Groundwater Quality Protection Through Monitoring

White Paper Prepared by the Texas Groundwater Protection Committee (TGPC)
Groundwater Issues (GWI) Subcommittee

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Executive Summary

In establishing the TGPC[1] in 1989, the Texas Legislature determined that, "consistent with the protection of the public health and welfare, the propagation and protection of terrestrial and aquatic life, the protection of the environment, the operation of existing industries, and the maintenance and enhancement of the long-term economic health of the state, it is the goal of groundwater policy in this state that the existing quality of groundwater not be degraded." (Texas Water Code (TWC) Title 2 Section 26.401(b)[2]).

Groundwater quality can be protected by conducting judicious monitoring and making informed decisions based on the data. The TGPC conducted a survey in 2023 focused on groundwater quality monitoring programs in the state and their associated datasets. This white paper shares the responses to that survey and offers a resulting list of continuing research needs and recommendations that would support a variety of groundwater quality protection efforts in Texas.

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Acronym List

6PPD	6 p-phenylenediamine
6PPD-q	6 p-phenylenediamine-quinone
ACE	Army Corps of Engineers
AgriLife Extension	Texas A&M AgriLife Extension Service
AgriLife Research	Texas A&M AgriLife Research
AMR	Anti-microbial Resistance
API	Application Programming Interface
ASR	Aquifer Storage and Recovery
BMP	Best Management Practice
BRACS	Brackish Resources Aquifer Characterization System
BTEX	benzene, toluene, ethylbenzene, and xylenes
CDC	Centers for Disease Control and Prevention
CWS	Community Water System
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DSHS	Texas Department of State Health Services
DWW	Drinking Water Watch
EAA	Edwards Aquifer Authority
E. coli	*Escherichia coli*
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FMT	Financial, Managerial, and Technical
FTE	Full Time Equivalent
GAU	Groundwater Advisory Unit
GBEP	Galveston Bay Estuary Program
GCD	Groundwater Conservation District
GIS	Geographic Information System
GW	Groundwater
GWDB	Groundwater Database
GWI	Groundwater Issues
IBWC	International Boundary and Water Commission

ICE	Industry Council on the Environment
IPD	Interagency Pesticide Database
ITRC	Interstate Technology and Regulatory Council
LCRA	Lower Colorado River Authority
MAR	Managed Aquifer Recharge
MCL	Maximum Contaminant Level
Meadows Center	Meadows Center for Water and the Environment
MTBE	Methyl tert-butyl ether
N/A	Not Applicable
NAWQA	National Water-Quality Assessment
NGO	Non-governmental Organizations
NGWMN	National Ground-Water Monitoring Network
NWIS	National Water Information System
O&G	Oil and Gas
OSSF	On-site Sewage Facilities
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PDF	Portable Document Format
PFAS	Per- and polyfluoroalkyl Substances
PPG	Performance Partnership Grant
PST	Petroleum Storage Tank
PWS	Public Water Supply
RHCP	Regional Habitat Conservation Plan
RRC	Railroad Commission of Texas
RWPG	Regional Water Planning Group
SDR	Submitted Drillers Report
SVOC	Semi-volatile Organic Compound
TAGD	Texas Alliance of Groundwater Districts
TBA	To Be Announced
TCEQ	Texas Commission of Environmental Quality
TDA	Texas Department of Agriculture
TGPC	Texas Groundwater Protection Committee
TDLR	Texas Department of Licensing and Regulation

TDS	Total Dissolved Solids
TPWD	Texas Parks and Wildlife Department
TRWA	Texas Rural Water Association
TSSWBC	Texas State Soil and Water Conservation Board
TTU	Texas Tech University
TWC	Texas Water Code, Texas Water Commission
TWCA	Texas Water Conservation Association
TWDB	Texas Water Development Board
TWON	Texas Well Owner Network
TWRI	Texas Water Resources Institute
TxPWC	Texas Produced Water Consortium
USGS	United States Geological Survey
UTBEG	Bureau of Economic Geology of The University of Texas at Austin
VOC	Volatile Organic Compound
WHO	World Health Organization
WUTAP	Water Utilities Technical Assistance Program

Introduction

Groundwater quality protection is important not only because of the need for a dependable source of water that is safe for drinking and other uses, but also due to the difficulty, cost, and time needed to remediate contaminated aquifers. In order to detect emerging threats and track established contamination, groundwater quality data should be collected with sufficient temporal frequency, spatial coverage, and analyte types to establish baselines, identify new problems, and reveal trends.

The following contaminants, challenges, data collection mechanisms, and monitoring methodology suggestions have been listed in recent comprehensive articles and reports about groundwater quality around the world[3,4,5,6].

Contaminants:

- Nutrients (e.g., nitrate, nitrite, ammonium, phosphate, etc.).
- Organics (e.g., methyl tert-butyl ether (MTBE), Volatile and Semi-volatile Organic Compounds (VOCs/SVOCs), petroleum hydrocarbons, Polycyclic Aromatic Hydrocarbons (PAHs), chlorinated solvents, dioxins and furans, etc.).
- Inorganics (e.g., Total Dissolved Solids (TDS), arsenic, fluoride, iron, manganese, chromium, lead, other metals, etc.).
- Pesticides (e.g., atrazine, diazinon, 2,4-D, metolachlor, glyphosate, other herbicides, insecticides, fungicides, and rodenticides, etc.).
- Microbes (e.g., fecal pathogens, total coliforms, fecal coliforms, *Cryptosporidium*, *Escherichia coli* (*E. coli*), *Cyclospora*, *Giardia*, algae, other bacteria, viruses, and parasites, etc.).
- Radionuclides (e.g., uranium, radon, radium, etc.).
- Stable isotopes (e.g., deuterium, etc.).
- Pharmaceuticals (e.g., hormones, antibiotics, steroids, other personal care products, etc.).
- Water and wastewater treatment products (e.g., disinfection byproducts, etc.).
- Microplastics and nanoplastics.
- Legacy and emerging contaminants (e.g., Per- and polyfluoroalkyl Substances (PFAS), 6 p-phenylenediamine-quinone (6PPD-q), 1,4-dioxane, tri(2-chloroethyl) phosphate, n,n-diethyltoluamide, bisphenol A, sulfamethoxazole, 4-octylphenol monoethoxylate, etc.).
- Byproducts of oil and gas extraction (e.g., from fracking, the mobilization of natural methane and uranium, etc.) and mining (e.g., from ore processing, acid mine drainage which mobilizes geogenic contaminants, heavy metals attached to sediments, mining waste, etc.).

Challenges:

- Surface water contaminating groundwater.
- Increased groundwater salinity due to irrigation.
- Changes in precipitation patterns resulting in:
  - Reduced recharge in some locations, which can concentrate contaminants in the groundwater.
  - Enhanced flooding and stormwater runoff in other locations, which can infiltrate groundwater with surface contamination (reducing recharge quality) and increased water temperatures (changing the survival times of groundwater microbes and increasing the rate of physical and biochemical underground reactions).
- Anti-microbial Resistance (AMR) facilitated by nutrients, pharmaceuticals, pesticides, and heavy metals.
- Saline water intrusion of coastal aquifers, especially in karst aquifers.
- The special sensitivity of karst aquifers to contamination.
- Aquifer Storage and Recovery (ASR) and Managed Aquifer Recharge (MAR).
- Carbon sequestration.
- Geothermal wells.

Data collection mechanisms:

- The state's water quality wells in the U.S. National Ground-Water Monitoring Network (NGWMN[7]) and their temporal sampling.
- Remote sensing combined with Geographic Information System (GIS) analysis, machine learning, and predictive numerical modeling of contaminant fate and transport or human exposure pathways.
- Community scientists and community-based monitoring.
- Special borehole designs such as clusters, piezometer nests, or multi-level devices to monitor groundwater quality at different depths.
- Continuous monitoring of water wells or piezometers via in-situ sensors or probes connected to a data logger and telemetry system or electromagnetic logging tools, respectively.

Monitoring methodology suggestions:

- Groundwater quality parameters could be considered at various scales depending on the key risks for different uses (e.g., drinking water, ecosystems, food – particularly irrigation, energy production, and other industries).

- In addition to longer-term, larger-scale systematic monitoring programs to identify general spatial patterns and temporal trends in groundwater quality, programs could be targeted and designed according to the purpose of the monitoring (e.g., specific contamination tracing and remediation, short-term campaigns to understand local contamination issues, etc.).
- Monitoring upstream (e.g., contributing streams and soils) and downstream (e.g., receiving streams, springs, wetlands, or coastal areas) from a targeted water well or spring could be informative.
- Data sharing for transboundary aquifers would help fill knowledge gaps and aid joint protection programs.
- If monitored water wells or springs are lacking in an area of interest, nearby surface water quality data may provide an indication of the groundwater quality.

An additional legacy challenge is abandoned and deteriorated water wells which can provide surface contamination a direct conduit into an aquifer with no opportunity for natural filtration by soils or geologic materials[8]. An additional emerging source of potential contaminants related to groundwater quality is the beneficial use of oil and gas (O&G) produced water[9] (e.g., the surface application of untreated and treated O&G produced water, and the discharge of untreated and treated O&G produced water to surface water and groundwater, including as a source for ASR or MAR).

State Agency Ambient Groundwater Quality Monitoring and Reports

Groundwater quality monitoring programs in Texas can help identify whether any of the above concerns are impacting, or may impact, the state's nine major and 22 minor aquifers. The TGPC's annual *Joint Groundwater Monitoring and Contamination Report* ("*Joint Report*")[10] describes the current status of groundwater quality monitoring activities conducted, or required by, each of its members. The *Joint Report* also describes the groundwater protection programs of each TGPC member and provides the enforcement status of each active and inactive groundwater contamination case. In 2022, the *Joint Report* documented 2,943 active and 1,758 inactive cases.

A significant effort is the Texas Water Development Board (TWDB) Ambient Groundwater Monitoring Program[11,12] which samples a representative number of wells and springs from each of the state's nine major and 22 minor aquifers approximately once every four years. The purpose of this program is to monitor changes in groundwater quality over time and establish the ambient water quality conditions of naturally-occurring constituents (i.e., non-anthropogenic) in the state's aquifers. Samples are collected for field water quality parameters (e.g., pH, conductivity, temperature, and alkalinity), naturally-occurring metals and nutrients, radionuclides, and occasionally isotopes for special studies. In conjunction with this program, the Springs Monitoring Program[13] was initiated in 2020 to monitor and inventory a consistent network of springs across the state and document short- and long-term

changes in flow rate and water quality. Groundwater quality data collected and submitted by other groups that follow TWDB's sampling guidelines or equally stringent protocols (e.g., Groundwater Conservation Districts (GCDs)) are also uploaded to the TWDB Groundwater Database (GWDB[14]). TWDB provides analytical funding for several of these groups as budget is available. Over a four-year sampling period, approximately 1,500 groundwater quality analyses are collected by TWDB staff and cooperating entities. Note that it is not within the scope of TWDB monitoring programs to sample for bacteria or other anthropogenic constituents and TWDB has no regulatory authority to enforce Maximum Contaminant Level (MCL) exceedances.

Every two years, the Texas Commission on Environmental Quality (TCEQ) utilizes information from the TWDB GWDB to inventory ambient water quality in each of the state's major and minor aquifers for selected primary (i.e., MCL) and secondary drinking water standards during the most recent ten-year period. This effort is summarized in the *State of Texas Water Quality Inventory Groundwater Assessment* as part of the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* ("*Texas Integrated Report*")[15]. The 2022 report included data from approximately 2,300 wells that were sampled between September 1, 2011, and August 31, 2021.

A number of other reports and white papers concerning groundwater quality in Texas are available on the TGPC Groundwater Information webpage[16]. While many of these are constituent- or aquifer-specific, this list includes the comprehensive statewide *Ground-Water Quality of Texas – An Overview of Natural and Man-Affected Conditions*, a 1989 Texas Water Commission (TWC) report[17]. In addition, the Bureau of Economic Geology of The University of Texas at Austin (UTBEG) completed a 2011 contract report for TWDB on *Naturally Occurring Groundwater Contamination in Texas*[18], and TWDB's Groundwater Reports webpage[19] includes some reports that address groundwater quality.

Survey Background

In 2013, TWDB and UTBEG conducted a survey[20] of groundwater quality data collection programs (i.e., samples collected from water wells and springs) that were administered by statewide agencies and organizations. It was funded by the U.S. Centers for Disease Control and Prevention (CDC) and conducted over a two-year period (2011 – 2013) as part of an initiative to provide guidance to private water well owners in Texas who depend on their well for drinking purposes. A follow-up survey[21], which also included local groups and individuals as respondents, was conducted by the TGPC in 2023. Based on the results from this recent survey, a number of categories of continuing research needs and recommendations are identified regarding possible changes and/or additions to these programs, including:

- Contaminants
- Surface Impacts

- Water Wells
- Transboundary Aquifers
- ASR and MAR
- Collaboration
- Outreach
- Technology
- Dataset Format and Availability
- Monitoring Purpose
- Monitoring Locations and Sources
- Monitoring Frequency
- Analytes and Analysis
- Monitors and Programs
- Survey Frequency
- Comprehensive Statewide Groundwater Quality Report
- Small PWSs Groundwater Quality Data
- Private Water Well Testing

Discussion

Survey Development

The TGPC drafted an initial online survey using the Microsoft Forms application as a pilot. This pilot survey was conducted on May 3 – 18, 2023, and the survey was subsequently updated based on the feedback from five respondents.

The TGPC then conducted its updated Groundwater Quality Monitoring Survey on June 15 – July 28, 2023. This survey focused on groundwater quality monitoring programs in Texas and their associated datasets. The purpose of the survey was to gain a better understanding of the various groundwater quality data collection efforts taking place across the state in order to identify potential data gaps, monitoring needs, and opportunities for collaboration. For this survey:

- A monitoring program was defined as routine (proactive or reactive) sampling that followed an approved protocol; and,

- A dataset was defined as related information that was grouped together and organized into a shareable format for either an individual sampling event or a series of sampling events.

The link to the survey was posted on the TGPC homepage, along with the blank form for reference. Several TGPC members posted the survey announcement on their websites and social media accounts and shared it with their stakeholders. In addition, a number of other organizations that have an interest in Texas groundwater were invited to participate in and/or advertise the availability of the survey, including:

- U.S. Army Corps of Engineers (ACE) – Southwestern Division and Galveston Regulatory District
- Edwards Aquifer Authority (EAA) Regional Habitat Conservation Plan (RHCP)
- Industry Council on the Environment (ICE)
- Texas Water Conservation Association (TWCA)
- Texas Water Resources Institute (TWRI)
- Galveston Bay Estuary Program (GBEP)
- Texas Stream Team
- Lower Colorado River Authority (LCRA) Colorado River Watch Network
- Texas Ecological Restoration
- International Boundary and Water Commission (IBWC) – Environmental Management Division

Even those organizations that did not currently conduct groundwater quality monitoring were encouraged to answer just six of the survey questions that would still provide valuable information (i.e., their contact information, did they have a program, and what, if anything, was preventing them from doing groundwater quality monitoring).

It is significant to note that the survey responses did not capture all TGPC member groundwater regulatory programs (e.g., some of the TCEQ and Railroad Commission of Texas (RRC) monitoring, assessment, and remediation programs) due to internal data format and sharing limitations. These are the programs most likely to collect groundwater quality data on man-made (i.e., anthropogenic) and legacy chemicals, and these programs play a key role in monitoring for these types of contaminants. This absence of data may have affected the overall survey results and associated continuing research needs and recommendations.

The blank survey form, the original responses, and a user-friendly summary of those responses are available online[22].

Survey Results

There were 44 survey responses. Below are the 18 survey questions, summaries of the responses to each question, and corresponding recommendations, if appropriate. Note that questions followed by an asterisk (*) indicate those that required a response.

Questions 1 – 3 (Q1 – Q3) – Respondent contact information *

Responses to questions 1 – 3 (i.e., the respondent's name, email address, and phone number) are not included here, but they are available online[23].

Q4 – Respondent affiliation *

Summary – There were 14 responses from state and federal agencies and organizations, 17 from GCDs, four from researchers, three from water utilities, four from water organizations, and two other responses.

State and federal agencies and organizations:

- UTBEG
- TCEQ – four responses
- Texas Parks and Wildlife Department (TPWD) – two responses
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)
- U.S. Geological Survey (USGS)
- Texas State Soil and Water Conservation Board (TSSWCB)
- Texas Department of State Health Services (DSHS)
- TWDB – two responses
- Texas Department of Agriculture (TDA)

GCDs:

- Brush Country GCD
- Pecan Valley GCD
- Upper Trinity GCD
- Rolling Plains GCD

- Uvalde County Underground Water Conservation District (UWCD)
- Kenedy County GCD
- Panhandle GCD
- Duval County GCD
- Fayette County GCD – two responses
- North Plains GCD
- Post Oak Savannah GCD
- Barton Springs Edwards Aquifer Conservation District – two responses
- Gonzales County UWCD
- Real-Edwards Conservation and Reclamation District
- Edwards Aquifer Authority

Researchers:

- Texas A&M University – three responses
- Texas Water Resources Institute (TWRI)

Water Utilities:

- City of Houston Public Works
- Mustang Special Utility District (SUD)
- Austin Water (City of Austin) Balcones Canyonlands Preserve Program

Water Organizations:

- Colorado and Lavaca Rivers and Matagorda and Lavaca Bays Basin and Bay Area Stakeholder Committee (BBASC) and Region P Water Planning Group
- Texas A&M AgriLife Extension Service (AgriLife Extension) – Texas Well Owner Network (TWON)
- The Meadows Center for Water and the Environment (Meadows Center) – Texas Stream Team
- Meadows Center – Staff

Other (note: all responses to Other are listed verbatim):

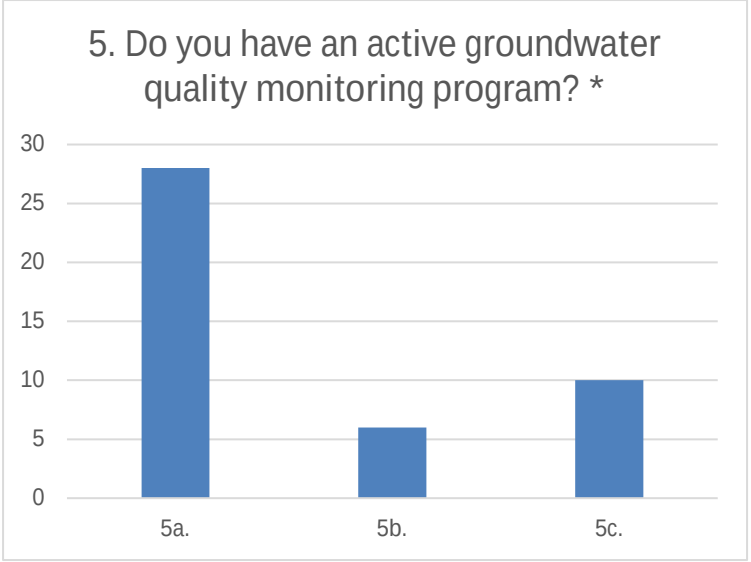
- Self
- Graphic Packaging International

Q5 – Do you have an active groundwater quality monitoring program? *

Note that percentages listed in the charts are rounded to the nearest whole number, thus sometimes resulting in a total that is not exactly 100%.

Summary – Twenty eight respondents had a program, six may/would have a program in the near future (August 2023 through the end of 2024), and 10 did not have a program (Figure 1). Specifically:

- The majority of TGPC members did not report having an active program;
- The majority of GCDs (14 of their 17 responses) indicated that they had an active program;
- None of the researchers that responded had an active program;
- The majority of water utilities that responded did not have an active program;
- The majority of water organizations that responded had an active program; and,
- Two other respondents reported having an active program.



5a. Yes (64%)

5b. Not currently (14%)

5c. No (23%)

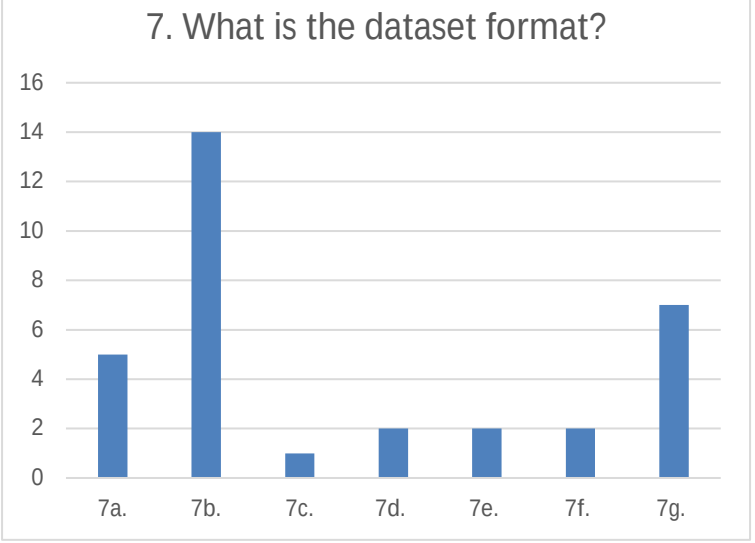
Figure 1. Survey responses to Question 5.

Q6 – What is the monitoring program and/or dataset name?

The responses are not included here, but they are available online[24].

Q7 – What is the dataset format?

Summary – Most of the datasets were in Microsoft Excel format (Figure 2).



7a. Hard copy (15%)
7b. Microsoft Excel (42%)
7c. Microsoft Access (3%)
7d. GIS geodatabase (6%)
7e. Oracle (6%)
7f. SQL server (6%)
7g. Other (21%)

Figure 2. Survey responses to Question 7.

Other (note: [square bracket text] added for acronym clarification):

- Lab results uploaded to database in pdf format
- Mix of hardcopy, excel, and geodatabase
- Halff Database
- HALFF database
- Access through NWIS [National Water Information System] web at present
- Hard copies and excel
- Aquarius Samples

Recommendation – Migrate hard copy datasets containing groundwater quality monitoring information to an electronic format, with Microsoft Excel being a popular and user-friendly application.

Q8 – Is the dataset available online?

Summary – Most of the datasets were not available online (Figure 3).

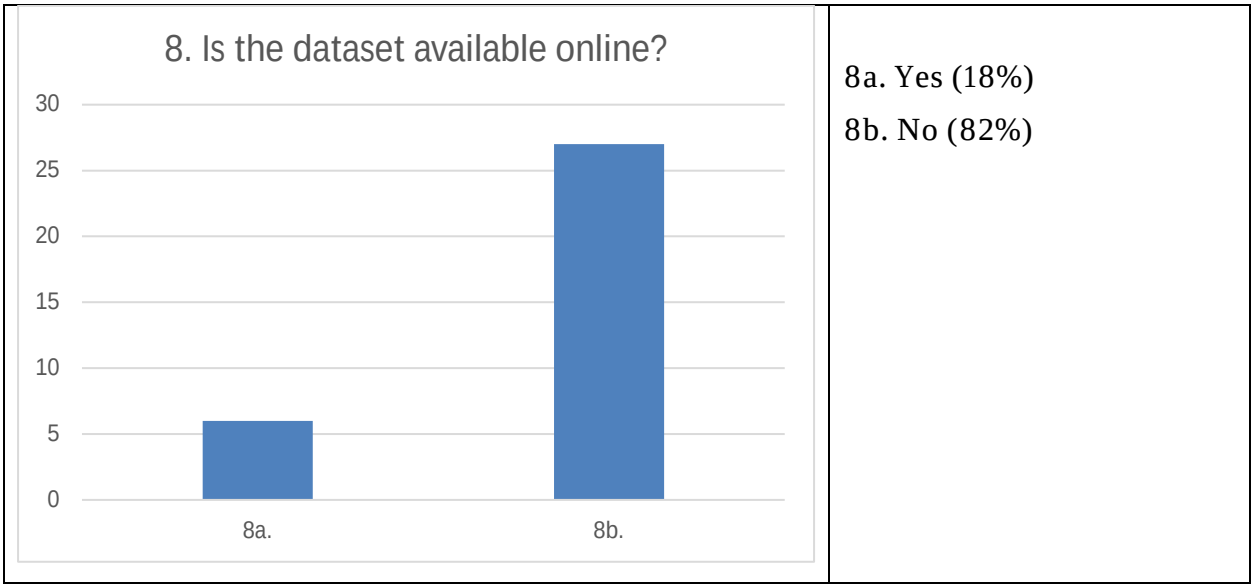


Figure 3. Survey responses to Question 8.

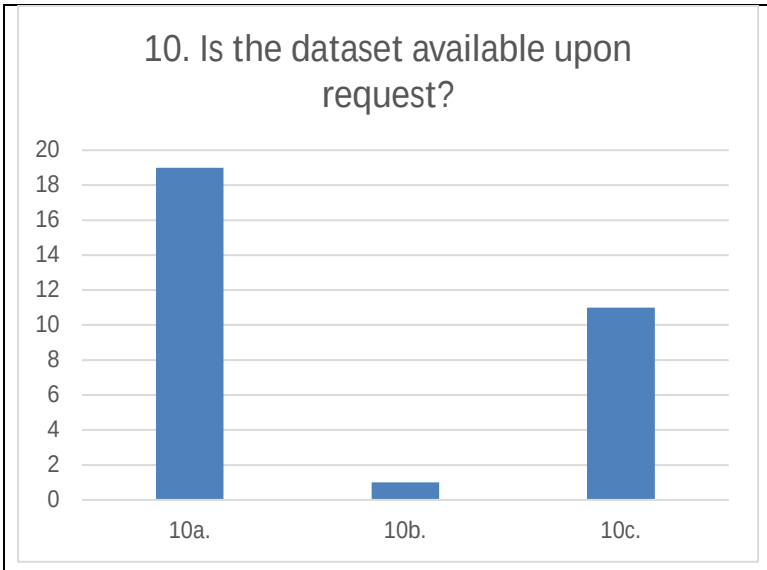
Recommendation – Provide public access to groundwater quality monitoring datasets in an online electronic format. In addition, submission of these datasets to TWDB is encouraged for integration into their GWDB which provides online public access to all of their groundwater quality monitoring datasets.

Q9 – What is the URL for the dataset?

The responses are not included here, but they are available online[25].

Q10 – Is the dataset available upon request?

Summary – Most of the datasets were available upon request (Figure 4).



10a. Yes (61%)

10b. No (3%)

10c. Partially (35%)

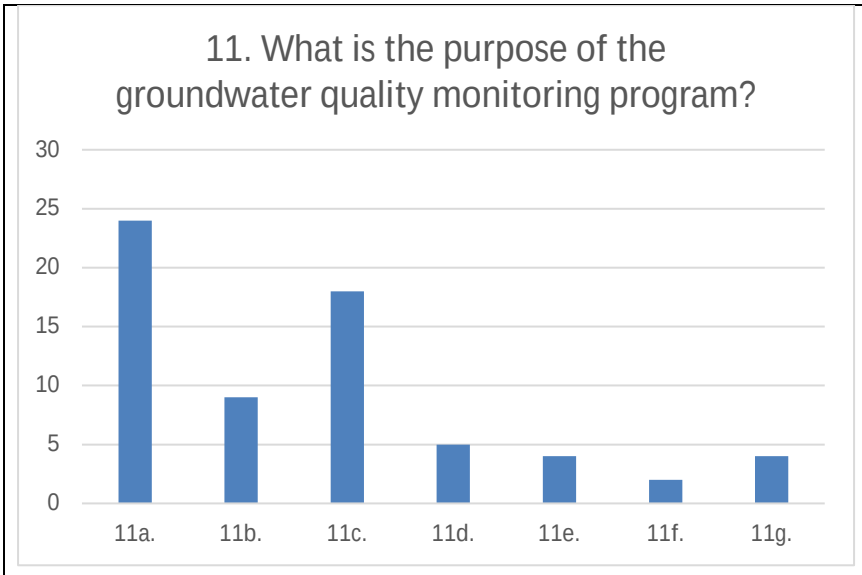
Figure 4. Survey responses to Question 10.

Recommendation – For groundwater quality monitoring datasets that are not (or are only partially) available upon request, redact sensitive information in order to provide public access to them in an online electronic format, or provide redacted datasets upon request. Note that, for groundwater quality data that is submitted electronically to TWDB for inclusion in their GWDB, sensitive information (e.g., location) can be kept confidential when necessary so that the non-confidential information can be made publicly available.

Q11 – What is the purpose of the groundwater quality monitoring program?

Note that questions 11 – 17 allowed multiple answers.

Summary – Most of the programs collected ambient (i.e., general, baseline, or background) data or were research-oriented (Figure 5). For GCDs, specifically, a little over half (11 of their 17 responses) indicated that they performed ambient monitoring, with fewer responses for public outreach and education (5), research (5), investigation (3), regulatory (2), post-disaster response (1), and other (2 – "possible contamination from oil/gas activity" and "monitoring changing conditions").



11a. Ambient (36%)

11b. Public outreach and education (14%)

11c. Research (27%)

11d. Investigation (8%)

11e. Regulatory (6%)

11f. Post-disaster response (3%)

11g. Other (6%)

Figure 5. Survey responses to Question 11.

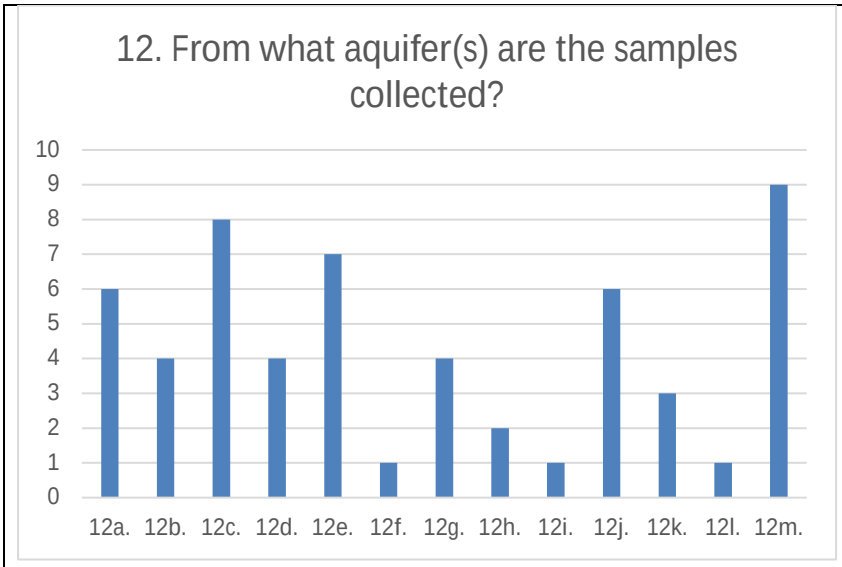
Other:

- FIFRA [Federal Insecticide, Fungicide, and Rodenticide Act] and 106 Groundwater PPG [Performance Partnership Grant] grants
- Possible contamination from oil/gas activity
- Monitoring Changing Conditions
- Evaluate management practices

Recommendation – None – the survey received responses from just six affiliation types; however, based on those responses, there appears to be an appropriate distribution of program purposes in the state.

Q12 – From what aquifer(s) are the samples collected?

Summary – Samples were collected from each of the nine major aquifers in the state, but mostly from the Edwards (Balcones Fault Zone), Gulf Coast, and Trinity Aquifers, and fewer samples were collected from the state's 22 minor aquifers (Figure 6).



12a. Every major/minor aquifer (11%)

12b. Carrizo-Wilcox (7%)

12c. Edwards (BFZ) (14%)

12d. Edwards-Trinity (Plateau) (7%)

12e. Gulf Coast (13%)

12f. Hueco-Mesilla Bolsons (2%)

12g. Ogallala (7%)

12h. Pecos Valley (4%)

12i. Seymour (2%)

12j. Trinity (11%)

12k. One or more minor aquifers (5%)

12l. Unknown (2%)

12m. Other (16%)

Figure 6. Survey responses to Question 12.

Other:

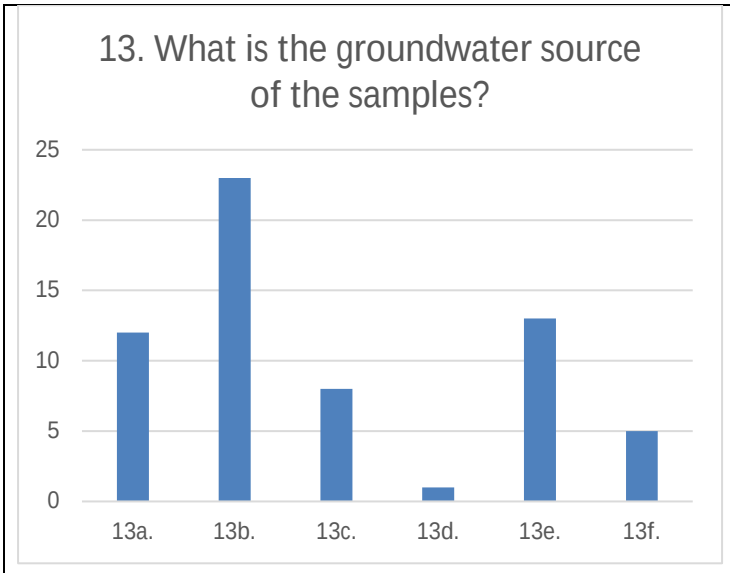
- Statewide
- Woodbine
- Dockum and Blaine/Whitehorse
- Multiple aquifers statewide (57 stations on spring/seep/artesian wells) – information available upon request
- One Dockum well is continually monitored
- Queen City, Sparta, Yegua-Jackson
- Maverick TBA [To Be Announced]

- Chicot
- Ellenburger-San Saba – the current program network is limited in scope, with plans to eventually expand the network into more aquifers

Recommendation – Continue groundwater quality monitoring in all of the state's major and minor aquifers, with expanded sampling of karst and minor aquifers.

Q13 – What is the groundwater source of the samples?

Summary – Private water wells were the most common source of the samples, with springs and Public Water Supply (PWS) wells also being important sources (Figure 7).



13a. Public water supply well (19%)

13b. Private water well (37%)

13c. Standard monitor well (13%)

13d. Multiport monitor well (2%)

13e. Spring (21%)

13f. Other (8%)

Figure 7. Survey responses to Question 13.

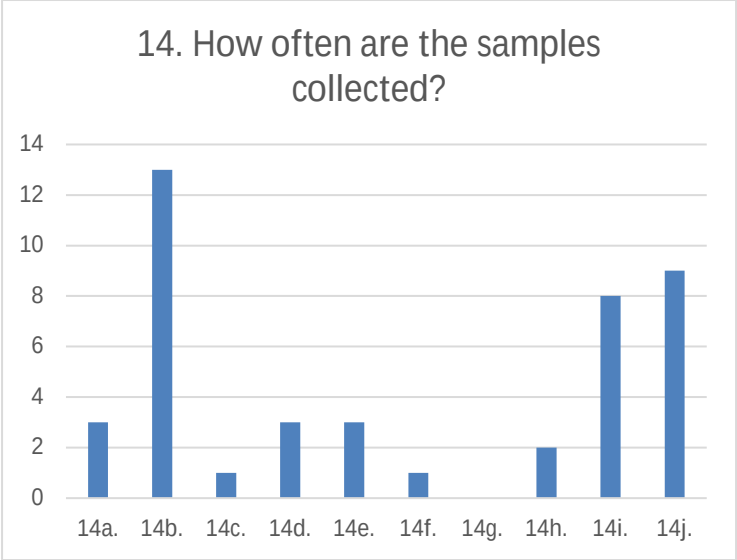
Other:

- Spring/seep/artesian wells
- Rainfall entering the Edwards aquifer
- Cave drip
- Household water supply sources
- Surrounding surface water features are used as needed to assist with discharge/flow rate measurement calculations

Recommendation – Install additional standard and multiport groundwater quality monitor wells across the state and add them to the NGWMN, if appropriate. Note that TWDB is a NGWMN data provider, and if the data from wells meeting the criteria for the NGWMN are shared with TWDB, they can add it to the NGWMN. Based on resource availability and a program's goals and scope, continuous (i.e., time-dense sampling and analysis) sensors and real-time online data access could also be considered.

Q14 – How often are the samples collected?

Summary – The majority of samples were collected annually, with other frequencies (e.g., as required) also being reported (Figure 8).



14a. Less frequently than annually (7%)

14b. Annually (30%)

14c. Twice per year (2%)

14d. Quarterly (7%)

14e. Monthly (7%)

14f. Weekly (2%)

14g. Daily (0%)

14h. Continuously (5%)

14i. As required (19%)

14j. Other (21%)

Figure 8. Survey responses to Question 14.

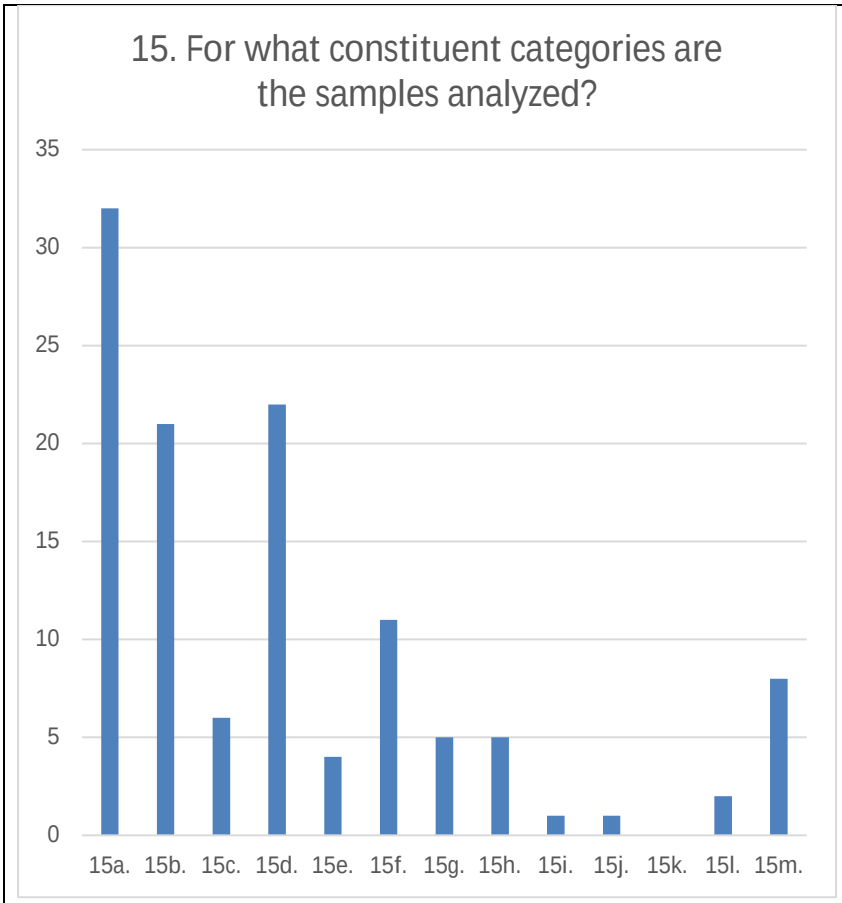
Other

- Triggered source monitoring per regulations
- Approximately every 5-7 years, as authorized by GCD Board
- Once
- Biennially
- Wells samples once for this study between 2013 and 2017
- Every two years
- Water Quality 1x year, Water Level 3x year
- Samples are collected annually from different parts of the state so that every major and minor aquifer is sampled once every four years. We collect additional limited sampling on an as-needed frequency for special studies or other needs as funds allow.
- Network springs are currently sampled annually; however, the scope of the program is being assessed and may change to a four year cycle, similar to our well sampling program, in order to maximize resources.

Recommendation – Collect ambient groundwater quality data more frequently if continuous monitoring is not available (or it is outside of the program's scope), with an annual or biannual (i.e., twice per year) sampling frequency being a reasonable goal for entities with convenient access to local sites, depending on the program's scope and resource availability. A one-size-fits-all approach is not appropriate for all programs, and sampling frequencies will depend on the program's scope, target constituents, and resources.

Q15 – For what constituent categories are the samples analyzed?

Summary – Field parameters (e.g., pH, temperature, conductivity, etc.) were collected with about a third of the groundwater samples, and inorganics and nutrients were the most common constituent categories for which the samples are analyzed, but no respondents reported analyzing their samples for microplastics or nanoplastics (Figure 9).



15a. Field parameters (27%)

15b. Nutrients (18%)

15c. Organics (5%)

15d. Inorganics (19%)

15e. Pesticides (3%)

15f. Microbes (9%)

15g. Radionuclides (4%)

15h. Stable isotopes (4%)

15i. Pharmaceuticals (1%)

15j. Water / wastewater treatment products (1%)

15k. Microplastics / nanoplastics (0%)

15l. Other specific legacy/emerging contaminants (2%)

15m. Other (7%)

Figure 9. Survey responses to Question 15.

Other:

- Sediment and Biological (habitat, macrobenthics, fish)
- Sulfates, Iron, Chloride
- PFAS
- Periphyton biomass and periphyton chlorophyll-a
- Optical brighteners

- Ions
- Isotopes are reserved for special studies. Pesticides are collected by TWDB staff as part of the TCEQ cooperative program; however analyses and results are paid for and stored in a database by TCEQ. Pesticides are not part of TWDB program and have not been selected here for the purposes of this survey. Radionuclides are collected from aquifers known to have naturally occurring material.
- Isotopes are usually collected when the spring is initially sampled only. Field parameters are collected each time a spring is visited in conjunction with the discharge/flow rate. Nutrients and inorganics are collected annually; however a recent program change was implemented where only field parameters were collected during repeat visits to network sites in order to maximize resources. This will be assessed going forward. Radionuclides are collected from aquifers where they are know to exist naturally. Pesticides are collected by TWDB staff as part of the TCEQ cooperative program; however analyses and results are paid for and stored in a database by TCEQ. Pesticides are not part of TWDB program and have not been selected here for the purposes of this survey.

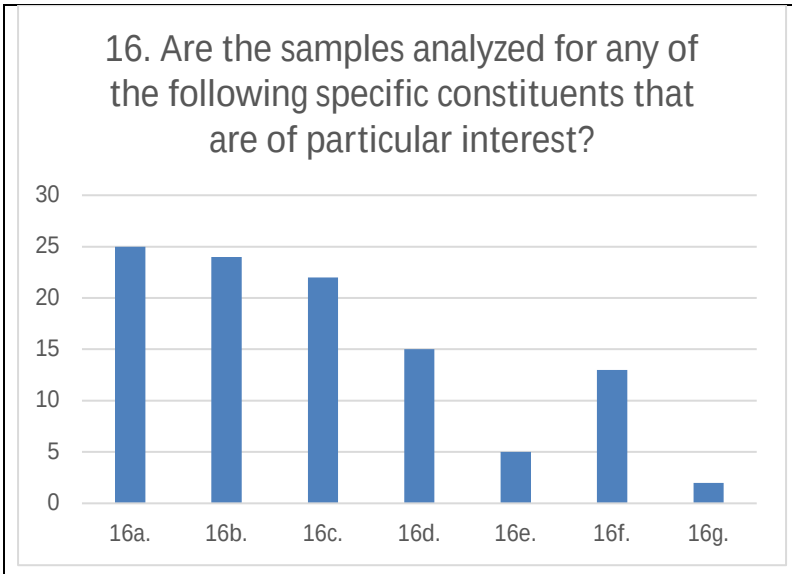
Note: For question 15, one respondent selected “Other specific legacy/emerging contaminants” but did not specify it in “Other”. However, their answer to question 16 indicates that it is PFAS.

Recommendations:

- Continue to collect field parameters, nutrient, and inorganic data from all of the state’s major and minor aquifers.
- Collect additional organic, pesticide, microbe, radionuclide, stable isotope, pharmaceutical, water/wastewater treatment product, and legacy/emerging contaminant data from all of the state’s major and minor aquifers.
- Collect microplastics/nanoplastics, 6PPD-q, and AMR data from all of the state’s major and minor aquifers because they are constituents/challenges of possible emerging interest.

Q16 – Drilling down into some of the categories in the previous question, are the samples analyzed for any of the following specific constituents that are of particular interest?

Summary – Samples were analyzed for all of the specific constituents of particular interest, but some analyses (e.g., conductivity, nitrate, and TDS) were more common than others (e.g., atrazine and PFAS) (Figure 10).



16a. Conductivity (24%)
16b. Nitrate (23%)
16c. TDS (21%)
16d. Arsenic (14%)
16e. Atrazine (5%)
16f. *E. coli* (12%)
16g. PFAS (2%)

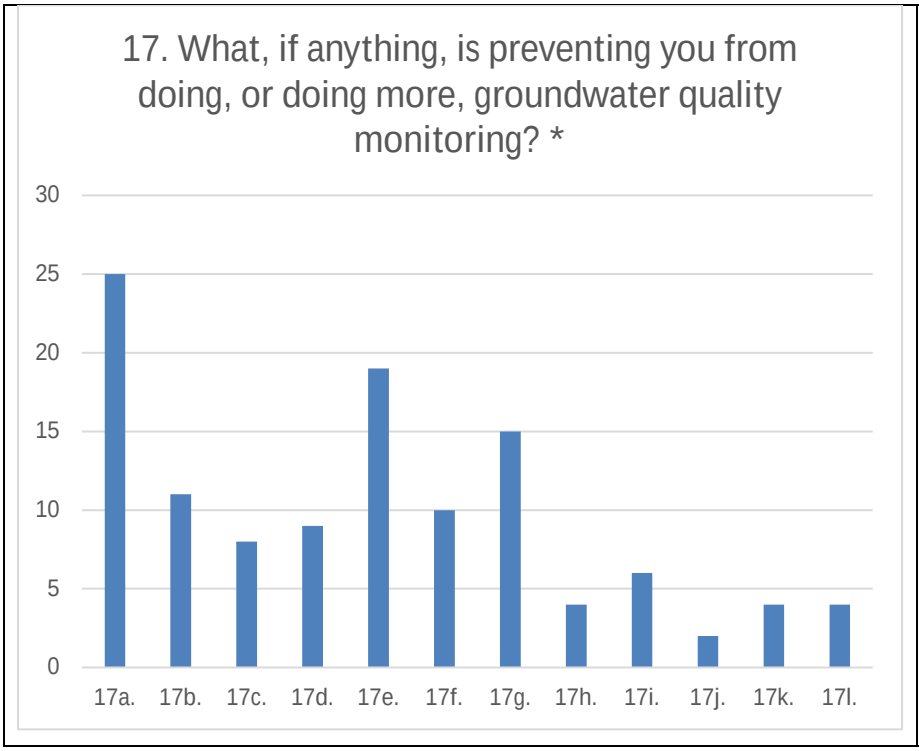
Figure 10. Survey responses to Question 16.

Recommendation – Continue to collect conductivity, nitrate, TDS, arsenic, *E. coli*, atrazine, and PFAS data on an expanded basis from all of the state's major and minor aquifers because they are constituents of particular interest.

Q17 – What, if anything, is preventing you from doing, or doing *more*, groundwater quality monitoring? That is, what are you lacking? *

Summary – The top three resources preventing respondents from doing, or doing more, groundwater quality monitoring were funding, staff, and time (Figure 11). However, for those that may/would have a program, or did not have a program, funding was the major resource that they were lacking. Specifically:

- Not all TGPC members responded, but those that did indicated that the resources they lacked the most were funding and staff, with the lack of approval or mandate also being reported;
- GCDs indicated that the resources they lacked the most were funding and equipment, with the cost of analyses and the lack of training, staff, access, and time also being reported;
- Researchers indicated that the resource they lacked the most was funding, with staff and access also being reported;
- Water utilities indicated that the resource they lacked the most was staff, with funding also being reported;
- Water organizations indicated that the resources they lacked the most were funding, staff, and time, with the cost of analyses and the lack of equipment, training, access, approval or mandate, and logistics also being reported; and,
- One other respondent indicated that the resources they lacked the most were time and logistics, and another indicated that their program was sufficient for their needs.



17a. Funding (21%)

17b. Analysis cost (9%)

17c. Equipment (7%)

17d. Training (8%)

17e. Staff (16%)

17f. Access (9%)

17g. Time (13%)

17h. Approval or mandate (3%)

17i. Logistics (5%)

17j. Unknown (2%)

17k. Not applicable (3%)

17l. Other (3%)

Figure 11. Survey responses to Question 17.

Other:

- It is not really within our committees' purview
- Project specific reasons
- A program has not been established
- N/A [Not Applicable] – We do not have a groundwater monitoring program as part of our federal mandate or mission

An additional analysis of question 17 compares the responses of those that A) have, B) may/will have, and C) do not have an active groundwater quality monitoring program.

Q17-A – For those that have a program, what was preventing them from doing more groundwater quality monitoring?

Summary – Similar to the overall response to question 17, a lack of funding, staff, and time were the top three resources preventing them from doing more monitoring (Figure 12).

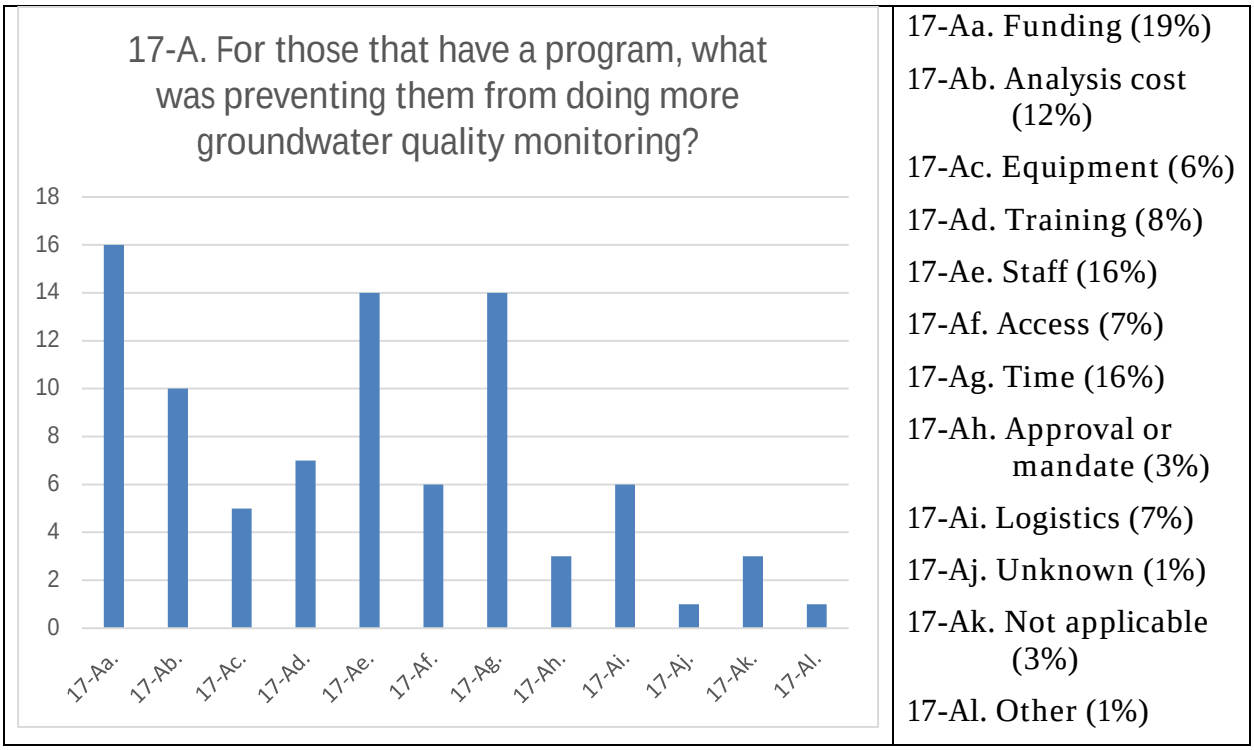


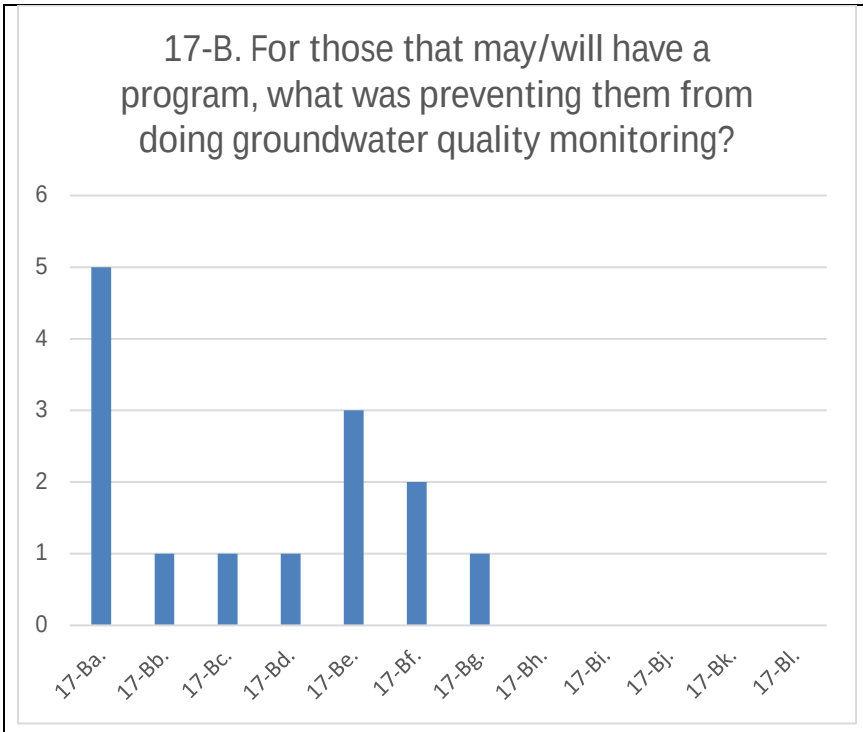
Figure 12. Survey responses to Question 17-A, a subset of responses from those that have a groundwater quality monitoring program.

Other:

- Project specific reasons

Q17-B – For those that may/will have a program, what was preventing them from doing groundwater quality monitoring?

Summary – A lack of funding was the major resource preventing them from doing groundwater quality monitoring followed by staff and access (Figure 13).



17-Ba. Funding (36%)

17-Bb. Analysis cost (7%)

17-Bc. Equipment (7%)

17-Bd. Training (7%)

17-Be. Staff (21%)

17-Bf. Access (14%)

17-Bg. Time (7%)

17-Bh. Approval or mandate (0%)

17-Bi. Logistics (0%)

17-Bj. Unknown (0%)

17-Bk. Not applicable (0%)

17-Bl. Other (0%)

Figure 13. Survey responses to Question 17-B, a subset of responses from those that may/will have a groundwater quality monitoring program.

Q17-C – For those that do not have a program, what was preventing them from doing groundwater quality monitoring?

Summary – A lack of funding was the major resource preventing them from doing groundwater quality monitoring followed by equipment, staff, and access (Figure 14).

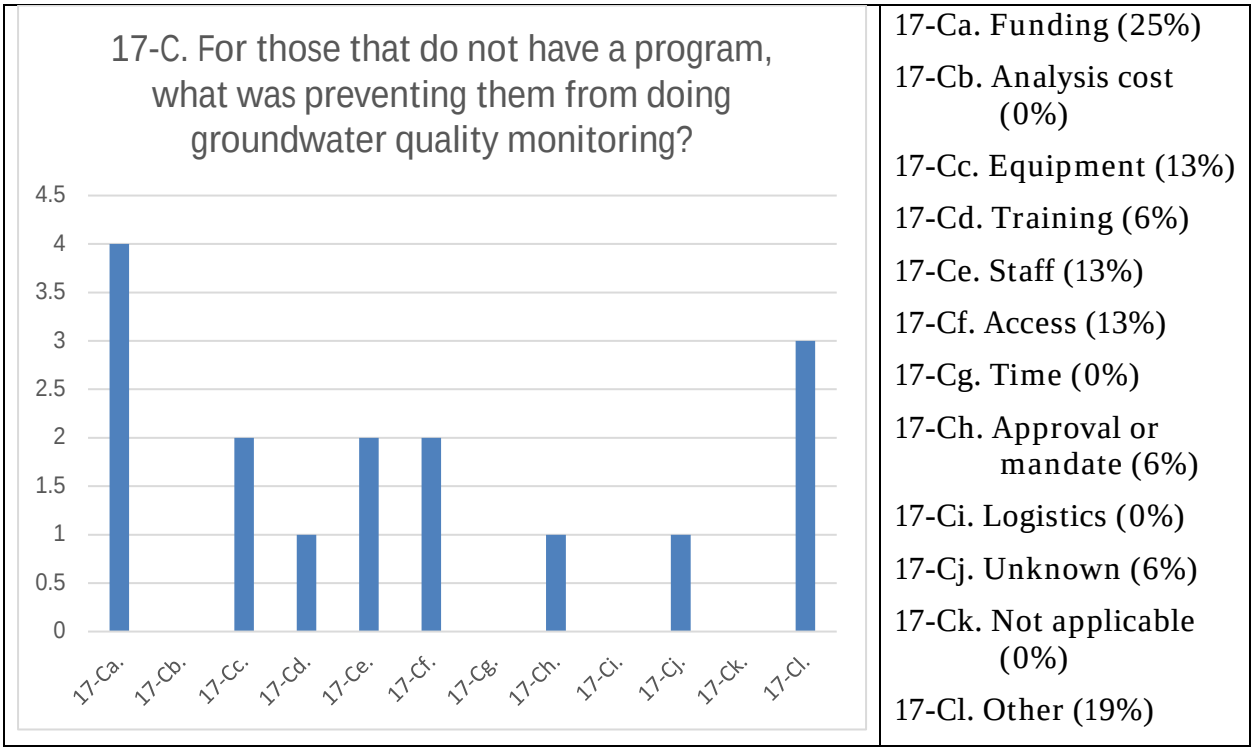


Figure 14. Survey responses to Question 17-C, a subset of responses from those that do not have a groundwater quality monitoring program.

Other:

- It is not really within our committees' purview
- A program has not been established
- N/A – We do not have a groundwater monitoring program as part of our federal mandate or mission

Recommendations:

- A lack of funding was the most common resource preventing respondents from doing, or doing more, groundwater quality monitoring. Obtain additional funding sources (e.g., legislative recommendations and requests, or grant applications) to provide for equipment, staff, analyses, and training.

- Staff was the next most cited resource lacked by respondents. Researchers, community scientists (e.g., Texas Master Naturalists), and trained volunteer water quality monitors, either statewide (e.g., Texas Stream Team) or local (e.g., LCRA Colorado River Watch Network), could assist those who have access to water wells and springs but not enough staff or time to collect groundwater quality data.
- According to respondents, the cost of groundwater quality analyses was another challenge. Investigate how to negotiate analyses costs with laboratories (i.e., economy of scale). Entities in the state with groundwater quality monitoring programs should collaborate and explore cost-sharing opportunities and resources.
- Some TGPC members have a legislative mandate to protect groundwater[26] (e.g., by conducting groundwater quality monitoring). TGPC members should investigate whether there are any gaps in their existing groundwater quality regulatory programs due the lack of a legislative mandate, and if so, make an appropriate recommendation in their next report to the Texas Legislature.

Q18 – Do you have any additional feedback or information to share related to this survey?

Note that responses to question 18 are listed verbatim.

- TCEQ Water Availability Division:
  - The IPD [Interagency Pesticide Database] database contains more than just the Cooperative Pesticide Monitoring data, much of it being USGS data available from their online database, as well as several other sources. The USGS data and TCEQ data are in a very different format that requires considerable effort and time to combine. The National Water Quality Monitoring Council's Methods and Data Comparability Board has been working to compare various databases and sources in an effort to develop a system that all sources can agree on and is more compatible with each other. Also, there are data qualifiers, especially for old data that had higher reporting and qualifier limits, and no Quality Assurance or Quality Controls, and may have some essential information or data missing. Other state's programs and data should be checked to see what they have already done with related data rather than reinventing the wheel, so to speak.
- Three separate researchers at Texas A&M University (one response each):
  - Accessing the TCEQ water quality records is challenging. The platform is not easy to navigate.
  - My lab analyzes PFAS, pharmaceutical and personal care products, and other organic molecules. I am interested in understanding them in groundwater but do not have access to a groundwater site.
  - The plan to collect samples for the coastal groundwater study starts Spring 2024.

- TCEQ Water Quality Planning Division:
  - Generally, groundwater samples are collected at the groundwater/surface water interface as part of a larger ambient surface water monitoring program. Samples may also be collected as part of special studies to determine possible effects of groundwater intrusion in surface waters.
- Fayette County GCD (two separate responses):
  - Our volunteer monitoring wells and the data from those wells are used to enhance knowledge of the aquifers underlying the Fayette County GCD and to monitor for any potential issues with those aquifers. Currently, the district samples 10-30 wells each year.
  - This study was conducted to mirror the 1965 county-wide water quality study by the TWDB. Analytical results indicated that there was no significate variation in water quality between the two studies.
- North Plains GCD:
  - Our district has 30 wells across the district that we take water quality samples from. We sample 15 each year, so all 30 are almost every two years. We also conduct water quality sampling for stakeholders, and that data is collected and kept in the district water quality database.
- USDA NRCS:
  - The USDA Natural Resources Conservation Service NRCS provides technical and financial assistance to the public through a network of more than 3,000 service centers in communities nationwide. It helps agricultural producers and other private landowners in implementing soil, water, and other natural resource conservation measures. NRCS relies on other Federal and State agencies to provide surface and ground water monitoring data.
- Austin Water (City of Austin) Balcones Canyonlands Preserve Program:
  - Water quality sampling is required for our federal Balcones Canyonlands Conservation Plan 1996 permit and provides evaluation of our management practices. However, since I am the only staff with extensive water quality education and experience, and am also program manager, we don't immediately analyze all of the data we collect.
- Gonzales County UWCD:
  - Gonzales County Underground Water Conservation District conducts Water Quality testing annually on 75-85 water wells in multiple formations. A PFD [PDF, Portable Document Format] copy of the reports is available here: https://gcuwcd.org/water-quality
- USGS:
  - Several aquifers monitored for various constituents but not necessarily on a consistent basis. Can pull information from NWIS web to see what may have been analyzed for GW [groundwater] in Texas.

- AgriLife Extension TWON:
  - TWON is an Extension [AgriLife Extension] educational program that covers the state of Texas and we work with private well owners. We do not have access to a set of wells to do our program more often.
- Meadows Center:
  - Texas Stream Team community science water quality monitoring program includes sampling at various springs across the state. https://www.meadowscenter.txst.edu/research/water-conservation/how-much-water-is-in-the-hill-country.html
- TWDB (two separate responses):
  - The TWDB Groundwater Database contains data collected both by TWDB and external entities/cooperators. The scope of cooperator monitoring programs and associated analytes they collect/areas they sample will differ from the TWDB program. For the purposes of this survey, we included information for the scope of the TWDB ambient groundwater monitoring program.
  - Most of the springs monitoring data we collect is uploaded and stored in the SQL server. However, our database does not currently have a field to capture spring discharge/flow rate information, which is currently stored in an excel file/hard copy field sheets and can be shared upon request. Plans are in progress to update the SQL server to incorporate discharge information.
- TDA:
  - TDA over the past decades has defaulted, either by choice or legislative mandate, to our sister agencies to monitor groundwater and report the results out which we might use. There is currently no movement to fund TDA or provide FTEs [Full Time Equivalents] for us to monitor any surface or groundwater. TDA expects the status quo for the foreseeable future.

Survey Lessons Learned

In hindsight, several aspects of the survey could be improved the next time it is conducted. Specifically:

- A question related to the dataset format (e.g., hard copy, Microsoft Excel, Microsoft Access, GIS geodatabase, Oracle, Microsoft SQL Server, and other) should allow multiple answers;
- Additional pilot testing would be beneficial; and,
- The introduction should clearly note that responses (including names and affiliations, but not including email addresses and phone numbers) would be compiled and posted online after the survey closed.

Several organizations also indicated that they were not prepared to respond to the survey in 2023, but after hearing about it, they would be taking a closer look at their program, or initiating a program, and they hoped to participate the next time a survey is offered.

Note that the survey responses did not capture all TGPC member groundwater regulatory programs (e.g., some of the TCEQ and RRC monitoring, assessment, and remediation programs). Reports submitted to these programs from responsible parties or contractors can contain some groundwater quality data, but it is project-specific, it is not already grouped together and organized into a shareable format (i.e., accessible online or able to be provided upon request), and it is not entered into any database – individual project managers would need to be contacted for access to this data. Future surveys should consider the best way to include this important source of additional groundwater quality information.

Continuing Research Needs

Below are applicable continuing research needs and recommendations suggested by the TGPC's academic organizations and other members. Note that the listed items are not ranked within each category.

Contaminants:

- Research manganese in groundwater (i.e., as a source of drinking water for both PWSs and private water wells).
- Research drinking water treatment (e.g., disinfection by-products) in PWSs and private water wells in the south-central U.S. and its impact on groundwater quality.
- Research groundwater quality (e.g., how widespread, how deep, and how distributed) and its impact on treatment options.
- Research the treatment and disposal of oil and gas produced water in relation to protecting groundwater quality.
- Research the disposal and impact of brine from brackish water treatment on groundwater quality.
- Collect groundwater quality data on arsenic in south Texas and the Permian Basin.
- Conduct research regarding the influence of OSSFs on PFAS in groundwater and nearby water wells.
- Develop a simple method for detecting PFAS in groundwater.
- Collect data on microplastics in groundwater.
- Map the location and concentration of a broad range of groundwater constituents across the state to allow comparisons of constituent changes over time.

- Review USGS National Water-Quality Assessment (NAWQA) groundwater quality data for Texas.
- Research additional groundwater quality in deep aquifers.
  - Note that TWDB currently collects and interprets groundwater TDS data as part of their BRACS program.
  - Note that RRC has a Groundwater Advisory Unit (GAU) dedicated to the identification, research, mapping, and protection of deep and remote aquifers during O&G operations in Texas, and the GAU also coordinates with various stakeholders (e.g., TWDB, GCDs, USGS, landowners, and O&G operators). The 2019 discovery of fresh groundwater in the deep Glen Rose Formation in southwest Texas is just one notable example. Groundwater quality data is also collected in support of the RRC P-13 permit program which allows operators of O&G wells to repurpose them into water wells and then transfer their ownership to a landowner.
- Develop a statewide water quality database and implement standardization and improved submission methods (e.g., Application Programming Interfaces (APIs)). Consider utilizing the existing TWDB GWDB as a platform for this need.

Surface Impacts:

- Research the impact of climate extremes (e.g., floods and droughts) on groundwater quality.
- Research the interaction of groundwater quality under the influence of surface water quality.

Water Wells:

- Conduct an updated comprehensive statewide survey of abandoned and deteriorated water wells to determine the scope and scale of the problem.
- Conduct studies related to the data collection and reporting of groundwater quality impacts from abandoned and deteriorated water wells.
- Determine the drivers of non-compliance of Community Water Systems (CWSs), including geogenic and anthropogenic sources particularly relevant to groundwater systems.
- Identify the communities that are vulnerable to contamination in their groundwater-supplied drinking water and whether they are protected.
- Conduct a survey of private water well owners and their needs related to groundwater quality.
- Consolidate municipal water well field (e.g., PWSs) quality data that is reported to TCEQ, facilitate the sharing of this data with TWDB and the co-located GCD, and make it available online.

- Sample multiport monitor wells to determine groundwater quality at different depths which could help with planning future water well placement and screening intervals, as well as understanding problems with water wells (e.g., a water well completed in the Pecos Valley Aquifer (which lies above the high-sulfate Dockum Aquifer) resulted in mixing of the groundwater and subsequent microbial corrosion of the well hardware).
- Obtain and maintain access to selected private water wells, as well as the resources and authority required to maintain them, to facilitate groundwater quality monitoring across the state.
- Based on evolving concerns for new water supply well sites and new chemicals of concern, prioritize existing or new sampling locations and analyses of target chemicals to inform potential water suppliers and consumers. These decisions should consider the past and current locations of the groundwater quality data that is available from TWDB's internal and external sources, and the TCEQ Texas Drinking Water Watch (DWW[27]), and relative to projected needs such as pertinent future water management strategies in the state's regional water plans[28].

Transboundary Aquifers:

See the TGPC white paper, *Transboundary Groundwater Resources along the Texas-Mexico Border*[29], for continuing research needs related to transboundary aquifers. In addition:

- Collaborate with Oklahoma regarding groundwater quality (e.g., radionuclides).
- Facilitate discussions about groundwater quality with neighboring states.
    - Note that New Mexico has a DWW program[30] similar to the Texas DWW program and municipal water well fields (e.g., PWSs) near the state border could be prioritized.
- For transboundary aquifers, facilitate groundwater quality data sharing between GCDs and the neighboring states and Mexico, perhaps via research consortiums and/or state or federal agencies.
- Develop a research program that investigates the risks and vulnerability of Texas' border aquifers that could be impacted by neighboring states/countries.
- Investigate marginalized communities with water wells along the border with Mexico and neighboring states.
    - This could be accomplished using downscale and accessible training and/or guidelines regarding groundwater quality testing, perhaps via direct mailings[31]. TWON, GCDs, and/or the state's agricultural extension offices could potentially provide this service.

ASR and MAR:

See the TGPC white paper, *Opportunities and Challenges in Aquifer Storage and Recovery*[32], for continuing research needs related to ASR.

Collaboration:

- Collaborate with the Association of State Drinking Water Administrators (ASDWA[33]), Western States Water Council (WSWC[34]), Texas Association of Regional Councils (TARC[35]), Non-governmental Organizations (NGOs), and Texas Rural Water Association (TRWA[36]) on groundwater quality issues.
- Use a common database repository to facilitate sharing information from academic groundwater quality research projects that are often site-specific (i.e., dependent on the site's unique geology, contamination, groundwater constituents, etc.). Consider utilizing the existing TWDB GWDB as a platform for this need.
- Collaborate with the TCEQ Financial, Managerial, and Technical (FMT) assistance program[37] to help PWSs and wastewater systems comply with regulations, prevent and address operational problems, deliver technical trainings, and perform consolidation or capacity assessments, or with the similar TWDB Water Utilities Technical Assistance Program (WUTAP[38]).
- Researchers could collaborate with the state's agricultural extension offices that exist in every county.
- Consolidate Regional Water Planning Group (RWPG) groundwater quality data relating to water management strategies for future unmet needs and make it available online as new water wells are installed. Note that submission of these datasets to TWDB is encouraged for integration into their GWDB which provides online public access to all of their groundwater quality monitoring datasets.

Outreach:

- Investigate the use of Proposition 6 funds for the Statewide Water Public Awareness Program "to educate residents of this state about water" (TWC 16.026(a)[39], relating to the statewide water public awareness program).
- Inform realtors of the resources available to share with new landowners regarding water well maintenance and that water well reports can be found in the TWDB Submitted Drillers Reports (SDR) Database[40]. Water well reports located in the SDR could increase the likelihood of landowners being notified of a contamination issue in the vicinity of their well.

Technology:

- Research USGS machine learning regarding groundwater quality.
- Research brush control in relation to groundwater quality.

Recommendations Based Directly on Survey Responses

Below are recommendations drawn directly from the data collected by the 2023 TGPC Groundwater Quality Monitoring Survey. Note that the listed items are not ranked within each category.

Dataset Format and Availability:

- Migrate hard copy datasets containing groundwater quality monitoring information to an electronic format (e.g., Microsoft Excel), redact sensitive information (if needed), and provide public access to it online or upon request. Note that redacted groundwater quality monitoring information submitted to TWDB in an electronic format can be integrated into their GWDB which provides online public access to all of their groundwater quality monitoring datasets.
- Investigate data format standardization methods to facilitate sharing and archiving.
- It is strongly recommended that groundwater quality data be submitted to TWDB in electronic format for inclusion in their GWDB as a state repository for groundwater data. The GWDB provides online public access to statewide groundwater quality monitoring datasets in addition to other groundwater data, and it is an existing database that is accessible to the public with resources in place to maintain operations and keep sensitive information confidential when necessary. Additionally, TWDB is a NGWMN data provider and can add submitted data to the NGWMN for qualifying monitoring sites.

Monitoring Purpose:

- No recommendation – the survey received responses from just six affiliation types; however, based on those responses, there appears to be an appropriate distribution of program purposes in the state.

Monitoring Locations and Sources:

- Continue groundwater quality monitoring in all of the state's major and minor aquifers, with expanded sampling of karst and minor aquifers.
- Install additional standard and multiport groundwater quality monitor wells across the state and add them to the NGWMN, if appropriate. Note that TWDB is a NGWMN data provider, and if the data from wells meeting the criteria for the NGWMN are shared with TWDB, they can add it to the NGWMN. Based on resource availability and a program's goals and scope, continuous (i.e., time-dense sampling and analysis) sensors and real-time online data access could also be considered.

Monitoring Frequency:

- Collect ambient groundwater quality data more frequently if continuous monitoring is not available (or it is outside of the program's scope), with an annual or biannual (i.e., twice per year) sampling frequency being a reasonable goal for entities with convenient access to local sites, depending on the program's scope and resource availability. A one-size-fits-all approach is not appropriate for all programs, and sampling frequencies will depend on the program's scope, target constituents, and resources.

Analytes and Analysis:

- Continue to collect field parameters, nutrient, and inorganic data from all of the state's major and minor aquifers.
- Collect additional organic, pesticide, microbe, radionuclide, stable isotope, pharmaceutical, water/wastewater treatment product, and legacy/emerging contaminant data from all of the state's major and minor aquifers.
- Collect microplastics/nanoplastics, 6PPD-q, and AMR data from all of the state's major and minor aquifers because they are constituents/challenges of possible emerging interest.
- Continue to collect conductivity, nitrate, TDS, arsenic, *E. coli*, atrazine, and PFAS data on an expanded basis from all of the state's major and minor aquifers because they are constituents of particular interest.

Monitors and Programs:

- A lack of funding was the most common resource preventing respondents from doing, or doing more, groundwater quality monitoring. Obtain additional funding sources (e.g., legislative recommendations and requests, or grant applications) to provide for equipment, staff, analyses, and training.
    - There should be clearly delineated funding mechanisms that allow for cost-sharing opportunities between state agencies and organizations and GCDs[41].
    - Establish long-term grant funding at a state agency or organization to be used for various groundwater quality protection projects performed by GCDs (e.g., plugging abandoned water wells, groundwater quality monitoring, installing standard and multiport monitor wells, groundwater quality data sharing, etc.).
    - Share resources and provide training to stakeholders on external grant funding opportunities for improvement to, management of, and collection and sharing of groundwater data (e.g., the NGWMN).
- Establish a formal tracking process for groundwater quality data provided by a GCD for an investigation or study such that the GCD is kept informed of the status and final results.

- Staff was the next most cited resource lacked by respondents. Researchers, community scientists (e.g., Texas Master Naturalists), and trained volunteer water quality monitors, either statewide (e.g., Texas Stream Team) or local (e.g., LCRA Colorado River Watch Network), could assist those who have access to water wells and springs but not enough staff or time to collect groundwater quality data.
    - Note that groundwater samples do not always need to be collected from wellheads or springs – some constituents (e.g., arsenic, fluoride, and radionuclides) are not affected by collection from an indoor faucet.
    - The Texas Stream Team, a statewide water quality monitoring community science program, is currently designed to train community scientists to sample water quality of surface water sites, only. With over 31 years in existence, this program has a wealth of data available to the public on the Texas Stream Team Waterways Dataviewer[42] that supports river protection across the state and numerous ongoing research endeavors. With additional research funding, the Texas Stream Team would have the opportunity to expand its community science activities to include groundwater quality monitoring of wells and surface water quality monitoring of springs and seeps.
    - The Meadows Center, a research center at Texas State University, performs groundwater quality monitoring across the state as part of numerous research projects to gain a better understanding of groundwater and surface water interactions. This valuable data could be catalogued and made available to interested parties by the Meadows Center's creation of a statewide database of water quality data that is collected by GCDs, USGS staff, and other professionals. Note that submission of these datasets to TWDB is encouraged for integration into their GWDB which provides online public access to all of their groundwater quality monitoring datasets.
    - Note that TWDB and TAGD have discussed potential GCD training opportunities (e.g., in the office, in the field, and recorded videos) on various topics, including groundwater quality sampling, with certifications once the training is completed. This type of effort could be extended and applied to community scientist trainings to ensure continuity of data collection standards.
- TWON[43] offers voluntary private water well screening events across the state. If this groundwater quality sampling data (e.g., total coliform, *E. coli*, nitrate-nitrogen, TDS, and/or arsenic) was aggregated and/or normalized (e.g., by county or aquifer), it could be made available upon request while still maintaining individual anonymity.
    - The TWON intake form could have a check box which would allow participants to "opt in" to sharing their data. If they checked the box, their data could be entered it into a database where analysis results would be aggregated and/or normalized (e.g., by county or aquifer, thus maintaining individual anonymity) and used only for research purposes by academia and state/federal agencies.
    - The TWON intake form could also ask for details about the source of the sample (e.g., the street location, well pump depth, county, etc.) so that researchers would know the specific aquifer that was sampled.

- Additionally, the TWON intake form could have a check box which would allow participants to "opt in" to allowing state agencies or other entities access to their property for future water well sampling and water quality testing events. If they checked the box, their contact information could be shared with these state agencies or other entities.

· According to survey respondents, the cost of groundwater quality analyses was another challenge. Investigate how to negotiate analyses costs with laboratories (i.e., economy of scale). Entities in the state with groundwater quality monitoring programs should collaborate and explore cost-sharing opportunities and resources.

· Some TGPC members have a legislative mandate to protect groundwater[44] (e.g., by conducting groundwater quality monitoring). TGPC members should investigate whether there are any gaps in their existing groundwater quality regulatory programs due the lack of a legislative mandate, and if so, make an appropriate recommendation in their next report to the Texas Legislature.

· For our transboundary aquifers, facilitate groundwater quality data sharing with New Mexico, Oklahoma, Arkansas, and Louisiana in the U.S., and with Chihuahua, Coahuila, Nuevo León, and Tamaulipas in Mexico.

Additional Recommendations

Below are several additional recommendations that emerged through the course of performing the survey and discussing the results.

Survey Frequency:

· Conducting this type of survey more frequently in the future, reviewing the results, and then making adaptive management decisions (e.g., changing the monitoring frequency, locations, and/or constituents sampled) by continuing outreach and coordination with survey participants would contribute to safeguarding the quality of groundwater in Texas. With a survey frequency of every five years being a reasonable goal, 2028 would be the target date for the next survey.

Comprehensive Statewide Groundwater Quality Report:

· The last state agency report to summarize both the naturally-occurring and the anthropogenic groundwater constituents found across Texas was published 35 years ago. In order to determine whether there any potential gaps in the effectiveness of existing groundwater monitoring and regulatory programs in the state, or any potential contaminants that are not being addressed by these programs, an updated comprehensive statewide groundwater quality report should be produced. Funding may be needed to contract out a report of this scope.

Small PWSs Groundwater Quality Data:

- When USGS started the NGWMN pilot program in 2009, TCEQ and TWDB initiated a joint project to share PWS "raw" water quality data from approximately 700 small PWSs that had one well providing the sole source of water. Most of TCEQ's sampling data is from PWS treated water, but these small PWSs are the exception. Resuming a similar joint project between TCEQ and TWDB could help make more of this data publicly available and easily accessible, and this data could also be shared with the NGWMN.

Private Water Well Testing:

- Provide for a fund and outreach program to assist private water well owners with general water quality testing on a prescriptive basis. Programs like those at TWDB are occasionally able to fit these requests into routine sampling activities, and TWON assists water well owners on a specified schedule – consider expanding this to a general fund that could assist private water well owners with sampling logistics and analytical fees. To receive assistance, the owner could be required to allow public release of their well sampling information and future access to stage agencies conducting water quality monitoring programs.

Conclusion

Maintaining and improving the quality of the state's aquifers is critically important to those that rely on groundwater, both now and in the future. Monitoring provides the data needed to make sound decisions and assists with protecting the quality of our groundwater resources. Based on the published literature review and discussion of the results of the 2023 TGPC Groundwater Quality Monitoring Survey, there are a number of options regarding groundwater quality monitoring that can close critical knowledge gaps, better detect emerging threats, track established constituents in Texas aquifers, and benefit many entities and projects across the state (e.g., ASR, Brackish Resources Aquifer Characterization System (BRACS), the beneficial use of oil and gas produced water, public and private water well placement and screening, etc.).

The 2023 TGPC Groundwater Quality Monitoring Survey accomplished its goal of gaining a better understanding of the various groundwater quality data collection efforts taking place across the state. High-level data gaps, monitoring needs, and collaboration opportunities learned through this survey include the desire for:

- An updated comprehensive statewide groundwater quality report;
- Funding for expanded sampling of all Texas aquifers (particularly karst and minor aquifers), additional constituents, new monitor wells, and laboratory analyses, as well as water quality testing by private water well owners;

- Coordination between state agencies/organizations, GCDs, and stakeholders to submit groundwater quality data to TWDB in electronic format for inclusion in their GWDB as a state repository for groundwater data available to the public; and,
- Increased information sharing between TGPC members and other organizations that have an interest in Texas groundwater, and between Texas, neighboring states, and Mexico related to transboundary aquifers.

One of the duties of the TGPC is to "study and recommend to the legislature groundwater protection programs for each area in which groundwater is not protected by current regulation" (TWC Title 2 Section 26.405(3)[45]). One of the goals of the TGPC GWI Subcommittee[46] is to support the intent of the *Texas Groundwater Protection Strategy*[47] "to assist in the determination of the effectiveness of existing regulatory programs and to identify potential groundwater contaminants not addressed by existing regulatory programs". This white paper is part of the TGPC's ongoing efforts to meet its statutory duties and goals.

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TGPC GWI Subcommittee

TGPC GWI Subcommittee members include, but are not limited to:

- Texas Commission of Environmental Quality (TCEQ);
- Texas Water Development Board (TWDB);
- Railroad Commission of Texas (RRC);
- Texas Department of State Health Services (DSHS);
- Texas Department of Agriculture (TDA);
- Texas State Soil and Water Conservation Board (TSSWCB);
- Texas Alliance of Groundwater Districts (TAGD);
- Texas A&M AgriLife Research (AgriLife Research);
- Bureau of Economic Geology of The University of Texas at Austin (UTBEG);
- Texas Department of Licensing and Regulation (TDLR);
- Texas Parks and Wildlife Department (TPWD);
- Texas Tech University (TTU);
- Texas A&M AgriLife Extension Service (AgriLife Extension);
- Meadows Center for Water and the Environment (Meadows Center); and,
- United States Geological Survey (USGS).

The primary goals of the TGPC GWI Subcommittee are to:

- Facilitate interagency communication for assessment programs addressing groundwater contamination;
- Coordinate and assist member agencies with monitoring programs for:
  - Ambient groundwater conditions;
  - Pesticides; and,
  - Emerging contaminants or constituents of concern;
- Support the intent of the *Texas Groundwater Protection Strategy* (https://www.tceq.texas.gov/downloads/groundwater/publications/as-188-texas-groundwater-protection-strategy.pdf) by:
  - Reviewing published data reports, and evaluating data independent of published reports, to assist in the determination of the effectiveness of existing regulatory programs and to identify potential groundwater contaminants not addressed by existing regulatory programs;
  - Developing recommendations for consideration by the TGPC to address potential groundwater contamination identified through monitoring and data review; and,

- Developing white papers on the groundwater issues listed in their biannual *Activity Plan* which summarize the best available scientific data on a specific groundwater issue, identify areas where there is insufficient scientific data to thoroughly assess the issue, evaluate the effectiveness of existing regulatory programs to address the issue, and provide recommendations or policy options to the TGPC regarding the issue.

The above recommendations or policy options represent the opinion of the TGPC GWI Subcommittee and do not necessarily reflect the views and policies of each participating organization. The United States Geological Survey (USGS) may have contributed scientific information, only.

For more information about this white paper, please contact the TGPC (https://tgpc.texas.gov/contact-us/).

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