Section

M

An Overview of Ground Water Quality in Ohio

M1. Introduction

Section M summarizes water quality assessment data for Ohio's major aquifers based on information requested in the 2006 Integrated Reports Guidance and the 1997 Guidelines for Preparation of the Comprehensive State Water Quality Assessments.

Ground water protection programs for Ohio are briefly summarized in Section M2 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, the Division of Drinking and Ground Waters (DDAGW) carries out these functions, and coordinates various ground water monitoring efforts within the agency and with other state programs through the Ohio Water Resources Council and the State Coordinating Committee on Ground Water. The program descriptions are significantly reduced from what was presented in past Ground Water Chapters in the belief that links to program-based web pages provide the most current information.

Ohio's three major aquifer types are described in Section M3. Where possible, the water quality data are associated with major aquifer types. The aquifer descriptions allow the reader to associate water quality impacts with geologic settings.

Sections M4 and M5 summarize sites with verified ground water contamination and identify the major nonpoint sources of ground water contamination in Ohio. These data were obtained from various sources including:

- Ground Water Impacts Database (maintained by Ohio EPA, DDAGW);
- Potential contaminant sources inventoried as part of the Source Water Assessment and Protection Program (SWAP);
- Underground injection control sites identified in Ohio EPA – DDAGW and Ohio Department of Natural Resources (ODNR) – Division of Mineral Resource Management (DMRM) databases;
- Leaking and formerly leaking underground storage tanks from Bureau of Underground Storage Tank Regulations (BUSTR) databases; and
- 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.

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

Section M6 summarizes ground water quality impairments by parameter within Ohio's major aquifers. Two primary data sets are used to characterize ground water quality in this analysis: the drinking water compliance data for public water systems (PWSs); and the ambient ground water quality data. Ohio's public water system compliance monitoring data represents water quality for treated (post-processing) water distributed to the public and was used to characterize ground water quality within Ohio's major aquifers. The Ambient Ground Water Quality

Monitoring Program (AGWQMP) is the Ohio EPA DDAGW program created to monitor "raw" (untreated) ground water. The program's 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 (MCL) levels or secondary maximum contaminant levels (SMCL) for drinking water were used.

Section M7 briefly discusses ground water-surface water interaction (GW-SW) and a few special studies that provide insight on the interaction, which lead to suggestions for future ground water monitoring efforts. Section M8 presents conclusions and recommendations for future direction concerning statewide ground water monitoring and protection of Ohio's major aquifers.

M2. Ohio's Ground Water Programs

Ohio Water Resources Council - On July 1, 2001, Governor Bob Taft established a permanent Ohio Water Resources Council (OWRC) with the mission: Guide the development and implementation of a dynamic process to advance the management of Ohio's water resources. The State Agency Coordination Group, with representatives from the state agencies dealing with water issues, was also established to serve as a technical resource for the OWRC. The current 10-year vision and four year action plan focuses on water resources in the following areas: data and information, education and outreach, watershed management, water quality, water quantity, water resource infrastructure, and water related natural hazards. http://www.dnr.state.oh.us/tabid/15378/default.aspx.

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 of the SCCGW is to promote and guide the implementation of coordinated, comprehensive, and effective ground water protection and management programs for Ohio. The SCCGW used the OWRC's four-year action plan to outline SCCGW priorities. Details on the SCCGW priority actions for data and information, education and outreach, watershed management, water quality, water quantity, water resource infrastructure, and water related natural hazards are provided in the priorities section of the SCCGW Web site. http://wwwapp.epa.ohio.gov/ddagw/SCCGW/index.html

Ohio Ground Water Protection Programs - Programs to monitor, evaluate, and protect ground water resources in Ohio are administered by federal, state and local agencies. The Ohio EPA is the designated state ground water quality management agency. The ODNR Division of Water 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 M-1 (Table 5-2, U.S. EPA 305(b) Guidelines, 1997) summarizes agencies responsible for administering the various ground water programs in Ohio.

Table M-1. Summary of Ohio ground water protection programs.

Programs or Activities	Check (✓)	Implementation Status	Responsible State Agency
Active SARA Title III Program	✓	E	OEPA - DERR
Ambient ground water monitoring system	✓	E	OEPA - DDAGW
Aquifer vulnerability assessment	✓	CE	ODNR – DSWR OEPA – DDAGW
Aquifer mapping	✓	CE	ODNR – DSWR OEPA – DDAGW
Aquifer characterization	✓	CE	ODNR – DSWR
Comprehensive data management system	✓	UR [a]	OWRC
Consolidated Cleanup Standards	NA		
Ground water Best Management Practices	✓	E	ODNR, ODA
Ground water legislation	✓	UR [b]	All Agencies
Ground water classification	✓	E [c]	OEPA, ODNR
Ground water quality standards (program specific)	✓	E [d]	OEPA
Interagency coordination for ground water protection initiatives	✓	E	OWRC, SCCGW
Nonpoint source controls	✓	CE	ODA, OEPA, ODNR
Pesticide State Management Plan	✓	E [e]	ODA
Pollution Prevention Program	✓	E	OEPA - OCAPP
Resource Conservation and Recovery Act (RCRA) Primacy	✓	E	OEPA - DMWM
Source Water Assessment Program	✓	E	OEPA - DDAGW
State Property Clean-up Programs	✓	E	OEPA - DERR
Susceptibility assessment for drinking water/wellhead protection	✓	E	OEPA
State septic system regulations	✓	UR [f]	ODH, OEPA
Underground storage tank installation requirements	✓	E	SFM/BUSTR
Underground Storage Tank Remediation Fund	✓	E [g]	SFM/BUSTR
Underground Storage Tank Permit Program	✓	E	SFM/BUSTR
Underground Injection Control Program	✓	E [h]	OEPA – DDAGW ODNR – DMRM
Well abandonment regulations	✓	E [i]	ODNR, OEPA DDAGW, ODH
Wellhead Protection Program (EPA-approved)	✓	E [j]	OEPA
Well installation regulations	✓	E [k]	OEPA, ODH

Table Notes: **E** – Established; **CE** - Continuing Effort; **UD** - Under Development; **UR** - Under Revision

[a] Data management occurring on an agency level. A web based ground water metadata site was developed to provide links to ground water quality data in Ohio and OWRC proposed expanding this site to develop an Ohio Water Information Gateway. It appears, however, improvements in search engines make this effort unnecessary.

[b] Rules are required to be reviewed every 5 years by state statute.

[c] Established through program specific classifications.

[d] Standards are program-specific.
[e] ODA received cooperative commitment from other Ohio agencies for the Generic Pesticide Management Plan. The requirement for Specific Pesticide Management Plan was dropped.
[f] The recent changes to law regarding home and small flow sewage treatment systems allow the ODH to move forward with the development of new statewide sewage rules. The current version of the Ohio Administrative Code (OAC) Chapter 3701-29 has not changed and will remain in effect until new rules are adopted after January 1, 2012. In addition, more stringent local health district rules that have been adopted since the state rule change in 2007, also remain in effect until new state rules are adopted after January 1, 2012. All existing sewage treatment system approvals and special device approvals authorized by the Director of Health remain approved until new rules are adopted. Larger systems are regulated by Ohio EPA under separate regulations.
[g] Remediation funds are available from the Petroleum Underground Storage Tank Release Compensation Fund.
[h] Ohio EPA regulates Class I and V injection wells; ODNR regulates Class II and III injection wells.
[i] Technical Guidance for Sealing Unused Wells prepared by SCCGW (1996).
[j] Wellhead Protection Program has evolved to the Source Water Protection Program.
[k] Technical Guidance for Well Construction and Ground Water Protection prepared by SCCGW (2000). Ohio EPA new wells workgroup has revised requirements for approving new PWS wells which incorporate elements of the Source Water Protection Program and water quality into the well approval process.

Program Web Sites:

ODA - Ohio Department of Agriculture
- Pesticide and Fertilizer Regulation Program http://www.ohioagriculture.gov/pesticides/
- Livestock Environmental Permitting Program http://www.agri.ohio.gov/divs/LEPP/Lepp.aspx

ODH - Ohio Department of Health http://www.odh.ohio.gov/odhPrograms/eh/sewage/sewage1.aspx

ODNR - Ohio Department of Natural Resources http://www.dnr.state.oh.us/
- Division of Soil and Water Resources http://www.dnr.state.oh.us/soilandwater
- Division of Mineral Resources Management http://www.dnr.state.oh.us/mineral/default/tabid/10352/Default.aspx
- Division of Oil and Gas Resource Management (see Division of Mineral Resources Management web site)
- Division of Geologic Survey http://www.dnr.state.oh.us//geosurvey

Ohio EPA - Ohio Environmental Protection Agency http://www.epa.ohio.gov/
- Division of Drinking and Ground Waters http://www.epa.ohio.gov/ddagw/Home.aspx
- Division of Surface Water http://www.epa.ohio.gov/dsw/Home.aspx
- Office of Compliance Assistance and Pollution Prevention http://www.epa.ohio.gov/ocapp/Home.aspx
- Division of Environmental Response and Revitalization http://www.epa.ohio.gov/derr/Home.aspx
- Division of Materials and Waste Management http://www.epa.ohio.gov/dhwm/Home.aspx

OWRC – Ohio Water resource Council http://www.ohiodnr.com/tabid/15378/default.aspx

SCCGW – State Coordinating Committee on Ground Water http://wwwapp.epa.ohio.gov/ddagw/SCCGW/

SFM/BUSTR – State Fire Marshall/ Bureau of Underground Storage Tank Regulations http://www.com.ohio.gov/fire/bustMain.aspx

M3. Ohio's Major Aquifers

Ohio has abundant surface and ground water resources. Average rainfall ranges between 30 to 44 inches a 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 M-1. The sand and gravel buried valley aquifers (in blue) are distributed through the state. The valleys filled by these sands are cut into sandstone and shale in the eastern half of the state (in rose) and into carbonate aquifers (in greens) in the western half of the state. The sandstone and carbonate aquifers generally provide sufficient production for water wells except where dominated by shale, as in southwest and southeast Ohio.

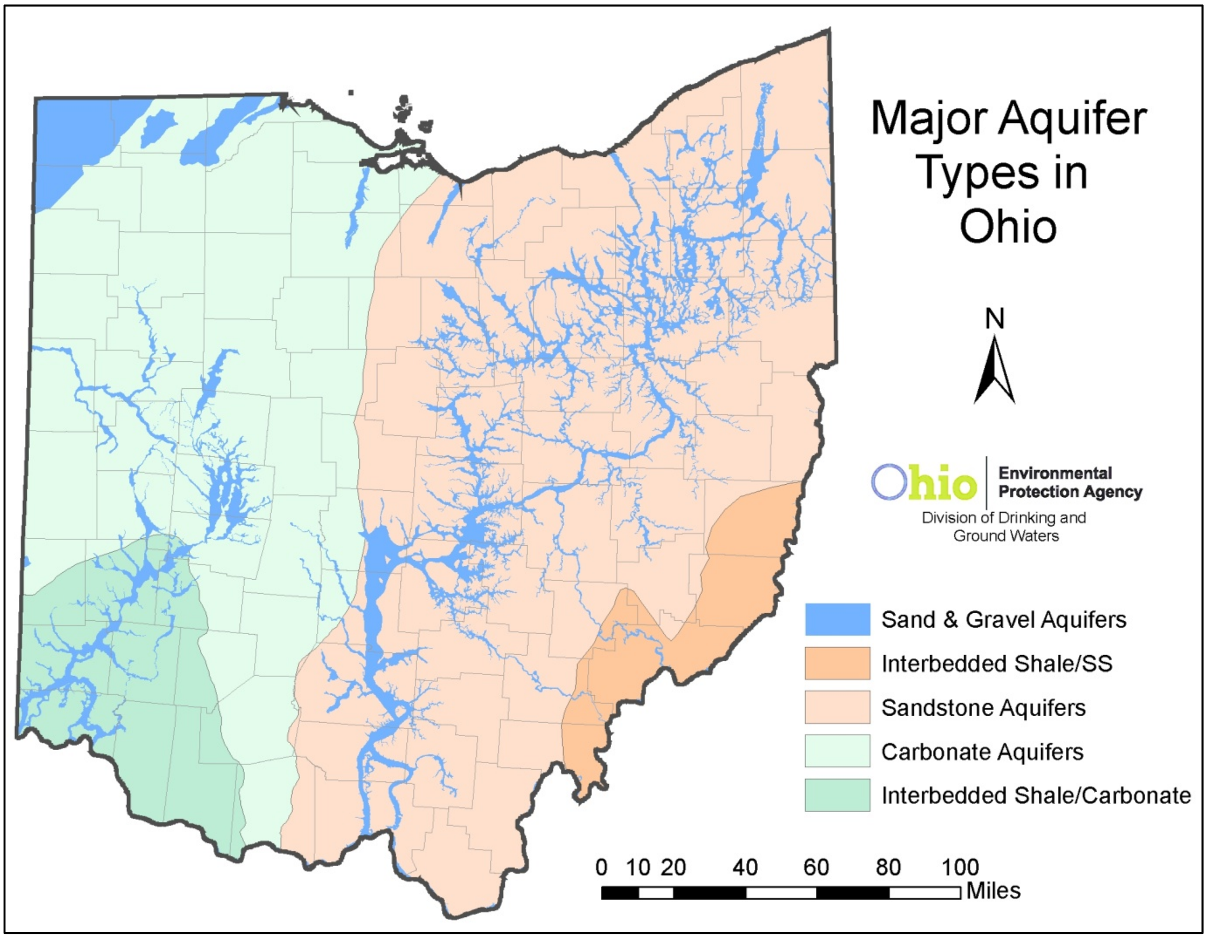

Figure M-1. Aquifer Types in Ohio modified from ODNR glacial and bedrock Aquifer Maps (ODNR, 2000; *http://www.dnr.state.oh.us/water/samp/default/tabid/4218/Default.aspx)*.

Sand and Gravel Aquifers - The unconsolidated sand and gravel units, typically associated with buried valley aquifer systems, are Ohio's most productive water-bearing formations or aquifers. These valleys were cut into the bedrock by pre-glacial and glacial streams and, subsequently, the valleys were back-filled with deposits of sand, gravel and other glacial drift by glacial and alluvial processes as the glaciers advanced and receded. Buried valley aquifers are found beneath and adjacent to the Ohio River, its major tributaries, and other pre-glacial stream channels such as the Teays River. The distribution of these Quaternary sand and gravel units is presented as thin bands of blue in Figure M-1 (modified from ODNR Glacial Aquifer Maps, 2000). In addition to the buried valley aquifers, several other types of productive sand and gravel aquifers are included in Figure M-1. In the northwest corner of the state, the triangular area of sand and gravel units bordering Michigan and Indiana includes sheets of outwash or sand and gravel that occur between sheets of glacial till. Present day stream processes deposit alluvial sand and gravel deposits that also serve as aquifers. Other geologic settings included in the sand and gravel aquifers are the outwash/kame and beach ridge deposits, including the Oak Opening Sands (large patches of sand and gravel in northwest Ohio).

Water production from the coarser-grained and thicker sand and gravel deposits ranges up to 500 to 1,000 gallons per minute. Lower yields from sand and gravel aquifers are more common. The production rate depends on the type, distribution, permeability, and thickness of permeable glacial/alluvial deposits and well construction parameters, such as well diameter and length of well screen.

Sandstone Aquifers - In eastern Ohio, Mississippian and Pennsylvanian sandstone units are the dominant bedrock aquifers (Figure M-1). Upper Paleozoic siltstone, sandstone, and conglomerate formations (Mississippian to Permian age) in eastern Ohio occur as numerous layers of siltstone and sandstone of variable thickness and areal extent separated by layers of shale and minor amounts of limestone, clay and coal. The sandstone units generally dip a few degrees to the southeast, toward the Appalachian Basin. Some of the thicker sandstones and conglomerates are capable of yielding 50 to 100 gallons per minute, but 25 gallons a minute is a good yield for these aquifers. The more productive stratigraphic units include:

- **Pennsylvanian Sharon through Massillon Formations, and the Homewood Sandstone within the Pottsville and Allegheny Groups** - These sandstones were deposited on a stable coastal plain under conditions of rising sea level. These aquifers are most commonly used in the northern areas of Eastern Ohio. To the southeast, farther into the Appalachian Basin, the water in these units is generally too saline for drinking.

- **Mississippian Berea Sandstone, Cuyahoga Group, Logan and Blackhand Formations** - These siltstones and sandstones with minor conglomerate were sorted and deposited in deltaic complexes from material eroded from the Acadian Mountains (Late Devonian uplift) to the east. These units also extend to the SE, farther into the Appalachian Basin, but as with the Pennsylvanian units, the water becomes too saline for drinking.

In southeastern Ohio, Upper Pennsylvanian and Permian stratigraphic sections include low-yielding aquifers. The bedrock consists of varied sequences of thin-bedded shales, limestones, sandstones, clays, and coals of the Pennsylvania, Conemaugh and Monongahela Groups and the Permian Dunkard Group. Yields below five gallons per minute are common in these areas (see http://www.dnr.state.oh.us/water/samp/default/tabid/4218/Default.aspx).

Carbonate Aquifers - Carbonate bedrock is the dominant aquifer in western Ohio (Figure M-1). Middle Devonian and Silurian limestone and dolomite reach a total thickness of 300 to 600 feet, and are capable of yielding from 100 to over 500 gallons of water per minute. Higher production units are associated with fractures and dissolution features that increase the permeability. The high production aquifers, in order of deposition, are fractured or karst Silurian sub-Lockport/ Lockport Dolomite and equivalent units, the Salina Group, consisting of the Tymochtee and Greenfield Dolomites, and the Undifferentiated Salina Dolomite. The Devonian Delaware and

Columbus Limestones, exposed along the eastern edge of the Silurian Dolomites, and equivalent Devonian units in the northwest corner of Ohio (Ten Mile Creek Dolomite, Silica formation, Dundee Limestone, and Detroit River Group) are productive carbonate aquifers. These carbonates were generally deposited in warm, shallow seas with limited input of sediment from continental sources. Where the Devonian limestone is overlain by 100 feet or more of Devonian shale, the water quality is poor and generally cannot be considered a drinking water source.

Southwestern portion of the state is underlain by inter-bedded lower Ordovician carbonates and shales. These undivided Ordovician units are dominated by shale (Figure M-1). As a result, well yields are generally less than 10 gallons per minute, and in many areas, yields are less than one gallon per minute. In this area, public water systems depend on the buried valley aquifers as the main ground water source. The low yielding aquifers are only practical for low volume use, and consequently, this aquifer is not discussed further in this report. Another area with low yields is the region of Devonian shale that overlies the Columbus and Delaware Limestone aquifers. The narrow north-south trending area of the Devonian shale in central Ohio curves eastward along the Lake Erie shoreline. These shale bedrock units are poor aquifers yielding less than 5 gallons per minute. In addition, hydrogen sulfide is frequently present in these shales, which causes water quality problems.

M4. Site-Specific Ground Water Contamination Summary

Table M-2 (based on Table 5-3, U.S. EPA 305(b) Guidelines, 1997) provides a summary of the sites that have verified ground water contamination in Ohio. These data come from various state programs and the quality of these data varies. Because the specific hydrogeologic settings for many of these sites is not included in the databases or is unknown, only a statewide summary is provided. Additional information is provided below for each program or subset of sites listed in Table M-2.

Federal National Priorities List (NPL): Currently, 35 sites in Ohio are on the NPL, most of which (31) have been found to be affecting ground water quality. The primary contaminants are volatile organic chemicals (VOCs) and heavy metals.

CERCLIS (non-NPL): Ohio has 402 sites in the federal CERCLIS database. Of these, 58 are known to have had a release to ground water.

DOD/DOE: The 124 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 more than 32,000 sites have been found to be leaking. Of these, 1,231 have confirmed releases, with 660 having a release to ground water. The primary contaminants are petroleum products benzene, toluene, ethylbenzene, xylenes (BTEX).

Table M-2. Ground water contamination summary.
Hydrogeologic Setting: Statewide
Data Reporting Period: As of September, 2011

Source Type	Number of sites	Number of sites that are listed and/or have confirmed releases	Number of sites with confirmed ground water contamination	Contaminants
NPL	35	35	31	Mostly VOCs and heavy metals; also, SVOCs, PCBs, PAHs and others
CERCLIS (non-NPL)	402	402	58	Varied
DOD/DOE	124[a]	68	68	Varied
LUST	32,613[b]	1,231	660[c]	BTEX
RCRA Corrective Action	130	130	130	VOCs, heavy metals, PCBs, and others
Underground Injection	Class[d]: I - 10 II - 385 III - 47 IV - 0 V - 50,000+	0 0 0 0 NA	0 0 0 0 NA	
State Sites [e]	752	617	246[f]	Varied
Nonpoint Sources	NA	NA	NA	

Notes:
NA - Numbers not available
[a] Includes DOE, DOD, FUSRAP and FUD sites
[b] Includes only active LUST sites. Source: Ohio's Bureau of Underground Storage Tank Regulations
[c] Sites in Tier 2 or Tier 3 cleanup stages. Source: Ohio's Bureau of Underground Storage Tank Regulations
[d] Class II and Class III injection wells regulated by the Ohio Department of Natural Resources. Class IV injection wells are illegal in Ohio. The total number of Class V injection wells in Ohio is unknown.
[e] Facilities in Ohio EPA's Ground Water Impacts database
[f] A site is considered to be contaminating ground water if the "Uppermost Aquifer" or "Lower Aquifer" is noted to be impacted, found in Ohio EPA's Ground Water Impacts database

RCRA Corrective Action: Currently, 130 facilities are in RCRA corrective action. All of these have confirmed releases to ground water. The primary contaminants are VOCs and heavy metals. This information was obtained from the RCRA Facility Database, an internal DDAGW tracking system.

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; there are none in Ohio);
Class V wells comprise all of the injection wells not included in Classes I-IV.

The Ohio Department of Natural Resources, Division of Mineral Resource Management regulates Class II (385) and Class III (47) wells. The number of Class II wells (brine injection wells) is increasing because of their use in disposal of fluids used in oil and gas drilling and shale gas development. Neighboring states have been applying to inject their brine waste into Class II wells in Ohio.

Ohio EPA DDAGW regulates Class I (10), Class IV (0), and Class V (+50,000) wells. Although owners and operators of Class V wells are required to register their wells, there are still many that are unknown and unregistered throughout the state.

State Sites: State sites include landfills, RCRA-regulated hazardous waste sites, 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 September, 2011, the database contained 617 sites. Of the 617 sites, 246 sites have affected ground water quality within the uppermost aquifer or lower aquifer, the local aquifers that can be used as drinking water sources.

Figure M-2 illustrates the distribution of the sites with verified ground water quality releases as recorded in the Ground Water Impacts Database. Several types of saturated ground water zones or aquifers are identified for each site depending on the regulatory program and the zone being monitored. The monitored zones include but are not limited to significant zones of saturation and uppermost aquifers. For the purpose of Figure M-2 (and state sites in Table M-2), contamination had to be present in either the uppermost aquifer or lower aquifer to be counted as having ground water contamination (246 facilities). The type of contaminants varies with the majority being VOCs and heavy metals. The majority of the sites are concentrated near the large, urban areas, such as Cincinnati/Dayton in southwest Ohio, Columbus in central Ohio, and the Cleveland/Akron area in northeast Ohio. Of the 246 sites, landfills are found to contribute the most to ground water contamination (126, or 51%). Most likely, these are from older, unlined landfills, many of which are currently closed.

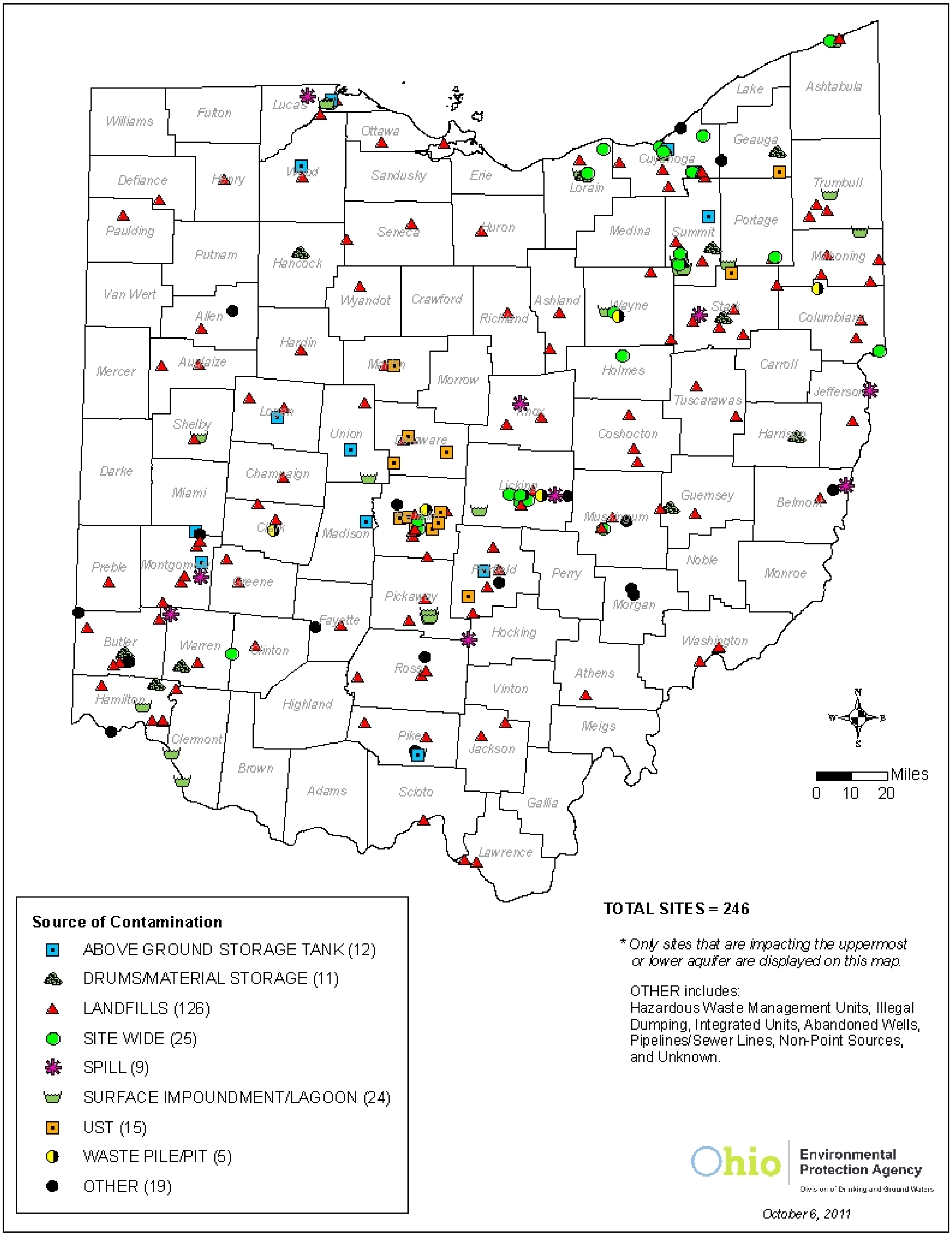

Figure M-2. Locations of sites with documented ground water impacts in Ohio.

M5. Major Sources of Ground Water Contamination

Although available data show that much of Ohio's ground water is of high quality and has not been widely influenced by anthropogenic activities, 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, that are applied, stored, and disposed of on the land. Consequently, ground water quality is susceptible to contamination from a range of contaminants and a variety of land use activities.

The ten major sources of ground water contamination in Ohio are indicated in Table M-3 (Table 5-1, U.S. EPA 305(b) Guidelines, 1997) by checks (✓). These data were obtained from two sources: Ohio's Source Water Assessment and Protection (SWAP) Program and DDAGW's Ground Water Impacts Database. The SWAP Program has completed an inventory of the potential sources of ground water contamination in the delineated Drinking Water Source Protection Areas. Ninety-nine percent (99%) of the active public water systems that use ground water have had an inventory conducted, an analysis of the aquifer's susceptibility to contamination 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 M-3.

Some of the "potentially high priority" sources, indicated by crosses (×), 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 and may not be sited close to public water system well fields and, therefore, do not rank in the highest priority sources. However, where they are prevalent, these sources may be a threat to 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 of the sources listed in Table M-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 M-3 and discussed briefly to provide additional information.

<u>(✓) Highest Priority Sources</u>

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

- **Land Application of Manure and Sludge:** The concerns for land application of manure and sludge are similar to the issues of fertilizer application described above, with the addition of pathogen sources. Agriculture practices dominate much of Ohio's landscape. The growth of animal feeding operations and sewage treatment facilities increases the land application of manure and sludge that is being spread on fields as fertilizer.

Table M-3. Major sources of ground water contamination.

Contaminant Source	Highest-Priority Sources	Factors Considered in Selecting a Contaminant Source	Contaminants
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots	×	6, 8	E, J, K, L
Drainage wells			
Fertilizer applications	✓	1, 2, 3, 4, 5	E, J, K, L
Irrigation practices			
Pesticide applications			
On-farm agricultural mixing and loading			
Land application of manure	✓	1, 3, 5	E, J, K, L
Storage and Treatment Activities			
Land application	×	6, 8	E, J, K, L
Material stockpiles	✓	6	H, M
Storage tanks (above/below ground)	✓	1, 2, 3, 4, 5, 6, 7	C, D, H, M
Surface impoundments	✓		G, H, M
Waste piles			
Waste tailings			
Disposal Activities			
Deep injection wells			
Landfills	✓	1, 2, 3, 4, 5, 6	A, B, C, D, H, J, K, L, M
Septic systems	✓	1, 2, 3, 4, 5, 6	E, H, J, K, L
Shallow injection wells	✓	1, 2, 3, 4, 5, 6, 8	C, D, G, H, M
Other			
Hazardous waste generators			
Hazardous waste sites	✓	1, 2, 3, 4, 5, 6, 7	A, B, C, D, H, I, M
Large industrial facilities			
Material transfer operations			
Mining and mine drainage	×	6, 8	G, H
Pipelines and sewer lines			
Salt storage and road salting	×	6	G
Spills	×	6	C, D, H, M
Transportation of materials			
Urban runoff (storm water management)	✓	2, 4	A, B, C, D, G, H
Small-scale manufacturing and repair shops			

Notes: (✓) Highest Priority; (×) Potentially High Priority
Factors and Contaminants codes on next page.

FACTORS
1. Human health and/or environmental risk (toxicity)
2. Size of the population at risk
3. Location of the sources relative to drinking water sources
4. Number and/or size of contaminant sources
5. Hydrogeologic sensitivity
6. State findings, other findings
7. Documented from mandatory reporting
8. Geographic distribution/occurrence

CONTAMINANTS
A. Inorganic pesticides
B. Organic pesticides
C. Halogenated solvents
D. Petroleum compounds
E. Nitrate
F. Fluoride
G. Salt/Salinity/brine
H. Metals
I. Radionuclides
J. Bacteria
K. Protozoa
L. Viruses
M. Other (VOCs)

- **Material Stockpiles:** A material stockpile can consist of almost any type of material. For example, it can include manure, biosolids, salt, or a hazardous substance or waste.

- **Storage Tanks (Underground and Above-ground):** The 1994 State of Ohio Nonpoint Source Assessment Ground Water Component Report documented that underground storage tanks (USTs) were a major source of ground water contamination. The large number of USTs and their hidden nature contributes to the lack of proper maintenance. There are around 660 USTs known to be leaking or undergoing remediation in Ohio. Leaking above-ground storage tanks from commercial and industrial facilities are less of an issue. There are only nine known to be contributing to ground water contamination from regulated facilities; most are hazardous waste sites. The smaller above-ground tanks used to store fuel oil to heat individual homes may be a bigger concern. Many of these above ground tanks are old and rusty with no containment in the event of a leak or spill. Fuel oil tanks are found throughout Ohio, primarily in rural areas.

- **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. Proper engineering controls are encouraged for surface impoundments for shale gas drilling and hydrofracturing activities.

- **Landfills:** Currently, there are about 126 landfills with documented ground water contamination in Ohio. This constitutes 51 percent of the sites known to be affecting ground water quality based on information in Ohio EPA's Ground Water Quality Impacts database. Most likely, these are from older, unlined landfills, many of which are currently closed. The current siting, design, and construction standards for landfills are more stringent than twenty years ago, with the result that new landfills have significantly lower potential to impact ground water quality. Efforts to update siting and design criteria for Construction and Demolition Debris (C&DD) landfills are geared to reducing ground water quality impacts at C&DD sites.

- **Septic Systems:** Over 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 (e.g., shallow fractured bedrock and sand and gravel deposits).

- **Shallow Injection Wells:** Class V injection wells are widespread throughout the state, with some areas having a high concentration of wells. It is estimated that Ohio has over 50,000 class V injection 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. Ohio has closed 582 motor vehicle waste disposal wells (e.g., oil, radiator fluids, etc.) since 2000.

- **Hazardous Waste Sites:** Ohio generates a large amount of hazardous waste. Industrial sites and other locations where hazardous waste is generated or stored are not considered hazardous waste sites until hazardous waste has been spilled or released. Hazardous waste sites are a serious threat to ground water. There are 60 RCRA hazardous waste facilities, 15 Voluntary Action Program sites, and 61 unregulated hazardous waste remediation sites with documented releases to ground water (uppermost or lower aquifer) based on the GW Impacts Database.

- **Suburban /Urban Runoff:** 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 recent practice of constructing storm water retention basins increases the likelihood that storm water runoff infiltrates into ground water. Elevated chloride concentrations are documented in urban areas within glacial aquifers by Mullaney et al. (2009) and we see indications of positive trends in chloride concentrations in Ambient Ground Water Quality Monitoring data at some sites.

<u>(×) Potentially High Priority Sources</u>

- **Concentrated Animal Feeding Operations (CAFO):** It is difficult to identify ground water impacts associated with CAFOs. Nevertheless, the growth of these operations 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 and fertilizer application and surface impoundments, so they are not considered one of the ten highest priority sources.

- **Land Application (for wastewater treatment):** The concerns for land application of wastewater sludge are similar to the issues for land applying manure and sludge described above. The growth of sewage treatment facilities increases the land application of wastewater and sludge.

- **Mining and Mine Drainage:** The bedrock (Pennsylvanian Units) that underlies eastern Ohio includes significant coal resources. The relatively high sulfur content of Ohio coal, concerns about acid rain, and clean air standards have resulted in a reduction of Ohio coal production. The number of operating coal mines is decreasing more rapidly than total coal production, as production is concentrated in larger underground mines. 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.

- **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 chlorine contamination of shallow ground water (Jones and Sroka 1997; Mullaney et al. 2009). Local impact of salt storage sites is significant, and over the past two years Ohio has documented impacts to ground water at numerous salt storage facilities. Ohio is exploring ways to encourage implementation of BMPs for proper salt storage. Alternative chemicals like acetate-based deicers in combination with reduced salt usage are being promoted in pollution prevention programs.

- **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 into the surface and near surface environment is certainly one of the greatest threats to ground water quality. Several of the sources of leaks, such as LUST, storage facilities, and surface impoundments, are included with the Highest Priority Sources. Shale gas drilling and hydrofracturing activity in Ohio has potential to impact ground water through improper handling of development and production brines. Reducing leaks and spills of brines and disposal of brines in Class II injection wells are critical activities to minimize the potential for drinking water impact.

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 tills 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. However, in sensitive settings (e.g., sand and gravel aquifers, shallow bedrock aquifer), 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.

M6. Summary of Ground Water Quality by Aquifer

Tables M-4A and M-4B (Table 5-4, U.S. EPA 305(b) Guidelines, 1997) summarize water quality compliance data from Ohio public water systems (PWSs) and raw water data from the Ambient Ground Water Quality Monitoring Program (AGWQMP), respectively. The compliance data for

Ohio EPA's PWSs (Table M-4A) documents water quality for treated water (post processing) and some raw (untreated) water quality (like new well samples). It is used primarily to track PWS compliance; however, parameters that are generally unaffected by standard treatment, such as nitrate, may be used to characterize Ohio's ground water quality. DDAGW created the AGWQMP program (Table M-4B) 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 the Ohio's major aquifer systems.

Ohio does not have statewide ground water quality standards, so data for the major aquifers are summarized using percentages of primary maximum contaminant level (MCL) or secondary maximum contaminant level (SCML) parameters. 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.

Primary and secondary MCLs are used as practical benchmarks for water quality characterization in Tables M-4A and M-4B. Fifty percent of the MCL to the MCL is used as the range for the **"watch list"** determination. The PWSs or wells identified in this category may warrant monitoring to identify increasing trends. Exceedance of the MCL is used as the criteria for the **"impaired"** category. Tables M-4A and M-4B were generated using the last 10 years of data (2001-2010) and mean concentrations of a parameter are used for deciding if a PWS or well is included in the watch list (50% to 100 % MCL) or impaired category (> MCL). 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 PWS compliance data for 2001-2010 to determine the number of PWSs on the watch list and in the impaired category. A ten year period of record was used to increase the statistical significance of the determination due to the infrequent sampling requirements (e.g., once per three year period). **PWSs included in the impaired category may not match Safe Drinking Water Act regulatory determinations of a violation due to the method of calculation.** An MCL exceedance for compliance is generally an annual average, so the decadal average presented in Table M-4A is not a compliance number, but rather a comparison to MCL values as a benchmark to identify PWSs in the watch list and impaired categories.

Table M-4A lists all parameters with MCLs (and SMCLs), the standard, and summarizes the number of PWSs in the watch list and impaired category for both raw and treated water quality data. The results for each parameter are divided into the major aquifer types. The total number of PWSs with data used in these determinations is presented to allow comparison of the total number of PWSs to those that exhibit elevated concentrations of MCL parameters. Data from active and inactive systems is included in Table M-4A.

Table M-4A. Counts of PWSs where 2001-2010 decadal mean values of compliance data occur in the Watch List and Impaired Category.
Note: presented by major aquifer types.

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL	Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL
Inorganics	Antimony	MCL	6 µg/L	Sand & Gravel	201	3		719	13	
				Sandstone	224	6	1	712	18	
				Carbonate	183	2		509	7	
	Arsenic	MCL	10 µg/L	Sand & Gravel	254	52	65	712	68	22
				Sandstone	234	21	9	671	30	9
				Carbonate	217	46	43	472	67	16
	Asbestos	MCL	$7x10^6$ fibers/L	Sand & Gravel	14			231		
				Sandstone	6			128		1
				Carbonate	3			114		
	Barium	MCL	2 mg/L	Sand & Gravel	205	2		685	5	
				Sandstone	229	5		662	1	
				Carbonate	186	1	2	457	2	
	Beryllium	MCL	4 µg/L	Sand & Gravel	198	2		689	1	
				Sandstone	228			668		
				Carbonate	179			468		
	Cadmium	MCL	5 µg/L	Sand & Gravel	209		1	681	1	
				Sandstone	234		1	661	4	
				Carbonate	201			456		
	Chloride	SMCL	250 mg/L	Sand & Gravel	201	8	2	22	3	
				Sandstone	219	14	13	21	5	
				Carbonate	178	5	1	16		
	Chromium	MCL	0.1 mg/L	Sand & Gravel	203			689		
				Sandstone	226	2	1	650		
				Carbonate	183			453		
	Cyanide	MCL	0.2 mg/L	Sand & Gravel	198			662		
				Sandstone	227			643		
				Carbonate	187			435		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL	Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL
	Fluoride	MCL	4 mg/L	Sand & Gravel	225	3		712	4	
				Sandstone	222	1		681		
				Carbonate	179	16		472	21	
	Iron	SMCL	0.3 mg/L	Sand & Gravel	203	10	169	121	13	22
				Sandstone	219	36	141	47	9	13
				Carbonate	194	26	137	61	6	29
	Manganese	SMCL	0.05 mg/L	Sand & Gravel	179	32	104	81	14	14
				Sandstone	217	36	139	50	3	17
				Carbonate	164	35	40	36	9	6
	Mercury	MCL	2 µg/L	Sand & Gravel	206			681		
				Sandstone	227	1		662	1	
				Carbonate	181	1		453		
	Nitrate * (Max Value)	MCL	10 mg/L	Sand & Gravel	229	10	8	1661	79	20
				Sandstone	231	3	2	2003	61	5
				Carbonate	209	3	5	1520	47	15
	Nitrite * (Max Value)	MCL	1 mg/L	Sand & Gravel	220		1	1685	10	2
				Sandstone	224			1863	9	
				Carbonate	197			1522	13	
	Selenium	MCL	50 µg/L	Sand & Gravel	199			691		
				Sandstone	225			677		
				Carbonate	185	2		451		
	Silver	SMCL	0.1 mg/L	Sand & Gravel	176			8		
				Sandstone	219			14		
				Carbonate	173		1	6		
	Solids, Total Dissolved	SMCL	500 mg/L	Sand & Gravel	nda	nda	nda	nda	nda	nda
				Sandstone	nda	nda	nda	nda	nda	nda
				Carbonate	nda	nda	nda	nda	nda	nda
	Sulfate	SMCL	500 mg/L	Sand & Gravel	192	14	16	31	10	2

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL	Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL
				Sandstone	222	13	13	15	1	2
				Carbonate	181	21	83	13	3	4
	Thallium	MCL	2 µg/L	Sand & Gravel	204	2	1	675	13	
				Sandstone	217		1	662	7	
				Carbonate	181			460	4	
	Zinc	SMCL	5.0 mg/L	Sand & Gravel	81			18		
				Sandstone	83			18		
				Carbonate	60			9		
Volatile Organic Chemicals	1,2-Dichloroethane	MCL	5 µg/L	Sand & Gravel	225			721		
				Sandstone	251			698		
				Carbonate	200			483		
	1,1-Dichloroethylene	MCL	7 µg/L	Sand & Gravel	222			713		
				Sandstone	243		0	677		
				Carbonate	192			488		
	1,2-Dichloropropane	MCL	5 µg/L	Sand & Gravel	223			718	1	
				Sandstone	246			690		
				Carbonate	194			488		
	Benzene	MCL	5 µg/L	Sand & Gravel	224	1		712		
				Sandstone	248			696		
				Carbonate	195			488		
	Carbon Tetrachloride	MCL	5 µg/L	Sand & Gravel	227			719		
				Sandstone	245		1	693		
				Carbonate	194			488		
	Cis-1,2-Dichloroethylene	MCL	70 µg/L	Sand & Gravel	229			718		
				Sandstone	245			691		
				Carbonate	200			483		
	Dichloromethane	MCL	5 µg/L	Sand & Gravel	222	2		708		1
				Sandstone	251	1		693		1

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL	Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL
				Carbonate	197			484	3	
	Pentachlorophenol	MCL	1 µg/L	Sand & Gravel	5			99		
				Sandstone	nda	nda	nda	47		
				Carbonate	0			25		
	Polychlorinated Biphenyls (PCB)	MCL	1 µg/L	Sand & Gravel	5			100		
				Sandstone	nda	nda	nda	43		
				Carbonate	nda	nda	nda	25	1	
	Styrene	MCL	0.1 mg/L	Sand & Gravel	225			715		
				Sandstone	251			692		
				Carbonate	198			488		
	Tetra-chloroethylene	MCL	5 µg/L	Sand & Gravel	228	2		717		
				Sandstone	250		1	690		1
				Carbonate	197			477		
	Trichloroethylene	MCL	5 µg/L	Sand & Gravel	227	2		716		
				Sandstone	251		1	699	0	
				Carbonate	197	1		484		
	Vinyl Chloride	MCL	2 µg/L	Sand & Gravel	228	3	1	715	1	1
				Sandstone	251			690		
				Carbonate	203			477		
Pesticides	Alachor	MCL	2 µg/L	Sand & Gravel	200			679		
				Sandstone	222			635		
				Carbonate	177			456		
	Atrazine	MCL	3 µg/L	Sand & Gravel	202			679		
				Sandstone	235			635		
				Carbonate	183			453		
	Simazine	MCL	4 µg/L	Sand & Gravel	205			683		
				Sandstone	236			638		
				Carbonate	184			453		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL	Total # PWSs	Watch List > 50% to 100% MCL	Impaired > MCL
Radiological	Gross Alpha	MCL	15 pCi/L	Sand & Gravel	196			351		
				Sandstone	219	4		226		
				Carbonate	171	12	2	179		
	Gross Beta	MCL	4 mrem/yr**	Sand & Gravel	136			19	1	
				Sandstone	149			14		
				Carbonate	123			12		
	Radium 226	MCL	5 pCi/L ***	Sand & Gravel	19			9	1	
				Sandstone	21	1		14	2	
				Carbonate	38	8	1	26		
	Radium 228	MCL	5 pCi/L ***	Sand & Gravel	94			337		
				Sandstone	94	3		249	1	
				Carbonate	88	2		178		

nda Indicates no data available
Blank spaces indicate no PWSs exceed the standards (zeros left out to highlight impacted PWSs).
* Numbers for nitrate and nitrite are based on maximum values to reflect the acute nature of 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

Beyond a new well analysis, there are no requirements for collecting and reporting raw water data so, generally, the number of PWSs with raw water data is less than the number of PWSs with treated water data. The PWS 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 PWS averages. For treated water data, PWS averages were generated only if there were at least two detections of a parameter. The inorganic parameters that place numerous PWSs in the watch list and impaired category warrant additional analysis.

The number of PWSs in Table M-4A in the watch list and the impaired category are low; however, several parameters do exhibit higher numbers of PWSs in these groups. Fortunately, most of these parameters have secondary MCLs. That is, the water quality impacts documented are mostly aesthetic issues and are not health-based. Groups of parameters are discussed individually.

Inorganic Parameters – Most of the inorganic data put few PWSs on the watch list or in the impaired category. For treated water, parameters with no PWSs with impaired values (>MCL or >SMCL) include **antimony, barium, beryllium, cadmium, chloride, chromium, cyanide, fluoride, mercury, selenium, silver, thallium and zinc.** Factors limiting the number of PWSs in these categories include limited solubility of the substance in water, low crustal abundance, local geology, and possibly treatment. For example, fluoride has no PWSs that exceed the MCL, but 21 PWSs 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. **Asbestos** has one impaired PWS with the decadal mean greater than the MCL. The asbestos MCL impairment is most likely tied to the treatment or distribution infrastructure since there is little asbestos present in Ohio Aquifers.

Inorganic parameters that do exhibit impairments in treated water include**: arsenic, iron, manganese, sulfate and nitrate and nitrite.** Several PWSs display elevated **chloride** concentrations, but no treated water exceeds the SMCL. The largest number of PWSs with elevated chloride is associated with the sandstone and sand and gravel aquifers. This may be to be related to oil and gas production from sandstone reservoirs and associated brines, or from local salt storage facilities overlying sensitive aquifers.

The number of PWSs with **arsenic** in raw water and treated water above the MCL (117 and 47, respectively) is consistent with the number of PWSs that DDAGW has 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 PWSs currently exceeding the arsenic MCL is less than what is listed in Table M4-A because numerous PWSs have installed treatment to remove arsenic since 2006, but the exceedances prior to 2006 are still included in the ten years of data used to generated the PWS decadal averages that are counted in the Table M4-A. Figure M-3 illustrates the distribution of the PWSs with arsenic in treated water greater than 50 % of the MCL listed in Table M-4A. The local aquifer must be reduced for arsenic to be elevated in the water.

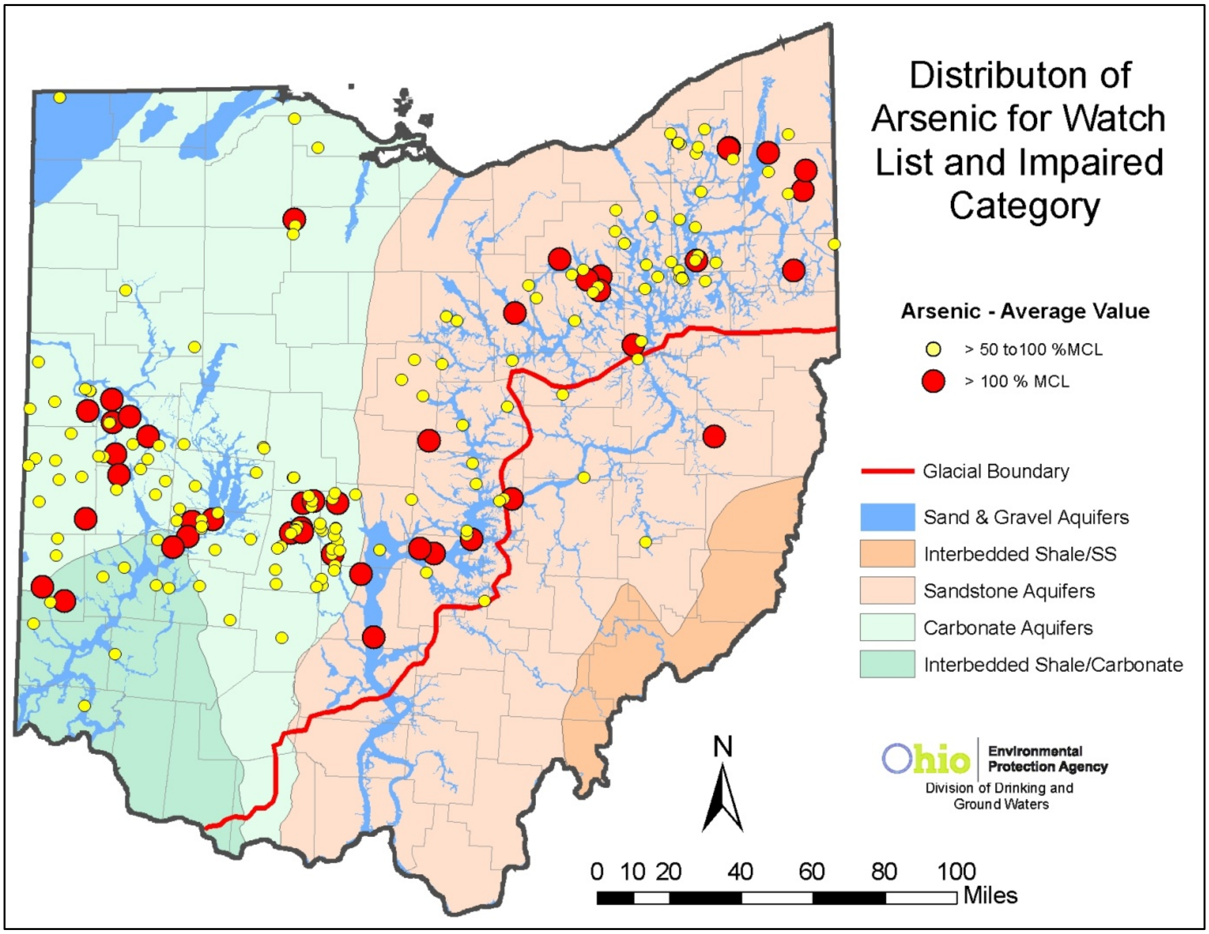

Figure M-3. Distribution of PWSs with treated water where arsenic is > 50 % MCL.

Iron and manganese, with similar oxidation-reduction solubility controls as arsenic, also exhibit elevated numbers of PWSs in the watch list and impaired category of Table M-4A. These numbers are controlled by the increased solubility of iron and manganese in reduced waters. The deeper wells generally exhibit more reduced conditions (e.g., reduced interaction with the atmosphere) and, consequently, higher iron and manganese. Iron and manganese have secondary MCLs so not as many PWSs have collected data for these parameters. For manganese, it appears that the carbonate aquifer is least likely to exhibit concentrations above the SMCL. Because of treatment to remove iron, manganese and arsenic, the percentage of PWSs that exhibit impairments in raw water is significantly higher than in treated water. Figure M-4 exhibits the distribution of PWSs with iron and manganese in treated water that is greater than 50 % of the respective SMCLs. The general distribution of these systems is similar to the PWSs with elevated arsenic since iron and manganese solubility also requires reduced aquifers.

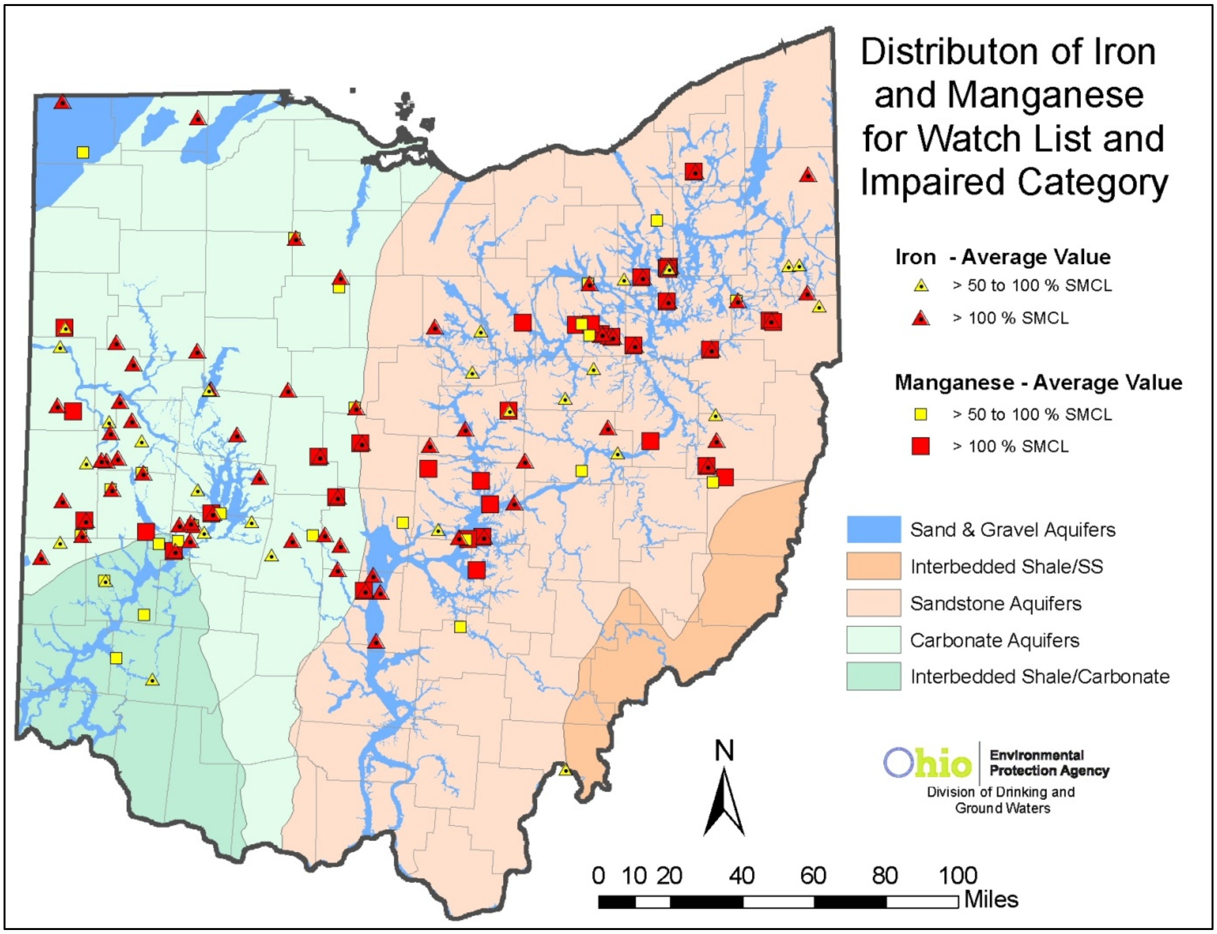

Figure M-4. Distribution of PWSs with treated water where iron and/or manganese are > 50 % MCL.

Sulfate also has an SMCL and, consequently, less data exists for identifying water quality impacts. Nevertheless, a significant number of PWSs exhibit elevated sulfate. The carbonate aquifers exhibit the highest percentage of PWSs on the watch list and in the impaired category due to the presence of evaporates (Gypsum, $CaSO_4 \cdot 2H_2O$) in the Salina Formation in northwest Ohio.

For **nitrate and nitrite,** the 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 4.3 percent (227 of 5184) of PWSs in Table M-4A have maximum values of nitrate greater than 50% of the MCL. Approximately 44 percent of these PWSs are located in sand and gravel aquifer settings. A PWS that exceeds 50% of the nitrate MCL is required to sample for nitrate on a quarterly basis. Thus, over the last decade, at least 227 PWSs have been required to increase nitrate sampling frequency to at least quarterly. Two PWSs showed maximum nitrite (NO_2) values exceeding the MCL in treated water. Figure M-5 illustrates the distribution of the PWSs with maximum nitrate concentrations above 50 % of the MCL for treated water. These PWSs are associated with the buried valley aquifers and areas of thin glacial drift over bedrock aquifers.

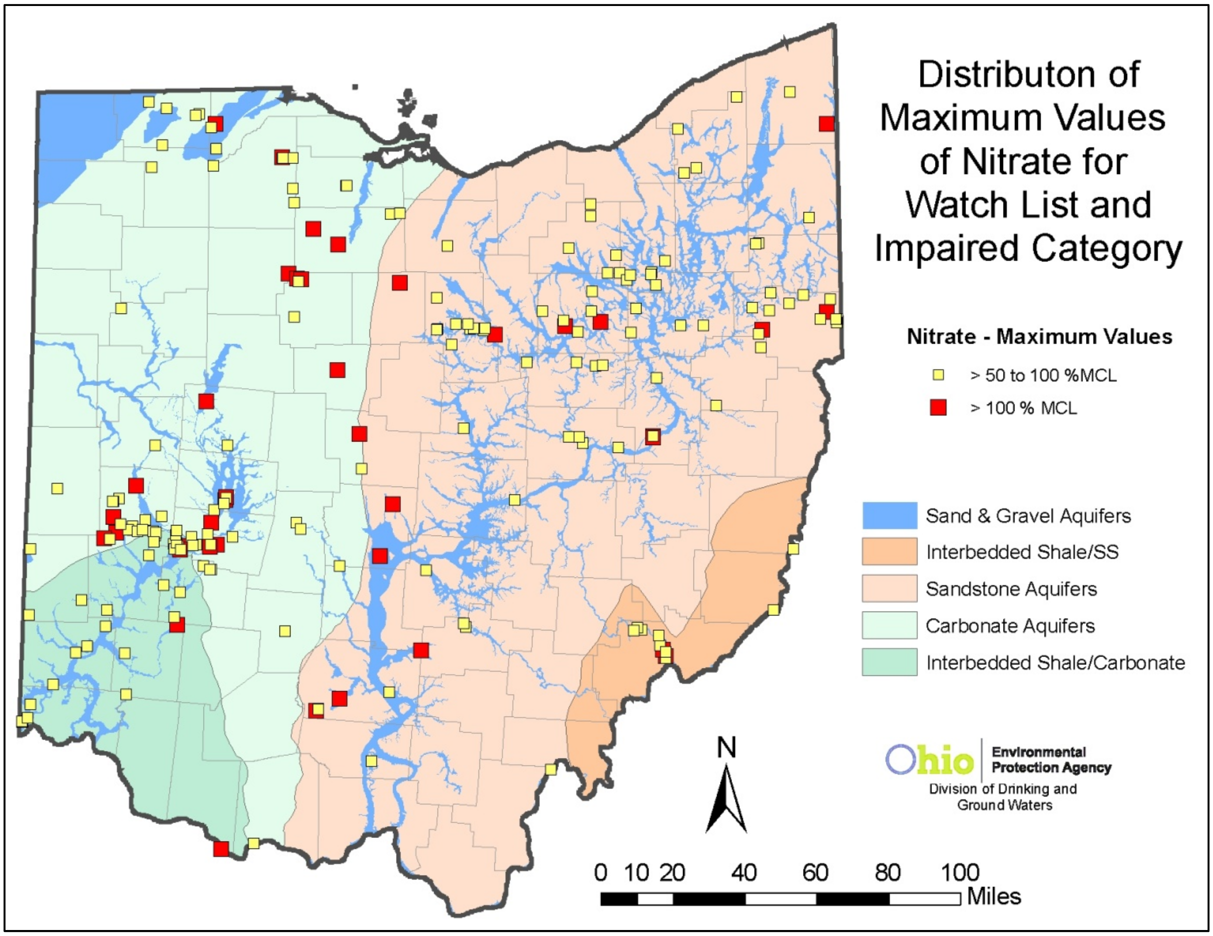

Figure M-5. Distribution of PWSs with maximum nitrate in treated water > 50 % MCL.

Organic Parameters - For the organic parameters, the mean concentration of treated water for only three parameters, **dichloromethane, tetrachloroethylene, and vinyl chloride,** have placed PWSs in the impaired category. Two of these three parameters are common solvents and the third is a compound used to make plastic. All are in the top ten contaminants detected in PWSs as documented in the 2006 305(b) Ground Water Quality Report (Ohio EPA 2006). **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 M-4A. In addition to the PWSs identified above, there are about 15 PWSs not using a production well or treating for volatile organic chemicals due to ground water contamination that are not identified in this treated water analysis. The raw water data may include some of these systems, but if these ground water-based PWSs were not treating for organic removal they would be considered "impaired."

Pesticides - There is little evidence for ground water impairment by pesticides with no ground water-based PWSs detecting pesticides with decadal averages in the watch list. As part of cooperative agreements with U.S. EPA, ODA's Pesticide & Fertilizer Regulation Section completes annual ground water sampling in areas identified as sensitive to pesticide contamination. Samples are analyzed for a broad array of pesticide parent and degradation compounds. The focus of the 2010 and 2011 sampling was an area above the Mad River Buried Valley in Champaign County, an area considered sensitive to transport of dissolved constituents. The 2010 and 2011 ODA sample results with no pesticide detections are consistent with Table M-4A.

Radiological Parameters – No PWSs are included listed in the impaired category for treated water due to radiological parameters, although several are included in the watch list. This is consistent with the Ohio's geologic setting having few natural sources of radioactive nuclides. The exceptions are low concentrations of potassium in glacial tills, uranium associated with reduced geologic settings like the Ohio Shale and coal deposits, and scattered thorium rich detrital grains in sandstones, but these settings are generally not utilized as aquifers. Gross beta compliance monitoring focuses on anthropogenic sources of radiation.

Ambient Ground Water Quality Monitoring Data
Mean values were calculated from the AGWQMP data (raw water) over the past ten years (2001-2010) to determine the number of wells in the watch list and impaired categories. These numbers are listed in Table M-4B by parameter and major aquifer for raw water. The number of wells with data used in the determinations is also presented to provide the relative number of wells that exhibit ground water quality with elevated concentrations of MCL parameters. A limited number of AGWMP wells are listed in the watch list and impaired category as was the case for the PWS compliance data. The results for groups of parameters are discussed below.

Inorganic Parameters – The AGWQMP does not collect data for **antimony, asbestos, beryllium, mercury, nitrite, silver, and thallium**, so no comparison can be made to the PWS data. These parameters are not analyzed due to their historically low concentrations in Ohio ground water. No well waters have averages that exceed the MCL or SMCL for **barium, chromium, cyanide, fluoride, selenium, and zinc**. Several wells exceed 50 percent of the fluoride MCL. Most of these wells produce water from the carbonate aquifer as was seen with PWSs in Table M-4A. A few AGWQMP well means are greater than 50 percent of the **barium** MCL, but no impairments were identified. Averages for **cadmium and chloride** exceed the MCL or SMCL in a few cases. Twenty wells have chloride samples with concentrations above 50 percent of the SMCL and two of these wells exceed the SMCL. The source of chloride contamination is likely associated with improper storage of salt for road deicing, oil and gas drilling brine disposal or brines in bedrock aquifers.

For **nitrate**, sample maximums were used rather than averages in order 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 M-4B. Nitrate concentrations are stable in oxidized environments and, if present, are more likely to be detected in shallower wells that have rapid exchange pathways with the atmosphere. 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 maximum nitrate concentrations that exceed the nitrate MCL. This is the case with about 9 percent of the sand and gravel wells exceeding 50 percent of the MCL. A similar percentage of the carbonate wells exceed 50 percent of the MCL, probably associated with sensitive, karst settings. No sandstone wells are on the watch list or in the impaired category for (maximum) nitrate concentrations. 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 (e.g., 10 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 PWS compliance data with the addition of TDS. TDS is not required or collected for PWSs compliance data. Except for arsenic, all of these parameters have SMCLs, so treatment is not required. However, iron and manganese treatment is required for community public water systems. Many PWSs remove iron, with the additional benefit of manganese and arsenic removal. This occurs due to the similarity in their controls on solubility. 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, over 90 percent of the ambient sites exceed 50 percent of the SMCL for sulfate which is significantly higher than the percentage for the sandstone and sand and gravel aquifers. The elevated TDS concentrations in raw water result 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 concentrations, but all three main aquifers exhibit high percentages of ambient sites with TDS concentrations that exceed 50 percent of the SMCL.

Organic Parameters – Detection of organic parameters at and above watch list concentrations is not common. Detected organic parameters above the MCL include **carbon tetrachloride, dichloromethane** (also a common lab contaminant), **tetrachloroethylene, trichloroethylene, and vinyl chloride**. These organic solvents were all detected in PWSs raw water samples as listed in Table M-4A.

Pesticides – No pesticides were detected in the AGWQMP wells above 50 percent of the MCL. 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 their pesticide sampling results, lead to the decision that further pesticide data collection is not cost effective for the AGWQMP for the parameters that the Ohio EPA lab analyzes.

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

Comparison of PWS and AGWQMP Data

Overall, we see similar trends in the PWS 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 PWSs. Thus, the AGWQMP goal of monitoring and characterizing the ground water quality utilized by PWSs in Ohio is validated by these empirical data.

It is interesting that the ground water quality differences documented between the major aquifers in previous 305(b) reports (2008 305(b) Report, Table 4; Ohio EPA 2008) are not obvious in Tables M-4A and M-4B. 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 aquifers. All of the major elements are needed for geochemical comparisons and identifying water types.

Chloride and sulfate do have SMCLs and exhibit some significant differences between the major aquifers as noted above. 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 PWSs 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. Treatment, such as softening, of PWS-distributed water can sometimes mask differences in water quality between major aquifers.

Table M-4B. Counts of wells where 2001-2010 decadal mean values of AGWQMP data occur in the Watch List and Impaired Category (maximum values used for nitrate).

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells – Raw Water: Total # Wells	Ambient GW Quality Wells – Raw Water: Watch List > 50% to 100% MCL	Ambient GW Quality Wells – Raw Water: Impaired > MCL
Inorganic Parameters	Antimony	MCL	6 µg/L	Sand & Gravel	nda	nda	nda
				Sandstone	1		
				Carbonate	nda	nda	nda
	Arsenic	MCL	10 µg/L	Sand & Gravel	145	44	21
				Sandstone	51	23	2
				Carbonate	46	9	5
	Asbestos	MCL	$7x10^6$ fibers/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Barium	MCL	2 mg/L	Sand & Gravel	143	4	
				Sandstone	55	1	
				Carbonate	49		
	Beryllium	MCL	4 µg/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Cadmium	MCL	5 µg/L	Sand & Gravel	146	1	1
				Sandstone	64		
				Carbonate	51		
	Chloride	SMCL	250 mg/L	Sand & Gravel	146	8	
				Sandstone	55	6	1
				Carbonate	51	4	1
	Chromium	MCL	0.1 mg/L	Sand & Gravel	144		
				Sandstone	54		
				Carbonate	77		
	Cyanide	MCL	0.2 mg/L	Sand & Gravel	77		
				Sandstone	19		
				Carbonate	28		
	Fluoride	MCL	4 mg/L	Sand & Gravel	142		
				Sandstone	54	1	
				Carbonate	49	5	
	Iron	SMCL	0.3 mg/L	Sand & Gravel	146	9	69
				Sandstone	54	28	22
				Carbonate	42	21	17
	Manganese	SMCL	0.05	Sand & Gravel	145	79	31

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells		
					Raw Water		
					Total # Wells	Watch List > 50% to 100% MCL	Impaired > MCL
			mg/L	Sandstone	56	32	13
				Carbonate	34	17	5
	Mercury	MCL	2 µg/L	Sand & Gravel	6		
				Sandstone	nda	nda	nda
				Carbonate	3		
	Nitrate * (max values)	MCL	10 mg/L	Sand & Gravel	141	11	2
				Sandstone	46		
				Carbonate	33	2	1
	Nitrite * (max values)	MCL	1 mg/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Selenium	MCL	50 µg/L	Sand & Gravel	135		
				Sandstone	38		
				Carbonate	42		
	Silver	SMCL	0.1 mg/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Solids, Total Dissolved	SMCL	500 mg/L	Sand & Gravel	133	79	31
				Sandstone	47	25	11
				Carbonate	36	23	8
	Sulfate	SMCL	250 mg/L	Sand & Gravel	141	1	1
				Sandstone	46	7	2
				Carbonate	35	22	11
	Thallium	MCL	2 µg/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Zinc	SMCL	5.0 mg/L	Sand & Gravel	141		
				Sandstone	46		
				Carbonate	35		
Volatile Organic Chemicals	1,2-Dichloro-ethane	MCL	5 µg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21		
	1,1-Dichloro-ethylene	MCL	7 µg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21		
	1,2-Dichloro-propane	MCL	5 µg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21		
	Benzene	MCL	5 µg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells Raw Water Total # Wells	Watch List > 50% to 100% MCL	Impaired > MCL
	Carbon Tetrachloride	MCL	5 µg/L	Sand & Gravel	108	1	1
				Sandstone	31		
				Carbonate	21		
	Cis-1,2-Di-chloroethylene	MCL	70 µg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21		
	Dichloro-methane	MCL	5 µg/L	Sand & Gravel	108	3	2
				Sandstone	31		
				Carbonate	21	0	0
	Pentachloro-phenol	MCL	1 µg/L	Sand & Gravel	40		
				Sandstone	4		
				Carbonate	14		
	Polychlorinated Biphenyls (PCB)	MCL	1 µg/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Styrene	MCL	0.1 mg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21		
	Tetrachloro-ethylene	MCL	5 µg/L	Sand & Gravel	108	1	1
				Sandstone	31		
				Carbonate	21		
	Trichloro-ethylene	MCL	5 µg/L	Sand & Gravel	108		
				Sandstone	31		
				Carbonate	21	1	1
	Vinyl Chloride	SMCL	2 µg/L	Sand & Gravel	108	1	1
				Sandstone	31		
				Carbonate	21		
Pesticides	Alachor	MCL	2 µg/L	Sand & Gravel	15		
				Sandstone	4		
				Carbonate	4		
	Atrazine	MCL	3 µg/L	Sand & Gravel	15		
				Sandstone	4		
				Carbonate	4		
	Simazine	MCL	4 µg/L	Sand & Gravel	15		
				Sandstone	4		
				Carbonate	4		
Radiological	Gross Alpha	MCL	15 pCi/L	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Gross Beta	MCL	4 mrem/yr	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells		
					Raw Water		
					Total # Wells	Watch List > 50% to 100% MCL	Impaired > MCL
				Carbonate	nda	nda	nda
	Radium 226	MCL	5 pCi/L **	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda
	Radium 228	MCL	5 pCi/L **	Sand & Gravel	nda	nda	nda
				Sandstone	nda	nda	nda
				Carbonate	nda	nda	nda

nda Indicates no data available
Blank spaces indicate no wells exceed the standards (zeros left out to emphasize impacted wells).
* Numbers for nitrate and nitrite are based on maximum values to reflect the acute nature of contaminant.
** MCL is for combined Radium 226 and Radium 228

M7. Ground Water-Surface Water Interaction

DDAGW special studies generally focus on water quality impacts in ground water associated with recharge in sensitive geologic settings. Thus, special studies provide information on the ground water-surface water (GW-SW) interaction related to surface water recharge and contaminants transported in the recharge. Two special studies completed in 2010 and 2011 document elements of the GW-SW interaction. Brief summaries of these studies are provided below.

A ground water investigation was conducted in an unconfined Silurian dolomite aquifer in Gibsonburg, Ohio (Sandusky County) to help quantify ground water flow rates and gain a better understanding of karst development in the region. Since surficial karst features such as sink-holes, caves, and springs, were not apparent in the study area, dye traces were conducted using artificial injection and receptor sites, including public water system wells, monitoring wells, and quarries. Two fluorescein dye traces were conducted under different public water system pumping scenarios. Dye was injected in a shallow monitoring well screened between 10 and 20 feet below ground surface. The dye traces documented flow rates between of 3,500 to 8,600 feet/day with dye detected in production wells, monitoring wells and a quarry. This was the first hydrogeologic investigation in Ohio to utilize an artificial injection site and public water system well receptor sites and provides evidence that even though the area lacks surficial karst features, it still exhibits fast ground water flow rates indicative of a karst aquifer. Data from this study will be used to refine the drinking water source protection area for Gibsonburg and other public water systems utilizing this karst aquifer (Gibsonburg Karst Investigation; April 2010; see http://www.epa.state.oh.us/portals/28/documents/swap/GibsonburgDyeTracesReport_DRAFT_July2011.pdf for more information).

An Unsafe Water Supply Investigation at the Putnam Community Water Association that serves Devola in Washington County examined the possible nitrate sources causing MCL violations. Although there were some agricultural sources in the area, this study documented the impact of elevated nitrate associated with septic systems and drywells in the unsewered portions of Devola flowing to the Putnam well field on the banks of the Muskingum River. Annual reductions of nitrate in Putnam distribution water (reductions of up to 8 mg/L) were associated with the high flow stage of the Muskingum River and surface water recharge of low nitrate river water. This ground water-surface water interaction is critical to understanding the magnitude of local nitrate impacts (see http://www.epa.state.oh.us/portals/28/documents/gwqcp/devola-putnam_investigation.pdf).

M8. Conclusions and Future Directions for Ground Water Protection

Ohio is fortunate that ground water is plentiful across the state. With the exceptions of a couple of areas that exhibit effects of over-pumping, decreasing static water levels have not been documented in extensive areas. 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 as easily as diminished quantities.

As documented in the previous sections, numerous sites exhibit ground water contamination from anthropogenic and natural point and nonpoint sources. The only alternative for 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 alternatives for managing anthropogenic sources of contamination 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. The discussion of ground water contamination sites listed in Table M-2 indicated that the contamination of ground water from landfills is associated with older sites. New design standards, improved siting criteria, and revised rules for ground water monitoring around landfills currently under development will improve ground water protection at landfills. These kinds of proactive practices can lead to sustainability of Ohio's high quality ground water resources.

The completion of Source Water Assessment Reports for Ohio's public water systems has raised awareness of the ground water quality issues and has helped promote source water protection planning. The complex nature of this planning identifies new issues, for instance, ground water protection requirements for geothermal wells and the identification of salt storage piles producing significant water quality impacts. SCCGW has just drafted guidance that provides recommendations for the construction and decommissioning of and recordkeeping for geothermal heating and cooling boreholes, wells and loops based on best industry practices and the experiences of other states. Due to the identification of improper salt storage as a significant water quality impact, the SWAP staff targeted salt storage areas in Drinking Water Protection Areas as sites for ground water evaluation with the discovery of associated water quality impacts.

The SWAP potential contaminant source inventory data was instrumental in identifying major sources of contamination as listed in Table M-3. Our documentation and regulation of point source (site specific location) contamination is significantly better than documentation and regulation of nonpoint source contamination, as is the case elsewhere in the U.S. Nonpoint source contamination in combination with the SW-GW interaction is a significant threat to water quality resources. Ohio's ground water resources are reasonably well protected with widespread glaciated tills naturally protecting water supply aquifers and land drainage tiles that tend to transport agricultural contaminants more rapidly to surface waters rather than recharge shallow aquifers. Nonpoint source pollution from surface water resources is affecting the quality of ground water resources in sensitive areas. Ohio EPA continues to refine the determination of areas with sensitive aquifers and to promote efforts to more effectively monitor shallow ground water in Ohio. Long-term efforts for protecting ground water quality need to focus protection programs in areas where aquifers are influenced by rapid recharge in shallow fractured bedrock, karst bedrock and sand and gravel aquifer settings. The Ground Water Rule raw water sampling is generating data that can be used to identify areas where pathogen contamination of aquifers is more likely.