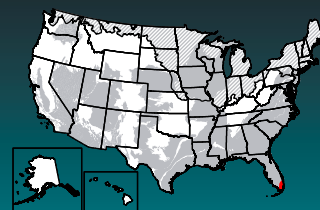


National Water Quality Program
National Water-Quality Assessment Project

Groundwater Quality in the Biscayne Aquifer, Florida



Groundwater provides nearly 50 percent of the Nation's drinking water. To help protect this vital resource, the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Project assesses groundwater quality in aquifers that are important sources of drinking water (Burow and Belitz, 2014). The Biscayne aquifer constitutes one of the important aquifers being evaluated.

Background

The Biscayne aquifer underlies an area of about 4,000 square miles in southeastern Florida. About 4 million people live in this area, and the Biscayne aquifer is the primary source of drinking water with about 700 million gallons per day (Mgal/d) withdrawn for public supply in 2000 (Maupin and Barber, 2005; Arnold and others, 2020a). The study area for the Biscayne aquifer underlies much of Broward and Miami-Dade Counties in southeastern Florida and includes the cities of Miami and Fort Lauderdale. Most of the area overlying the aquifer is developed and consists of about 63 percent urban and 9 percent agricultural land use. The remaining area (28 percent) is undeveloped (Homer and others, 2015).

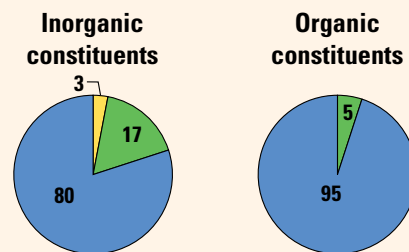
The Biscayne aquifer is an unconfined, surficial aquifer made up of shallow, highly permeable limestone as well as some sandstone units (Miller, 1990). Because of the shallow depth of the units that make up this aquifer, the connection to surface water is an important aspect of the hydrogeology of the Biscayne aquifer (Miller, 1990). A system of canals and levees are used to manage the freshwater resources of southern Florida. The system conserves freshwater, provides flood control, and minimizes saltwater encroachment in the aquifer along the coast (Miller, 1990). Recharge to the aquifer is from drainage of surface water from canals and from infiltration of rainfall (Miller, 1990), and groundwater generally flows from west to east, discharging in the Atlantic Ocean. Where large withdrawals occur, flow directions have been changed (Miller, 1990).

Groundwater quality in the Biscayne aquifer was evaluated by sampling 40 public-supply wells randomly distributed in an equal area grid. Water-quality data collected from wells in a network designed in this way are representative of the spatial distribution of the water quality in the study area (Belitz and others, 2010). Results from these wells were used to estimate the percentage of the study area with

concentrations that are high, moderate, and low with respect to constituent benchmarks. The accuracy of the estimates depends upon the distribution and number of wells, not on the size of the area (Belitz and others, 2010). The wells range from about 20 to 150 feet (ft) deep with an average depth of about 91 ft. Samples were collected between June and September of 2016, and the samples were analyzed for a large number of natural and man-made constituents.



Overview of Water Quality



CONSTITUENT CONCENTRATIONS

● High ● Moderate ● Low or not detected

Values are a percentage of the study area with concentrations in the three specified categories. Percentages might not sum to 100 because of rounding.

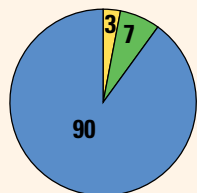
Principal Aquifer Studies (Burow and Belitz, 2014) are designed to evaluate untreated groundwater used for public supply. Groundwater quality is assessed by comparing concentrations to benchmarks established for drinking-water quality. Benchmarks and definitions of high, moderate, and low relative concentrations are discussed in the inset box on page 3.

Many inorganic constituents are present naturally in groundwater; however, concentrations can be affected by human activities. One or more inorganic constituents with human-health benchmarks were present at high concentrations in about 3 percent of the study area and at moderate concentrations in about 17 percent.

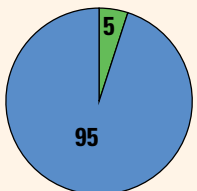
Man-made organic constituents are found in products used in the home, business, industry, and agriculture. Organic constituents can enter the environment through normal use, spills, or improper disposal; however, they were detected infrequently, and concentrations were typically low. One or more organic constituents with human-health benchmarks were detected at moderate concentrations in about 5 percent of the study area, and none were detected at high concentrations.

Results: Groundwater Quality at the Depth Zone Used for Public Supply in the Biscayne Aquifer

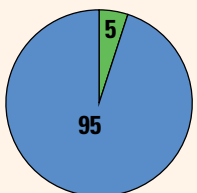
INORGANIC CONSTITUENTS



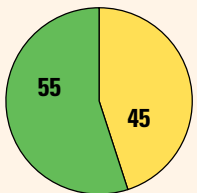
Trace elements and major and minor ions



Radioactive constituents



Nutrients



Constituents with non-health benchmarks

Inorganic Constituents With Human-Health Benchmarks

Trace elements and major and minor ions are naturally present in the minerals of rocks, soils, and sediments and in the water that comes into contact with those materials. Samples were analyzed for 34 trace elements and major and minor ions, of which 22 have human-health benchmarks (health-based screening level [HBSL] benchmarks were updated in 2018 to include aluminum, cobalt, and iron). Strontium was the only inorganic constituent detected at high and moderate concentrations in about 3 and 7 percent of the study area (the depth zone used for public supply), respectively.

Radioactivity is the release of energy or energetic particles during the spontaneous decay of unstable atoms, and humans are continuously exposed to small amounts of natural radioactivity. Most of the radioactivity in groundwater comes from the decay chain of naturally occurring isotopes of uranium and thorium. Samples were analyzed for eight radioactive constituents, of which four have human-health benchmarks. Radioactive constituents were present at moderate levels in about 5 percent of the study area. The sum of radium-226 and radium-228 were the only radiochemical constituents detected at moderate concentrations.

Nutrients are naturally present at low concentrations in groundwater; high and moderate concentrations (relative to human-health benchmarks) generally are a result of human activities. Samples were analyzed for five nutrients, of which two (nitrate and nitrite) have human-health benchmarks. Common sources of nutrients, aside from soils, include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. Nitrate was present at moderate concentrations in 5 percent of the study area.

Inorganic Constituents and Field Measurements With Non-Health Benchmarks

(Not included in water-quality overview charts shown on the front page)

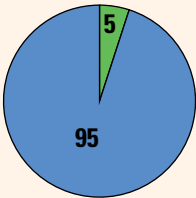
Some constituents affect the aesthetic properties of water, such as taste, color, and odor, or can create nuisance problems, such as staining and scaling. The benchmarks used for these constituents are non-regulatory secondary maximum contaminant level (SMCL) benchmarks established for public drinking water. Some constituents such as manganese have both human-health benchmarks and SMCLs. Samples were analyzed for 11 constituents that have SMCLs. One or more of these constituents were present at high concentrations in about 45 percent of the study area and at moderate concentrations in about 55 percent.

Total dissolved solids (TDS) concentration is a measure of the salinity of the groundwater based primarily on the concentrations of ions, and all water naturally contains TDS because of the weathering and dissolution of minerals in rocks and sediments. Total dissolved solids concentrations can be high because of natural factors or human activities such as road salting and some agricultural activities. Total dissolved solids were present at moderate concentrations relative to the SMCL throughout the study area.

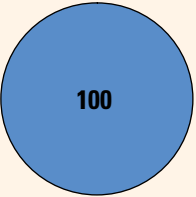
Anoxic conditions in groundwater (low concentrations of dissolved oxygen) can result in the release of naturally occurring iron and manganese from minerals into groundwater. Iron was present at high concentrations relative to the SMCL in about 45 percent of the study area and at moderate concentrations in about 13 percent.

Results: Groundwater Quality at the Depth Zone Used for Public Supply in the Biscayne Aquifer

ORGANIC CONSTITUENTS



VOCs



Pesticides

Volatile Organic Compounds With Human-Health Benchmarks

Volatile organic compounds (VOCs) are present in many household, commercial, industrial, and agricultural products and are characterized by their tendency to volatilize (evaporate) into the air. Samples were analyzed for 85 VOCs, of which 51 have human-health benchmarks. Volatile organic compounds were not detected at high concentrations; however, vinyl chloride was detected at moderate concentrations in about 5 percent of the study area.

Pesticides With Human-Health Benchmarks

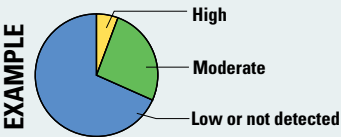
Pesticides, including herbicides, insecticides, and fungicides, are applied to crops, gardens and lawns, around buildings, and along roadways to help control unwanted vegetation (weeds), insects, fungi, and other pests. Samples were analyzed for 225 pesticide compounds (pesticides and their breakdown products), of which 119 have human-health benchmarks. Pesticide compounds were detected at low concentrations throughout most of the study area, but no concentrations were moderate or high relative to human-health benchmarks.

BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

The USGS NAWQA Project uses benchmarks established for drinking water to provide context for evaluating the quality of untreated groundwater. The quality of water received by customers may be different from results presented herein because after withdrawal, groundwater may be treated prior to delivery. Federal regulatory benchmarks for protecting human health are used for this evaluation of water quality when available. Otherwise, non-regulatory human-health benchmarks and non-regulatory aesthetic benchmarks are used. Not all analyzed constituents have associated benchmarks and thus are not considered in this context. Human-health benchmarks are available for 28 of 55 inorganic constituents and properties and 170 of 310 organic constituents.

Concentrations are considered high if they are greater than a human-health benchmark (Norman and others, 2018) or SMCL. For inorganic constituents, concentrations are moderate if they are greater than one-half of a benchmark. For organic constituents, concentrations are moderate if they are greater than one-tenth of a benchmark; this lower threshold was used because organic constituents are generally less prevalent and have smaller concentrations relative to benchmarks than inorganic constituents (Toccalino and others, 2004).

PERCENTAGE OF STUDY AREA



Values are a percentage of the study area with concentrations in the three specified categories. Percentages might not sum to 100 because of rounding.

Benchmark Type and Value for Selected Constituents

This table presents benchmarks for those constituents detected at high concentrations in the Biscayne aquifer. Benchmark types are regulatory U.S. Environmental Protection Agency (EPA) maximum contaminant levels (MCLs), non-regulatory health-based screening levels (HBSLs), and non-regulatory EPA secondary maximum contaminant levels (SMCLs).

[ppb, part per billion (ppb) or microgram per liter (µg/L); ppm, part per million (ppm) or milligram per liter (mg/L); pCi/L, picocurie per liter]

Constituent	Benchmark	
	Type	Value
Strontium	HBSL	4,000 ppb
Iron	SMCL	300 ppb

Moderate to High Iron Concentrations Were Common

Although most of the wells sampled for this study were less than 150 ft deep, concentrations of anthropogenic contaminants were low relative to available human-health benchmarks. However, all of the sampled wells in this study had a detection of at least one organic constituent, indicating the aquifer is vulnerable to contamination. These results are similar to previous studies (McPherson and others, 2000; Bradner and others, 2005). Overall, few constituent concentrations were high relative to human-health benchmarks. Iron and TDS concentrations were moderate to high relative to their SMCLs. Concentrations of TDS were moderate throughout the study area. Iron concentrations tended to be low in the extreme northern and southern parts of the study area, but moderate to high concentrations were measured throughout the study area. Elevated concentrations of iron and dissolved organic carbon (Miller, 1990) are indicative of reducing conditions, which may play a role in keeping nitrate concentrations low in this relatively shallow aquifer because of denitrification.

By James A. Kingsbury

REFERENCES CITED

- Arnold, T.L., Bexfield, L.M., Musgrove, M., Erickson, M.L., Kingsbury, J.A., Degnan, J.R., Tesoriero, A.J., Kulongoski, J.T., and Belitz, K., 2020a, Groundwater-quality and select quality-control data from the National Water-Quality Assessment Project, January through December 2016, and previously unpublished data from 2013 to 2015: U.S. Geological Survey Data Series 1124, 135 p., <https://doi.org/10.3133/ds1124>.
- Arnold, T.L., Sharpe, J.B., Bexfield, L.M., Musgrove, M., Erickson, M.L., Kingsbury, J.A., Degnan, J.R., Tesoriero, A.J., Kulongoski, J.T., and Belitz, K., 2020b, Datasets from groundwater-quality and select quality-control data from the National Water-Quality Assessment Project, January through December 2016, and previously unpublished data from 2013 to 2015: U.S. Geological Survey data release, <https://doi.org/10.5066/P9W4RR74>.
- Belitz, K., Jurgens B., Landon, M.K., Fram, M.S., and Johnson, T., 2010, Estimation of aquifer scale proportion using equal area grids: Assessment of regional scale groundwater quality: Water Resources Research., v. 46, 14 p., <https://doi.org/10.1029/2010WR009321>.
- Bradner, A., McPherson, B.F., Miller, R.L., Kish, G., and Bernard, B., 2005, Quality of ground water in the Biscayne aquifer in Miami-Dade, Broward, and Palm Beach Counties, Florida, 1996–1998, with emphasis on contaminants: U.S. Geological Survey Open-File Report, 2004–1438, 20 p., <https://doi.org/10.3133/ofr20041438>.
- Burow, K.R., and Belitz, K., 2014, Groundwater studies—Principal aquifer surveys: U.S. Geological Survey Fact Sheet 2014–3024, 2 p., <https://doi.org/10.3133/fs20143024>.
- DeSimone, L.A., McMahon, P.B., and Rosen, M.R., 2014, The quality of our Nation's waters—Water quality in principal aquifers of the United States, 1991–2010: U.S. Geological Survey Circular 1360, 151 p., <https://doi.org/10.3133/cir1360>.
- Homer, C., Dewitz, J., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N., Wickham, J., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States—Representing a decade of land cover change information: Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345–354.
- Maupin, M.A., and Barber, N.L., 2005, Estimated withdrawals from principal aquifers in the United States, 2000: U.S. Geological Survey Circular 1279, 46 p., <https://doi.org/10.3133/cir1279>.
- McPherson, B.F., Miller, R.L., Haag, K.H., and Bradner, A., 2000, Water quality in southern Florida; Florida, 1996–98: U.S. Geological Survey Circular 1207, 32 p., <https://doi.org/10.3133/cir1207>.
- Miller, J.A., 1990, Ground water atlas of the United States—segment 6, Alabama, Florida, Georgia, and South Carolina: U.S. Geological Survey Hydrologic Atlas no. HA-730G, accessed December 12, 2017, at <http://pubs.er.usgs.gov/publication/ha730G>.
- Norman, J.E., Toccalino, P.L., Morman, S.A., 2018, Health-based screening levels for evaluating water-quality data (2d ed.): U.S. Geological Survey National Water-Quality Assessment Program web page, <https://doi.org/10.5066/F71C1TWP>.
- Toccalino, P.L., Norman, J.E., Phillips, R.H., Kauffman, L.J., Stackelberg, P.E., Nowell, L.H., Krietzman, S.J., and Post, G.B., 2004, Application of health-based screening levels to ground-water quality data in a state-scale pilot effort: U.S. Geological Survey Scientific Investigations Report 2004–5174, 64 p., <https://doi.org/10.3133/sir20045174>.

Principal Aquifer Studies

The USGS NAWQA Project has been assessing the quality of groundwater since 1991. The NAWQA studies include Land Use Studies (LUS), Major Aquifer Studies (MAS), and Principal Aquifer Studies (PAS). These three study types are based on the sampling of networks of wells distributed across an area of interest. The LUS networks typically consist of observation wells that are relatively shallow; MAS networks typically consist of domestic-supply wells that are intermediate in depth; and PAS networks typically consist of public-supply wells that are relatively deep. A national synthesis of shallow and intermediate depth groundwater quality was reported by DeSimone and others (2014). This fact sheet provides a summary of PAS data for 40 public-supply wells sampled in 2016 in the Biscayne aquifer principal aquifer (data available in Arnold and others, 2020b).

The PAS assessments like this one allow for the comparison of constituent concentrations in untreated groundwater with benchmarks established for the protection of human health and for aesthetic qualities for drinking water and provide a basis for comparison of groundwater quality among principal aquifers.

The data collected by the NAWQA Project include chemical analyses generally not available as part of regulatory compliance monitoring, including measurements at concentrations much lower than human-health benchmarks and measurement of constituents that can be used to trace the sources and movement of groundwater.

For more information

Technical reports and hydrologic data collected for the USGS NAWQA Project may be obtained from

NAWQA Chief Scientist
U.S. Geological Survey
12201 Sunrise Valley Drive, MS 413
Reston, VA 20192-0002
Email: nawqapublicinfo@usgs.gov
WEB: <https://water.usgs.gov/nawqa/>

ISSN 2327-6916 (print)
ISSN 2327-6932 (online)
<https://doi.org/10.3133/fs20193056>

