An Overview of Ground Water Quality in Ohio
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**L1. Introduction**


Ground water protection programs for Ohio are briefly summarized in Section L2 as required by Section 106(e) of the Clean Water Act. Programs to monitor, evaluate and protect ground water resources are implemented by various state, federal and local agencies. Ohio EPA is the designated agency for monitoring and evaluating ground water quality and assessing ground water contamination problems. Within Ohio EPA, these functions are shared among the Divisions of Drinking and Ground Waters (DDAGW), Materials and Waste Management (DMWM), Environmental Response and Revitalization (DERR), and Surface Water (DSW). Short program descriptions are provided with links to program-based web pages to provide the most current information.

Ohio’s three major aquifer types are described briefly in Section L3. Where possible, the water quality data are associated with major aquifer types. The aquifer descriptions allow the reader to associate water quality with geologic settings.

Section L4 summarizes major sources of ground water contamination in Ohio. These data were obtained from various sources including:

- Potential contaminant sources inventoried as part of Ohio EPA – DDAGW’s Source Water Assessment and Protection (SWAP) program;
- Underground injection control sites identified in Ohio EPA – DDAGW and Ohio Department of Natural Resources (ODNR) – Division of Oil and Gas Resource Management databases;
- Leaking and formerly leaking underground storage tanks from Ohio Department of Commerce – Division of Fire Marshal’s Bureau of Underground Storage Tank Regulations (BUSTR) databases;
- Federal databases listing Department of Development/Department of Energy (DOD/DOE) facilities and National Priorities List/Comprehensive Environmental Response, Compensation and Liability Act (NPL/CERCLA) sites; and
- Resource Conservation and Recovery Act (RCRA) Corrective Action sites with ground water contamination in Ohio obtained from the U.S. EPA RCRA Info Database.

In many instances, these data are not associated with the geologic setting of the impacted aquifer, so statewide summaries are provided.

Section L5 summarizes ground water quality by parameter within Ohio’s major aquifers. Two primary data sets are used in this analysis: the drinking water compliance data for public water systems; and the Ambient Ground Water Quality Monitoring Program (AGWQMP) data. The public water system compliance data represents treated (post-processing) water distributed to the public. AGWQMP is an Ohio EPA - DDAGW program created to monitor raw (untreated) ground water. The goal is to collect, maintain and analyze raw ground water quality data to measure long-term changes in the water quality of major aquifer systems. Since Ohio does not have statewide ground water quality standards, comparisons to primary maximum contaminant levels (MCLs), secondary maximum contaminant levels (SMCLs), health advisory levels (HALs), action levels (lead and copper) and drinking water health advisory levels were applied.

Section L6 presents conclusions and recommendations for future direction concerning statewide ground water monitoring and protection of Ohio’s major aquifers.
L2. Ohio’s Ground Water Protection Programs

State Coordinating Committee on Ground Water — The State Coordinating Committee on Ground Water (SCCGW) was created in 1992 by the directors of the state agencies that have ground water program responsibilities. The purpose is to promote and guide the implementation of coordinated, comprehensive and effective ground water protection and management programs for Ohio. The SCCGW is composed of ground water technical or management staff from seven state agencies, two federal agencies and The Ohio State University Extension office. Information about the SCCGW bi-monthly meetings and meeting summaries are available on the SCCGW website: epa.ohio.gov/ddagw/SCCGW.aspx.

Ohio Ground Water Protection Programs — Programs to monitor, evaluate and protect ground water resources in Ohio are administered by federal, state and local agencies. Ohio EPA is the designated state ground water quality management agency. The ODNR - Division of Water Resources is responsible for evaluation of the quantity of ground water resources. Ground water-related activities at the state level are also conducted by the Ohio Departments of Agriculture, Commerce (Division of State Fire Marshal), Health and Transportation. The United States Geological Survey (USGS), Ohio Water Science Center, contributes to these efforts with water resource research. Table L-1 (based on Table 5-2, U.S. EPA 305(b) Guidelines, 1997) summarizes agencies responsible for administering the various ground water programs in Ohio.

Program Websites

ODA - Ohio Department of Agriculture

ODH - Ohio Department of Health

ODNR - Ohio Department of Natural Resources (ohiodnr.gov/)
- Division of Water Resources — water.ohiodnr.gov/
- Division of Mineral Resources — minerals.ohiodnr.gov/
- Division of Oil and Gas Resources — oilandgas.ohiodnr.gov/
- Division of Geologic Survey — geosurvey.ohiodnr.gov/

Ohio EPA - Ohio Environmental Protection Agency (epa.ohio.gov)
- Division of Drinking and Ground Waters — epa.ohio.gov/ddagw/
- Division of Surface Water — epa.ohio.gov/dsw/
- Division of Environmental and Financial Assistance — epa.ohio.gov/defa/
- Office of Compliance Assistance and Pollution Prevention — epa.ohio.gov/ocapp/
- Division of Materials and Waste Management — epa.ohio.gov/dmwm/
- Division of Environmental Response and Revitalization — epa.ohio.gov/derr/

OWRC – Ohio Water Resource Council (epa.ohio.gov/dsw/owrc.aspx)

SCCGW – State Coordinating Committee on Ground Water (epa.ohio.gov/ddagw/SCCGW.aspx)
Table L-1 — Summary of Ohio groundwater protection programs.

<table>
<thead>
<tr>
<th>Programs or Activities</th>
<th>State Activity</th>
<th>Implementation Status*</th>
<th>Responsible Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active SARA Title III Program</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DERR</td>
</tr>
<tr>
<td>Ambient Ground Water Monitoring Program</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DDAGW</td>
</tr>
<tr>
<td>Aquifer vulnerability assessment</td>
<td>✓</td>
<td>CE</td>
<td>ODNR – DWR</td>
</tr>
<tr>
<td>Aquifer mapping</td>
<td>✓</td>
<td>CE</td>
<td>ODNR – DWR</td>
</tr>
<tr>
<td>Aquifer characterization</td>
<td>✓</td>
<td>CE</td>
<td>ODNR – DWR</td>
</tr>
<tr>
<td>Ground water best management practices</td>
<td>✓</td>
<td>E</td>
<td>ODNR; ODA</td>
</tr>
<tr>
<td>Ground water legislation</td>
<td>✓</td>
<td>UR*</td>
<td>All Agencies</td>
</tr>
<tr>
<td>Ground water classification</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA; ODNR</td>
</tr>
<tr>
<td>Ground water quality standards (program specific)</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA</td>
</tr>
<tr>
<td>Ground water quality investigations</td>
<td>✓</td>
<td>CE</td>
<td>Ohio EPA DDAGW</td>
</tr>
<tr>
<td>Interagency coordination for ground water protection initiatives</td>
<td>✓</td>
<td>E</td>
<td>SCCGW</td>
</tr>
<tr>
<td>Nonpoint source controls</td>
<td>✓</td>
<td>CE</td>
<td>ODA; Ohio EPA; ODNR</td>
</tr>
<tr>
<td>Pesticide State Management Plan</td>
<td>✓</td>
<td>E</td>
<td>ODA</td>
</tr>
<tr>
<td>Pollution Prevention Program</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DEFA (OCAPP)</td>
</tr>
<tr>
<td>Resource Conservation and Recovery Act (RCRA) Primacy</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DERR</td>
</tr>
<tr>
<td>Source Water Assessment Program</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DDAGW</td>
</tr>
<tr>
<td>State Property Clean-up Programs</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DERR</td>
</tr>
<tr>
<td>Susceptibility assessment for drinking water/wellhead protection</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DDAGW</td>
</tr>
<tr>
<td>State septic system regulations</td>
<td>✓</td>
<td>E</td>
<td>ODH; Ohio EPA</td>
</tr>
<tr>
<td>Underground storage tank installation requirements</td>
<td>✓</td>
<td>E</td>
<td>SFM/BUSTR</td>
</tr>
<tr>
<td>Underground Storage Tank Remediation Fund</td>
<td>✓</td>
<td>E</td>
<td>SFM/BUSTR</td>
</tr>
<tr>
<td>Underground Storage Tank Permit Program</td>
<td>✓</td>
<td>E</td>
<td>SFM/BUSTR</td>
</tr>
<tr>
<td>Underground Injection Control Program</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DDAGW; ODNR – DMRM</td>
</tr>
<tr>
<td>Well abandonment regulations</td>
<td>✓</td>
<td>E</td>
<td>ODH; Ohio EPA – DDAGW; ODNR</td>
</tr>
<tr>
<td>Wellhead Protection Program (EPA-approved)</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA – DDAGW</td>
</tr>
<tr>
<td>Well installation regulations</td>
<td>✓</td>
<td>E</td>
<td>Ohio EPA; ODH</td>
</tr>
</tbody>
</table>

* Table Notes: E = Established; CE = Continuing Effort; UD = Under Development; UR = Under Revision
* Rules are required to be reviewed every five years by state statute.
* Established through program-specific classifications.
* Standards are program-specific.
* ODA received cooperative commitment from other Ohio agencies for the Generic Pesticide Management Plan. The requirement for Specific Pesticide Management Plan was dropped.
* The updated Household Sewage Treatment Systems Rules became effective on Jan. 1, 2015 (Ohio Revised Code (ORC) Chapter 3718 and Ohio Administrative Code Chapter 3701-29). Larger systems are regulated by Ohio EPA under separate regulations.
* Remediation funds are available from the Petroleum Underground Storage Tank Release Compensation Fund.
* Ohio EPA regulates Class I and V injection wells; ODNR regulates Class II and III injection wells.
* Revised guidance for sealing wells was completed March 2015 by SCCGW workgroup: Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes.
* Wellhead Protection Program has evolved to the Source Water Protection Program.
* Technical Guidance for Well Construction and Ground Water Protection prepared by SCCGW (2000). Private Water System rules (OAC 3701-28) are in the process of being updated. Water Well Standards (OAC 3745-7) for public water systems were last revised in 2016.
L3. Ohio’s Major Aquifers

Introduction
Ohio has abundant surface and ground water resources. Average rainfall ranges between 30 and 44 inches/year (increasing from northwest to southeast), which drives healthy stream flows. Infiltration of a small portion of this rainfall (3-16 inches) recharges the aquifers and keeps the streams flowing between rains. Ohio’s aquifers can be divided into three major types as illustrated in Figure L-1. The sand and gravel buried valley aquifers (in blue) are distributed through the state. The valleys filled by these sands and gravels are cut into sandstone and shale in the eastern half of the state (in tans) and into carbonate aquifers (in greens) in the western half. The buried valley aquifers are productive aquifers. The sandstone and carbonate aquifers generally provide sufficient production for water wells except where dominated by shale, as in southwest and southeast Ohio. An Ohio EPA report, *Major Aquifers in Ohio and Associated Water Quality* (2015), provides more detailed descriptions of these aquifers.

![Figure L-1 — Aquifer Types in Ohio modified from ODNR Glacial and Bedrock Aquifer Maps (ODNR, 2000; water.ohiodnr.gov/maps/statewide-aquifer-maps).](image)

Characterizing Aquifers
In a continuing effort to characterize ground water quality for the professional/technical community and the public, Ohio EPA-DDAGW is writing technical reports and fact sheets on the distribution of specific parameters in Ohio. The goal of the technical reports is to provide water quality information from the major aquifers, indicate areas with elevated concentrations and identify geologic and geochemical controls. This information is useful for assessing local ground water quality, water resource planning and evaluating areas where specific water treatment may be necessary. A series of parallel fact sheets targeted for the public provide basic information on the distribution of the selected parameters in ground water. The information in the fact sheets is presented in a less technical format, addresses health effects, outlines treatment options and provides links to additional information.
### Table L-2 — Ground water contamination summary.
Hydrogeologic Setting: Statewide Data Reporting Period: As of August 2019

<table>
<thead>
<tr>
<th>Source Type</th>
<th>Number of sites</th>
<th>Number of sites that are listed and/or have confirmed releases</th>
<th>Number of sites with confirmed ground water contamination</th>
<th>Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPL - U.S. EPA</td>
<td>38 proposed</td>
<td>30</td>
<td>30</td>
<td>Mostly VOCs and heavy metals; also, SVOCs, PCBs, PAHs and others</td>
</tr>
<tr>
<td>CERCLIS (non-NPL) - U.S. EPA</td>
<td>411</td>
<td>411</td>
<td>20</td>
<td>Varied</td>
</tr>
<tr>
<td>DOD/DOE</td>
<td>129&lt;sup&gt;a&lt;/sup&gt;</td>
<td>72</td>
<td>68</td>
<td>Varied</td>
</tr>
<tr>
<td>LUST</td>
<td>34,992&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4,133</td>
<td>206</td>
<td>VOCs, heavy metals, PCBs and others</td>
</tr>
<tr>
<td>RCRA Corrective Action</td>
<td>254</td>
<td>206</td>
<td>206</td>
<td>Varied GW Impacts</td>
</tr>
<tr>
<td>Underground Injection</td>
<td>Class&lt;sup&gt;c&lt;/sup&gt;: I-17 II – 417 III – 48 IV – 6 V – 61,276</td>
<td>0 0 0 19,493</td>
<td>0 0 0 19,493</td>
<td>Varied GW Impacts</td>
</tr>
<tr>
<td>State Sites&lt;sup&gt;e&lt;/sup&gt;</td>
<td>776</td>
<td>776</td>
<td>264&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Varied GW Impacts</td>
</tr>
<tr>
<td>Nonpoint Sources</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

Notes: NA - Numbers not available
<sup>a</sup> Includes DOE, DOD, FUSRAP and FUD sites
<sup>b</sup> Includes only active LUST sites - Source: Ohio’s State Fire Marshal, BUSTR
<sup>c</sup> Sites in Tier 2 or Tier 3 cleanup stages. Source: Ohio’s State Fire Marshal, BUSTR
<sup>d</sup> Class I and V injection wells are regulated by Ohio EPA. Class II and Class III injection wells are regulated by the Ohio Department of Natural Resources, Division of Oil and Gas Resources. Class IV injection wells are illegal in Ohio, except where approved as part of a remediation plan.
<sup>e</sup> Facilities in Ohio EPA’s ground water impacts database
<sup>f</sup> A site is considered to be contaminating ground water if the Uppermost Aquifer or Lower Aquifer is noted to be impacted, as documented in Ohio EPA’s Ground Water Impacts database.

**Federal National Priorities List (NPL):** Currently, 38 sites in Ohio are on the NPL, most of which (30) have been found to be affecting ground water quality. The primary contaminants are volatile organic compounds (VOCs) and heavy metals. Other contaminants include semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

**Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) (non-NPL):** Ohio has 411 sites in the federal CERCLIS database.

**DOD/DOE:** The 129 sites on this list are the Department of Defense (DOD)/Department of Energy (DOE) sites in Ohio, including those that are Formerly Used Defense Sites (FUDS) and Formerly Utilized Sites Remedial Action Program (FUSRAP) sites. Of these, 68 have had confirmed releases to ground water.

**Leaking Underground Storage Tanks (LUST):** In Ohio, underground storage tanks (USTs) are under the jurisdiction of the State Fire Marshal, Bureau of Underground Storage Tank Regulation (BUSTR). Current data indicates that approximately 35,000 sites have been found to be leaking. Of these, 4,133 have confirmed releases, with 111 having a release to ground water. The primary contaminants are the petroleum products of benzene, toluene, ethyl benzene and xylenes.

**RCRA Corrective Action:** Currently, 254 facilities are in RCRA corrective action. Of these, 206 have confirmed releases to ground water. The primary contaminants are VOCs and heavy metals. This information was obtained from the U.S. EPA RCRA Info Database.
**Underground Injection:** There are five classes of underground injection wells:

- Class I wells inject hazardous wastes or other wastewaters beneath the lowermost aquifer;
- Class II wells inject brines and other fluids associated with oil and gas production beneath the lowermost aquifer;
- Class III wells inject fluids associated with solution mining of minerals beneath the lowermost aquifer;
- Class IV wells inject hazardous or radioactive wastes into or above aquifers (these wells are banned unless authorized under a federal or state ground water remediation project);
- Class V wells comprise all injection wells not included in Classes I-IV;
- Class VI wells are regulated by U.S. EPA for carbon sequestration.

The Ohio Department of Natural Resources, Division of Oil and Gas Resources Management regulates Class II (417) and Class III (48) injection wells. There has been an increase in the number of Class II disposal wells (one of three types of Class II wells in Ohio) permitted, drilled, and operated since 2017. In addition to the 223 active Class II Disposal wells there are 18 wells that are between the permitted and active stage. The other types of Class II wells include 125 enhanced recovery wells and 69 annular disposal wells.

Ohio EPA DDAGW regulates Class I (17), Class IV (6) and Class V (61,276) wells. Although owners and operators of Class V wells are required to register or permit their wells, there are still many that are unknown and unregistered throughout the state.

**State Sites:** State sites include landfills, RCRA-regulated hazardous waste facilities, unregulated sites (pre-RCRA) and sites investigated through the Voluntary Action Program (VAP). Ground water contamination summary information concerning many of these sites is tracked in the ground water impacts database, maintained by Ohio EPA-DDAGW. The database consists of sites with verified contaminant release to ground water. As of August 2017, the database contained 776 sites. Of the 776 sites, 264 have affected ground water quality within the uppermost aquifer or lower aquifer. This database is deprecated but is consulted to investigate documented ground water impacts.

**L4. Major Sources of Ground Water Contamination**

Data show much of Ohio’s ground water is of high quality and has not been widely influenced by anthropogenic activities, but individual cases of contamination are documented every year from point (site-specific locations) and nonpoint sources. Ohio has a diverse economy and the state uses and produces a range of potential contaminants applied, stored and disposed of in various land use practices. Consequently, ground water quality is susceptible to contamination from a range of substances and a variety of land use activities. From a statewide perspective, major sources are discussed below.

The major sources of ground water contamination in Ohio are indicated in Table L-3 (Table 5-1, U.S. EPA 1997) by checks (✔). These data were obtained from two main sources: Ohio’s Source Water Assessment and Protection (SWAP) program and DDAGW’s ground water impacts database (deprecated). The SWAP program has completed an inventory of the potential sources of ground water contamination in the delineated Drinking Water Source Protection Areas. This inventory is updated when the SWAP delineation is revised, for example, when new wells are approved. Of the active public water systems that use ground water, 99 percent have had an inventory conducted, an analysis of the aquifer’s susceptibility to contamination completed and a determination of whether the ground water quality has been impacted by anthropogenic activities. The ground water impacts database provides information regarding sites where contamination of ground water has been confirmed. These data were evaluated and those sources of highest concern were given a check mark (✔) in Table L-3.
Some of the potentially high priority sources, indicated by (✓), were selected based on professional knowledge of the types of sources that exist in Ohio. These sources, such as animal feedlots and mining, are limited in their extent, or are concentrated in regions of the state and may not be sited close to public water system well fields. Thus, they do not rank in the highest priority sources. However, where they are prevalent, these sources may be a threat to local ground water resources, especially in areas with sensitive hydrogeologic settings. Land use activities within sensitive areas have a greater potential of affecting ground water quality.

**Contaminant Source Discussion** - All sources listed in Table L-3 are potential contaminant sources in Ohio and each may cause ground water quality impacts at a local scale. The sources identified as highest priority or potentially high priority are listed below in the order presented in Table L-3 and discussed briefly to provide additional information.

(✓) **Highest Priority Sources**

**Fertilizer Applications:** Improper use and handling of fertilizers, manure and biosolids can cause ground water pollution. Human and animal biosolids used as fertilizer and chemical fertilizers contribute to nitrate contamination in ground water. Nitrates in ground water represent one of the better examples of the widespread distribution of nonpoint source pollution. Non-agricultural sources, such as lawn fertilization, sludge application and septic systems also contribute to localized nitrate ground water contamination. Public water systems utilizing sand and gravel aquifers have higher average nitrate levels than public water systems using sandstone and carbonate aquifers, primarily due to the higher vulnerability of unconsolidated aquifers and the shallower nature of the sand and gravel aquifers.

**Storage Tanks (Underground and Above-ground):** There are 5,312 USTs known to be leaking or undergoing remediation in Ohio. Of these, 1,321 are in drinking water source protection areas for public water systems using ground water. Above-ground tanks are also prevalent throughout Ohio, with 1,225 located in drinking water source protection areas for public water systems using ground water. Many of these are smaller tanks used to store fuel oil for heating individual homes and many are old and rusty with no containment in the event of a leak or spill. Leaking above-ground storage tanks (ASTs) from commercial and industrial facilities are less of an issue, although catastrophic failure can create significant pollution problems to both ground water and surface water. There are only 14 ASTs in the (deprecated) ground water impacts database known to be contaminating ground water from regulated hazardous waste facilities.

**Landfills:** Currently, there are 130 landfills with documented ground water contamination in Ohio. This constitutes 50 percent of the sites known to be affecting ground water quality based on information in Ohio EPA’s (deprecated) ground water impacts database. Most likely, these are from older, unlined landfills (many of which are closed) or construction and demolition debris landfills (C&DD) with limited construction standards. The current siting, design and construction standards for landfills are more stringent than 20 years ago, resulting in new landfills with significantly lower potential to impact ground water quality. Efforts to monitor C&DD landfills and characterize associated ground water quality impacts were initiated in 2015.

**Septic Systems:** More than 1,000,000 household wastewater systems, primarily septic tanks and leach fields, or in some cases injection wells, are present throughout the rural and unsewered suburban areas of Ohio. A number of these systems are improperly located, poorly constructed or inadequately maintained and may cause bacterial and chemical contamination of ground water which may supply water to nearby wells. Improperly operated and maintained septic systems are considered significant
contributors to elevated nitrate levels in ground water in vulnerable geologic settings (for example, shallow fractured bedrock and sand and gravel deposits). More than 1,960 septic systems are in drinking water source protection areas. There are 220 septic systems discharging to surface water and 1,740 systems discharging to tanks, leachfields/mounds. The updated Household Sewage Treatment Systems Rules became effective on Jan. 1, 2015 (Ohio Revised Code Chapter 3718 and Ohio Administrative Code 3701-29) and should help correct deficiencies of failing septic systems.

**Shallow Injection Wells:** Class V injection wells are widespread throughout the state. Ohio EPA has records for 61,276 Class V wells. The bulk of these (over 40,000) are reported to be closed and abandoned. Of the identified wells, the majority are mine backfill wells used to inject grout into deep mines underneath roadways. The next largest segment of Class V wells (16,459) are used to inject fluids to assist in remediating contaminated aquifers. The last major segment of Class V wells are storm drainage wells. The fact that these wells are used to inject fluids directly into vulnerable aquifers in the State is the main cause for concern. These shallow injection wells provide a direct pathway for nonpoint source contamination and illegal waste disposal into vulnerable aquifers.

**Hazardous Waste Sites:** Ohio generates a large amount of hazardous waste. Legacy hazardous waste sites are a serious threat to ground water. There are 76 RCRA hazardous waste facilities, 18 Voluntary Action Program sites and 62 unregulated hazardous waste remediation sites (pre-1980) with documented releases to ground water (uppermost or lower aquifer) based on the ground water impacts database.

**Pipelines and Sewer Lines:** Pipelines and sewer lines all have potential for failure with release of the transported material. In addition, the construction of these lines, with the pipe embedded in permeable material, allows the trench to provide rapid flow paths for other surface contaminants. This is especially true if the trench is dug into fractured bedrock. Numerous gas, oil and industrial pipelines (1,145) and sewer lines (819) have been inventoried in drinking water source water protection areas.

**Salt Storage and Road Salting:** The widespread use of salt or mixtures of salt and sand for deicing roads has been documented as a nonpoint source contributor of sodium and chloride contamination of shallow ground water (Jones and Sroka 1997; Mullaney et al. 2009). Spreading of salt on roads certainly contributes to ground water quality impacts, but the greatest local impact is associated with salt storage. Seventy-six salt storage piles were identified directly in drinking water source protection areas with 47 of these located in sensitive aquifer settings. One hundred and twenty-four are within one-half mile of a source water protection area and 79 are within a half-mile of a designated sensitive aquifer. Most of these sites had adequate covering and pads. In addition to addressing these sites, Ohio is exploring ways to encourage implementation of best management practices for proper salt storage. Alternative chemicals like acetate-based deicers in combination with reduced salt usage are being promoted in pollution prevention programs. A workgroup, consisting of members from the Ohio Water Resources Council and the State Coordinating Committee on Ground Water, developed guidance for salt storage in 2013: Recommendations for Salt Storage: Guidance for Protecting Ohio’s Water Resources, located on the web at: [epa.ohio.gov/portals/35/owrc/SaltStorageGuidance.pdf](epa.ohio.gov/portals/35/owrc/SaltStorageGuidance.pdf).

**Suburban Runoff (including storm drains and storm water management):** With expanding suburban areas, nonpoint source contamination from suburban/urban runoff is an increasing source of ground water contamination, in contrast with most of the other sources discussed. In addition, the practice of constructing storm water retention basins increases the likelihood that storm water runoff infiltrates into ground water. More than 1,250 storm drains are located within drinking water source protection areas, with many of these going directly to nearby water bodies. Elevated chloride is
documented in urban areas within glacial aquifers by Mullaney et al. (2009) and positive trends in chloride concentrations in Ambient Ground Water Quality Monitoring data are present at some sites.

**Small-Scale Manufacturing and Repair Shops:** Small-scale manufacturing and repair shops include 1,693 facilities in drinking water source protection areas. These include: auto and boat repair shops and dealers; gas stations; junk yards; equipment rental and repair; machine shops; metal finishing and welding shops; and other various small businesses. These businesses typically handle chlorinated solvents (for cleaning) and petroleum products. Limited knowledge of best management practices for handling and disposing of these products increases the risk of impacting ground water.

**Fire Training Facilities:** Foams containing PFOA and PFOSs are known to have been applied to fight fuel-based fires at airbases and other fire training facilities. These chemicals could have entered the ground water due to releases during training, usage or storage. Ohio EPA has performed sampling (2016-2017) in partnership with the Ohio Air National Guard (OANG), the Ohio Department of Health and local health districts to assess potential health risks to private well users. These Ohio EPA-DDAGW investigations were not intended to take the place of the upcoming detailed federal investigations; rather, they were focused on evaluating risks to private well users based on available information regarding local ground water conditions and the location of fire training areas.

**(‡) Potentially High Priority Sources**

**Concentrated Animal Feeding Operations (CAFO):** The growth of CAFOs in numbers and size makes them a significant potential source if the waste is not properly managed. The ground water threats associated with CAFOs are captured in other categories as well, such as manure, sludge and fertilizer application and surface impoundments, so they are not considered one of the 10 highest priority sources. Improper storage or management of the animal waste is the greatest threat to ground water contamination in sensitive hydrogeologic settings, but land application in solid or liquid form also poses risks for ground and surface water contamination.

**Surface Impoundments:** Surface impoundments are one of the most common waste disposal concerns at RCRA facilities. Historically, they have been a major source for ground water contamination. Older impoundments were not subject to the same engineering standards as newer impoundments and, consequently, the probability of fluids leaching to the ground water was greater. Current siting and engineering requirements have improved this situation. Twenty-five surface impoundments are known to be contaminating ground water based on information obtained from Ohio EPA’s ground water impacts database (deprecated), the majority being from regulated and unregulated hazardous waste facilities.

**Mining and Mine Drainage:** The bedrock (Pennsylvanian Units) that underlies eastern Ohio includes significant coal resources. The disruption of the stratigraphic units and oxidation of sulfides associated with coal mining produces ground water contamination by acid mine waters. Acid mine waters are considered a significant threat to ground water in mined areas.

**Spills and Leaks:** Leaks and spills of hazardous substances from underground tanks, surface impoundments, bulk storage facilities, transmission lines and accidents are major ground water pollution threats. More than a thousand leaks and spills are reported each year. This release of chemicals on to the surface and into near surface environments is certainly one of the greatest threats to ground water quality. The development of shale gas and associated hydrofracturing activity in eastern Ohio has raised concerns about potential for aquifer impacts. Historically, the surface management of brines has been the greatest cause of ground water contamination associated with oil production and
hydro fracking activities (State Oil and Gas Agency Groundwater Investigations and Their Role in Advancing Regulatory Reforms, GWPC, August 2011). Revised regulations address the management and disposal of oil and gas production brines with the preferred mode of disposal as injection into Class II injection wells.

The major sources of ground water contamination listed include point and nonpoint sources in roughly equal proportions. In strict terms, a point source is a discharge from a discernable, confined and discrete conveyance, but in practical terms, the distribution or spatial scale of a contaminant controls the designation of a source as point or nonpoint. For example, salt applied for de-icing along roads exhibits nonpoint source behavior, while salt stockpiles behave more like point sources, with the potential for continual release of concentrated brine that may affect ground water quality. This dichotomy is typical of many agricultural contaminants, manure spreading versus storage, fertilizer application versus storage or mixing sites. In Ohio, we generally have better documentation of ground water contamination associated with point source contamination than nonpoint source contamination due to the extensive ground water monitoring programs at regulated facilities.

Rapid runoff in glacial till areas overlying much of Ohio and drainage tiling have protected many of Ohio’s aquifers from traditional nonpoint source pollution sources such as nitrate, chloride, pesticides or bacteria. In sensitive settings (for example, sand and gravel aquifers, shallow bedrock aquifers), indicators of nonpoint source pollution are more clearly identified in Ohio’s Ambient Ground Water Quality Monitoring program and the public water system compliance monitoring data. However, these monitoring programs do not focus on shallow aquifers, which have a higher likelihood of being influenced by nonpoint source pollution such as agricultural practices.
Table L-3 — Major sources of potential ground water contamination.

<table>
<thead>
<tr>
<th>Contaminant Source</th>
<th>Highest-Priority Sources</th>
<th>Factors Considered in Selecting a Contaminant Source</th>
<th>Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agriculture Activities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural chemical facilities</td>
<td>×</td>
<td>4, 5, 6, 8</td>
<td>E, J, K, L</td>
</tr>
<tr>
<td>Animal feedlots</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage wells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer applications (manure application)</td>
<td>✓</td>
<td>1, 2, 3, 4, 5, 8</td>
<td>E, J, K, L</td>
</tr>
<tr>
<td>Irrigation practices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide applications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-farm agricultural mixing and loading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land application of manure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Storage and Treatment Activities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material stockpiles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage tanks (above/below ground)</td>
<td>✓</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>C, D, H, M, N</td>
</tr>
<tr>
<td>Surface impoundments</td>
<td>×</td>
<td>6</td>
<td>G, H, M</td>
</tr>
<tr>
<td>Waste piles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste tailings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Disposal Activities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep injection wells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landfills</td>
<td>✓</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>A, B, C, D, H, M, N</td>
</tr>
<tr>
<td>Septic systems</td>
<td>✓</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>E, H, J, K, L</td>
</tr>
<tr>
<td>Shallow injection wells</td>
<td>✓</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>C, D, G, H, M</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire training areas</td>
<td>✓</td>
<td>1, 3</td>
<td>N</td>
</tr>
<tr>
<td>Hazardous waste generators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazardous waste sites</td>
<td>✓</td>
<td>1, 2, 3, 4, 5, 6</td>
<td>A, B, C, D, H, I, M, N</td>
</tr>
<tr>
<td>Large industrial facilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material transfer operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining and mine drainage</td>
<td>×</td>
<td>6, 8</td>
<td>G, H</td>
</tr>
<tr>
<td>Pipelines and sewer lines</td>
<td>✓</td>
<td></td>
<td>D, E, J, K, L</td>
</tr>
<tr>
<td>Salt storage and road salting</td>
<td>✓</td>
<td>6</td>
<td>G</td>
</tr>
<tr>
<td>Spills</td>
<td>×</td>
<td>6</td>
<td>C, D, H, M</td>
</tr>
<tr>
<td>Transportation of materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban runoff (storm water management, storm drains)</td>
<td>✓</td>
<td>2, 4</td>
<td>A, B, C, D, G, H, J</td>
</tr>
<tr>
<td>Small-scale manufacturing and repair shops</td>
<td>✓</td>
<td>4, 6</td>
<td>C, D, H, M, N</td>
</tr>
</tbody>
</table>

Notes: (✓) Highest Priority  (×) Potentially High Priority
Factor and Contaminant codes on next page.
L5. Summary of Ground Water Quality by Aquifer

Table L-4 and Table L-5 (Table 5-4, U.S. EPA 1997) summarize water quality compliance data from Ohio public water systems and raw water data from the AGWQMP, respectively. The compliance data for public water systems in Ohio (Table L-4) documents water quality for treated water (post processing) and some raw (untreated) water quality (new well samples). Parameters generally unaffected by standard treatment, such as nitrate, may be used to characterize Ohio’s ground water quality because post treatment values are similar to ground water values. DDAGW created the AGWQMP program (Table L-5) to monitor raw (untreated) ground water. This program’s goal is the collection, maintenance and analysis of raw ground water quality data to measure long-term changes in the water quality of Ohio’s major aquifer systems.

Ohio does not have statewide ground water quality standards, so data for the major aquifers are compared to primary maximum contaminant levels (MCLs), secondary maximum contaminant levels (SCMLs), health advisory levels (HALs), action levels (copper and lead), and drinking water advisory levels (sodium and sulfate). Primary MCLs are the highest level of a contaminant that is allowed in public drinking water and are set as close to MCL goals (a health-based standard) as feasible using the best available treatment technology and economic considerations. Primary MCLs are enforceable standards. Secondary MCLs are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor or color) in drinking water. HALs are levels in drinking water below which there are no adverse health effects over different time periods, such as one day, 10-day, long-term or lifetime. Action levels for lead and copper are set such that if more than 10 percent of tap water samples are above the action level, requirements may be triggered including: water quality parameter monitoring; corrosion control treatment; source water monitoring/treatment; public education; and/or lead service line replacement. Drinking water advisory levels for sodium and sulfate provide information on contaminants that can cause human health effects and are known or anticipated to occur in drinking water. The sodium drinking water advisory level applies only to adults on a low-salt diet.

Primary and secondary MCLs, HALs, action levels and drinking water advisory levels are used as practical benchmarks for water quality characterization in Table L-4 and Table L-5. For primary and secondary MCLs, 50 to 100 percent of the benchmark is used as the range for the watch list determination. The public water systems or wells identified in this category may warrant additional monitoring to identify increasing trends. Benchmark exceedances are used as the criteria for the impaired category for each of the five benchmarks: primary and secondary MCLs, HALs, action levels and drinking water advisory levels. Table L-4 and Table L-5 were generated using the last 10 years of data (1/1/2007-8/17/2017). Mean

<table>
<thead>
<tr>
<th>Factors</th>
<th>Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Human health and/or environmental risk (toxicity)</td>
<td>A. Inorganic pesticides</td>
</tr>
<tr>
<td>2. Size of the population at risk</td>
<td>B. Organic pesticides</td>
</tr>
<tr>
<td>3. Location of the sources relative to drinking water sources</td>
<td>C. Halogenated solvents</td>
</tr>
<tr>
<td>4. Number and/or size of contaminant sources</td>
<td>D. Petroleum compounds</td>
</tr>
<tr>
<td>5. Hydrogeologic sensitivity</td>
<td>E. Nitrate</td>
</tr>
<tr>
<td>6. State findings, other findings</td>
<td>F. Fluoride</td>
</tr>
<tr>
<td>7. Documented from mandatory reporting</td>
<td>G. Salt/Salinity/brine</td>
</tr>
<tr>
<td>8. Geographic distribution/occurrence</td>
<td>H. Metals</td>
</tr>
<tr>
<td></td>
<td>I. Radionuclides</td>
</tr>
<tr>
<td></td>
<td>J. Bacteria</td>
</tr>
<tr>
<td></td>
<td>K. Protozoa</td>
</tr>
<tr>
<td></td>
<td>L. Viruses</td>
</tr>
<tr>
<td></td>
<td>M. Other (VOCs)</td>
</tr>
<tr>
<td></td>
<td>N. PFAS</td>
</tr>
</tbody>
</table>
concentrations of a parameter are used to decide if a public water system or well is included in the watch list (50 to 100 percent of the benchmark) or impaired category (> benchmark). Maximum concentrations of nitrate and nitrite are reported in these tables instead of averages, due to the acute nature of their health concerns.

**Public Water System Compliance Data**

Mean values were calculated from public water system compliance data for 2007-2017 to determine the number of public water systems on the watch list and in the impaired category. A 10-year period of record was used to increase the statistical significance of the determination due to the infrequent sampling requirements (once per three-year period). **Public water systems included in the impaired category may not match Safe Drinking Water Act regulatory determinations of a violation due to the method of calculation.** A benchmark exceedance for compliance is generally an annual average, so the **decadal average presented in Table L-4 is not a compliance number**, but rather a comparison to set values, as a benchmark to identify public water systems in the watch list and impaired categories.

Table L-4 lists all parameters with MCLs, SMCLs, HALs, action levels and drinking water advisory levels and summarizes the number of public water systems in the watch list (MCLs and SMCLs only) and impaired category for both raw and treated water quality data (all five benchmarks). The results for each parameter are further divided into major aquifer type categories. The total number of public water systems with data used in these determinations is presented to allow comparison of the total number of public water systems to those that exhibit elevated levels. Data from active and inactive systems is included in Table L-4. For parameters with non-MCL benchmarks, treated water data is limited or absent because compliance data is generally not required for aesthetic water quality issues.

Except for a new well analysis, there are no requirements for collecting and reporting raw water data, so the number of public water systems with raw water data is less than the number with treated water data. The public water system data were linked to geologic settings using the DDAGW Source Water Assessment data, which allowed the breakout of the data by major aquifer. In this analysis, any detection in raw water data was used to generate public water system averages. For treated water data, public water system averages were generated only if there were at least two detections of a parameter. The inorganic parameters that place numerous public water systems in the watch list and impaired category warrant additional analysis.

The number of public water systems in the watch list and the impaired categories of Table L-4 for treated water are generally low; however, several parameters do exhibit higher numbers of public water systems in these groups. Fortunately, most of these occurrences are for secondary MCLs, not primary MCLs, HALs, action levels or drinking water advisories. That is, the water quality impacts documented are mostly aesthetic issues and are not health-based. Groups of parameters are discussed individually.
Table L-4 — Counts of public water systems where 2007-2017 decadal mean values of compliance data occur in the Watch List and Impaired Category.

<table>
<thead>
<tr>
<th>Chemical Group</th>
<th>Chemical</th>
<th>Std. Type</th>
<th>Standard</th>
<th>Major Aquifer</th>
<th>Total # public water systems</th>
<th>Raw Water</th>
<th>Public Water Systems</th>
<th>Treated Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Watch List &gt; 50% to 100% Standard</td>
<td>Impaired &gt; Standard</td>
<td>Watch List &gt; 50% to 100% Standard</td>
<td>Impaired &gt; Standard</td>
</tr>
<tr>
<td>Inorganics</td>
<td>Aluminum</td>
<td>SMCL</td>
<td>200 µg/L</td>
<td>Sand and Gravel</td>
<td>Sandstone</td>
<td>Carbonate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Lifetime</td>
<td>HAL</td>
<td>30 mg/L</td>
<td>Sand and Gravel</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antimony</td>
<td>MCL</td>
<td>6 µg/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>112</td>
<td>1</td>
<td>625</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>67</td>
<td></td>
<td>645</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>87</td>
<td></td>
<td>376</td>
<td>1</td>
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<tr>
<td>Arsenic</td>
<td>MCL</td>
<td>10 µg/L</td>
<td></td>
<td>Sand &amp; Gravel</td>
<td>156</td>
<td>6</td>
<td>12</td>
<td>634</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>103</td>
<td>1</td>
<td>6</td>
<td>646</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>116</td>
<td>3</td>
<td>6</td>
<td>391</td>
</tr>
<tr>
<td>Asbestos</td>
<td>MCL</td>
<td>7x106 fibers/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>5</td>
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<td>162</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>47</td>
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<td>58</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>MCL</td>
<td>2000 µg/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>120</td>
<td></td>
<td>625</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>89</td>
<td></td>
<td>646</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>93</td>
<td></td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>1/10 Day HAL</td>
<td>700 µg/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>120</td>
<td>1</td>
<td>625</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>89</td>
<td></td>
<td>646</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>93</td>
<td></td>
<td>82</td>
<td>2</td>
</tr>
<tr>
<td>Beryllium</td>
<td>MCL</td>
<td>4 µg/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>103</td>
<td></td>
<td>625</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>64</td>
<td></td>
<td>645</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>87</td>
<td></td>
<td>375</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>MCL</td>
<td>5 µg/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>106</td>
<td></td>
<td>625</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Sandstone</td>
<td>66</td>
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<td>645</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>86</td>
<td></td>
<td>375</td>
<td>1</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Lifetime HAL</td>
<td>5 µg/L</td>
<td></td>
<td>Sand and Gravel</td>
<td>106</td>
<td></td>
<td>625</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>66</td>
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<td>645</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Carbonate</td>
<td>86</td>
<td></td>
<td>375</td>
<td></td>
</tr>
</tbody>
</table>

<p>| Inorganics     | Cadmium  | 40 µg/L   | Sand and Gravel | 106 | 625 |</p>
<table>
<thead>
<tr>
<th>Chemical Group</th>
<th>Chemical</th>
<th>Std. Type</th>
<th>Standard</th>
<th>Major Aquifer</th>
<th>Raw Water</th>
<th>Total # public water systems</th>
<th>Watch List &gt; 50% to 100% Standard</th>
<th>Impaired &gt; Standard</th>
<th>Treated Water</th>
<th>Total # public water systems</th>
<th>Watch List &gt; 50% to 100% Standard</th>
<th>Impaired &gt; Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chloride</td>
<td>SMCL</td>
<td>250 mg/L</td>
<td>Sand and Gravel</td>
<td>102</td>
<td>375</td>
<td>66</td>
<td>645</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandstone</td>
<td>92</td>
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Note: presented by major aquifer types.
Blank spaces indicate no public water systems exceed the standards (zeros left out to highlight impacted public water systems)
“nda” Indicates no data available
* Numbers for Nitrate and Nitrite are based on maximum values to reflect the acute nature of the contaminant.
** Sodium drinking water advisory level is for adults on low-salt diets.
*** If Gross Beta result is less than 50 pCi/L no conversion to mrem/yr is necessary – table used 50 pCi/L as standard.
**** MCL is for combined Radium 226 and Radium 228
Table L-5 — Counts of wells where 2007-2017 decadal mean values of AGWQMP data occur in the Watch List and Impaired Category (maximum values used for nitrate).

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# 2020 Integrated Water Quality Monitoring and Assessment Report

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**Chemical Group** | **Chemical** | **Standard Type** | **Standard** | **Major Aquifer** | **Ambient GW Quality Wells** | **Raw Water** |
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<td>Carbonate</td>
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Blank spaces indicate no public water systems exceed the standards (zeros left out to highlight impacted public water systems)

* "nda" Indicates no data available
* Numbers for Nitrate and Nitrite are based on maximum values to reflect the acute nature of the contaminant
** If Gross Beta result is less than 50 pCi/L, no conversion to mrem/yr is necessary – table used 50 pCi/L as standard
*** MCL is for combined Radium 226 and Radium 228
Inorganic Parameters

MCL Parameters

Only a few public water systems fall into the watch list or the impaired MCL category based on inorganic parameters. For treated water data, parameters with MCLs and no public water systems in the impaired category (values > MCL) include: asbestos; barium; cadmium; chromium; cyanide; fluoride; and selenium. The use of detection limits at or greater than 50 percent of the MCL and using the reporting limit for the non-detect value can result in public water systems placed in the watch list with no detection of the parameter. The data has been reviewed to assure that public water system in the watch list have detected the parameter. Factors limiting the number of public water systems in these categories include limited solubility of the substance in water, low crustal abundance, local geology and possibly treatment. For example, in treated water, no public water systems exceed the fluoride MCL, but 20 public water systems that draw water from carbonate aquifers exceed 50 percent of the MCL. This association is controlled by secondary fluorite mineralization along fractures and voids in limestone in northwest Ohio.

Several parameters including antimony, beryllium, mercury and thallium have low numbers of public water systems in the MCL impaired category for treated water. This small number is consistent with the low solubility and scarcity of these metals in Ohio’s geology. The use of decadal averages for determining both watch list and impaired categories may overestimate the numbers of public water systems when compared to actual MCL, SMCL or HAL calculations which use annual averages.

The number of public water systems with arsenic in raw water and treated water above the MCL (139 and 91, respectively) is consistent with the number of public water systems that DDAGW worked with to reduce arsenic to meet the 2006 revised MCL of 10 µg/L. These systems are associated with reduced ground water and local areas of naturally occurring arsenic. Sand and gravel and carbonate aquifers are more likely than the sandstone aquifers to exhibit arsenic-impaired ground water. The number of public water systems currently exceeding the arsenic MCL is significantly less than what is listed in Table L-4 because numerous public water systems have installed treatment to remove arsenic since 2006. The elevated arsenic results collected from 2007 and beyond (while treatment processes were installed and refined) are included in the 10 years of data used to generate the public water system decadal averages. These elevated values increase the decadal mean calculated for Table L-4 and thus, result in impaired systems on a decadal mean, but these systems are currently serving water below the arsenic MCL.

SMCL Parameters

Secondary MCL parameters for drinking water are directed at non-health related issues such as taste and odor. Public water systems do not collect compliance data for most parameters with SMCLs. Table L-4 utilized only compliance data and, consequently, it includes little data for treated water for parameters with SMCLs. The raw water data collected through new well samples, however, provides information on the distribution of these parameters.

Multiple public water systems display elevated chloride. The largest numbers of public water systems with elevated chloride are associated with the sandstone aquifers followed by sand and gravel aquifers and carbonate aquifers. This may be related to limited natural oil and gas deposits occurring within aquifers, contamination of local aquifers from surface handling of oil and gas production brines, local salt storage facilities overlying sensitive aquifers, road salt application or septic systems. Transportation routes are concentrated in the broad, flat buried valleys and consequently, large salt piles are stored on these broad valleys, which contain sensitive aquifers. Activities to address chloride contamination are discussed in the Major Sources of Ground Water Contamination section.
**Iron and manganese** have similar oxidation-reduction solubility controls as arsenic and widespread distribution and exhibit elevated numbers of public water systems in the watch list and impaired category of Table L-4 for raw water. Table L-4 utilized only compliance data so little data for treated water is included for iron and manganese. The raw water concentration for Fe and Mn are controlled by the increased solubility of iron and manganese in reduced waters. The deeper wells generally exhibit more reduced conditions (reduced interaction with the atmosphere) and, consequently, elevated iron and manganese. Iron is a common element and is present in all three major aquifers. For manganese, the carbonate aquifer is least likely to exhibit concentrations above the SMCL. Many public water systems remove iron and manganese, so the percentage of public water systems that exhibit impairments in treated water is significantly lower than in raw water.

**Sulfate** also has an SMCL and only raw water data exists for identifying water quality impacts. A significant number of public water systems exhibit elevated sulfate in the both the watch and impaired categories. Although these sites are distributed in all major aquifers, the carbonate aquifers in NW Ohio exhibit the highest percentage of public water systems on the watch list and in the impaired category (42 percent of carbonate vs. 10-11 percent for sandstone and sand and gravel) due to the presence of evaporates (Gypsum, CaSO_4·2H_2O) in the Salina Formation in northwest Ohio.

For **Fluoride** results, no public water systems show up in the impaired category for raw or treated water, however, a number of public water systems exhibit watch list concentrations in treated and raw water. Fluoride is unusual in that it has a primary and secondary MCL and the SMCL is 50 percent of the MCL. Thus, all the systems on the watch list for the MCL exceed the SMCL. The *Fluoride Technical Report* (2012) describes how fluorite, which was deposited as a secondary mineral in fractures in the carbonate aquifers, controls the distribution of elevated fluoride.

For **nitrate and nitrite**, maximum values were used rather than average values to reflect the acute nature of the nitrogen MCLs. As a parameter that is stable in oxidized environments, nitrate is more likely to be present in shallower wells. Approximately 2.5 percent (122 of 5,053) of public water systems in Table L-4 (treated water) have maximum nitrate greater than 50 percent of the MCL. Approximately 50 percent of these public water systems are in sand and gravel aquifer settings. A public water system that exceeds 50 percent of the nitrate MCL is required to sample for nitrate on a quarterly basis. Thus, over the last decade, at least 146 public water systems have been required to increase nitrate sampling to at least quarterly. For nitrate in treated water and raw water, 24 and 20 public water systems fall into the impaired category, respectively. Public water systems with maximum results greater than the MCL do not necessarily indicate an MCL exceedance, which is an annual average.

Public water systems with elevated nitrate tend to be associated with more sensitive aquifers such as buried valleys and areas of thin glacial drift over bedrock. Stable nitrate (where decadal averages are relatively high) tend to be found in systems that combine a shallow aquifer with rapid pathways between surface and ground water and stable oxic or sub-oxic ground water. The number of public water systems with maximum nitrates in treated water in the watch list or impaired categories has decreased since 2010 based on the 2010 (243 public water systems), 2012 (227 public water systems), 2014 (181 public water systems), 2016 (149 public water systems) and 2018 (146 public water systems) integrated reports. This is encouraging, but probably reflects improved treatment or use of alternative sources, rather than reduction in nitrate loading.

**HAL Parameters**

HALs are constituent levels below which there are no adverse health effects over different time periods, such as one day, 10-day, long-term or lifetime. For HAL parameters, only an exceedance of the HAL
(impaired status) was calculated in Table L-4. For raw water, a percentage of public water systems are included in the impaired category for barium (two percent) and manganese (8.5 percent). Barium and manganese exceedances are spread evenly between sand and gravel and sandstone aquifers. For treated water supplies, a very small percentage (<1 percent) of public water systems exceed their respective HAL for barium and nickel. Two public water system wells, one in carbonate and one in sand and gravel, exceed the lifetime HAL for strontium.

**Drinking Water Advisory Parameters**

Exceedances of drinking water advisory levels for sodium and sulfate can cause human health effects. The sodium drinking water advisory level applies only to adults on a low-salt diet. Only an exceedance of the drinking water advisory (impaired status) was calculated in Table L-4. For raw water, a percentage of public water systems are included in the impaired category for sodium (41.3 percent) and sulfate (7.6 percent). Sodium exceedances are found most often in sandstone, then carbonate aquifers. The large percentage of public water systems with sodium exceedances may be due to oil and gas production brines, salt storage facilities or road salt applications. Sulfate exceeds the drinking water advisory level most commonly in the carbonate aquifers again due to the presence of evaporates.

**Organic Parameters**

Only seven organic parameters’ mean concentrations for treated water samples place public water systems in the impaired category: 1,2-dichloroethane; 1,1-dichlorethylene; 1,2-dichloropropane; carbon tetrachloride; dichloromethane; tetrachloroethylene; and vinyl chloride. Two of these parameters are common solvents and a third is a compound used to make plastic. Dichloromethane (methylene chloride) is a known lab contaminant, but it is also possible that it can leach to ground water before it volatilizes, so it is included in Table L-4. In addition to the public water systems identified above, there are about 15 public water systems that are not using a production well or are using air strippers to remove VOC contamination from ground water prior to use. The raw water data may include some of these systems, but if these ground water-based public water systems were not removing VOC contaminants, additional constituents would be identified as a cause of impairment.

**Pesticides and Synthetic Organics**

One pesticide and synthetic constituent is identified as a cause of impairment, di(2-ethylhexyl) phthalate. These data confirm that although we see impact from pesticides and other organic compounds migrating to major aquifers, the protection that the till cover and tile drainage provide to protect Ohio ground water is significant.

**Radiological Parameters**

For treated water, several public water systems are included on the watch list and the impaired category for gross alpha and radium 228. The limited number of public water systems in the watch list and impaired category is consistent with the Ohio’s geologic setting having few natural sources of radionuclides. The exceptions are uranium associated with reduced geologic settings like glacial tills, the Ohio Shale and coal deposits, but these settings are generally not utilized as aquifers. Gross beta compliance monitoring focuses on anthropogenic sources of radiation. The distribution of radionuclides is discussed in the DDAGW technical report *Radionuclides in Ohio’s Ground Water* (July 2015).

**Ambient Ground Water Quality Monitoring Data**

Mean values were calculated from the AGWQMP data (raw water) for each well over the past 10 years (2007 through 2017) to determine the number of wells in the watch list and impaired categories for each constituent. These numbers are listed in Table L-5 by parameter and major aquifer. The number of wells
used in the determinations is also presented to provide the relative number of wells that exhibit ground water quality with elevated concentrations of MCL, SMCL, HAL and drinking water advisory parameters. A limited number of AGWMP wells are listed in the watch list and impaired category, as was the case for the public water system compliance data. The results for groups of parameters are discussed below.

**Inorganic Parameters**

The AGWQMP does not collect data for **antimony** (except for one sandstone well), **asbestos**, **beryllium**, **cyanide**, **mercury**, **nitrite**, **silver** and **thallium**, so no comparison can be made to the public water system data. These parameters are not analyzed due to their historically low concentrations in Ohio ground water. No well waters are impaired (have decadal averages that exceed the MCL or SMCL) for **alkalinity**, **cadmium**, **chromium**, **copper**, **fluoride**, **nickel**, **nitrate**, **selenium** or **zinc**. Very few wells exceed the lifetime HAL for cadmium (0.07 percent), nickel (0.1 percent), selenium (0.3 percent) and zinc (0.1 percent). Six wells exceed 50 percent of the fluoride MCL. These wells produce water from the carbonate aquifer, as was seen with public water systems in Table L-4. A few well means are greater than 50 percent of the **barium** MCL, with one MCL and nine HAL impairments identified. Averages for **chloride** exceed the SMCL in five cases. Thirteen wells have chloride above 50 percent of the SMCL. The source of contamination is likely associated with improper storage of salt for road deicing, oil and gas drilling brine disposal, brines in bedrock aquifers with a history of oil production, or road deicing.

For **nitrate**, well maximums were used rather than averages to reflect the acute nature of the nitrate MCL. This approach makes it difficult to compare the nitrate numbers to numbers for other parameters in Table L-4. Nitrate is stable in oxidized environments and, thus, is more likely to be detected in shallower wells that have rapid exchange pathways with the atmosphere and surface water. In the AGWQMP, the sand and gravel wells are generally the shallowest and consequently, would be expected to exhibit the largest number of wells with elevated nitrate concentrations. This is the case with about seven percent of the sand and gravel wells exceeding 50 percent of the MCL. Three percent of the carbonate wells exceed 50 percent of the MCL, probably associated with sensitive karst settings and only two percent of the sandstone wells are on the watch list for (maximum) nitrate. The AGWQMP tends to collect samples from higher production wells located deeper in aquifers; consequently, it is not the best program to evaluate ground water quality in shallow (25 to 50 feet), sensitive aquifer settings.

**Arsenic**, **iron**, **manganese**, **total dissolved solids (TDS)** and **sulfate** mean concentrations result in significant numbers of wells on the watch list and in the impaired category. These are the same parameters identified in the public water system compliance data, with the addition of TDS. TDS is not required or collected for public water systems compliance data. Except for arsenic, all parameters have SMCLs and treatment is generally not required. Many public water systems remove iron, with the additional benefit of manganese and arsenic removal, since arsenic and iron solubility are controlled by similar redox controls. Sulfate in the AGWQMP is elevated in carbonate aquifers due primarily to the presence of evaporates in the Salina Formation, in the upper portion of the Silurian carbonate aquifer. For the carbonate aquifers, 57 percent of the ambient sites exceed 50 percent of the SMCL for sulfate, which is significantly higher than the percentage of sandstone and sand and gravel aquifers (six percent and 11 percent respectively). The elevated TDS in raw water results from the relative solubility of aquifer material and the residence time for ground water in all of Ohio’s major aquifers. The carbonate aquifers generally have higher mean TDS, but all three main aquifers exhibit high percentages of ambient sites with TDS exceeding 97 percent of the SMCL.

HAL exceedances for **strontium** occur most commonly in carbonates followed by unconsolidated aquifers resulting most likely from the presence of the naturally occurring mineral celestite (SrSO₄). Twenty-five
ambient wells have strontium values greater than the one- and 10-day HAL of 25,000 µg/L (nine percent) while 86 wells (30 percent) exceeded the life-time HAL of 4,000 µg/L.

**Organic Parameters** - Detection of organic parameters at and above watch list concentrations is not common in the AGWQMP. Organic parameters, each detected at one public water system above the MCL, include carbon tetrachloride and trichloroethylene. These organic solvents were detected in public water systems raw water samples as listed in Table L-4.

**Pesticides** – Benzo(a)pyrene, 1,2-dibromo-3-chloropropene (DBCP), di(2-ethylhexyl) phthalate (1), ethylene dibromide (EDB), hexachlorobenzene (1) and pentachlorophenol were pesticides detected in the AGWQMP wells above their respective MCLs. The AGWQMP does not analyze for pesticides on a regular basis, as reflected in the low number of wells listed for pesticides, due to the lack of pesticide detections during several sampling rounds in the late 1990s. This sampling and consultations with the Ohio Department of Agriculture regarding its pesticide sampling results, suggests that further pesticide data collection is not cost-effective for the AGWQMP. Review of available data supports the conclusion that the glacial till provides protection for Ohio's ground waters based on low detections rates and low concentrations detected. Nevertheless, local sensitivity and improper use of pesticides can lead to pesticide impacts. The historic data points to the greatest impacts occurring at the mixing sites or areas of spills.

**Radiological Parameters** – Radiological parameters are not included in the AGWQMP sampling.

**Comparison of Public Water System and AGWQMP Data**

Overall, we see similar trends in the public water system compliance and the AGWQMP data. This confirms that the AGWQMP data are appropriate for identifying long-term trends in the ground water quality of the major aquifers utilized by the public water systems. Thus, the AGWQMP goal of monitoring and characterizing the ground water quality utilized by public water systems in Ohio is validated by these empirical data.

It is interesting that the ground water quality differences documented between the major aquifers in AGWQMP data based on major components are not obvious in Table L-4 and Table L-5. The major elements or components (Ca, Mg, Cl, Na, K, sulfate and alkalinity) are generally the parameters utilized to identify water types. However, Ca, Mg, K and alkalinity do not have MCLs or SMCLs, so MCL and SMCL comparisons are limited in their capacity to delineate geochemical differences among waters from different aquifers. Chloride and sulfate do have SMCLs and exhibit significant differences between the major aquifers as noted above in Table L-4 and Table L-5. Treatment, such as softening, of public water system-distributed water can mask differences in water quality between major aquifers.

The most recognizable geochemical differences between the major aquifers in Ohio relate to the concentrations of calcium, magnesium, bicarbonate and strontium. These differences relate to the higher solubility of carbonate rocks and the long water-rock reaction time of ground water. The carbonate waters are characterized by elevated calcium, manganese, bicarbonate and strontium compared to water in sandstone and sand and gravel aquifers. The higher percentages of public water systems that exhibit watch list and impaired category results for TDS and sulfate in the carbonate aquifers reflects the dissolution of gypsum within the carbonate stratigraphy. Summary data from the AGWQMP provides a description of Ohio's major aquifers and their water quality available in the technical report, *Major Aquifers in Ohio and Associated Water Quality (2015)*.
Review of Chloride Data from AGWQMP Wells

Many states are experiencing increasing chloride concentrations in ambient ground water quality due to increasing human population and activity\(^1\), and Ohio is no exception. Ohio’s Ambient Ground Water Quality Monitoring Program database is comprised of ground water quality results spanning the years 1941 and 2019 obtained from 214 actively sampled and 270 historically sampled Ambient Network wells (wells). Among 275 active and historical wells with sufficient data for statistical comparisons, 158 show a statistically significant increasing trend in chloride, and an additional 48 wells have elevated chloride and other parameter concentrations that indicate impacts from anthropogenic sources and/or brine intrusion.

Geographic Information Systems (GIS) analytical tools and various statistical methods are being used on the AGWDB to evaluate how chloride concentrations vary by aquifer, land use and hydrogeologic variables, and to help determine the leading causes of elevated or increasing chloride concentrations in Ohio’s ambient ground water.

Among the three main aquifer types in Ohio [Unconsolidated (UNC), Sandstone (SS) and Carbonate (CB)], median chloride concentrations were highest in unconsolidated wells, second highest in sandstone wells, and lowest in carbonate wells. Median chloride concentrations increase nearly 10 milligrams per liter (mg/L) across aquifer types, as seen in the box plot in Figure L-2. Variance in chloride was greatest among sandstone wells and least among unconsolidated wells.

Figure L-2 — Median chloride concentrations in Ohio’s major aquifer types.

Median chloride concentrations in unconsolidated aquifer wells were highest in shallow wells [i.e. casing length less than 50 feet below ground surface (bgs)], with median chloride concentrations decreasing with

casing length down to a depth of approximately 100 feet bgs, then increasing again at casing lengths greater than 175 feet bgs (Figure L-3). Median chloride concentrations in carbonate wells (Figure L-4) followed a similar trend, decreasing with well casing length down to a depth of approximately 100 feet bgs. However, median chloride concentrations in sandstone wells followed the opposite trend – increasing with casing length down to approximately 100 feet bgs, shown in Figure L-5.

Figure L-3 — Median chloride concentrations in unconsolidated aquifers by casing length.

Chloride in Ambient Wells by Well Casing Length - Unconsolidated Aquifers
Figure L-4 — Median chloride concentrations in carbonate aquifers by casing length.

Figure L-5 — Median chloride concentrations in sandstone aquifers by casing length.
The 2016 National Land Cover Dataset (NLCD) was used in GIS to attribute a dominant land use type to each ambient well, based on a 500-meter radius of influence\(^2\) around each ambient well location. As demonstrated in the distinct 95 percent confidence interval bands around the medians in Figure L-6, statistically significant differences exist between median chloride concentrations from wells in the four dominant land use types. The highest median chloride concentrations were seen in the Open Water (i.e. quarry lakes and rivers) land use type, followed by Developed, Forest and Agricultural land use types.

![Figure L-6 — Median chloride concentrations in all wells by dominant Land Use Type.](image)

Chloride/bromide ratios are commonly used to help identify and differentiate among various sources of chloride in ground water. A plot of the chloride/bromide ratio versus chloride concentration (in mg/L) per sample against plotted curves of mixing ratios between unimpacted ground water and several common sources of chloride impacts (e.g. sewage/septic, road salt/halite, basin/oil field brine) can help identify the sources of impact.\(^3\) Plots of ambient well results shown in Figure L-7 indicate that the majority of Ohio’s ambient wells have some anthropogenic impact (e.g. septic/sewage, road salt/halite), with smaller clusters indicating some impact from basin/oil brines or no impact. Other patterns evident from comparison and contrast of the chloride/bromide plots in Figure L-7 and Figure L-8 include the following:

- Unconsolidated aquifer wells have the highest average level of anthropogenic impact among the three aquifer types, whereas carbonate aquifer wells have the lowest; both are consistent with the pattern of median chloride concentrations shown in Figure L-2;
- Agricultural aquifer wells clustered more densely around the halite/road salt curve and less towards septic/sewage curve, reflecting influences from road salt as well as fertilizer impact.
- Wells plotting along the brine-influenced curve were dominantly bedrock aquifer (i.e. carbonate, sandstone) wells, as expected.

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• Wells in Open Water land use category plotted almost exclusively in the sewage-road salt mixing zone, indicating a mixture of chloride contamination sources.

Other statistical and graphical data evaluation procedures are being used to identify additional patterns in the AGWQMP and to determine sources of chloride impacts to specific ambient wells and to inform future source water protection strategies in Ohio.

Figure L-7 — Chloride/Bromide ratios in Ambient wells by dominant Land Use Type.
L6. Conclusions and Future Directions for Ground Water Protection

Ohio is fortunate that ground water is plentiful across the state. With the exceptions of a few areas that exhibit effects of over-pumping, decreasing static water levels have not been documented across extensive areas. Some new, high-yielding agricultural wells are being installed, but the duration of pumping is generally limited, so annual recharge appears to replenish the aquifer. Although the quantity of ground water appears stable, the documentation of water quality impacts in this document illustrate that continued protection of ground water resources is necessary. Ground water contamination can eliminate the potential use of water resources, just like diminished quantities. If other water sources are not available, additional treatment will increase the cost of providing a needed resource.

As documented in the previous sections, numerous sites exhibit ground water contamination from anthropogenic and natural point and nonpoint sources. The alternative to combat natural sources of contamination that cause impairment of drinking water is to develop and install treatment that removes the contamination or to locate another water source. The options for managing anthropogenic sources are more numerous, with the most constructive focusing on prevention of releases that migrate to ground water. Instituting best management practices (especially for the use of fertilizers and salt storage), implementing appropriate siting criteria for new waste storage and disposal sites and improving design for material storage and waste disposal facilities are proactive approaches to prevent releases to ground water. These kinds of proactive practices are critical to the sustainability of Ohio’s high-quality ground water resources.
The ongoing implementation of the Source Water Protection Program (SWAP) for Ohio’s public water systems helps raise awareness of ground water quality issues and promotes source water protection planning. The SWAP potential contaminant source inventory data is instrumental in identifying and ranking major sources of contamination near public water systems. SWAP staff has also had key roles in the development of several guidance documents to help protect ground water in association with the SCCGW.

Generally, awareness and concern about ground water resources is increasing. State agencies are working together to develop appropriate guidance or guidelines for activities that may threaten ground water. This is documented by the development of the *Recommendations for Geothermal Heating and Cooling Systems* (February 2012) and *Recommendations for Salt Storage* (February 2013). A recent guidance is the updated *Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes*, finalized in March 2015. ODNR, in conjunction with several other agencies, has revised and developed fact sheets and best management practices to provide information on water resource issues associated with shale gas development. These documents are available on the ODNR Division of Oil and Gas Resources web page in the Shale activity section: [oilandgas.ohiodnr.gov/shale#SHALE](http://oilandgas.ohiodnr.gov/shale#SHALE).

To help provide well owners information on water quality, Ohio EPA worked with ODH and OSU Extension on the development of a new web-based water quality interpretation tool for private well owners. In the *Know Your Well* tool, water sample results from a lab sheet are entered into the tool and with one click, well owners are provided with the standard for the parameter of interest, the natural range in ground water in Ohio for comparison, recommendations on actions, health effects and treatment options if applicable. The tool is part of the website hosted at OSU Extension at: [ohiowatersheds.osu.edu/know-your-well-water](http://ohiowatersheds.osu.edu/know-your-well-water).