approximately a third of the wells also were tested for SDW radionuclide constituents and lesser numbers were tested for Volatile Organic Compounds (VOCs) and pesticide analyses.

The percentage of sampled wells that are safe to be used for domestic purposes was determined from the analytical results and provides an estimate of the overall percentage of wells in Arizona that meet SDW standards. Based on specific constituent exceedance patterns, economical suggestions for water quality testing are provided for private well owners who choose not to sample for the full suite of SDW constituents as recommended by ADEQ.

Figure 1 - A 1,350-foot deep well produces water to irrigate crops near Casa Grande.

Background

Groundwater constitutes about 3.1 million acre-feet or 43 percent of Arizona's annual water use (ADWR, 2010). The vast majority of groundwater in Arizona is used to irrigate crops *(Figure 1)* and for public water supplies (82%).

To a lesser extent, groundwater is also used for mining, industrial, domestic, stock, and other purposes throughout the state. Groundwater discharge creates the base flow for many streams, lakes, and wetlands thereby directly impacting surface water quality *(Figure 2)*.

Groundwater quality is of major importance, especially when utilized for municipal and domestic water supply purposes. All aquifers in the state are protected for drinking water designated use by Arizona's 1986 Environmental Quality Act and Aquifer Boundary and Protected Use Classification

Figure 2 - Brown Spring contributes flow to Little Ash Creek and its riparian area located in the Agua Fria basin.

(R18-11, Article 5). Arizona's Aquifer Water Quality Standards (R18-11, Article 4) are protective of the drinking water use and are equivalent to the SDWA standards except for arsenic.

Despite this safeguard, groundwater contamination can be a serious problem. Potential point sources in Arizona include industrial waste, underground storage tanks, landfills, mines, and wastewater treatment plants. These activities are specifically regulated and monitored through programs operated by ADEQ. However, there are other major groundwater pollution sources that are not comprehensively addressed by ADEQ programs. These nonpoint sources include agricultural activities and septic wastewater disposal systems. The largest influence on groundwater quality is natural sources which, obviously, are unregulated. The extent and impact of both nonpoint and natural sources on groundwater quality throughout Arizona is not well known in many areas of the state.

To fill this data gap, ADEQ pursues its mandated mission to characterize groundwater in the state. The agency also investigates the influences of agricultural practices, septic systems, and natural sources on water quality. The majority of the sampled wells (98 percent) were collected as part of baseline investigations of groundwater quality in 30 of the state's 51 groundwater basins officially designated by the Arizona Department of Water Resources *(Table 1) (Map 1)*.

These studies were designed to examine broad, regional groundwater quality conditions existing within the basins. Limited sampling consisting of 31 samples was conducted in five additional basins because of special sampling requests or basin studies were not completed.

Below is the link for the studies.
http://www.azdeq.gov/environ/water/assessment/ambient.html

Figure 3 - A 520-foot domestic well located by Date Creek in the Bill Williams basin is being purged in preparation for sampling.

Objective

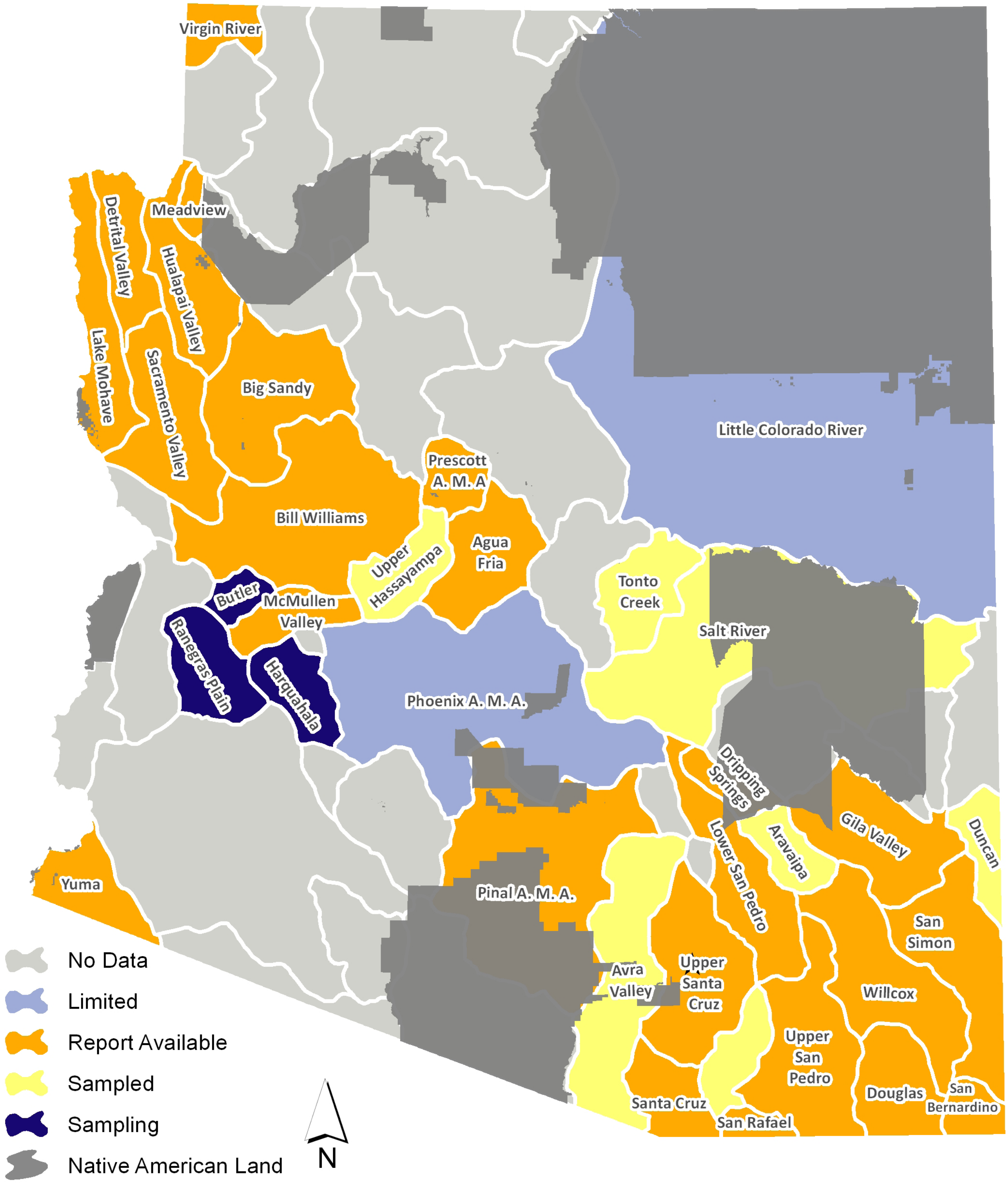
This study will examine sample results collected over a 15-year period beginning in 1995 by ADEQ. The purpose of this comprehensive analysis is twofold:

- To highlight groundwater quality concerns on a state-wide scale.
- To provide recommendations for private well owners interested in a limited, cost-effective strategy for determining if groundwater they use meets health-based, water quality standards.

The quality of water delivered through public supplies is strictly regulated; this resource is routinely monitored to verify it meets state and federal standards set to protect public health. However, there are more than 100,000 private domestic wells *(Figure 3)* whose owners represent about 5 percent of Arizona's population that are not subject to Safe Drinking Water regulations required of public water systems, and thus, are not required to conduct water quality tests (ADWR, 2010).

Table 1. Summary of ADEQ Ambient Groundwater Monitoring Program Activities

Basin	Year Sampled	Year Report Published	Comments
Yuma	1995	1997	
Douglas	1995-96	1999	
Duncan Valley	1995-2002	-	Part of Upper Gila Watershed Report
Upper San Pedro	1996-97	1999	Joint Study w/ U.S. Geological Survey
Virgin River	1997	1999	
Prescott AMA	1997-98	2001	
Upper Santa Cruz	1998	2000	Joint Study w/ U.S. Geological Survey
Sacramento Valley	1999	2001	
Willcox	1999	2001	
Lower San Pedro	2000	2002	
Hualapai Valley	2000	2005	
Meadview	2000-03	2005	
Avra Valley	2001	-	
San Rafael	2002	2003	
Detrital Valley	2002	2003	
San Simon	2002	2004	
Cienega Creek	2002	-	
Salt River	2002	-	
Tonto Creek	2002	-	
San Bernardino	2002	2011	
Lake Mohave	2003	2005	
Aravaipa Canyon	2003	-	
Big Sandy	2003-04	2006	
Bill Williams	2003-09	2011	
Upper Hassayampa	2003-09	-	
Little Colorado River	2003-	-	Special ADEQ sampling
Gila Valley	2004	2010	
Dripping Springs	2004-05	2011	
Agua Fria	2004-06	2008	
Phoenix AMA	2004-	-	Special ADEQ sampling
Pinal AMA	2005-06	2008	
McMullen Valley	2008-09	2011	
Butler Valley	2008-	-	Basin sampling not yet completed
Harquahala	2008-	-	Basin sampling not yet completed
Ranegras Plain	2009-	-	Basin sampling not yet completed



Map 1. ADEQ Ambient Groundwater Monitoring Program Activity by Basin, 1995-2009

Private well owners often have not had analytical tests conducted on the quality of water produced by their wells and may be unaware of the presence of contaminants that could adversely affect their health. The large numbers of untested private domestic wells make comprehensive and reliable information on the occurrence and levels of contaminants in groundwater essential to protect public health in Arizona.

Previous assessments of groundwater quality in Arizona have indicated distressing results. Marrero-Ortiz and others (2009) reported 95 percent of wells sampled for microbial, physical, and chemical constituents exceeded at least one U.S. Environmental Protection Agency (EPA) Primary and/or Secondary drinking water standard or guideline based on 49 wells sampled in seven counties in Arizona.

In a national survey of about 2,100 domestic wells, 23 percent of sampled wells contained one or more contaminants at a concentration greater than a human-health benchmark. These contaminants were most often inorganic chemicals with all but nitrate derived primarily from natural sources. Almost half (48 percent) of the sampled wells contained at least one constituent at a concentration outside the range of aesthetic values recommended by U.S. EPA Secondary drinking water guidelines (DeSimone and others, 2009).

Investigation Methods

Several factors were considered in selecting wells and springs for sampling. Important considerations included physical characteristics, land uses, hydrologic complexity (such as the presence of multiple sub-basins, aquifers and/or perennial streams) and the number and distribution of wells and springs.

Three strategies were used to characterize basin groundwater quality:

- stratified random sampling using computer generated, equal area polygons
- stratified random sampling using township blocks and/or physiographic areas
- random sampling.

Targeted sampling was often subsequently used near sites having constituent concentrations with health-based water quality standards in order to determine the spatial extent of impacted groundwater quality.

Sampling Protocol

Production wells used for domestic, stock, irrigation, and public water supply were commonly sampled for the studies. Monitoring wells originally installed to delineate the extent of fuel leaks from underground storage tanks were occasionally sampled to assist in characterizing shallow aquifers. Springs for stock and/or domestic use were sometimes sampled especially in remote areas lacking wells.

Sampling protocol followed the ADEQ Quality Assurance Project Plan (ADEQ, 1991) with only minor deviations. In all instances, the collected sample consisted of freshly pumped groundwater as determined by well casing capacity and field parameters such as temperature, pH, and specific conductivity. In some instances, less than three bore volumes were evacuated before sampling because of factors inherent in field work. These issues range from concerns of the well owner to uncertainty of how long some wells, such as windmills, would continue to pump water. However, in all cases field parameters indicated water freshly pumped from the aquifer was sampled.

At each site, an inorganic sample was collected for physical parameters, general mineral characteristics, major ions, nutrients and trace elements for analysis by the Arizona Department of Health Services (ADHS) laboratory in Phoenix, Arizona. The inorganic suite incorporated the vast majority of constituents regulated by the U.S. Environmental Protection Agency (USEPA) Safe Drinking Water (SDW) Act including those having health-based, water quality standards called Primary Maximum Contaminant Levels (MCLs) and those having aesthetics-based, water quality guidelines called Secondary MCLs. These water quality standards are provided in Table 2 (USEPA, 2010).

Table 2. US EPA Safe Drinking Water Act Primary* and Secondary Maximum Contaminant Level Water Quality Standards

Primary Constituent	Primary MCL
Nutrients	
Nitrite (NO_2-N)	1.0
Nitrate (NO_3-N)	10.0
Trace Elements	
Antimony (Sb)	0.006
Arsenic (As)*	0.01 / 0.05
Barium (Ba)	2.0
Beryllium (Be)	0.004
Cadmium (Cd)	0.005
Chromium (Cr)	0.1
Copper (Cu)	1.3
Fluoride (F)	4.0
Lead (Pb)	0.015
Mercury (Hg)	0.002
Nickel (Ni)	0.1
Selenium (Se)	0.05
Thallium (Tl)	0.002
Radiochemistry Constituents	
Gross Alpha	15
Ra-226+Ra-228	5
Radon **	300
Radon **	4,000
Uranium	30
Secondary Constituent	**Secondary MCL**
Physical Parameters	
pH - field	<6.5 ; >8.5
General Mineral Characteristics	
TDS	500
Major Ions	
Chloride (Cl)	250
Sulfate (SO_4)	250
Trace Elements	
Fluoride (F)	2.0
Iron (Fe)	0.3
Manganese (Mn)	0.05
Silver (Ag)	0.1
Zinc (Zn)	5.0

All units are mg/L except gross alpha, radium-226+228 and radon (pCi/L), uranium (ug/L) and pH (su).
Health-based drinking water quality standards are based on a lifetime consumption of two liters of water per day over a 70-year life span.
* All established Primary MCLs are also Arizona Aquifer Water Quality Standards with the exception of arsenic at 0.05 mg/L.
** Proposed EPA Safe Drinking Water Act standards for radon in drinking water.

Federal Primary MCLs are synonymous with state Aquifer Water Standards: Drinking Water Protected Use (AWQ) with three exceptions. There is no copper or turbidity standard and arsenic has 0.05 mg/L state standard compared with the 0.01 mg/L Primary MCL.

Other types of samples were sometimes collected at these sites depending on budgetary considerations and whether there was a probable chance of detecting elevated concentrations of naturally occurring radionuclide constituents and/or detecting anthropomorphic compounds. See Table 3 for a summary of analyses by parameter for the basins sampled.

Radionuclide samples were collected and analyzed according to USEPA SDW protocols by the Arizona Regulatory Radiation Agency (ARRA) laboratory in Phoenix, Arizona at 553 sites (38 percent) mostly considered to have high potential for elevated radiation activity because of nearby geology and/or mining land use.

Volatile Organic Compounds (VOCs) samples were collected at 287 sites (19 percent) mostly in urban areas. Samples for currently registered pesticides were collected at 72 sites (5 percent) and for banned pesticides at 43 sites (3 percent) in areas of irrigated farmland. Both VOC and pesticide analysis was conducted by the ADHS laboratory in Phoenix, Arizona.

The effects of sampling equipment and procedures were evaluated using quality control samples including equipment blanks, duplicate samples, split samples and, occasionally, spiked samples. Data were also validated using seven measurements including cation/anion balances.

In two studies conducted in conjunction with the U.S. Geological Survey, the field protocols and laboratories of each agency were evaluated using split samples (Coes and others, 2000). Based on these indices, the impacts of sampling procedures and lab analysis were found not to be significant except in very specific circumstances.

Sampling Results

Primary MCLs / AWQ Standards - Water quality data from 1,477 wells and springs were compared to inorganic USEPA SDW requirements and/or AWQ standards. SDW Primary MCLs are water quality standards that public water systems must meet when providing water to their customers. There are 16 inorganic constituents that have Primary MCLs including antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride, lead, mercury, nitrate, nitrite, selenium, thallium, and turbidity (USEPA, 2010).

The ADEQ Ambient Groundwater Monitoring program routinely tests for turbidity but elevated levels were not considered Primary MCL exceedances as this standard applies only to public systems using surface water or groundwater under the direct influence of surface water. Turbidity has no health effects itself, but can interfere with disinfection and provide a medium for microbial growth (USEPA, 2010). Asbestos and cyanide were not routinely tested for because of their rare occurrence and the specialized sampling and testing procedures required for these constituents.

Of the 1,477 sites sampled, 391 sites (26 percent) exceeded at least one inorganic water quality standard. Three constituents commonly exceeded water quality standards: arsenic, fluoride, and nitrate. Maps are provided for each of these constituents that show in a very general way, the spatial variability of concentrations across Arizona.

Table 3. Summary of Types of Samples Collected, ADEQ Ambient Groundwater Monitoring Program 1995 – 2009

Basin	Sites Sampled	Inorganic Samples	Radionuclide Samples	VOC Samples	Pesticide Samples
Yuma	55	55	7	-	57
Douglas	52	52	7	13	7
Duncan Valley	55	55	20	10	12
Upper San Pedro	73	73	-	2	-
Virgin River	38	38	10	-	3
Prescott AMA	58	58	10	-	2
Upper Santa Cruz	65	65	-	36	4
Sacramento Valley	48	48	40	48	-
Willcox	58	58	44	54	4
Lower San Pedro	63	63	19	25	2
Hualapai Valley	26	26	16	21	-
Meadview	8	8	2	1	-
Avra Valley	42	42	22	19	-
San Rafael Valley	20	20	5	2	-
Detrital Valley	28	28	11	-	-
San Simon	77	77	23	-	4
Cienega Creek	20	20	6	10	-
Salt River	41	41	35	22	-
Tonto Creek	23	23	18	8	-
San Bernardino	14	14	-	-	-
Lake Mohave	43	43	15	-	-
Aravaipa Canyon	15	15	-	-	-
Big Sandy	56	56	29	-	-
Bill Williams	101	101	55	-	-
Upper Hassayampa	34	34	14	-	-
Ltl Colorado River	7	7	3	-	-
Gila Valley	65	65	20	-	4
Dripping Springs	12	12	7	-	-
Agua Fria	46	46	33	-	-
Phoenix AMA	11	11	-	-	-
Pinal AMA	86	86	25	14	14
McMullen Valley	124	124	53	-	2
Butler Valley	2	2	1	-	-
Harquahala	4	4	-	-	-
Ranegras Plain	7	7	3	-	-
Total	**1477**	**1477**	**553**	**287**	**115**

Sampling Results by Constituent

Arsenic - Arsenic concentrations at 276 sites (or 19 percent) exceeded the 0.01 milligram per Liter (mg/L) Primary MCL that became effective January 26, 2006). In contrast, only 30 sites (or 2 percent) had arsenic concentrations that exceeded the former Primary MCL and current state AQW standard of 0.05 mg/L. Although elevated arsenic concentrations are found throughout Arizona, the highest concentrations are generally located in southeastern and western Arizona *(Map 2)*.

Fluoride – Fluoride concentrations at 141 sites (10 percent) exceeded the 4.0 mg/L federal Primary MCL/state AQW standard *(Map 3)*. Also shown on the map are fluoride concentrations (367 sites or 24 percent) that exceed the aesthetics-based, Secondary Maximum Contaminant Levels. Although fluoride concentrations elevated over the Primary Maximum Contaminant Level are found throughout Arizona, the highest concentrations are generally located in southeastern and western.

Nitrate – Nitrate concentrations at 115 sites (8 percent) exceeded the 10 mg/L federal Primary MCL/state AQW standard *(Map 4)*. Elevated nitrate concentrations most commonly occur at groundwater sites located near major expanses of irrigated farmland in central and western Arizona.

Other Inorganic Constituents - Antimony (6 sites), barium (1 site), beryllium (4 sites), cadmium (2 sites), chromium (1 site), copper (0 sites), lead (2 sites), mercury (0 sites), nitrite (0 sites), selenium (2 sites), and thallium (0 sites) were rarely, if ever, detected at concentrations above water quality standards. These 11 constituents combined to exceed water quality standards at about 1 percent of sites.

Gross Alpha - There are three radionuclide constituents that have Primary MCLs: gross alpha, radium-226 and 228, and uranium. Radionuclide samples were collected at 553 of the 1,477 sites that were typically in or near bedrock, particularly in areas in proximity to mines and/or granite rock.

Of the 553 sites sampled for radionuclides, water quality exceedances included gross alpha (101 sites or 18 percent) (Map 5), uranium (42 sites or 8 percent) and radium-226 and 228 (12 sites or 2 percent). All uranium and radium-226 and 228 exceedances occurred at sites where gross alpha concentrations also exceeded health-based, water quality standards. Thus, gross alpha was considered representative of radionuclide results; uranium and radium-226 and 228 were not used in further analyses. Gross alpha exceedances occur throughout the state, but most commonly occur in northwestern Arizona especially in the Cerbat and Hualapai mountains.

Of the 1,477 sites sampled, 459 sites (31 percent) exceeded at least one inorganic and/or radionuclide water quality standard. Four constituents commonly exceeded water quality standards: arsenic, fluoride, nitrate, and gross alpha *(Figure 4)*.

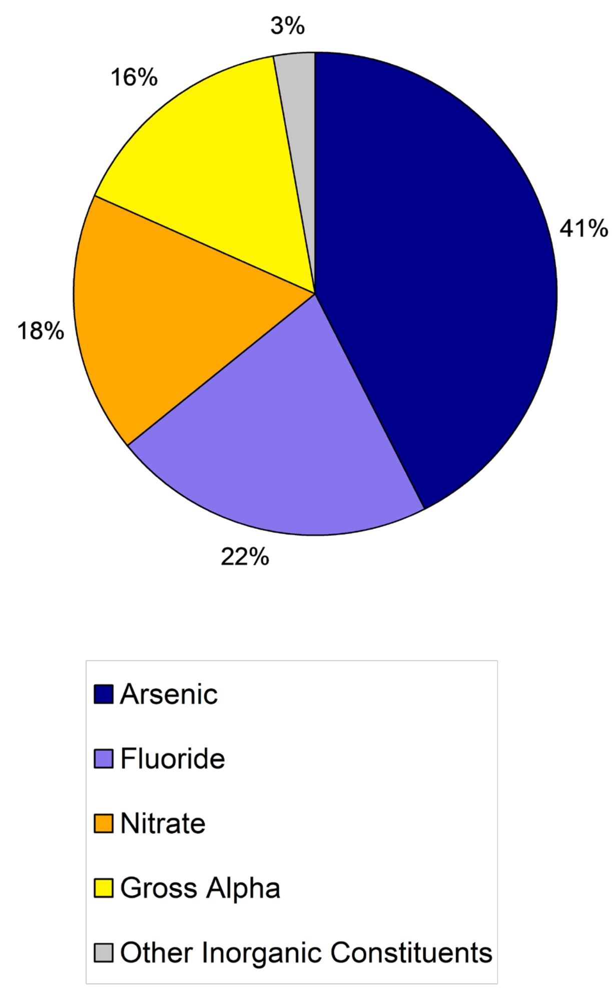


Figure 4 - Primary MCL Exceedances by Constituent

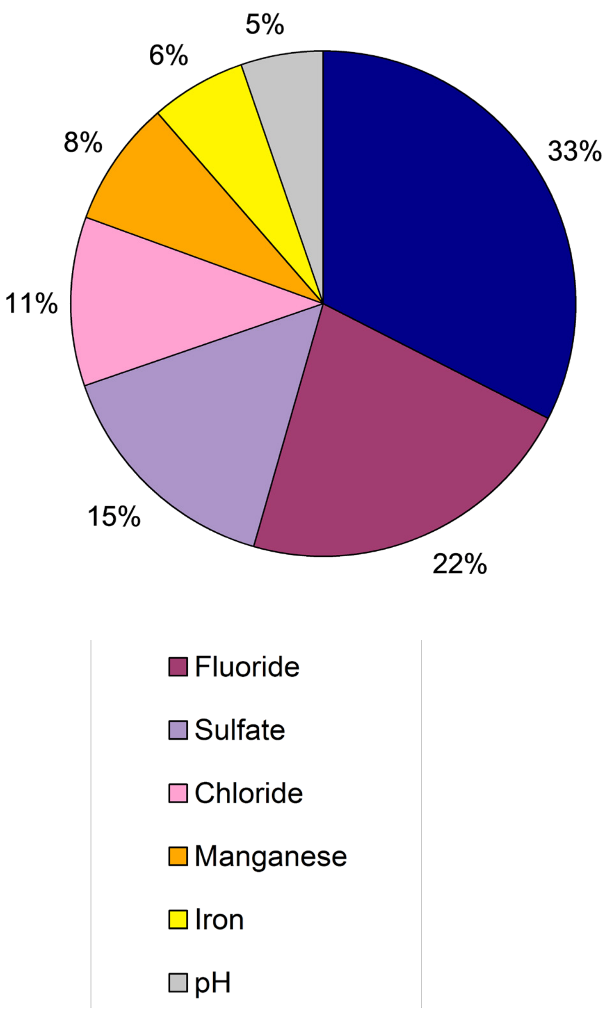


Figure 5 - Secondary MCL Exceedances by Constituent

Secondary MCLs - There are 15 inorganic constituents that have Secondary MCLs including aluminum, chloride, color, copper, corrosivity, fluoride, foaming agents, iron, manganese, odor, pH, silver, sulfate, total dissolved solids (TDS) and zinc.

The ADEQ ambient groundwater monitoring program does not routinely test for color, corrosivity, foaming agents or odor which are somewhat subjective and can be evaluated by domestic well owners

Of the 1,477 sites where samples were collected, 761 or (52 percent) exceeded at least one water quality guideline. The constituents that mostly commonly exceeded the water quality standards *(Figure 5)* include TDS (555 sites or 37 percent) *(Map 6)*, fluoride (367 sites or 24 percent) *(Map 3)*, sulfate (263 sites or 18 percent), chloride (184 sites or 13 percent), manganese (136 sites or 9 percent), iron (104 sites or 6 percent), and pH (83 sites > 8.5 su and 4 sites < 6.5 or 6 percent outside range).

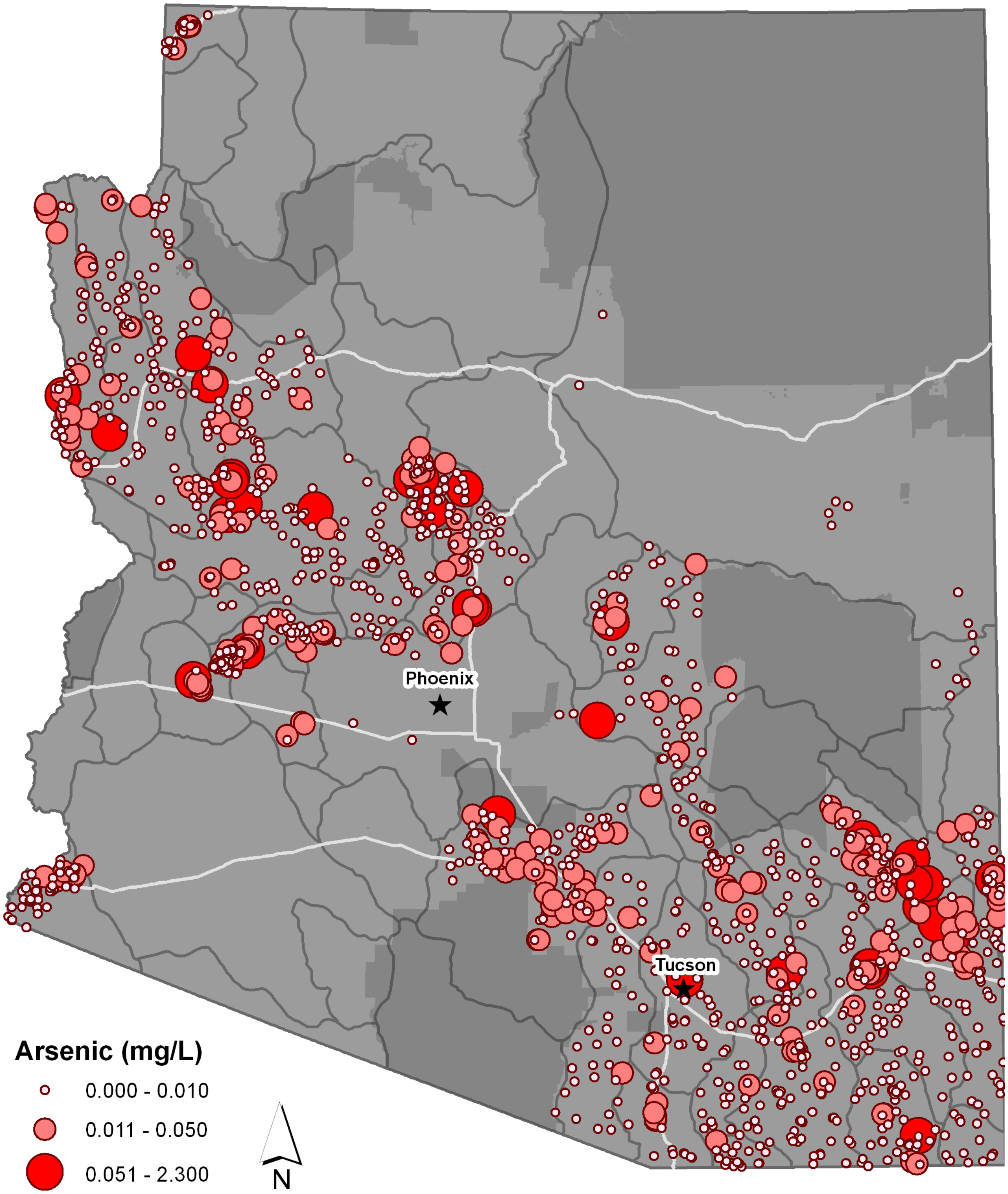
Aluminum (0 sites), copper (0 sites), silver (0 sites), and zinc (1 site) were rarely, if ever, detected at concentrations above water quality guidelines. These 4 constituents combined to exceed water quality standards at less than 1 percent of sites.

TDS – TDS concentrations at 555 sites (37 percent) exceeded the 500 mg/L aesthetics-based, water quality standard *(Map 6)*. TDS concentrations elevated over the water quality standard are typically naturally occurring but may be influenced by human activities including agricultural activities and septic tank effluent. Although TDS concentrations elevated over the aesthetics-based, water quality standard occur throughout the state, exceedances most commonly occur in agricultural areas of the southern Arizona including near the cities of Casa Grande, Safford, and Yuma.

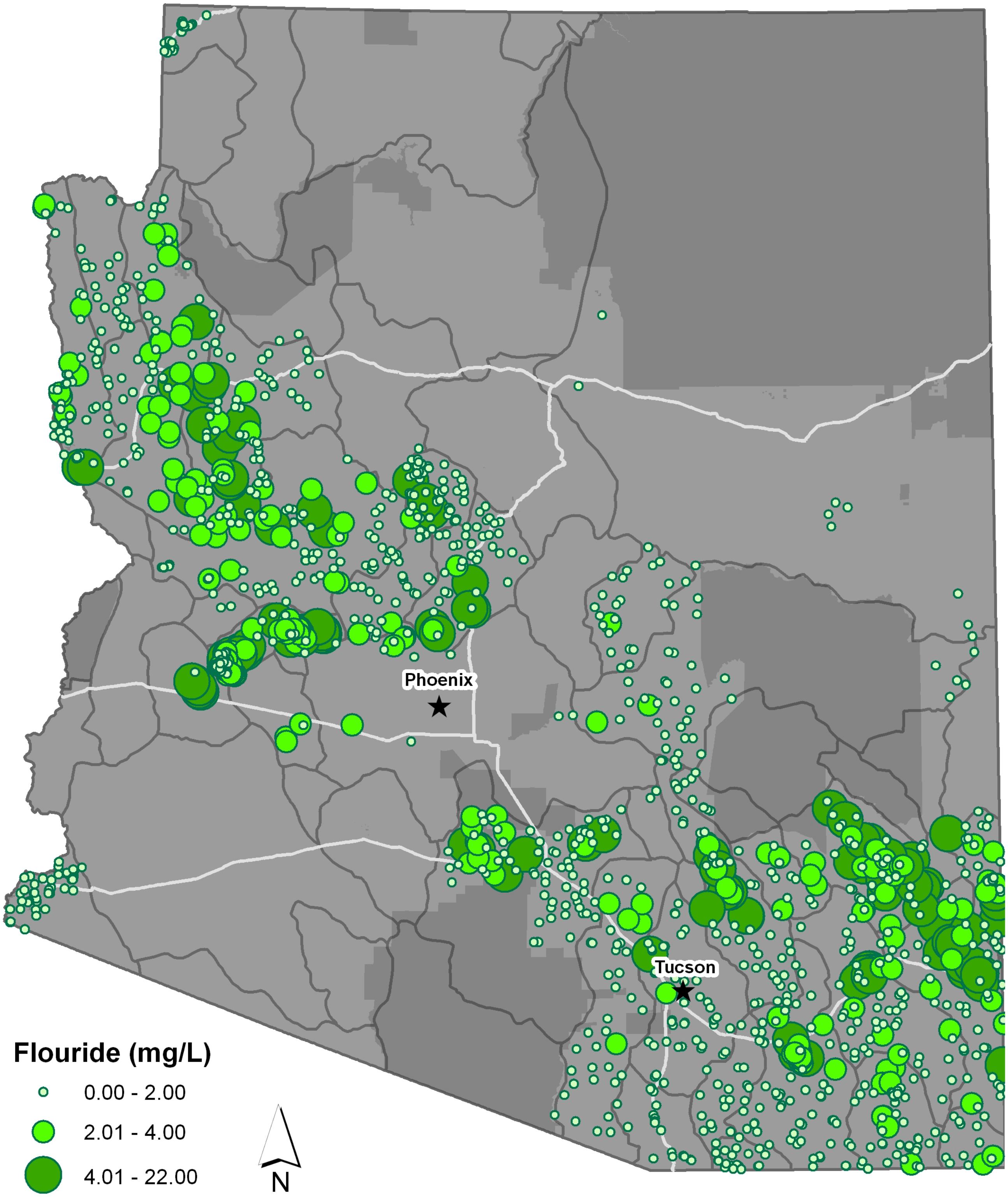
From the limited collection of VOC and pesticide samples, few anthropomorphic organic compounds were detected and these did not exceed Primary MCLs. VOC detections could usually be traced to disinfection by-products or by PVC glue used by the well owner to create a sample port near the wellhead a day or two before sampling by ADEQ.

VOC contamination of groundwater is typically found in the vicinity of industrial or defense facilities. These sites are being remediated through various federal EPA programs or the state Water Quality Assurance Revolving Fund (WQARF) program. These sites are found throughout the state but many are located in the Phoenix and Tucson metropolitan areas.

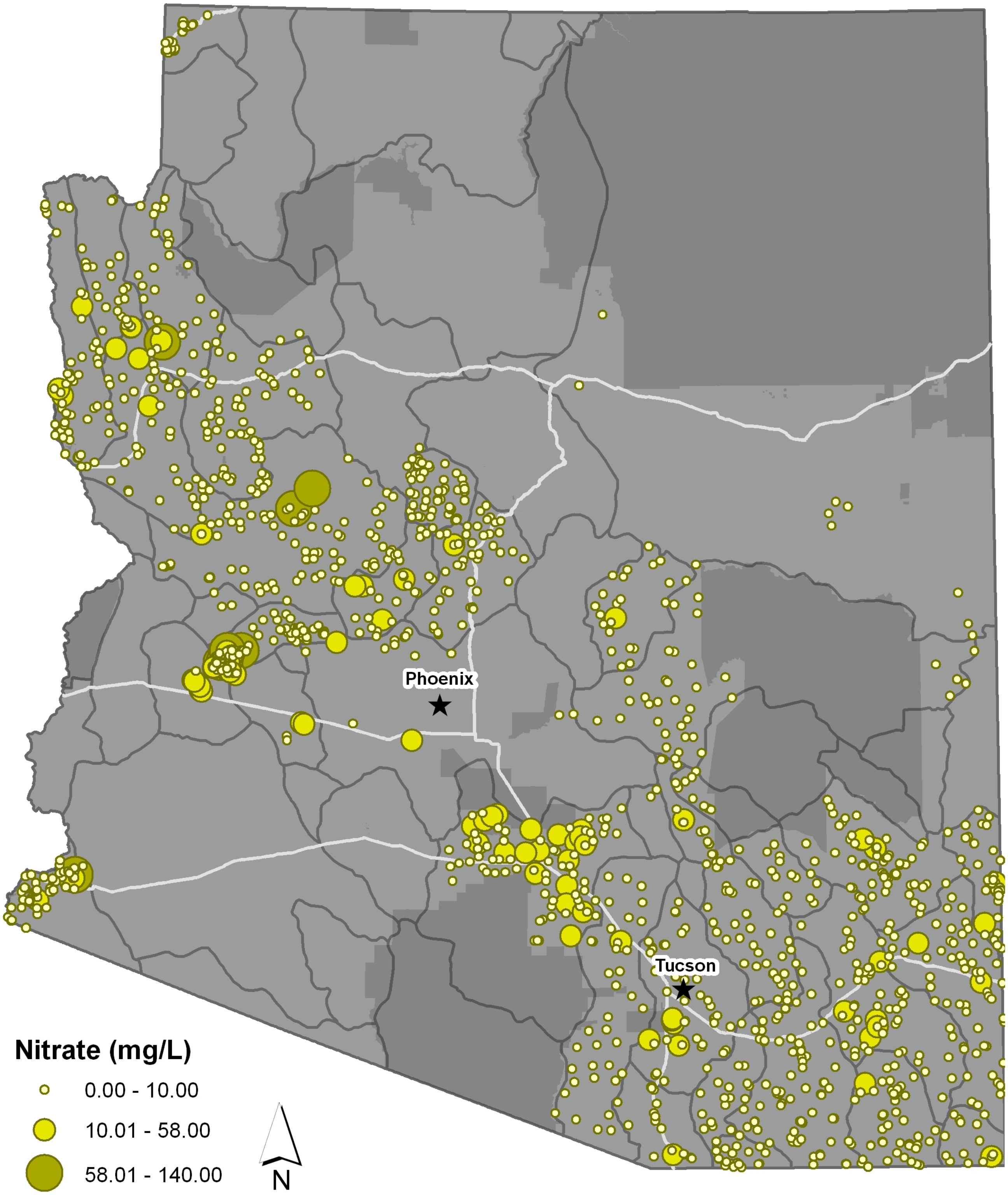
A complete listing of sites is on the ADEQ website at *http://www.azdeq.gov/environ/waste/sps/siteinfo.html*



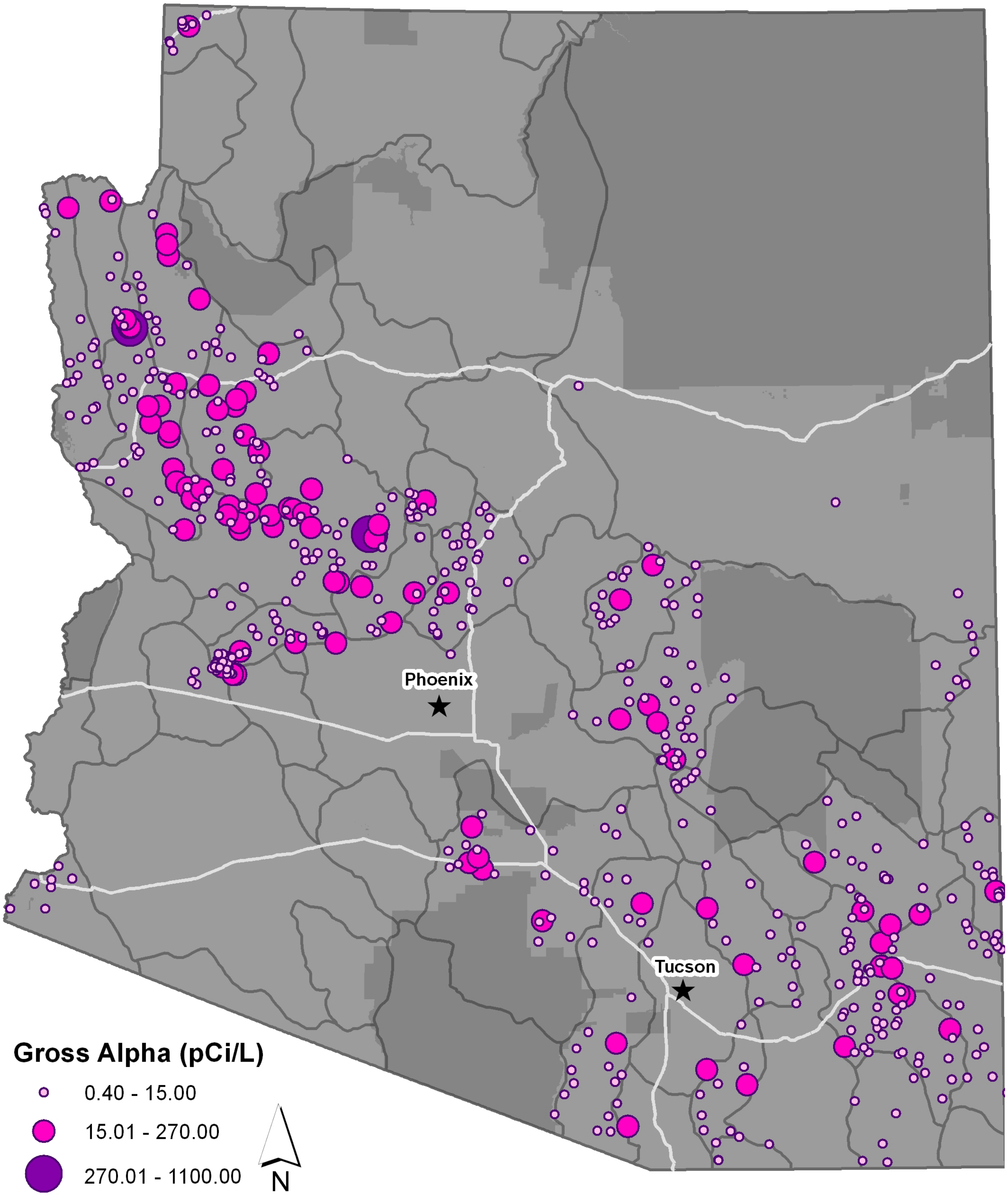
Map 2. Arsenic Concentrations (mg/L) at ADEQ Sample Sites, 1995-2009. The federal health-based, Primary Maximum Contaminant Level (MCL) for arsenic was 0.05 mg/L but was lowered to 0.01 mg/L in 2006. The state AWQ standard remains at 0.05 mg/L.



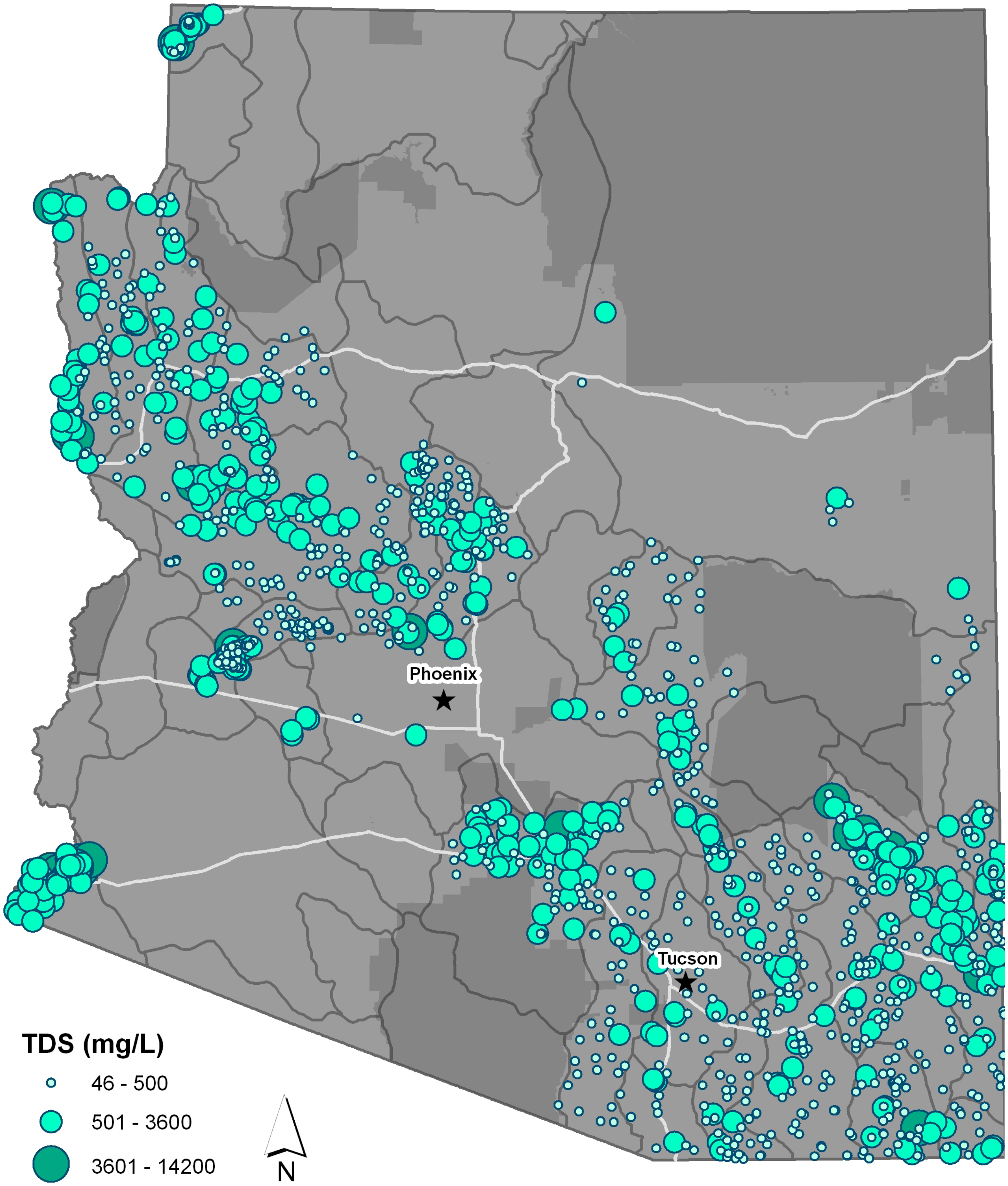
Map 3. Fluoride Concentrations (mg/L) at ADEQ Sample Sites, 1995-2009. The health-based, federal Primary MCL / state AQW standard for fluoride is 4.0 mg/L. Fluoride is unique in that it has also has a Secondary MCL of 2.0 mg/L.



Map 4. Nitrate (as Nitrogen) Concentrations (mg/L) at ADEQ Sample Sites, 1995-2009. The health-based, federal Primary MCL / state AQW standard for nitrate (as nitrogen) is 10 mg/L.



Map 5. Gross Alpha Concentrations (piC/L) at ADEQ Sample Sites, 1995-2009. The health-based, federal Primary MCL / state AQW standard for gross alpha is 15 pCi/L.



Map 6. Total Dissolved Solids (TDS) Concentrations (mg/L) at ADEQ Sample Sites, 1995-2009. The aesthetics-based, Secondary Maximum Contaminant level for TDS is 500 mg/L.

Sampling Results by Site

Of the 1,477 sites sampled *(Map 7)*:

- 624 sample sites (42 percent) met all Primary and Secondary MCLs
- 1018 sample sites (69 percent) met all Primary MCLs

Generally, sites sampled in the southeastern quadrant of Arizona tended to have fewer water quality exceedances except for agricultural areas located near the communities of Casa Grande, Safford and San Simon. Primary and Secondary MCL exceedances tended to occur more frequently in the northwest quadrant of the state and also in the extreme southwestern corner of Arizona. Some of these sites are correlated with agricultural areas such as near the communities of Salome and Yuma; other exceedances involve gross alpha concentrations in the Cerbat and Hualapai Mountains.

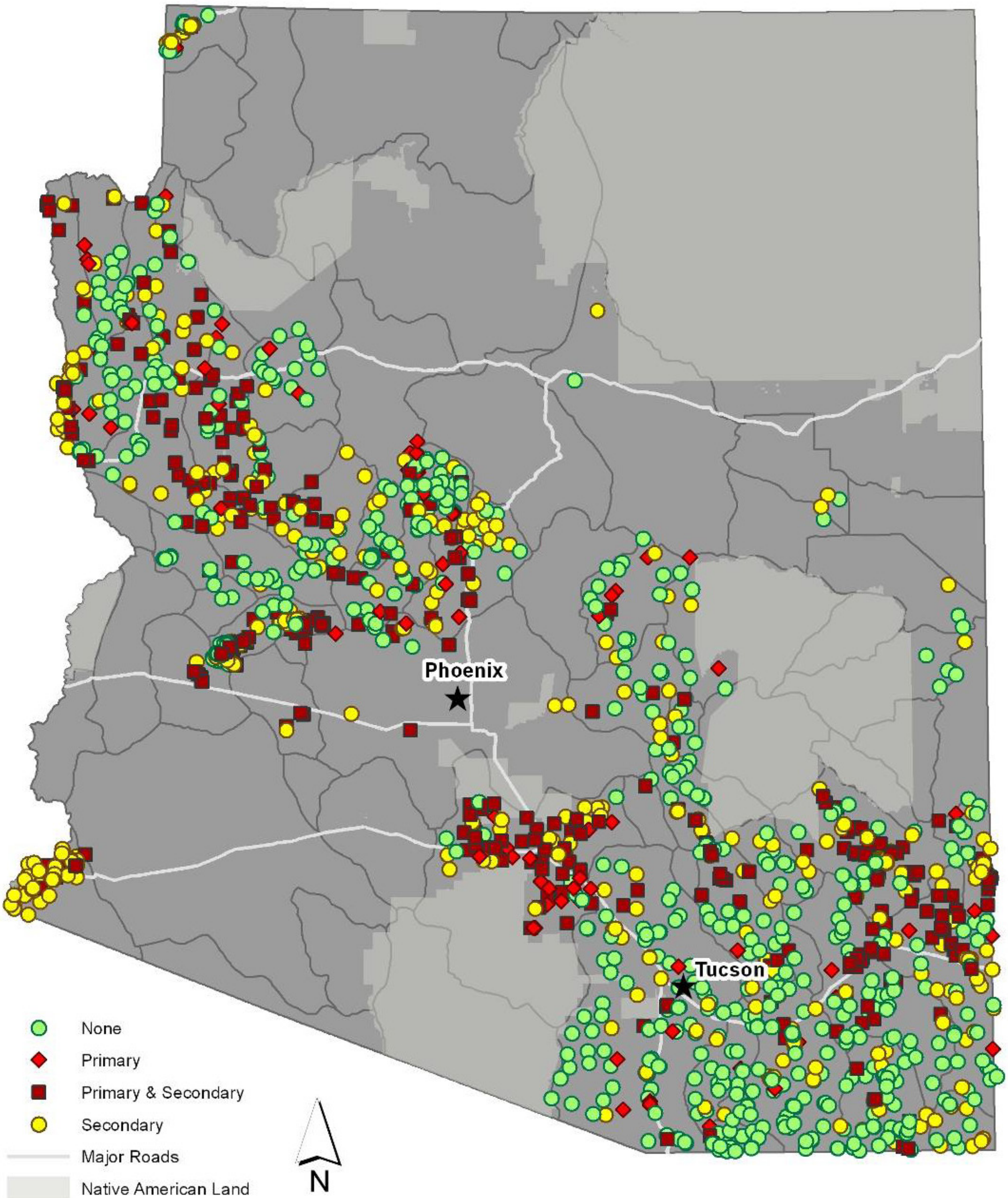
Of the 459 samples sites (31 percent) that had Primary MCL exceedances, 325 (71 percent) only exceeded water quality standards for one constituent *(Map 8)*. Of the remainder, 118 (26 percent) exceeded water quality standards for two constituents, 16 (3 percent) exceeded water quality standards for three constituents, and no sites exceeded water quality for four constituents.

Sampling Results by Basin

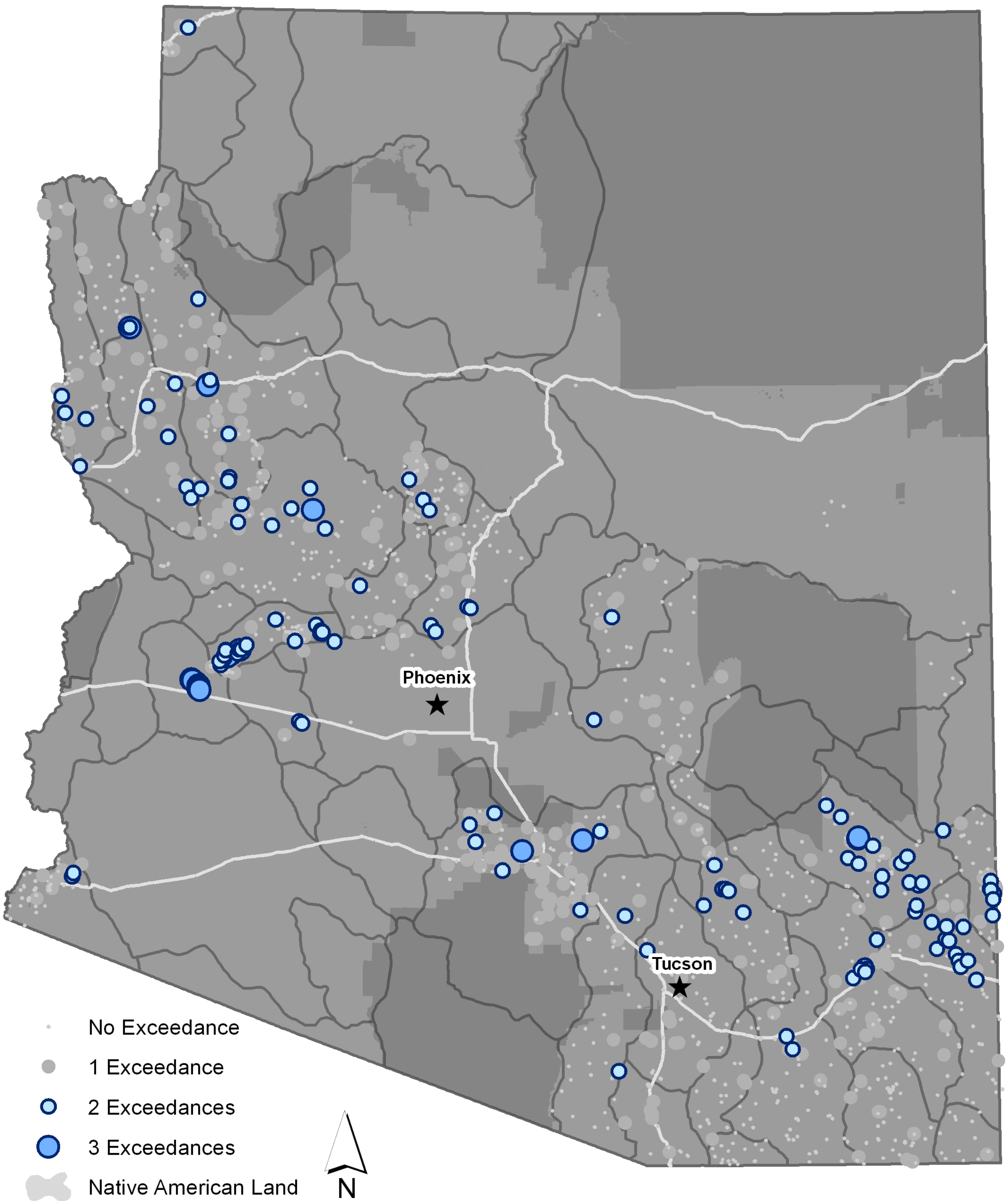
Water quality standards exceedances occur statewide, but there is much variability among individual groundwater basins *(Tables 4 and 5)*.

The basins with the highest percentage of Primary MCL exceedances such as the Pinal Active Management Area (AMA) (70 percent), Gila Valley (46 percent), Willcox (46 percent) and McMullen Valley (45 percent) tend to have both large expanses of irrigated cropland that impact nitrate concentrations along with aquifer materials that sometimes produce elevated concentrations of arsenic and fluoride. Other basins such as Sacramento Valley (48 percent) and Big Sandy (42 percent) mostly lack irrigated cropland but do have aquifer materials that sometimes produce elevated concentrations of arsenic, fluoride and gross alpha.

In contrast, basins with the lowest percentage of Primary MCL exceedances such as Aravaipa Canyon, Dripping Springs Wash and San Bernardino Valley (all 0 percent), Avra Valley, San Rafael and Upper San Pedro (all 10 percent), Salt River (12 percent), Douglas (14 percent) and Cienega Creek (15 percent) were generally characterized as having limited expanses of irrigated farmland. Generally, lower numbers of radionuclide samples were also collected in these basins. Most of these basins are located in the southeastern Arizona and many of the Primary MCL exceedances occurred at artesian wells producing very old water from deep, confined aquifers.



Map 7. Primary and Secondary MCL Exceedances at ADEQ Sample Sites, 1995-2009.



Map 8. Number of "Big Four" (Arsenic, Fluoride, Nitrate and Gross Alpha) Primary MCL Exceedances at ADEQ Sample Sites, 1995-2009.

Table 4. Summary of the Water Quality Status of Sampling Results by Groundwater Basin, ADEQ Ambient Groundwater Monitoring Program, 1995-2010

Basin	# of Sites Sampled	Sites Over PMCLs		Sites Over both MCLs		Sites Over only SMCLs		Sites Under both MCLs	
Yuma	55	11	20 %	11	20 %	44	80 %	0	0 %
Douglas	52	8	15 %	6	6 %	10	20 %	34	65 %
Duncan Valley	55	12	21 %	8	14 %	26	46 %	19	33 %
Upper San Pedro	73	7	10 %	5	7 %	19	26 %	47	64 %
Virgin River	38	9	24 %	5	13 %	20	53 %	9	24 %
Prescott AMA	58	17	29 %	5	9 %	4	7 %	37	64 %
Upr Santa Cruz	65	12	19 %	7	11 %	10	15 %	36	55 %
Sacramento Vly	48	23	48 %	22	46 %	6	8 %	19	40 %
Willcox	58	22	46 %	20	42 %	3	6 %	33	57 %
Lower San Pedro	63	19	30 %	17	27 %	12	19 %	32	51 %
Hualapai Valley	26	9	35 %	9	35 %	8	31 %	9	35 %
Meadview	8	3	38 %	2	25 %	2	25 %	3	38 %
Avra Valley	42	4	10 %	2	5 %	8	19 %	30	71 %
San Rafael	20	2	10 %	2	10 %	1	5 %	17	85 %
Detrital Valley	28	9	32 %	5	18 %	6	21 %	13	46 %
San Simon	77	25	32 %	24	31 %	24	31 %	28	36 %
Cienega Creek	20	3	15 %	0	0 %	2	10 %	15	75 %
Salt River	41	5	12 %	4	10 %	10	24 %	25	61 %
Tonto Creek	23	7	30 %	2	9 %	1	4 %	15	65 %
San Bernardino	14	0	0 %	0	0 %	6	43 %	8	57 %
Lake Mohave	43	15	35 %	12	28 %	19	44 %	9	21 %
Aravaipa Canyon	15	0	0 %	0	0 %	4	27 %	11	73 %
Big Sandy	56	24	43 %	19	34 %	9	16 %	23	41 %
Bill Williams	101	27	27 %	24	24 %	25	25 %	49	0 %
Upr Hassayampa	34	9	26 %	8	24 %	5	15 %	20	59 %
Ltl Colorado Rvr	7	0	0 %	0	0 %	4	57 %	3	43 %
Gila Valley	65	30	46 %	30	46 %	24	37 %	11	17 %
Dripping Spring	12	0	0 %	0	0 %	0	0 %	12	100 %
Agua Fria	46	14	30 %	11	24 %	20	44 %	11	24 %
Phoenix AMA	11	5	45 %	4	36 %	4	36 %	2	18 %
Pinal AMA	86	60	70 %	42	49 %	18	21 %	8	9 %
McMullen Vly	124	56	45 %	52	42 %	35	28 %	33	27 %
Butler Valley	2	0	0 %	0	0 %	0	0 %	2	100 %
Harquahala	4	3	75 %	3	75 %	1	25 %	0	0 %
Ranegras Plain	7	6	86 %	6	86 %	1	14 %	0	100 %
Total	**1477**	**459**	**31 %**	**369**	**25 %**	**392**	**27 %**	**624**	**42 %**

PMCLs – Primary Maximum Contaminant Levels
SMCLs – Secondary Maximum Contaminant Levels
Both – Primary and Secondary Maximum Contaminant Levels

Table 5. Summary of Arsenic, Fluoride, Nitrate and Gross Alpha Sampling Results by Groundwater Basin, ADEQ Ambient Groundwater Monitoring Program 1995 – 2010

Basin	# of Sites Sampled	Sites > Arsenic MCL		Sites > Fluoride MCL		Sites > Nitrate MCL		Sites > Gross Alpha MCL	
Yuma	55 / 7	9	16 %	0	0 %	5	9 %	0	0 %
Douglas	52 / 7	5	10 %	0	6 %	1	2 %	2	29 %
Duncan Valley	55 / 20	14	25 %	6	11 %	2	4 %	2	10 %
Upper San Pedro	73 / 0	6	8 %	3	4 %	0	0 %	0	0 %
Virgin River	38 / 10	9	24 %	0	0 %	0	0 %	1	10 %
Prescott AMA	58 / 10	15	26 %	4	5 %	1	2 %	1	10 %
Upr Santa Cruz	65 / 0	9	14 %	1	2 %	7	11 %	0	0 %
Sacramento Vly	48 / 40	6	13 %	4	8 %	6	13 %	18	45 %
Willcox	58 / 44	9	16 %	8	14 %	5	9 %	7	16 %
Lower San Pedro	63 / 19	12	19 %	8	13 %	1	2 %	2	11 %
Hualapai Valley	26 / 26	3	12 %	2	8 %	3	12 %	3	19 %
Meadview	8 / 2	1	3 %	0	0 %	0	0 %	2	100 %
Avra Valley	42 / 22	2	5 %	0	0 %	0	0 %	3	14 %
San Rafael	20 / 5	0	0 %	0	0 %	0	0 %	1	20 %
Detrital Valley	28 / 11	3	11 %	0	0 %	3	11 %	3	27 %
San Simon	77 / 23	16	21 %	19	25 %	3	4 %	3	13 %
Cienega Creek	20 / 6	1	5 %	0	0 %	0	0 %	2	33 %
Salt River	41 / 35	5	12 %	1	2 %	0	0 %	1	3 %
Tonto Creek	23 / 18	5	22 %	0	0 %	1	4 %	2	11 %
San Bernardino	14 / 0	0	0 %	0	0 %	0	0 %	0	0 %
Lake Mohave	43 / 15	14	33 %	1	2 %	3	7 %	0	0 %
Aravaipa Canyon	15 / 0	0	0 %	0	0 %	0	0 %	0	0 %
Big Sandy	56 / 29	13	23 %	11	20 %	0	0 %	8	28 %
Bill Williams	101 / 55	10	10 %	4	4 %	3	3 %	16	29 %
Upr Hassayampa	34 / 14	1	3 %	0	0 %	4	12 %	5	36 %
Ltl Colorado Rvr	7 / 3	0	0 %	0	0 %	0	0 %	0	0 %
Gila Valley	65 / 20	21	32 %	20	31 %	4	6 %	3	15 %
Dripping Spring	12 / 7	0	0 %	0	0 %	0	0 %	0	0 %
Agua Fria	46 / 33	12	26 %	5	11 %	1	2 %	1	3 %
Phoenix AMA	11 / 0	4	36 %	0	0 %	1	9 %	0	0 %
Pinal AMA	86 / 25	33	38 %	7	8 %	23	27 %	5	20 %
McMullen Vly	124 / 53	29	23 %	32	26 %	30	22 %	10	19 %
Butler Valley	2 / 1	0	0 %	0	0 %	0	0 %	0	0 %
Harquahala	4 / 0	3	75 %	0	0 %	2	50 %	0	0 %
Ranegras Plain	7 / 3	6	86 %	6	86 %	5	71 %	0	0 %
Total	**1477**	**276**	**19 %**	**141**	**10 %**	**115**	**8 %**	**101**	**18 %**

Conclusions

The results of this study indicate that generally the majority of groundwater sites (69 percent) meet EPA's Primary SDW requirements and could be used for public water supply without any more than standard treatment. However, this percentage should be used somewhat cautiously as several biases in the data may alter the rate of sites meeting Primary MCLs. Certainly, using the state AQW standard of 0.05 mg/L instead of the federal Primary MCL of 0.01 mg/L for arsenic would also increase the percentage of groundwater sites meeting that could be used for public water supply without any more than standard treatment.

A major factor that might increase the percentage of sites not meeting Primary MCLs is that radionuclide samples were not collected at 61 percent of sites including some basins without a single well or spring sampled for radionuclide constituents. Collecting radionuclide samples at each of the 1,477 sites would have probably increased the frequency of Primary MCL exceedances but by how much is unknown.

Other types of samples such as VOCs and pesticides were collected at far lower frequencies than radionuclides. However, their results, (overwhelmingly non-detect) indicate that sampling for these contaminants at each of the 1,477 sites would probably not have significantly impacted the frequency of Primary MCL exceedances.

On the other hand, some factors indicate that 69 percent might be too low since when a site exceeded a Primary MCL, especially when it was a high outlier, additional targeted samples were collected in the area to determine the extent of the plume. Thus, targeting some samples around sites with extreme examples of poor quality groundwater would tend to increase the number of sites not meeting health based, water quality standards.

The most significant regulatory impact to the percentage of groundwater sites meeting SDW requirements was lowering of the arsenic standard from 0.05 mg/L to 0.01 mg/L that took effect nationwide on January 26, 2006. The change in the standard resulted in Primary MCL exceedances for arsenic in the 1,477 sites increasing from 27 sites (2 percent) evaluated under the former 0.05 mg/L standard to 276 sites (19 percent) using the current 0.01 mg/L standard. With the change, arsenic became, by far, the most prominent Primary MCL exceedance in Arizona.

Discussion

Some general observations may be made concerning the hydrologic conditions and spatial locations where these constituents tend to be found at concentrations that exceed water quality standards. However, the maps contained in this report should be used cautiously since there are severe limitations in representing a three-dimensional groundwater unit on a two-dimensional map. As an example, two wells adjacent to one another could be drawing groundwater from different aquifers that have a very different water quality. Generally, fluoride, arsenic, and gross alpha are naturally occurring although the latter may be increased by mining activity (Lowry, 1988).

Elevated fluoride concentrations may occur throughout Arizona but tend to be most common in the southeastern and west central portions of the state. Fluoride concentrations above 5 mg/L are controlled by calcium through precipitation or dissolution of the mineral fluorite. In a chemically closed hydrologic system, calcium is removed from solution by precipitation of the calcium carbonate and the formation of smectite clays; high concentrations of dissolved fluoride may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution (Robertson, 1991). Thus, wells having soft, sodium-dominated, older water, such as artesian wells drawing from deep aquifers in southeastern Arizona, are likely to have elevated fluoride concentrations.

Arsenic concentrations tend to be the most difficult to predict with concentrations elevated over the Primary MCL occurring throughout Arizona. Arsenic concentrations may be influenced by similar reactions as fluoride, including exchange on clays or with hydroxyl ions. Other factors such as a long aquifer residence time, an oxidizing environment, high pH levels, and an abundance of trace elements in alluvial sediments are also likely to impact arsenic concentrations (Robertson, 1991; Spencer, 2002).

Radionuclide concentrations such as gross alpha usually occur in areas located in or near granite rock or alluvial areas composed of eroded granite (Lowry, 1988). Mining activity also increases gross alpha concentrations because of the increased rock surface exposure. Gross alpha exceedances occurred where other radionuclide exceedances such radium 226+228 and uranium occurred, making this constituent an important harbinger of elevated radionuclides concentrations in general.

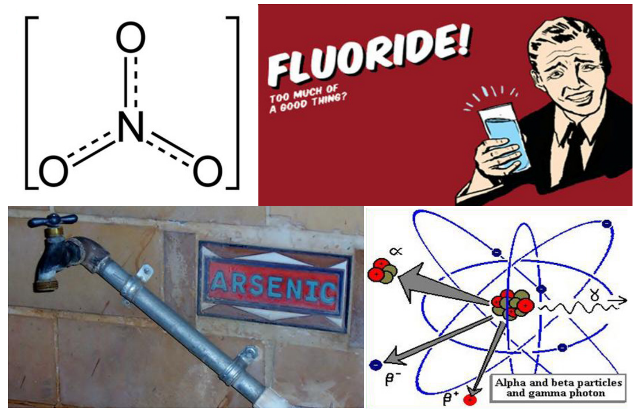
Elevated nitrate concentrations most commonly occur in groundwater samples collected from shallow wells located near major expanses of irrigated farmland. In Arizona, these areas are located within several basins including the Pinal AMA, McMullen Valley, Willcox, Safford, and Yuma. Nitrate concentrations can also occasionally exceed water quality standards in domestic wells impacted by septic systems especially in high densities, and in isolated stock wells situated by corrals where livestock linger for extended periods. In some Sonoran desert areas of Arizona, naturally occurring nitrate concentrations are elevated from nitrogen that has been accumulated in the soil by native legume plants (Thiros and others, 2012).

However, while there are sites where elevated concentrations of arsenic, fluoride, nitrate and gross alpha are likely to occur (Figure 6), domestic well owners should be aware that exceedances of these constituents can potentially occur in water produced by any well.

Recommendations

Although ADEQ recommends homeowners using a private well for domestic use have the water tested for the full suite of inorganic and radionuclide SDW requirements to ensure safety, this is an expensive venture. For 18 constituents (excluding asbestos, cyanide and turbidity), these combined analytical tests would cost $664.80 at a local laboratory certified by the Arizona Department of Health Services (Test America, 2010). The costs for inorganic constituents typically range from $7 - $45.

However, if the well owner is unable to afford such extensive testing, there is an alternative that will



(Figure 6). The "Big Four" constituents that most frequently exceed Primary MCLs in groundwater in Arizona. Sampling for these four constituents is highly recommended and this option would run only $85. (Test America, 2010).

likely reveal most water quality standard exceedances. Arsenic, fluoride, nitrate and gross alpha are the four constituents (nicknamed the "Big Four") that caused 97 percent of health based water quality exceedances in 1,477 wells scattered across Arizona.

Domestic well owners interested in testing their groundwater quality can find additional information on the EPA website at *http://water.epa.gov/drink/index.cfm.*

Local county extension offices can also provide technical assistance and occasionally offer limited water quality testing for well owners.

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