Groundwater Protection Program
Report to the Maryland General Assembly

Prepared for:
The Maryland General Assembly
Annapolis, MD

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MARYLAND DEPARTMENT OF THE ENVIRONMENT
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INTRODUCTION AND BACKGROUND

In 2021, House Bill 588 (Budget Bill, Chapter 357) required that the Maryland Department of the Environment (MDE) draft "a report on the status of the quality of groundwater that sources residential wells and that updates the Groundwater Protection Program report previously required under Joint Resolution 5 of 1985." The report is due to the Maryland General Assembly by Dec. 31, 2021. The 1985 resolution had required the development of a Comprehensive Groundwater Protection Strategy for the state to protect the quality and quantity of groundwater to be submitted by July 1, 1986, and annually thereafter. In 2015, Chapter 58 repealed the requirement to provide the annual report.

This report will fulfill the requirements of HB 588 (2021) and will describe the key elements of Maryland's Groundwater Protection Strategy. The strategy is guided by the following goal:

The State of Maryland is committed to protect the physical, chemical and biological integrity of the groundwater resource, in order to protect human health and the environment, to ensure that in the future an adequate supply of the resource is available, and in all situations, to manage that resource for the greatest beneficial use of the citizens of the State.

State, federal, and local agencies work cooperatively to achieve this goal with programs that educate businesses, industry members, and the public about the importance of water protection and conservation. Maryland is a leader in the implementation of land use practices that minimize the impacts of development on surface and groundwater with best management practices (BMPs) and sensitive area protection (forests, wetlands, groundwater recharge areas, etc.).

This report provides an overview of the condition of Maryland's groundwater resources, and a description of efforts from July 1, 2015, to June 30, 2021[1] to characterize, restore, allocate, conserve, and protect Maryland groundwater through programs implemented by MDE as well as other state and federal agencies**.**

MARYLAND'S GROUNDWATER RESOURCES

Groundwater is an abundant, but finite natural resource that sustains Maryland's natural ecosystems and population. Groundwater is the source of crucial, continuous base flows to Maryland's rivers, streams, and wetlands. It is also a large source of the freshwater that flows to the Chesapeake Bay and to coastal bays. Groundwater also provides freshwater for residential, agricultural, industrial, and energy production in Maryland. Four out of every 10 Marylanders rely on groundwater sources for domestic water[2], with one out of 10 using an individual well[3]. In southern Maryland and the Eastern Shore, groundwater meets practically all water supply needs.

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[1] Shorter time periods are used to provide some data throughout the report due to the gap of time created by the 2015 repeal.

[2] Dieter, C.A., Linsey, K.S., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Maupin, M.A., and Barber, N.L., 2018, Estimated use of water in the United States county-level data for 2015 (ver. 2.0, June 2018): USGS data release, doi.org/10.5066/F7TB15V5.

[3] mde.maryland.gov/programs/Water/Documents/MDE_WSA_MD%202020%20Capacity%20Development%20Governor%20Report_FINAL_12-18-2020.

Geologic Conditions

Geologic conditions vary widely across the state and produce significant variations in the quantity and quality of groundwater. Aquifers in Maryland fall into two major types. The first are unconsolidated Coastal Plain aquifers found east of the Atlantic Seaboard Fall Line, a geologic divide that generally coincides with the Interstate 95 corridor. Coastal Plain aquifers, composed primarily of sand and gravel layers separated by layers of silt and clay, are productive and generally of good quality. The second are hard rock or fractured rock aquifers found in the western part of the state. Hard rock aquifers, composed of consolidated sedimentary and crystalline rock, provide generally low to moderate water yields.

Unconfined aquifers, which sit directly below the ground surface, are found throughout the state and are the primary source of groundwater in the western part of the state. Water levels in these aquifers undergo seasonal fluctuation and are principally recharged by precipitation during the fall and winter months. Confined aquifers, in contrast, are not as directly influenced by precipitation and climate changes because they are separated from the ground surface by relatively impervious layers such as silt, clay, or rock. These aquifers are instead recharged by horizontal water movement and seepage from outcrop areas, where the permeable regions meet the land surface. In southern Maryland and on the Eastern Shore, confined aquifers are the primary source of drinking water. The water levels in some confined aquifers in southern Maryland and on the Eastern Shore show long-term steady declines in areas of high use. Increased water demands from a growing population places new stresses on these aquifers. More detailed monitoring and analysis of the state's groundwater resources is needed to assess the long-term viability of many of the state's aquifers in the face of existing and increasing demands for water.

In the Piedmont region, where aquifers consist largely of fractured, consolidated bedrock, successful groundwater production depends on the size and number of water-bearing fractures encountered at a particular well site. Consequently, some fractured-rock aquifers have the lowest yields in the state. Consolidated rocks of sedimentary origin, which can be found in parts of the Piedmont, Valley and Ridge, and Appalachian Plateau regions, can yield higher amounts of water than other fractured rock aquifers. Carbonate aquifers, located around Hagerstown and Frederick, have some of the highest yields of consolidated aquifers in Maryland due to the presence of potentially large solution cavities, a factor that also renders them susceptible to contamination from surface sources.

Declining water level trends in some areas of southern Maryland have raised questions about the long-term sustainability of current groundwater withdrawals. On the Eastern Shore, increases in irrigation continue to place greater demands on groundwater supplies. The uncertain degree to which groundwater moves between different aquifers in the Coastal Plain is a major obstacle for reliable predictions of sustained aquifer yields in both southern Maryland and the Eastern Shore. In hard rock aquifers in the western part of Maryland, the availability of groundwater to meet the increasing demands of growing communities is also uncertain, particularly where growth is concentrated.

Groundwater Quality and Quantity

Except in some urban and industrial areas, Maryland's groundwater generally meets drinking water standards. Contamination is usually localized near specific sources. However, geologic conditions in some areas of the state make groundwater more vulnerable to anthropogenic influences.

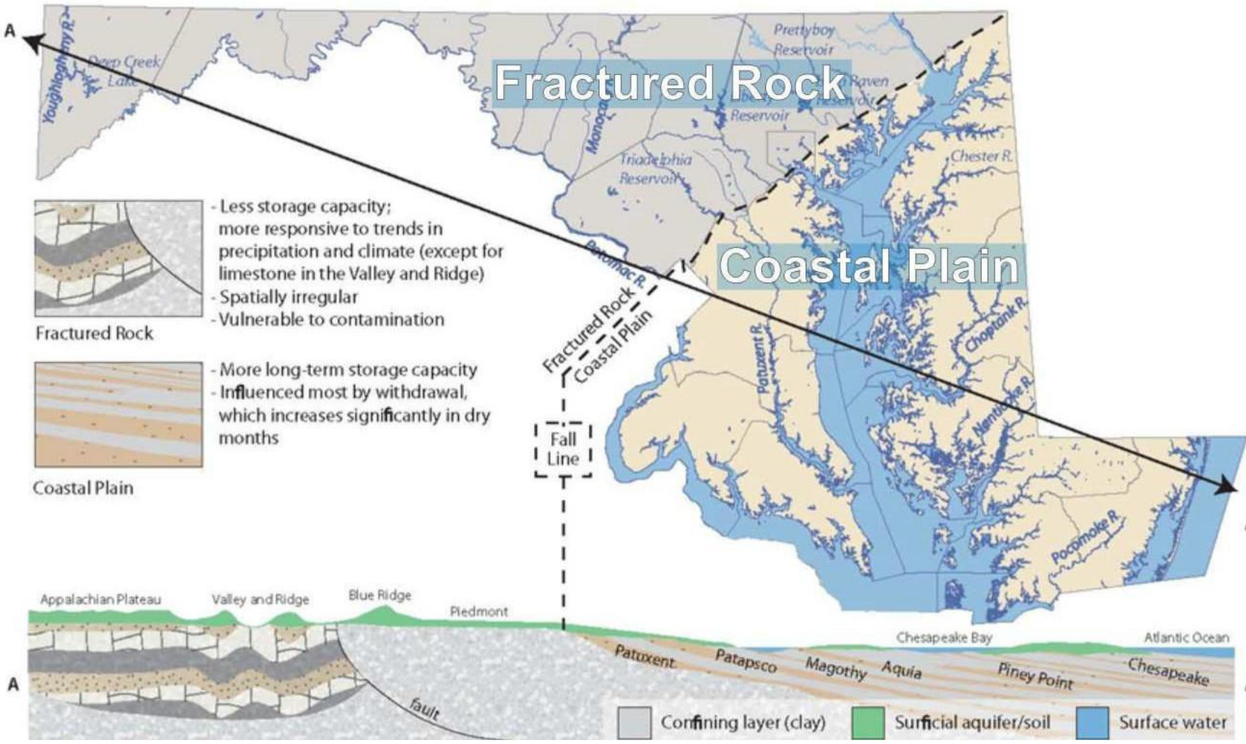

Figure 1 - Division and characteristics of fractured-rock and Coastal Plain geology in Maryland (from DNR)

Areas most susceptible to groundwater contamination from local land use include the carbonate rock areas of Allegany, Garrett, Washington, Fredrick, Carroll, and Baltimore counties; the unconfined Coastal Plain aquifers; the outcrop areas of major confined aquifers along the Baltimore-Washington corridor; and the hard rock aquifers of central and western Maryland. Potential contaminant sources include point sources such as landfills, underground storage tanks, spills, improper discharge of wastes containing solvents (such as dry-cleaning fluids), and the improper storage of salt, fertilizer, or other materials on bare ground. Military installations often present unique risks such as contamination from per- and polyfluoroalkyl substances (PFAS), perchlorate, etc.

Nonpoint sources of groundwater contamination include livestock waste, on-site sewage disposal, application of fertilizers and pesticides, infiltration of urban runoff, and road salt application. Nonpoint sources usually do not cause excessive contamination at specific well locations, but often represent the largest loadings of pollutants to groundwater over large areas. Since groundwater contributes a significant percentage of flow in rivers and streams, the subsurface transportation of nutrients can be a major pathway for pollution.

Local natural conditions affect both the availability and the quality of groundwater.
While natural groundwater quality is generally good, some areas may have hard water and high iron levels. Surveys of naturally occurring radionuclides in groundwater have shown that

portions of the Magothy and Potomac Group aquifers in the Coastal Plain, primarily in Anne Arundel County, are subject to high levels of radium. The Piedmont aquifers of central Maryland often have elevated radon levels. Levels of naturally occurring arsenic, above the federal drinking water standard, are not uncommon in Garrett County, the Aquia and Piney Point aquifers of southern Maryland, or the central Eastern Shore. In portions of the carbonate rock aquifers of central and western Maryland, groundwater may be directly influenced by surface water, presenting the risk of pathogen contamination.

Although water resource indicators for Maryland suggest there is an overall abundance of water to meet present and future needs, some areas have suffered serious water shortages. The 2002 drought ignited widespread concern for the sustainability of the state's water resources. Furthermore, Maryland's population is expected to increase by over 300,000 by 2030[4]. Population growth, increasing demand for water use, changes in land use, and climate change will further burden the state's water resources.

As water demand increases with population growth, certain communities may find it increasingly difficult to find sustainable supplies of water without reaching beyond the boundary where they have a clear right to withdraw groundwater. The need to preserve some groundwater as base flow discharge to local streams and wetlands also affects its availability for withdrawals. In some areas, water quality concerns have already limited the quantity of water available for withdrawal. For example, the threat of brackish water intrusion into the Aquia aquifer beneath Kent Island has precluded its full development as a drinking water supply source. Reliable assessments of water availability require sufficient data and analytical tools. These include well monitoring results and numerical models of groundwater movement within and between aquifers. The Maryland Observation-Well Network was established in 1943 and has provided state managers with critical information for calculating water allocations. Data gaps do exist, and additional network enhancements would support better groundwater management in the state.[5]

[4] planning.maryland.gov/MSDC/Documents/popproj/TotalPopProj.pdf (Accessed on September 24, 2021)
[5]mgs.md.gov/output/reports/OFR/OFR_12-02-19.pdf

GROUNDWATER RESOURCES PROTECTION

Coordination of Groundwater Protection

MDE has the primary responsibility for the protection of Maryland's groundwater resources. MDE's comprehensive approach involves coordination and collaboration with a number of state agencies and various stakeholders: the Maryland Department of Agriculture (MDA), the Maryland Department of Health (MDH), the Maryland Department of Natural Resources (DNR), Maryland Department of Planning (MDP), local governments, and scientific organizations such as the DNR Maryland Geological Survey (MGS) and the U.S. Geological Survey (USGS). Many programs within MDE regulate specific pollution sources to the state's water resources and address compliance with applicable regulations. In addition to the many water quality protection programs, MDE's Water Supply Program (WSP) manages water withdrawals to ensure sustainability of resources from unreasonable and wasteful use. Program activities related to groundwater are described in subsequent sections.

MDA coordinates with MDE on issues related to pesticide usage and nutrient management. The development of regulatory controls and BMPs for storage and application of pesticides helps to minimize groundwater contamination. MDE issues a General Discharge Permit for Discharges from the Application of Pesticides.[6] Nutrient management plans protect the health of waterways by establishing both short and long-term strategies for reducing nutrient levels in groundwater, streams, rivers, and the Chesapeake Bay. WSP also works with MGS on projects related to the assessment of water supplies and groundwater resources, including statewide groundwater quality and groundwater level monitoring initiatives.

Every September, WSP sponsors the Maryland Groundwater Symposium that includes more than 400 groundwater professionals from local governments, state and federal agencies, and private sector organizations. In 2020 and 2021, the symposium has been postponed due to the COVID-19 pandemic, but this event was a key source of topical information on the most current issues affecting groundwater management in the state. The topics were varied and included source water protection (drinking water, wells, water use, on-site sewage disposal, groundwater flow, contaminant transport, modeling, etc). Presenters included participants from local, state, and federal organizations, including MDE, DNR (including MGS), the U.S. Environmental Protection Agency (EPA), USGS, University of Maryland, MDH, and several consulting companies.

The state has a number of boards that regulate professionals involved in the groundwater industry: Environmental Health Specialists Board, Board of Well Drillers, and the Board of Water and Wastewater System Operators. To obtain and/or renew licenses, continuing education requirements must be satisfied.

In addition to coordinating with other state agencies, WSP partners with federal agencies, such as the USGS, to conduct technical projects on groundwater quality and resource availability. A listing of programs involved in groundwater protection is provided in Table 1.

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[6] mde.maryland.gov/programs/permits/watermanagementpermits/pages/gppesticides.aspx

Table 1 – Groundwater Protection Activities

Activity	Program/Office
Maryland Department of the Environment	
Water and Science Administration	
Activity	**Program/Office**
Water Appropriation and Use Permits	Water Supply Program
Source Water Protection	Water Supply Program
Safe Drinking Water Act Implementation & Technical Assistance	Water Supply Program
Water Audit	Water Supply Program
Drought Monitoring	Water Supply Program
Underground Injection Control	Wastewater Permits Program
On-Site Sewage Disposal Systems	Wastewater Permits Program
Water Well Construction	Wastewater Permits Program
Groundwater Discharge Permits	Wastewater Permits Program
Stormwater Management	Stormwater, Dam Safety and Flood Management Program
Land and Material Administration	
State and Federal Site Remediation	Land Restoration Program
Voluntary Cleanup Program	Land Restoration Program
Hazardous Waste Management	Land Restoration Program Solid Waste Program Resource Management Program
Underground Storage Tank Oversight	Oil Control Program
Oil Control	Oil Control Program
Solid Waste Management	Solid Waste Program
Waste Diversion & Utilization	Resource Management Program
Animal Feeding Operations Permits	Resource Management Program
Coal and Non-coal Mining Permits	Mining Program
Maryland Department of Natural Resources	
Maryland Geological Survey	Resource Assessment Service
Monitoring and Non-Tidal Assessments	Resource Assessment Service
Maryland Department of Agriculture	
Nutrient Management	Office of Resource Conservation
Pesticides Management	Office of Plant Industries and Pest Management
Maryland Department of Planning	
Saltwater Intrusion	Resource Conservation & Management
Maryland Department of Health	
Wells and Septic’s	Local Environmental Health Departments
U.S. Department of the Interior	
Water Resources Investigations	U.S. Geological Survey
U.S. Environmental Protection Agency	
The state coordinates with various offices within EPA to implement the Safe Drinking Water Act (SDWA), Source Water Protection Programs, Underground Injection Control Program, site remediation, and other activities.	

Management of Groundwater Resources

The Maryland Coastal Plain region is largely dependent upon groundwater for its water supply. Decades of pumping due to demand have created substantial cones of depression in confined aquifers of southern Maryland, which indicate the range of distance that the aquifer is affected by withdrawals.[7] To protect the storage capacity of these aquifers, WSP has begun directing new applicants for Water Appropriation and Use Permits to apply for withdrawal from deeper aquifers or to plan alternative sources. Switching water use to deeper aquifers has allowed both aquifer recovery and stabilization of water levels in some locations. Furthermore, MDE may reevaluate and reduce the allocation of some current permittees when their permits are due for renewal.

Central Maryland communities in the Piedmont region have expended considerable resources seeking sustainable water supplies to support new growth and enhance the reliability of their sources for existing users. While the largest towns and cities in the Piedmont rely on surface water, many medium and smaller towns rely primarily on groundwater sources. One challenge is that water systems need to consider how their sources may be impacted by drought conditions. That raises a significant concern since some communities have made commitments to provide water beyond the reliable drought capacity of their existing water supplies.

The conditions described above highlight the importance of managing water resources, including the management of both use and demand. WSP manages water use through its permitting program to ensure that water uses are beneficial and do not have an unreasonable impact on the resource or other users. WSP also reviews water and sewer plans to assist communities with reasonable water use plans based on available groundwater resources and to offer alternative water supplies in case of water scarcity in the area.

Demand management is a means for extending water supplies and delaying or eliminating the need to develop new sources. Sound water use practices reduce the amount of stress that we place on our resources, both by limiting water withdrawals and by decreasing wastewater discharges. Managing demand is one important alternative that water suppliers can use to help meet their water supply needs.

Water efficiency technologies, water reuse, and behavioral changes can reduce water demand by at least 10% to 20%, effectively extending existing water supplies. Demand management strategies can include a variety of options. Potential approaches include reducing losses from leakage, implementing rate structures or rate surcharges that encourage customers to conserve, providing incentives for customers to install low-flow fixtures or appliances, working individually with large-volume users to identify potential water savings, and using public outreach and education to encourage consumers to modify their behavior. Conducting leak detection surveys and installing more sophisticated metering systems will help communities determine locations of leaks, which can result in more rapid repair and greater water savings.

WSP currently requires the top 31 largest water systems to perform an annual audit of their water usage and, if the unaccounted water loss exceeds 10% of the total production, provide a water loss reduction plan to MDE.

[7] mgs.md.gov/publications/report_pages/OFR_20-02-01.html

Water Appropriation and Use Permitting

MDE, as the trustee of the state water resources, has the responsibility of controlling the impacts of groundwater withdrawal through the Water Appropriations and Use Permit process. Through the permit review process, WSP works to ensure that groundwater withdrawals do not exceed the sustained yield of the state's aquifers. The permitting process also ensures that public drinking water systems obtain the best possible source of water in regard to quality and sustainability.

The evaluation of Water Appropriations and Use Permit applications can include demand analysis, aquifer testing, fracture trace analysis, water level monitoring, evaluation of water balance, and other similar investigations. WSP also considers published scientific groundwater data and modeling from MGS and USGS in these evaluations. Review criteria is applied to determine whether the amount of water requested is reasonable for the proposed use and whether the proposed use will adversely impact the resource or other users. When issued, permits specify the water source, location of withdrawal, quantity of allowable use, purpose of use, and any other conditions, including withdrawal measurements and reporting. Permits are valid for a period of up to 12 years.

To date WSP manages approximately 6,900[8] Water Appropriation and Use Permits, with about 6,000 of these being specifically for groundwater withdrawals. Large permits are defined as those above 10,000 gallons per day (gpd), average use. There are about 1,500 large groundwater permits for agricultural water use and 1,000 large groundwater permits are for non-agricultural water use.

[8] As of September 9, 2021, Water Supply Information and Permitting System.

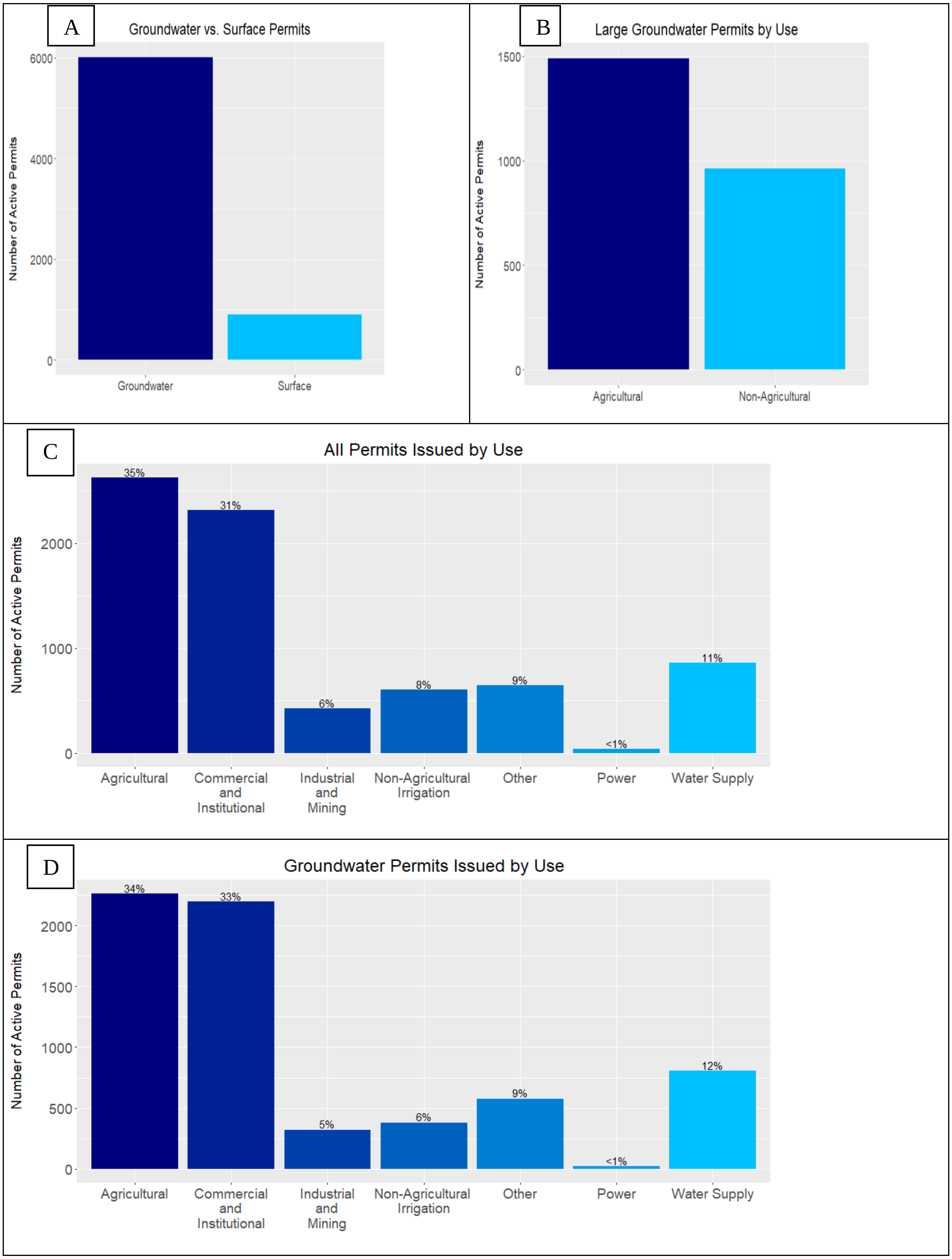

Figure 2 – Type of permits by: A. source; B. use; C. use percentage for all permits; and D. use percentage for groundwater permits.

In addition to processing permit applications, WSP evaluates requests for exemptions, per *Annotated Code of Maryland*, Environment Article §5-502. The law exempts most groundwater withdrawals of 5,000 gpd or less from the requirement to obtain a permit. Permits must still be obtained for community drinking water systems and withdrawals located in Water Management Strategy Areas. To date,[9] over 7,000 exemptions have been granted.

Environment Article §5-516 enacted civil penalties for violations of appropriation regulations or failing to comply with a Water Appropriations and Use Permit. This potentially allows MDE to enforce permit conditions more effectively.

As evidenced by the increasing number of permits and allocations, agricultural water use has been growing steadily over the past decade, particularly for irrigation on Maryland's Eastern Shore. In general, WSP directs large irrigators to use the unconfined aquifers, reserving the more protected confined aquifers for individual potable and municipal uses. In some areas, however, the unconfined aquifer produces low yields, or is nonexistent, compelling an increasing number of farmers to seek water appropriation permits for confined aquifers or surface water. In some of these instances the shallowest confined aquifers have many individual users and nearby municipal users. Analysis by WSP has resulted in advising some farmers to consider using deeper confined aquifers to avoid conflicts with individual well owners and municipal uses.

Withdrawals from Unconfined Aquifers

WSP permits water use from unconfined aquifers based on drought year recharge rates, with a set-aside for stream base flow protection. The use of drought year recharge rates ensures that long-term average recharge to an aquifer exceeds the allowed withdrawals from the aquifer. There are over 50 long-term water level monitoring wells in the unconfined aquifers across Maryland. While all of these wells show seasonal fluctuations, none show trends of long-term decline.

Changes in water levels in unconfined aquifers in response to long-term withdrawals are limited to the immediate vicinity of the withdrawal. Adverse impacts to other water users, if any, are typically less than 1,500 feet from the supply well. In the Coastal Plain, withdrawals from the unconfined aquifer account for the vast majority of the agricultural permits for crop irrigation. MDE has received no reports of impacts from these withdrawals to any unconfined aquifer well-constructed in accordance with Maryland's current well construction guidelines.

Even though withdrawals have been demonstrated to be sustainable, the technical water budget analysis framework based on infiltration rates, runoff and evapotranspiration data need to be revisited to incorporate climate change variability.

Water Levels in Confined Aquifers

Existing withdrawals from certain confined aquifers are causing water levels to decline in these aquifers. As compared to withdrawals from unconfined aquifers, impacts of large, confined aquifer withdrawals cover larger areas. Science based management decisions, which determines

[9] As of 9/13/2021, Water Supply Information and Permitting System

the usage from these aquifers, have a direct bearing on aquifer water levels, whereas seasonal recharge does not. Continued water uses result in less storage within the aquifer and surrounding confining units. Water level monitoring is essential for ensuring aquifer protection from excessive use. These observations, combined with analysis through numerical modeling, can predict areas to be concerned about. Real time access to three dimensional models could improve the planning and permitting of use from these aquifers.

Water withdrawal requests are evaluated by WSP to ensure that a proposed withdrawal will not result in a water level below Maryland's regulatory threshold (known as the 80% management level) for the term of the permit (not more than 12years). In the infrequent case where the 80% management level is reached, certain actions are triggered. For example, in 2007, WSP became aware that the water level in the Lower Patapsco aquifer in Charles County had reached the 80% management level along the Potomac River. With direction from WSP, water suppliers in this area reduced usage from the Lower Patapsco aquifer and increased withdrawals from the deeper Patuxent aquifer, which had significantly many more feet of available drawdown. Since 2007, permit allocations for the Lower Patapsco in Charles County have been reduced by nearly 5 million gpd as an annual average. Water levels in the Lower Patapsco aquifer in the decade since have rebounded by about 20 feet at the critical location, appeared relatively stabilized for over a decade; however, many developments had come to a complete halt after the housing market crash, and in recent years a declining trend seems to be starting again. As a result, WSP continues to closely monitor regional water levels in this area.

An earlier example of long-term water level decline in Maryland occurred in 2002 at the Aquia aquifer in southern Calvert County, and in the Hollywood to Lexington Park area of St. Mary's County. The water level decline in this aquifer prompted concerns regarding the sustainability of the aquifer. In response to this trend and based on WSP's advice, St. Mary's County reduced Aquia usage and increased usage from the deeper Upper Patapsco aquifer. This was done, in part, to avoid the elevated arsenic levels present in the Aquia aquifer, north of Lexington Park. Unlike the Charles County example, the water levels in the Aquia did not rebound as withdrawals decreased, but it did stop declining. Based on limited monitoring wells in this area, we now observe more fluctuation in Aquia because of seasonal withdrawal rates.

<u>Wellhead Protection/ Source Water Assessment Program</u>

The 1996 amendments of the SDWA initiated source water protection efforts. Beginning in 1999, WSP started to assess the vulnerability of all public drinking water sources in Maryland. The source water assessment plans use three main tools for assessing drinking water sources: source water delineation, contaminant surveys, and susceptibility analysis. The information gained through these tools is used to evaluate the susceptibility of a water supply source to contaminants that may affect the safety of the drinking water. With this information, local governments and water suppliers, in partnership with WSP and other agencies, can develop source water protection programs to improve the safety of each water supply in the state. WSP works closely with communities and local health departments to implement these plans so that systems can protect their water sources before contamination occurs. More than 3,600 water systems have been assessed. Community water suppliers are required to provide a brief description of the assessment results to their customers in their yearly Consumer Confidence Reports.

In addition, counties are required by law to develop and maintain County Water and Sewer Plans to provide for the orderly development and extension of community water supply and sewerage systems. WSP reviews County Water and Sewer Plans to identify and address issues that pertain to source water protection, water supply capacity, and SDWA requirements. WSP may disapprove a plan if it is inconsistent with existing laws, regulations, or policies.

Water Supply in the Piedmont Region of Maryland

Smart development occurs at a density of at least 3.5 residential units per acre, while drought year groundwater recharge in the Piedmont region is typically equivalent to 1 to 2 units per acre. Communities developing at densities beyond this, depend on recharge beyond the boundaries of their water service areas. Towns using groundwater as their sole water source have struggled with the problem of obtaining sufficient land to ensure that water recharge is sufficient to meet their communities' needs.

Environmental Article §5-501(b), grants priority for groundwater use to Priority Funding Areas (PFAs) within Carroll, Frederick, or Washington counties. The procedures for taking advantage of this priority allocation are contained in the "Application for Water Allocation: Guidance Document for Public Water Systems Providing Groundwater to Municipal Corporations or Priority Funding Areas in Carroll, Frederick, and Washington Counties."[10] Previous policies limited groundwater allocated to the amount of water recharged on lands owned or controlled by the water supplier, but this approach allows higher groundwater withdrawal allocations for public water systems (PWSs) in Carroll, Frederick, and Washington counties than is directly recharged on the land owned or controlled by the permittee. This policy was developed for the purpose of addressing the water needs for redevelopment and infill within a municipal boundary or PFA established on or before Jan.1, 2000, not for growth occurring outside of this established area. This allocation framework ensures that appropriate information is collected and analyzed when deciding on such county requests for increased allocations. In early 2017, WSP issued its first water appropriation permit using this approach to Frederick County for the Mill Creek residential subdivision, which is planned to be part of the future Libertytown community water system (CWS).

10 mde.maryland.gov/programs/Water/water_supply/Documents/Brinkley%20Guidance%20Doc_June%202014_1022 2014%20(3).pdf

Water Management Strategy Areas

Areas experiencing excessive drawdown or saltwater intrusion are delineated as Water Management Strategy Areas and are subject to special consideration when issuing permits. Management options for these areas include:

- limiting withdrawals in the aquifer,
- directing withdrawals to a different aquifer, or
- requiring additional scrutiny and/or water level monitoring when permits are requested for these areas.

Water Management Strategy areas in the state are identified in Table 2 and include the Aquia aquifer in the Annapolis Neck area of Anne Arundel County, the Magothy aquifer in Charles County, the Upper and Lower Patapsco aquifers in the Indian Head areas in the western extent of Charles County, and the Columbia aquifer beneath the Ocean Pines area in Worcester County.

Table 2 – Water Management Strategy Areas

Area(s)	**County(s)**	**Target Aquifer(s)**	**Issue(s)**
Annapolis Neck	Anne Arundel	Aquia	Saltwater Intrusion
Indian Head La Plata Waldorf	Charles Prince Georges	Lower and Upper Patapsco	Excessive Drawdown Saltwater Intrusion
Waldorf	Charles	Magothy	Excessive Drawdown
Kent Island	Queen Anne	Aquia	Saltwater Intrusion
St. Martin’s River Ocean Pines	Worcester	Columbia	Saltwater Intrusion

MGS continues to monitor and assess the effects related to saltwater intrusion. The Aquia aquifer on the Kent Island in Queen Anne’s County is affected by saltwater intrusion, which has been exacerbated by pumping. To prevent further degradation of the Aquia aquifer, new appropriations for Kent Island are directed to deeper aquifers.

In the 1980s, saltwater intruded into the Aquia aquifer in the shoreline areas of Arundel on the Bay and some neighboring communities. The elevated chloride levels were caused by a dip in the water table on the southeastern end of the Annapolis Neck Peninsula, which caused salty bay water to intrude into areas of the aquifer under the shoreline properties. WSP and Anne Arundel County required replacement wells to be drilled into the Magothy aquifer, a deeper aquifer in the same area, which has no direct connection to the Chesapeake Bay. A policy was implemented that does not allow additional appropriations from the Aquia aquifer in the area, and a map was developed to specifically identify the boundaries of the area of concern. Saltwater intrusion into the Aquia aquifer has been mitigated by this reduction of withdrawals, and the policy remains to prevent similar predicaments.

Excessive drawdown is identified to be a concern for the Lower Patapsco and Magothy aquifers in Charles County. By regulation, WSP is prohibited from allowing drawdown below the 80% management level when evaluating permit requests for withdrawals from confined aquifers (See Figure 3). The 80% management level represents 80% of the drawdown from the pre-pumping potentiometric surface (well water-level) to the top of the aquifer. In the 1980s, a plan was developed to limit water use from the Magothy aquifer to ensure that water levels stayed above the 80% management level and to develop wells in the Lower Patapsco aquifer to reduce the stress on the Magothy. Since the plan was implemented, water levels in the Magothy aquifer have been maintained above regulatory thresholds. By 2007, however, the new withdrawals from the Lower Patapsco aquifer resulted in water levels reaching the 80% management levels along the Potomac River. Subsequent reduction of withdrawals from the Lower Patapsco has allowed water levels to rebound, and WSP is working with groundwater users on a long-term solution for the water supply needs of Charles County.

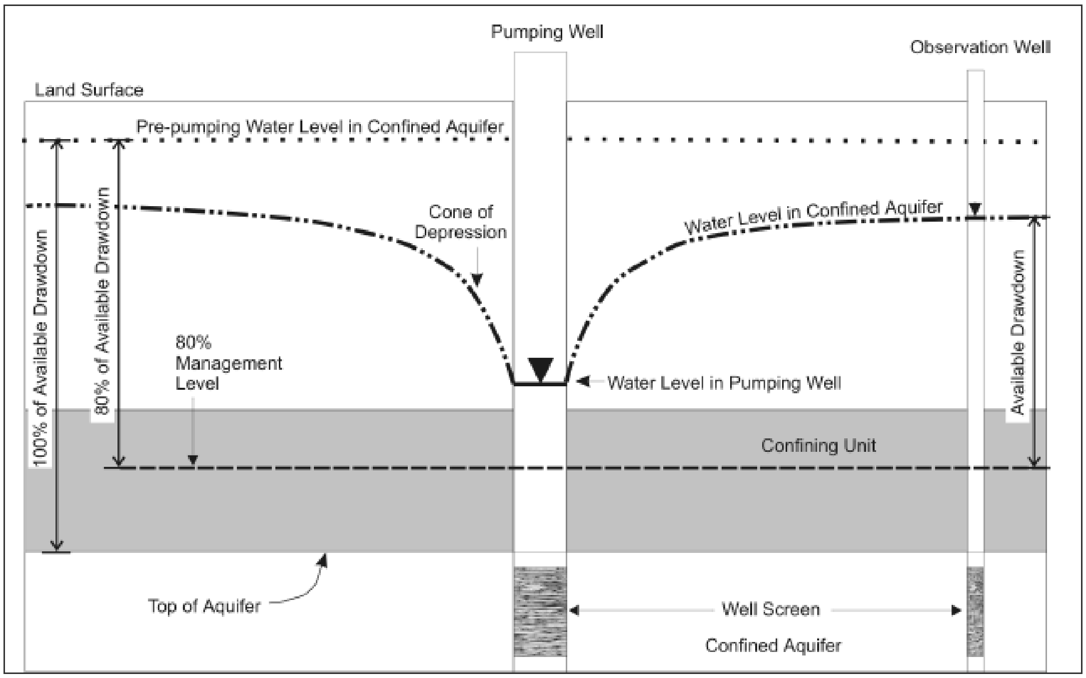

Figure - Illustration of the 80% Management Level in confined aquifers.

Drought Management

Drought conditions are evaluated on a regional basis, and drought status is assessed monthly during normal conditions and more frequently when drought conditions exist. During a period of drought emergency, WSP coordinates with local governments through a network of local drought coordinators and maintains continual contact with water suppliers to ensure that the detrimental impacts of a drought emergency are minimized.

The USGS has real time monitoring capability at 27 wells in Maryland and Delaware. Seven of the 19 wells used for drought status monitoring in Maryland have real time data available, which improves data availability and allows the state to better assess drought conditions.

WSP evaluates drought status for each region monthly using appropriate regional indicators, which may include rainfall, stream flow, groundwater levels, and reservoir storage. Rainfall is evaluated as percent departure from average, from the start of the Water Year (October 1). Stream flow is evaluated by comparing the 30-day average to the historic record of 30-day averages ending the same day of the year. Groundwater levels are evaluated either by comparison with the historic record of measured values in the same month of the year, or, for a confined aquifer, as a departure from trend. Reservoir levels are evaluated using an estimate of days of storage remaining. Regional assessments, however, may not accurately predict water shortages at specific localities and/or water systems. Some local governments have developed individualized drought response plans to meet their specific communities' needs.

As of Sept. 30, 2021, the drought monitoring data shows the State of Maryland is in normal hydrologic status in all regions. WSP's drought website[11] is accessible by the public and shows current hydrologic conditions and drought assessment data. When regions are "Normal" status, drought evaluation is performed at the end of the month.

[11] mde.maryland.gov/programs/Water/droughtinformation/Pages/index.aspx

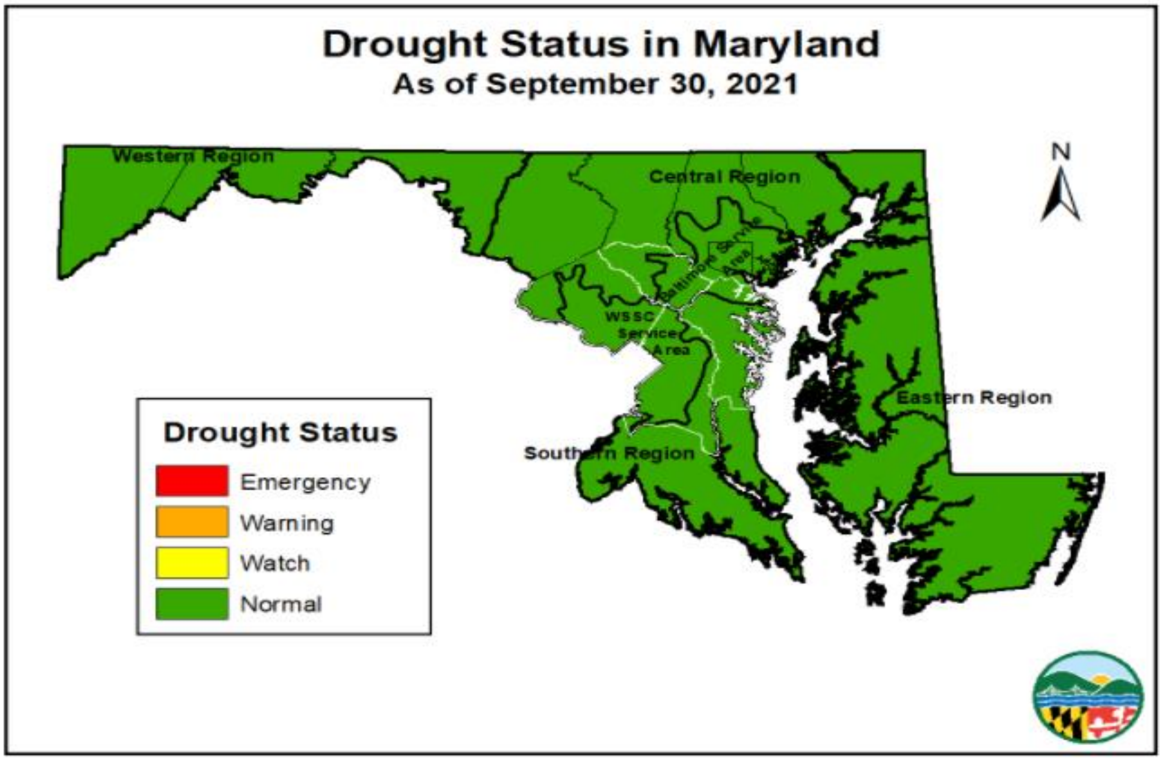

Figure 4 - Example of the Drought Status in Maryland as of September 30, 2021.

Ban on Fracking for Natural Gas

In April 2017, Governor Larry Hogan signed into law a bill, which banned hydraulic fracturing, or fracking, for natural gas. This bill represented an important step toward protecting groundwater quality in western Maryland.

Monitoring and Assessment of Groundwater

Many of the research initiatives and studies described below are ongoing efforts that provide critical support to other groundwater management programs in the state. These programs provide crucial short-term information, but their value in providing a comprehensive picture of groundwater resources over time cannot be overstated. An excellent place to stay abreast of recently published studies concerning groundwater in Maryland is the MGS website for Publications & Data[12]. This website provides access to studies of Maryland's natural groundwater quality, long-term water level records, and mapping and description of Maryland's geology and aquifers.

Fractured Rock Water Supply Studies

The 2008 Final Report of the Maryland Advisory Committee on the Management and Protection of the State's Water Resources identified the need for a comprehensive assessment of water resources in the part of Maryland underlain by fractured-bedrock aquifers. The fractured rock region is particularly susceptible to drought because groundwater is mostly unconfined and responds directly to recharge (or the lack thereof). The Fractured Rock Water Supply Study was

[12] mgs.md.gov/publications/index.html

initiated in 2009. Since 2015, multiple studies have been undertaken.

Regional Study on the Reliable Drought Yields of Public Water Supply Wells and the Impacts of Groundwater Withdrawals on Water Supplies and Resources in the Fractured Rock Areas of Maryland

During the drought period of 1998 to 2002, many municipal water suppliers in the fractured rock Piedmont/Blue Ridge areas of central Maryland, northwest of I-95, had to institute water restrictions due to declining well yields that were on average about half of previously estimated yields. The unconfined groundwater systems in the region are closely interconnected with surface water, like rivers and streams, and are affected by seasonal and climatic variations. During droughts, groundwater levels drop causing decreasing well yields, contributing to reduced streamflow's and potentially impacting aquatic habitat. Increased demand, over-allocation, population growth, and climate change can affect the future sustainability of water supplies in the areas of Maryland underlain by fractured rock.

These problems prompted WSP to reevaluate the availability of water resources within the state. In July 2008, the Final Report of the Advisory Committee on the Management and Protection of the State's Water Resources identified the challenges Maryland faces regarding use of its water resources and what was needed to achieve sustainability. Issues that may affect groundwater availability include increased demand due to population growth and agricultural irrigation; changing land-use patterns threatening water quality; competition between ground-water users, and climate change. The report recommended both basic data acquisition and development of a statewide water-supply plan, including the availability of groundwater in fractured-rock aquifers.

In 2012, *A science plan for a comprehensive assessment of water supply in the region underlain by fractured rock in Maryland*, USGS SIR 2012–5160 (Fleming et al., 2012)[13] was developed by MDE, MGS, DNR, and USGS, in response to those recommendations to provide scientific information, data analysis, and tools for the state to better manage water resources in the fractured rock region of Maryland. The science plan laid out five goals for the comprehensive assessment. The ongoing regional study is intended to address portions of goals two, three, and four for groundwater issues related to the reliable yields of public water supply wells and the impacts of groundwater withdrawals on nearby water users, streamflow, and the ecological integrity of streams. Goals two, three, and four are outlined in the following sections.

Reliable Yields of Public Water Supply Fractured Rock Wells

Most studies of fractured rock aquifers involve analytical models used for evaluating aquifer tests or numerical methods for describing groundwater flow, but there have been few investigations on how to estimate the reliable, long-term, drought yields of individual hard rock wells. Previous estimates of the well yields in Maryland were commonly based on extrapolating drawdowns, often from pseudo-equilibrium phases, measured during short-term, single well, hydraulic pumping tests to first, primary, water-bearing fractures, frequently resulting in

[13] pubs.usgs.gov/sir/2012/5160/pdf/sir2012-5160-508.pdf

substantially over-estimated well yields.

In addition to the graphical techniques, the study uses specialized diagnostic plots, conducts inverse analyses using a computer-assisted automatic curve fitting program, and applies derivative analysis methods to pumping test data and deconvolution solutions to step-test or other variable-rate data. The results were analyzed to determine the presence of internal or external boundaries, and the effects of aquifer dewatering. Once a solution was derived, the drawdown data was extrapolated forward to produce an estimated yield for a target operating water level in a well.

The estimated yield was verified by comparing it to production or water use data collected by municipal water purveyors. After reviewing nearly 200 aquifer/step tests, the primary focus of the investigation was on case studies developed from aquifer/step tests, geological information, and long-term test and/or production data.

Impacts of Groundwater Withdrawals on Individual Water Wells

WSP is compiling a report on the impacts of permitted groundwater withdrawals on individual wells. Much of the existing literature concerning the impacts of groundwater withdrawals consists of case studies on the effects of coal mine dewatering. Relatively few investigations have been published concerning impacts caused by pumping wells in fractured rock aquifers.

WSP's review of long-term test or monitoring data collected from several dozen projects suggests that the significant available data collected from projects throughout the years in Maryland can be used to assess additional scientific decisions. For example, decisions that can be informed include determining the adequacy of and what are the significant factors related to impacts on individual water supplies caused by groundwater withdrawals.

The main purpose of this ongoing investigation is to conduct detailed analyses of all the case studies in Maryland related to the impacts of groundwater withdrawals on water supplies, in addition to providing a synthesis of the existing studies found in the literature. There is no known complete state-wide study of such impacts or a compilation of the results of all significant published studies on the topic.

Nearly all the known impacts to domestic wells in Maryland can be attributed to withdrawals in consolidated sedimentary rock formations and a few more from supply wells drilled in low permeability, crystalline rocks. The impacts associated with these withdrawals have been successfully mitigated, mostly by drilling replacement wells, providing public water to affected homes, or by adjusting the withdrawals of the large users. Most of the projects in Maryland included estimates of impacts made prior to withdrawals and post-audits to determine the reliability of those predictions.

The project is divided into three phases, for which the reports are under final review:
1. Hydrological Impacts Caused by Dewatering of the Mettiki D-Mine, Garrett County, Maryland

2. Hydrological Impacts Caused by Groundwater Withdrawals from Public Supply Wells in the Crystalline Rock aquifers of central Maryland
3. Hydrological Impacts Caused by Groundwater Withdrawals from Public Supply Wells in the Consolidated Sedimentary Rock aquifers of central Maryland

Impacts of Groundwater Withdrawals on Stream Flows and Ecology

There have been very few studies that have addressed the impacts to stream flow caused by withdrawals from groundwater, and the subsequent response in biological communities, water quality, and habitat. Groundwater is an important source of relatively cool water that can sustain stream flow and water temperature during low flow periods. Several studies that addressed the impacts to stream flow and habitat were in large watersheds within the areas of the regionally extensive High Plains and Floridan aquifers. In those cases, the estimated uses greatly exceeded available recharge, which consequently, the results cannot be used to determine the upper limits of safe withdrawals rates. Two studies in headwater streams were conducted in Connecticut and the Piedmont area of Georgia, but researchers did not consider the effects of reservoir operations, temporal variation in water use, and actual versus permitted water withdrawals, which are factors to be considered during the present project.

Maryland has a fairly unique set of records related to water use as well as the impacts of withdrawals on stream flow and ecological integrity, which do not appear to exist in other northeastern states. The Maryland water use permitting program was effectively implemented in 1945. A computer database of semi-annual water use reports is available from 1979 with the very low reporting threshold of 10,000 gpd average. The Maryland Biological Stream Survey (MBSS) program also has sampled more than 3,700 sites throughout the state.

A hydrological/hydrogeological investigation of all known sites in the state (and one in Delaware) where groundwater withdrawals may have reduced stream flow will be completed to determine the extent to which the withdrawals may have changed flow regimes and ecological integrity. The report is currently under internal peer review within WSP.

Table 3 lists scientific reports published by either the MGS or the USGS pertaining to fractured rock aquifers.

Table 3 – Groundwater publications since 2015 in the Piedmont, Blue Ridge, Ridge and Valley, or Appalachian Plateaus Provinces

Name	Year	Summary
Well water quality in the Appalachian Plateau Physiographic Province of Maryland [RI 85]	2019	Water quality data from local, state, and federal agencies were compiled into one report to identify problems with well water quality over the Appalachian Plateau Region. Dissolved solids, hardness, pH, iron, and manganese tended to be higher and dissolved oxygen and nitrate tend to be lower in Appalachian Plateau well water compared to well water in the crystalline-rock regions in Baltimore, Cecil, and Howard Counties.
Water quality and temporal variations in chloride concentrations in groundwater in the Maryland Piedmont [ADMIN 19-02-01]	2019	Data from wells sampled between 1970 and the early 2000s within the Piedmont Region was analyzed to determine trends in groundwater chemistry. Chloride was focused on as a contaminant due to increased road salts and other sources from urban environments. Several wells had an increase in chloride concentration over time.
Geology and karst development of the Hagerstown Valley (Great Valley) of Maryland [RI 86]	2018	Karst features within Hagerstown Valley were identified, along with the sinkholes, springs, and depressions within these features. A Karst Susceptibility Index (KSI) was developed from the relationship between bedrock material and karst features for planners to use to identify the susceptibility of a region to sinkholes, the creation of which is accelerated by development.
Hydrogeology at three test-well sites in Garrett County, Maryland [OFR 15-02-03]	2017	Seven test wells between three different sites were drilled to get baseline data for hydrogeological characteristics and investigate hydraulic connections between shallow and deep aquifers and surface waters. The aquifer system was found to be highly heterogeneous, even between wells at the same site, making prediction of fate and transport of subsurface contaminants difficult.
Dissolved-methane concentrations in well water in the Appalachian Plateau Physiographic Province of Maryland [RI 82]	2016	Dissolved methane concentrations were measured in drinking-water wells to serve as a baseline for possible future natural gas production operations. Methane concentrations ranged from below 1.3 µg/l to above 1 milligrams per liter (mg/L), and concentrations tended to be higher in valleys than in uplands. The range of values detected was found to be similar to those found in PA, WV, and NY.
Potential corrosivity of untreated groundwater in the United States [USGS SIR 2016-5092]	2016	Corrosive groundwater, if untreated, can dissolve lead and other metals from pipes and other components in water distribution systems. Eleven states, including Maryland, were classified as having a high prevalence of potentially corrosive groundwater.

Coastal Plain Water Supply Studies

The Maryland Advisory Committee on the Management and Protection of the State's Water Resources identified the need for a comprehensive assessment of groundwater resources in the Maryland Coastal Plain.[14] Withdrawals from the confined aquifers of the Coastal Plain in southern Maryland and the Eastern Shore have caused water levels in some aquifers to decline by hundreds of feet from their original levels. This rate of decline is expected to increase as the population in these areas grows. A more comprehensive understanding of the confined aquifer systems and how much water is available in these systems is needed to make sound management decisions and appropriately evaluate water withdrawal requests.

Table 4 lists scientific reports published by either the MGS or the USGS pertaining to the Coastal Plain.

Table 4 – Groundwater publications since 2015 in the Coastal Plain Province.

Name	Year	Summary
Simulated Effects of Sea-Level Rise on the Shallow, Fresh Groundwater System of Assateague Island, Maryland and Virginia	2021	A groundwater flow model was developed and evaluated under different sea level-rise scenarios to understand the effects of possible sea level rise on the groundwater system on the barrier island. Sea level rises lead to inundation, elevated water table levels, and decrease freshwater recharge.
Machine-learning models to map pH and redox conditions in groundwater in a layered aquifer system, Northern Atlantic Coastal Plain, eastern USA	2020	Data from wells in the Coastal Plain aquifer system for pH and dissolved oxygen (DO) were compiled and a machine learning method was applied to the data to predict pH and low-oxygen conditions within the aquifers. Both pH and DO levels were influenced by travel time, confinement, depth, and distance from groundwater recharge areas.
The relation of geogenic contaminants to groundwater age, aquifer hydrologic position, water type, and redox conditions in Atlantic and Gulf Coastal Plain aquifers, eastern and south-central USA	2020	Groundwater age distribution was compared to concentrations of geogenic contaminants of concern in public supply wells through the Atlantic and Gulf Coastal Plain aquifers. Locations of recharge and confining layers affected both age and contaminant distribution. Arsenic, fluoride, and polonium were higher in older, high pH groundwater, while mercury and iron were higher in younger groundwater.
Simulated maximum withdrawals from the Upper Patapsco, Lower Patapsco, and Patuxent aquifer systems in Anne Arundel County, Maryland [ADMIN 20-02-01]	2020	Two models were used to simulate the remaining drawdown and travel times within the Upper Patapsco, Lower Patapsco, and Patuxent aquifers, which are the primary sources of public drinking water systems within Anne Arundel County. The report assessed the potential impacts of maximum withdrawal rates.
Summary of geologic data from three core holes drilled through the Potomac Group in the Coastal Plain of Cecil	2020	Cores drilled within the coastal plain sediments of Cecil County analyzed to better understand the stratigraphic makeup of the region. Between the three cores, the extent of the Potomac Group aquifers (Patapsco, Arundel, and Patuxent formations) varied more than

[14] mde.maryland.gov/programs/Water/water_supply/Pages/wolman_fullreport.aspx

County, Maryland [RI 87]		previously understood from geophysical logs, and demonstrate the need for palynological (pollen-based) and other age dating methods.
Potentiometric surface maps of selected confined aquifers in southern Maryland and Maryland's Eastern Shore, 2019 [OFR 20-02-01]	2020	Potentiometric surface maps of the Aquia, Magothy, Upper and Lower Patapsco, and Patuxent aquifers were developed based on measured water levels for the Western Shore and parts of the Eastern Shore. Significant cones of depression were identified in each aquifer.
Land subsidence monitoring to assess potential effects of groundwater withdrawals from coastal plain aquifers in Maryland: Fall, 2017 survey [ADMIN 18-02-03]	2018	GPS heights were measured at well fields in the coastal plain. Sites in Anne Arundel had slight declines since the 1990s but other sites only had data back to 2016 and thus no trends were discernible.
Effects of increased withdrawals from the Aquia aquifer on the Mayo Peninsula, Anne Arundel County, Maryland with an evaluation of water quality [RI 84]	2018	The effects of increased withdrawals on the Aquia aquifer at the Mayo Peninsula due to a new development were evaluated. Increased withdrawals will generally decrease the drawdown by less than 0.25 feet, but some areas have a higher potential drawdown of up to 2 feet, which may lead to saltwater intrusion. An analysis of water quality in existing wells found some were affected by brackish water intrusion.
Water-quality data from network wells used to monitor brackish-water intrusion of the Aquia aquifer, Kent Island, Queens Anne's County, Maryland: Data collected through 2017 [ADMIN 18-02-02]	2018	Results from a water quality monitoring network within the Aquia aquifer on Kent Island are compiled. Generally, in the central part of the bay-side shore, chloride concentrations were elevated and increasing, while the northern and southern ends saw levels elevated but not increasing. Chloride was not detected in inland wells.
Compilation of Coastal Plain groundwater-quality data from multiple data sources in Anne Arundel, Wicomico and Worcester Counties, Maryland [ADMIN 18-02-01]	2018	County, state, and federal data for water quality was compiled into a GIS database for Anne Arundel, Wicomico, and Worcester Counties. The project is meant to be a prototype, with the other counties included in the future. The constituents included (arsenic, chloride, iron, manganese, and nitrate) could be mapped to view concentration and sorted by aquifer.
Effects of projected (2086) groundwater withdrawals on management water levels and domestic wells in Anne Arundel County, Maryland [OFR 17-02-01]	2017	Model simulations indicate that projected withdrawals will not cause water levels to fall below the 80% management level in all well fields with the exception of the Upper Patapsco aquifer system at Severndale. Sufficient capacity is available in the Lower Patapsco aquifer system at Severndale, however, to shift the Upper Patapsco withdrawals to the Lower Patapsco.
Land subsidence monitoring at Arnold, Broad Creek, and Crofton Meadows wells fields in Anne Arundel County,	2017	GPS surveys between 1994 and 2017 to assess land subsidence.

Maryland: Fall, 2016 survey [ADMIN 17-02-04]		
The Maryland observation-well network in Coastal Plain aquifers: 2012 status, assessment and recommendations [OFR 12-02-19]	2016	The Maryland Observation-Well Network has been monitoring groundwater since 1943, with 166 total wells as of 2012. The report identifies a need for a review of water use and projected demand to determine additional monitoring locations. The report also proposes candidate wells to be integrated into the monitoring systems, which includes existing water supply wells.
Establishment of a land subsidence-monitoring network to assess the potential effects of groundwater withdrawals in southern Maryland [OFR 16-02-01]	2016	A network of 3D rod survey marks was installed to monitor changes in land elevation at areas with high levels of groundwater withdrawals and large cones of depression. The heights obtained at this survey will be used as a baseline for future monitoring.
Land subsidence monitoring at Arnold, Broad Creek, and Crofton Meadows well fields in Anne Arundel County, Maryland: 2016 survey [ADMIN 16-02-01]	2016	A network of 3D rod survey marks was installed to monitor changes in land elevation at areas with high levels of groundwater withdrawals and large cones of depression. The heights obtained at this survey will be used as a baseline for future monitoring.
Digital elevations and extents of regional hydrogeologic units in the Northern Atlantic Coastal Plain aquifer system from Long Island, New York, to North Carolina [USGS DS 996]	2016	Digital geospatial datasets of the extents and top elevations of the hydrogeologic units within the Northern Atlantic Coastal Plain aquifer system were developed. The data set includes the surficial unconfined aquifer, 9 confined aquifers, 9 confining units, and the bedrock surface. Data was interpreted from individual studies in each state.
Potentiometric surface and water-level difference maps of selected confined aquifers in southern Maryland and Maryland's Eastern Shore, 1975-2015 [OFR 16-02-02]	2016	Potentiometric surface maps of the Aquia, Magothy, Upper and Lower Patapsco, and Patuxent aquifers were developed based on measured water levels from September 2015. Water level differences were calculated using historical well data. Water levels have declined in each aquifer system as water withdrawals have increased.
Assessment of Groundwater Availability in the Northern Atlantic Coastal Plain aquifer System from Long Island, New York to North Carolina [USGS Professional Paper 1829]	2016	A groundwater flow model was developed to assess the sustainability of groundwater supplies in the North Atlantic Coastal Plain system, and changes in the hydrologic budget caused by groundwater withdrawals. The depletion of groundwater stored in the unconfined aquifers, confined aquifers and confining units were calculated for each time period. Very little depletion of storage in the unconfined aquifers is projected for the future period. Future period predicts an ongoing loss of storage of 32.6 million gallons of water per day from the Western Shore Coastal Plain, with 71% of the lost storage coming from the confining units. On the Delmarva Peninsula, the future scenario predicts 83.2 million gallons of water per day will be removed from storage with 90% of the lost storage

		coming from the confining units.
Hydrogeology of the Patuxent aquifer system in the Waldorf area, Charles County, Maryland [OFR 15-02-01]	2015	Four test wells were constructed in Waldorf, Charles County to characterize the Patuxent aquifer and quantify the effects of withdrawals on the system. Water levels are in decline within the aquifer, likely due to non-local pumping at Indian Head or the Chalk Point Power Plant. Despite a large amount of available drawdown, the use of water may be limited in Waldorf due to depths and low transmissivity.
Preliminary investigation of elevated radioactivity in groundwater in Charles County, Maryland [OFR 15-02-02]	2015	Existing data taken from public supply systems in Charles County for radioactivity was reviewed to identify aquifer regions with elevated radioactivity and other wells that could also be affected. Waters with elevated radioactivity were not unique to any specific stratigraphic levels or regions, and the heterogeneity of the sand layers within the Upper and Lower Patapsco aquifers make tracking any radiation sources difficult. Testing of more domestic wells is recommended to better characterize the extent of radioactivity.
Simulation of Groundwater Flow in the aquifer System of the Anacostia River and Surrounding Watersheds, Washington, D.C., Maryland, and Virginia	2015	A three-dimensional steady-state groundwater-flow model was developed for the Anacostia River and surrounding watersheds in D.C., Maryland, and Virginia to quantify groundwater flow into the river. Flow paths into the river pass through the surficial aquifer and the Patapsco and Patuxent aquifers. There is some recharge from the Anacostia River into the upper Patapsco sub crop south of D.C.

Maryland Groundwater Quality Monitoring Network

The Maryland Groundwater Quality Monitoring Network is an ongoing monitoring effort intended to document the chemical quality of Maryland aquifers.

In Federal Fiscal Years (FFYs) 2015 and 2016, MGS compiled well water quality data from local, state, and federal agency databases for the Appalachian Plateau Physiographic Province of Maryland (Garrett County and western Allegany County). Concentrations of major ions, nutrients, trace elements, radioactivity, and indicators were evaluated from 2,314 wells with respect to drinking water standards, geologic units, land use, topographic position, and other factors. This project is summarized in MGS Report of Investigations No. 85 "*Well water Quality in the Appalachian Plateau Physiographic Province of Maryland*".

In FFY16 and FFY17, MGS compiled existing groundwater quality data from local, state, and federal agency databases for three counties in the Coastal Plain Province of Maryland (Anne Arundel, Wicomico, and Worcester counties). Constituents included those with established drinking water standards as well as those that provide information about the chemical conditions within the aquifers (major ions, trace elements, pH, and specific conductance). The purpose of this work is to incorporate groundwater-quality datasets identified by source aquifer from multiple data sources into a GIS geodatabase with consistent and standard format that can be used for analysis by water managers and others, and that will provide a prototype for the future inclusion of additional counties. This project is summarized in MGS Administrative Report 18-02-01 "*Compilation of Coastal Plain Groundwater-Quality Data from Multiple Data Sources in Anne Arundel, Wicomico and Worcester Counties, Maryland.*"

Since FFY18, MGS with support from WSP has been studying the occurrence of chloride in the Piedmont Province of Maryland. With expanded urbanization of previously rural areas, there is an elevated risk of chloride contamination from road salt and other anthropogenic sources. The objectives of the studies have included mapping the spatial distribution of chloride in groundwater throughout the Piedmont region of Maryland, evaluating the temporal variation of chloride concentrations in groundwater, and determining potential associations between elevated chloride and other chemical constituents. Ongoing studies are focusing on a small basin to better understand localized movement of road-deicing salt in groundwater, the timing of road-deicing salt application compared to its arrival in well water, and the degree and rate of salt flushing from well water after rain events. The projects are summarized in MGS Administrative Report 19-02-01 "*Water Quality and Temporal Variations in Chloride Concentrations in Groundwater in the Maryland Piedmont*" and MGS Report of Investigations No. 89 "*Effects of Road-Deicing Salt on Groundwater in the Maryland Piedmont*" (in review).

Groundwater Level Monitoring

Water-level data is collected on an ongoing basis by MGS and USGS from statewide, regional, and county networks. The statewide network consists of approximately 200 wells that are monitored at intervals ranging from continuous recording (mostly in the unconfined aquifers) to biannually (in confined aquifers). Additionally, about 270 wells in the Maryland Coastal Plain region are measured once a year to monitor effects of groundwater withdrawals by power plants and other users. This data is used to construct potentiometric surface maps for five major aquifers every two years. Anne Arundel, Charles, and Queen Anne's counties also support groundwater-level monitoring in a total of 47 wells measured by MGS. All data collected by MGS and USGS personnel are stored in the USGS-National Water Information System (NWIS) database and available online.[15]

Many of Maryland's network wells are valuable long-term data sources (130 wells are over 50 years old), but they are also vulnerable to deterioration or blockages related to their old age and lack of pumping. To ensure that the collected data is reliable, consistent, and comparable, MGS has been performing well integrity testing on a subset of the well network using funds provided by the USGS National Groundwater Monitoring Network grant(s) awarded from 2018 to the present. To date, the work performed has included 75 hydraulic tests, 75 well camera surveys, 67 GPS surveys, and 25 wellhead repairs.

[15] nwis.waterdata.usgs.gov/nwis/gwlevels

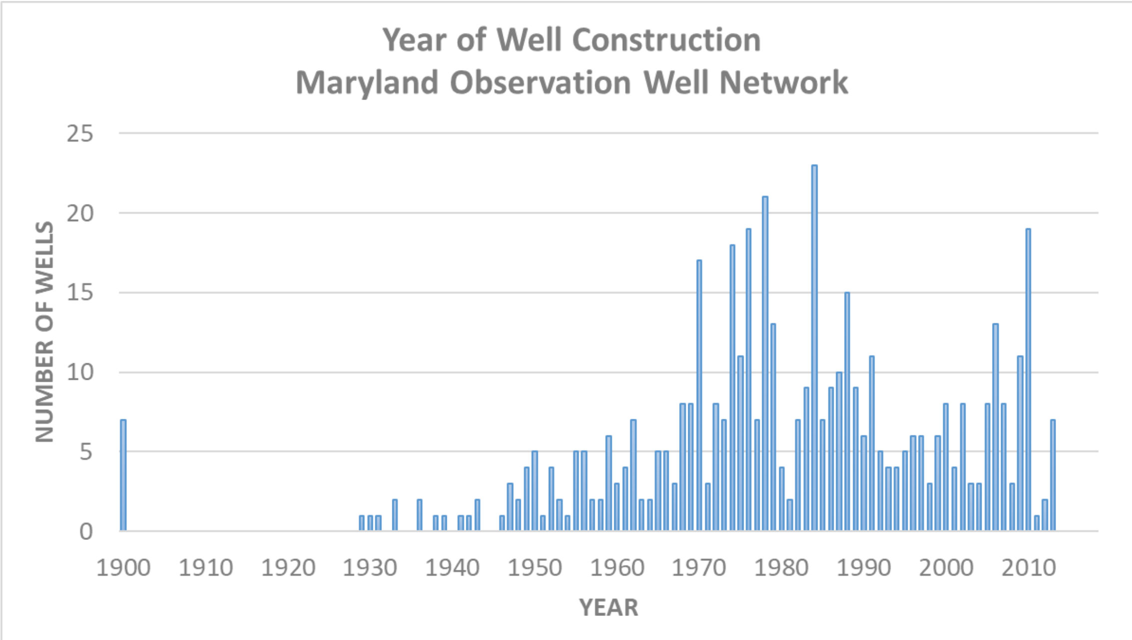

Figure 5 - Graph showing the year of construction for wells in the Maryland observation well network. The average age is 40 years old, and there are 130 wells that are over 50 years old.

Oversight of Water Systems

Public Water Systems

The federal SDWA establishes requirements for public drinking water systems to ensure the quality of drinking water. WSP has primacy authority for enforcing the federal requirements of the SDWA. Routine activities performed by staff in WSP include regular on-site inspections of water systems to identify sanitary defects, providing technical assistance to water systems, conducting routine monitoring of water quality, and ensuring that consumers are informed about their drinking water.

Public drinking water systems fall into three categories: community, non-transient non-community, and transient non-community. CWSs serve year-round residents. Non-transient non-community water systems (NTNCWS) serve non-residents (e.g., schools, businesses, etc.). Transient non-community water systems (TNCWS) serve different consumers each day (e.g., restaurants, campgrounds, etc.). WSP directly regulates CWS and NTNCWS. TNCWS are regulated and enforced by local county environmental health departments through state-county delegation agreements, with the exception of systems in Anne Arundel, Cecil, Harford, Montgomery, Prince George's, Washington, and Wicomico County, which are regulated directly by WSP.

CWS and NTNCWS must test for over 90 regulated contaminants on schedules, which vary based on source type, historical water quality data, and population. WSP receives data throughout the year and reviews it for compliance with the regulations. If systems are not compliant with the regulations, enforcement action will be taken.

Groundwater continues to be a reliable and safe source of drinking water for Maryland residents. WSP is responsible for ensuring that public drinking water supplies in Maryland are both safe and sustainable. Throughout the state, there are 463 CWSs, of which 406 use groundwater as their only water source. These groundwater systems serve more than 1 million Maryland residents. Additionally, there are about 534 Non-Community Non-Transient Water Systems (NTNCWSs that rely on groundwater. There are also about 2,239 TNCWSs that use their own groundwater wells.

Water systems that have groundwater sources may be susceptible to fecal contamination. In many cases, fecal contamination can contain disease causing pathogens. In 2006, EPA issued the Ground Water Rule (GWR) to improve drinking water quality and provide protection from disease-causing microorganisms. The GWR requires water systems with groundwater sources at risk of microbial contamination to take corrective action to protect consumers from harmful bacteria and viruses. Sanitary surveys are an important way for states to identify at-risk systems.

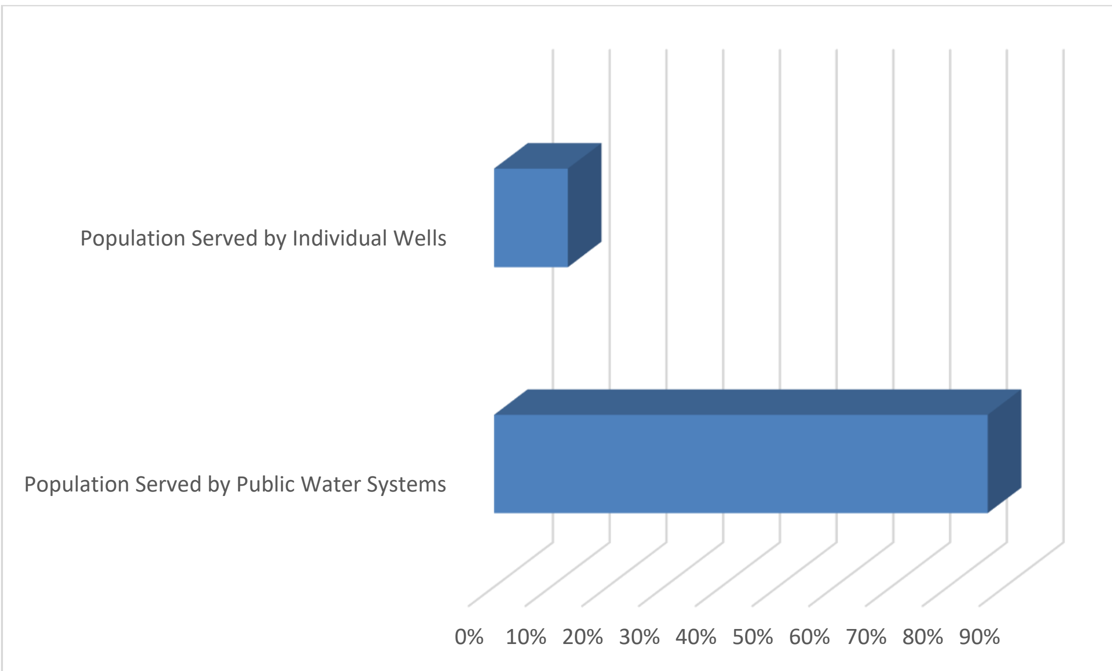

Figure 6- Percentage of population served by PWSs or individual (private) wells.

Recent Regulatory Initiatives

Testing for Lead in Drinking Water - Public and Nonpublic Schools

Lead is not naturally present in groundwater in Maryland; however, it can end up in the water supply by leaching from plumbing components due to the natural corrosivity of groundwater water, if it is not treated. Under Maryland law, all public, charter, and nonpublic schools that receive drinking water from a public utility are required to periodically test all their drinking water outlets for the presence of lead in the water on a state-established three-year cycle, unless a waiver from future testing has been granted. The law does not apply to schools that have their own individual wells (i.e., NTNCWSs), and are currently testing for lead in the drinking water under the federal Lead and Copper Rule (LCR).

Water Supply – Private Well Safety Program

While all CWSs are routinely monitored for more than 90 contaminants, private wells are tested for bacteria and nitrate only when a Certificate of Potability is issued prior to placing it in service. Afterward, the responsibility for water quality testing is on the well owner. MDE recommends that all private well owners test their well water quality at least once a year. In the 2021 legislative session, HB 1069 passed and went into effect on July 1 of the same year, which required the landlords of residential rental units on individual wells to test their water quality more frequently and inform the tenants of the results.

An owner of residential rental property that is served by a private water supply well is required to:

1. Test water quality every 3 years and to disclose to a tenant certain results;
2. Notify MDE and the local health department about well contamination; and,
3. Provide an ongoing potable water supply and resolve the contamination within 60 days.

Water Pollution – Stormwater Management Regulations and Water Implementation Plans-Review and Update

In 2021, SB 227 passed, which required MDE to update stormwater management regulations at least once every 5 years to incorporate updated precipitation data. Climate change may impact the amount of groundwater recharge. This statute helps to ensure stormwater management practices keep pace with climate change and thereby its potential impacts on groundwater recharge.

2018 Farm Bill Drinking Water Provisions

The 2018 federal Farm Bill includes $4 billion dollars over a 10-year period for conservation practices that protect sources of drinking water. The Farm Bill places an emphasis on source water protection through all Farm Bill conservation programs. Ten percent of National Resource Conservation Service (NRCS) conservation funding is directed toward source water protection. Also, water utilities are authorized to work with state technical committees in identifying priority areas in each state. Furthermore, additional incentives are provided for farmers who employ practices that benefit source waters.

In 2019, WSP was tasked with providing recommendations to NRCS on PFAs and practices under the 10% set-aside for Drinking Water protection. WSP staff analyzed 31 drinking water supply watersheds and ranked them based on the water supply's vulnerability to agricultural contaminants. WSP met routinely with NRCS and other stakeholders to gain insight on the NRCS funding process and to provide perspective on source water protection goals. Three watersheds (North East Creek, Liberty Reservoir and Cranberry Run) were selected by NRCS based on WSP recommendations, which directed approximately $900,000 in available funds in FY19 to growers in those watersheds for BMP implementation. The BMPs protect both groundwater and surface water resources.

Wellhead Protection

WSP has delineated wellhead protection areas around each public drinking water well in the state, and identified existing and potential sources of contamination, determined the susceptibility of the well to contamination, and offered recommendations for protecting the water supply sources. Measures for implementing protection plans, such as planning and zoning decisions, are typically the purview of local government, so WSP's role is to provide technical assistance and guidance to local authorities on wellhead protection issues. Since 2015, WSP has identified 108 new public supply groundwater sources and delineated wellhead protection areas for these sources. Once these delineations are finalized, the subsequent phase of this project will involve identification of potential contaminants, determining susceptibility of sources to contamination, and developing recommendations for protecting these sources. Several jurisdictions have incorporated wellhead protection ordinances to their planning and zoning regulations to protect their drinking water sources, with technical guidance and approval from WSP.

Well Siting

WSP ensures the safety of new public water supplies by reviewing and evaluating proposals for the siting of new wells. To ensure that wells are sited in the safest locations, WSPreviews existing records to identify existing or potential contamination sources, and conduct site investigations with local health department staff to verify this information and evaluate any additional factors and issues that might influence the safety of the water supply. Since 2015, WSP reviewed proposals for the siting of 159 new public water supply wells.

<u>Private Water Systems</u>
The SDWA does not regulate private wells. Approximately, 830,000 Marylanders rely on individual wells they own for their water supply source. Owners of these private wells are responsible for the safety of their water source. MDE encourages these homeowners to test their well water every year to ensure the integrity of their well water quality. HB 1069 (2021) requires water quality sampling at private wells serving residential rental property.

Oversight of water well construction is delegated to the local Approving Authority (AA). The local AAs are usually within the local health department but may be a separate entity. The local AAs have been delegated authority to issue permits, perform construction inspections, review well sampling data for Certificates of Potability, and review well locations for building permits or onsite sewage disposal system repairs. In some areas in Maryland, naturally occurring elements (cadmium and polonium), past land use impacts, petroleum releases, and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Resource Conservation and Recovery Act (RCRA) sites are known by the local AAs. Additional sampling and well construction requirements have been established by local AAs in some of these known areas. As a part of WSP, the state Well Drillers Board approves licenses for well drillers.

GROUNDWATER QUALITY PROTECTION AND RESTORATION

Groundwater supplies in Maryland are impacted by both natural influences and human-induced contamination. Over the past 100 years, growth and development have impacted water quality in both agricultural and urban areas in the state. Although Maryland has many programs in place to minimize and remediate existing groundwater contamination, challenges to groundwater quality increase as new homes, commercial development, and roads are built to meet the needs of the population.

Drinking Water Quality Issues

Public drinking water systems are required by federal law to monitor regularly to ensure compliance with EPA standards. In Maryland, private individual wells are typically tested only for limited contaminants (bacteria and nitrates) when the well is first drilled; any subsequent testing is at the discretion of the homeowner.

<u>Water Quality Testing is Necessary to Understand the Public Health Risk</u>
Public health protection requires a coordinated effort involving both testing and public outreach. Testing of well water reveals risks and is necessary for public health protection. By taking the steps to do effective public outreach that helps explain the public health risk and by making data available to those drilling wells will help decline the amount of unhealthy exposure to contaminants through groundwater.

Special studies and proactive monitoring can be used to determine the safety of vulnerable water supply sources to contaminants for standards that have not yet been developed. For example, Maryland implemented testing for methyl-tert-butyl-ether for all PWSs in the mid-1990s in the absence of a national standard, and the sampling revealed contamination at hundreds of public supply wells. These results enabled water systems to mitigate the risks to their customers and helped to identify sources of leaking underground storage of fuel for remediation. Monitoring needs to be targeted for systems that are at risk for specific types of contamination. Special studies that identify potential contaminant source locations is the first step in identifying water supply sources most likely to be at risk. The second step involves applying knowledge of hydrogeology to estimate groundwater flow directions and potential receptors. This includes a wider scope of potential receptors for sampling that is more revealing of risk than a narrow band.

Special studies not only provide valuable information to water suppliers and WSP, but also give valuable information to local health departments by informing professionals involved in approving individual wells and assisting homeowners with questions of water quality. It is essential that they are aware of the potential for contaminants to be present in a particular aquifer or location. For example, a 2010[16] water quality study on the occurrence of radium and arsenic

[16] mgs.md.gov/publications/report_pages/RI_78.html

was undertaken, resulting in maps[17] and GIS data layers showing the concentrations of arsenic and radium in specific aquifers. The maps and GIS products have enabled local health departments to target future sampling and designate appropriate aquifers or well depths to avoid contamination. Brochures that address the methods for water treatment, associated health risks, and other important information for the homeowner enabled the public to make informed choices to reduce the exposure from elevated arsenic and radium.

<u>Groundwater Quality Changes Over Time</u>

Changes in land use practices can influence groundwater quality, either positively or negatively, in unconfined aquifers. A water quality sample from a supply well represents the water that recharges the aquifer at particular points in time and travels along a particular set of flow paths before being withdrawn from the well. Today, any water being removed by a supply well in an unconfined aquifer is likely to reflect the land use activity from years, decades, or even centuries ago.

A long-term water quality monitoring program involving wells across the state, testing for a specified suite of contaminants would be helpful to improve public health protection. Examples of contaminants/water quality characteristics that change in an unconfined aquifer over time include nitrates, chlorides, sodium, radioactivity (radium), microbiological contaminants, and water corrosivity. If, for example, a large field that is used for growing hay is converted to a new subdivision on private wells and on-site septic systems, new sources of nitrogen, microbial pathogens, and salt (from deicing materials and in some instances brine backwash from water softening treatment) will be introduced into the subsurface. Water quality samples collected at the time of development will not show the impacts of those new sources of contamination. Thus, the sampling may indicate a safe water supply, but it will not reflect the conditions after several decades pass. Individual well owners may not realize that their water quality has changed and that they are being exposed to harmful levels of contaminants.

One of the most concerning changes are the impacts from increased salt into the aquifer system. Increased salt concentrations are correlated to increased levels of radium. Increased salt concentrations increase the corrosivity of the water, which will increase the concentration of lead derived from plumbing components of the water system. Other metals are also likely to be mobilized by increased salt concentrations in groundwater. The report *Water quality and temporal variations in chloride concentrations in groundwater in the Maryland Piedmont* [ADMIN 19-02-01] investigated the change in water quality through time.

<u>Groundwater is more vulnerable to contamination in certain areas and aquifers than others</u>

Groundwater conditions are specific to a particular location. The vulnerability of an aquifer becoming contaminated depends on the source and type of contamination and the geologic setting of the aquifer. Starting in 1999, WSP completed source water assessments for about 3,300 public water supply sources. Several key themes became apparent through this process, which are outlined below:

[17] mgs.md.gov/groundwater/arsenic%20interactive.html

1) The outcrop areas of many of the Coastal Plain aquifers coincide with major transportation corridors (Route 40 corridor north of Baltimore and Route 1 corridor south of Baltimore). As a result, water supplies in this region have a significant risk of contamination. Examples of contamination that have impacted Maryland's groundwater in this region are:

- Leaks from storage of petroleum (gasoline service stations and fuel terminals)
- Dry cleaning solvents and other industrial solvents
- Various practices at military installations
- Older landfills and dumps
- Steel manufacturing, chemical manufacturing, electroplating, metal finishing, wood treatment and manufacturing facilities

2) Nitrates are the most common anthropogenic contaminant in groundwater above drinking water standard. Water supply sources relying on unconfined aquifers are potentially vulnerable, while water supplies relying on confined aquifers are not. Carroll County has the highest number of PWSs impacted by elevated nitrates. Nitrates in PWSs are removed in the treatment process; however, this can increase treatment costs. In the case of individual private wells, there is insufficient data to assess regional nitrate levels. Data collected under HB 1069 (2021) could start to remedy this. Nitrates in groundwater most commonly originate from agricultural activities and on-site waste disposal. An in-house research study of PWS with elevated levels of nitrate in three Eastern Shore counties highlighted the correlation between the proximity of farming practices to the drinking water wells. A study in Garrett County showed that the groundwater in unconfined aquifers of Garrett County is generally not susceptible to elevated nitrates due to the anoxic conditions of the groundwater in the aquifers in this county.

3) Carbonate rock aquifers are vulnerable to contamination due to their high level of interconnectivity with surface water. Wells drilled into carbonate aquifers are more likely to contain disease causing organisms than wells in any other aquifer type in Maryland. Chlorine disinfection alone will not adequately treat pathogens present in surface water or in groundwater under the influence of surface water. Studies have shown sinkholes and losing streams to be the route of entry of surface water into carbonate aquifers. Sampling following significant precipitation events is necessary to assess risks. Public supplies with *E. coli* are required to employ treatment to meet national primary drinking water standards for the treatment of surface water. A general recommendation would be either to connect communities with private wells to an existing PWS or establish a CWS to better protect the public health.

4) Water supplies relying on the confined aquifers of the Coastal Plain are not vulnerable to contamination from local land use activity. Groundwater moves very slowly. A study of water age in the Upper Patapsco aquifer found ages from approximately 10,000 years old in sampling locations in Prince George's and Anne Arundel County, several hundred thousand years old further down gradient in Talbot County, and more than a million years old in Somerset County. Monitoring of hundreds of public supplies for the past several decades has not shown manmade contamination in confined public supply wells, unless due to well construction issues. Damaged well casings can allow contaminants from the shallow groundwater enter a well, and failure to properly grout a well from the land surface to the confining unit immediately above the aquifer

can also allow contaminants to travel along the outside of a well into the gravel pack and eventually into a supply well.

5) Relatively short groundwater flow paths in the Piedmont crystalline rocks result in relatively small wellhead protection areas for groundwater supplies in this hydrogeologic setting. The small size of the area, which contributes water to a supply well, makes the protection of the area feasible. Many local governments have adopted land use protection strategies to ensure the long-term safety of their water supply sources. Fewer protective measures are in place for small privately-owned water systems with equal vulnerability.

Selected Common Contaminants in Groundwater

MGS has published about 48 reports, including water quality analyses during the period 1966-2019. MGS has provided the local approval authorities various publications and groundwater analysis data in areas impacted by arsenic, radionuclides, and other contaminants of concern. The MGS Groundwater Quality website[18] and the University of Maryland Extension website[19] provide useful information.

Iron and Manganese

Iron and manganese are two of the most commonly occurring natural contaminants in Maryland's groundwater. Both have secondary drinking water standards. Their presence in water can cause metallic taste as well as staining of fixtures, appliances and pipes. Manganese in water is currently being evaluated as a potential primary contaminant by EPA due to a series of research studies connecting manganese with possible adverse health effects.

Arsenic

Arsenic is a naturally occurring contaminant that has been found in the Coastal Plain aquifers and in parts of the Hampshire and Pocono aquifers in western Maryland. Arsenic contamination can also be the result of pesticide historic uses. Arsenic has a primary drinking water standard under the SDWA. A handful of systems in Maryland have detected arsenic in their groundwater source; however, all provide some form of treatment and are in compliance with the drinking water standards. Arsenic has been shown to cause nausea, vomiting, diarrhea, paralysis, blindness, and several types of cancer.

Radium

Radium is a naturally occurring contaminant that is found in groundwater in some areas of the Coastal Plain, particularly in the confined parts of the Patuxent, Patapsco and Magothy aquifers in Anne Arundel County. It is also found in some areas of the Piedmont. Radium causes cancer. Radium is regulated as a primary drinking water standard under the SDWA.

Radon

Radon is a gas that occurs in groundwater in Maryland's Piedmont aquifers. Radon can be

[18] mgs.md.gov/groundwater/water_quality.html
[19] extension.umd.edu/resource/water-contaminants

released from water and soil into the air and subsequently inhaled. Radon causes lung cancer.

Bacteria and Protozoa

Bacteria and protozoa from human and animal waste are carried into aquifers by infiltration. Unconfined aquifers are vulnerable to bacteriological contamination. Especially vulnerable areas are where agricultural and septic systems occur in carbonate geology. Bacteria cause many ailments in humans.

Nitrate

Nitrate pollution in groundwater is problematic, especially in aquifers underlying agricultural areas. The primary sources of nitrate to groundwater are from agricultural land uses, including land application of commercial fertilizers and manure. Other major sources include wastewater treatment plants (WWTPs), on-site sewage (septic) systems, and atmospheric deposition of air pollutants.

Due to agricultural land use practices, nitrate concentrations in shallow waters of unconfined Coastal Plain aquifers on Maryland's Eastern Shore commonly exceed the federal Drinking Water Standard of 10 mg/L. Concentrations greater than 10 mg/L can cause methemoglobinemia, a dangerous blood disorder, in infants. While nitrate can be removed through treatment processes, this can add to the cost of water treatment. Shallow groundwater is generally used for irrigation and other non-potable uses, and in some cases for potable use by private well owners. However, water for public drinking water systems is generally pumped from deeper aquifers. Private residential wells are not monitored regularly, and many homeowners are not aware of potential contamination.

All PWSs are required to conduct monitoring for nitrate on at least an annual basis. If nitrate is detected above 50% of Maximum Contaminant Levels (MCL), the systems will be placed on a quarterly monitoring schedule. In 2020, 34 water systems reported exceedance of the drinking water standard for nitrate. Currently,[20] approximately 48 systems in Maryland have treatment systems indicated in the database for nitrate removal.

As part of its source water protection activities, WSP evaluates contaminants of concern, such as nitrate. Identification of nitrate sources and concentration trends can assist in the development of watershed management actions.

MDA's Nutrient Management Program works to enforce the Water Quality Improvement Act of 1998, widely known as Maryland's Nutrient Management Law. These regulations require farmers to implement nutrient management plans, which address nitrogen and phosphorus inputs to the environment.

Maryland's nutrient management regulations were revised again in January 2017. An emergency provision was added to avoid potential overflows of liquid manure, which can result in groundwater contamination. Farmers are prohibited from applying manure, commercial fertilizer, biosolids, and food wastes from December 16 to March 1, annually. In addition, nutrient application is prohibited when the ground is covered with snow greater than one inch, when the ground is hard-frozen, or when the soil is saturated (COMAR 15.20.07.02).

[20] As of June 17, 2021.

The MDA Animal Waste Technology Fund provides competitive funding for innovative practices to address excess animal waste. MDA has established a verification process to confirm previously installed conservation practices that are outside the practice life. Verifiers statewide inspect conservation practices on farms for compliance with technical standards. Additionally, SB 546 (2019) established new reporting requirements of all farmers in the state concerning the movement of poultry litter and other manures. All imported and exported manures must be reported and tracked with names and addresses of senders and receivers.

<u>Road Salt</u>

Chloride concentrations in streams in the northern United States have been observed to be increasing due to the application of road salts for winter maintenance activities. One study showed that between 1990 and 2011, chloride concentrations increased more rapidly than urbanization, indicating that salt application rates, per lane mile, were increasing. That study also suggests that shallow aquifers serve as reservoirs for chloride with an annual fluctuation, but a long-term upward trend in concentrations (Corsi 2015, River chloride trends in snow-affected urban watersheds: increasing concentrations outpace urban growth rate and are common among all seasons). MGS' study[21] of chloride in groundwater echoes some of these findings and establishes a direct correlation between groundwater chloride concentrations and proximity to roadways. This can lead to well contamination, and cause damage to pipes, plumbing fixtures and appliances. To understand the spatial scale of the salinization, Maryland's 2018 Integrated Report of Surface Water Quality shows 28 watersheds impaired by chloride pollution, primarily in the urbanized areas in central Maryland and the snowier west.

Several initiatives are underway to reduce the application of road salt in Maryland. Beginning in 2011, as required by state law, Maryland Department of Transportation State Highway Administration (MDOT SHA) developed and implemented a statewide salt management plan to optimize salt application and reduce the deleterious impacts of salt on the environment and infrastructure. The program has focused on the adoption of best practices and technologies such as the replacement of rock salt with salt brine, and the use of electronically-calibrated spreaders.

Starting in 2021, MDE's individual Municipal Separate Storm Sewer System (MS4) permits will require permittees to develop Salt Management Plans. These plans, similar to the one developed by MDOT SHA, will include evaluations of equipment and best practices for salt application, training and outreach, and tracking and reporting of salt use. These requirements will cover the nine most populous counties in the state, plus Baltimore City. While these efforts focus on municipal salt applicators, it is important to recognize that salt applications on private roads and parking lots can be significant sources of chlorides.

<u>Saltwater Intrusion</u>

Saltwater intrusion into groundwater, both into surficial and deeper confined aquifers, is a long-standing issue that has been studied for many decades; however, climate change is now increasing the extent of saltwater intrusion.

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[21] *Water quality and temporal variations in chloride concentrations in groundwater in the Maryland Piedmont*

Significant research has been conducted over the years such as developing numerical groundwater-flow and solute transport models to predict future changes to the saltwater-freshwater interface in select aquifers and monitoring to detect changes in chloride concentrations in targeted aquifers. While this research has provided valuable information to water managers, the extent of saltwater intrusion in many of Maryland's Coastal Plain aquifers remains unknown. Additionally, there is presently a lack of tools (flow and transport models) and monitoring networks to effectively track, forecast and manage saltwater intrusion as groundwater withdrawals continue or increase and sea level rises.

To better understand the scope of this challenge within Maryland, MGA required MDP to "establish a plan to adapt to saltwater intrusion," in consultation with DNR, MDE and MDA, by December 2019, and to update the plan at least once every five years. MDP submitted *Maryland's Plan to Adapt to Saltwater Intrusion and Salinization*[22] to Governor Hogan and MGA in December 2019.

PFAS

In September 2020, MDE initiated a risk-based, multi-phased approach to understand the presence of PFAS in state drinking water sources. In collaboration with the MDH's Laboratories Administration (MDH-LA), drinking water samples are analyzed for the 18 PFAS listed under EPA Method 537.1. Under Phase 1, finished drinking water samples were collected at 129 Water Treatment Plants (WTPs) from 59 CWSs from September 2020 to February 2021. PFAS were detected in approximately 75% of the samples, with only two finished drinking water samples exceeding the EPA's Health Advisory Level for PFOA + PFOS. These two samples were from the Town of Hampstead and the City of Westminster. WSP worked with these two systems to immediately take the sources out of distribution. The impacted sources remain offline while the municipalities explore treatment options to supplement their drinking water demand. A report outlining MDE's approach and highlighting Phase 1 findings is publicly available on MDE's PFAS webpage.

MDE conducted Phase 2 of their PWS study between March and May 2021. Under this phase, unfinished groundwater samples were collected from an additional 60 CWSs. PFAS were generally detected at lower levels as compared to Phase 1. MDE expects the report summarizing Phase 2 will be completed by late 2021. MDE's PFAS Landing page[23] provides information on these department wide PFAS initiatives. A comprehensive report on PFAS is being provided as a separate document.

[22] planning.maryland.gov/Documents/OurWork/envr-planning/2019-1212-Marylands-plan-to-adapt-to-saltwater-intrusion-and-salinization.pdf

[23] mde.maryland.gov/PublicHealth/Pages/PFAS-Landing-Page.aspx

Water Quality of Private and Public Groundwater Systems

Maryland does not maintain a comprehensive database for private groundwater systems as these systems are not regulated under the SDWA. In addition, each county health department collects and stores these data into their own database that often are not compatible with each other or MDH and MDE databases. MDH and MDE are currently exploring options for developing a platform for a uniform reporting mechanism.

For PWSs with groundwater sources, the most common contaminants detected are listed below.

Contaminant	Percentage of Systems above detection limit	Percentage of Systems above MCL
Arsenic	9%	1%
Barium	12%	0%
Cadmium	1%	0%
Chromium	3%	0%
Radionuclides	21%	1%
Nitrate	34%	1%
Disinfection Byproducts	37%	1%
Total Coliform	8%	0%

Figure 7 - Percentage of water systems with groundwater sources that were required to monitor for a particular contaminant that had results above detection limits, and the percentage of systems that had detections above the MCL. Contaminants that were detected in less than 1% of water systems were excluded.

Water Quality Study of Coastal Plain Aquifers

WSP initiated a study of the Coastal Plain aquifers in 2010. However, due to limited funding the study was not completed. In FY17, USGS, as part of its National Water Quality Assessment program (NAWQA), sampled groundwater quality in Maryland under the Modeling Support Study (MSS) initiative. Under the MSS, about 17 wells in confined aquifers throughout southern Maryland were sampled and analyzed for a broad array of water quality constituents, including major ions, nutrients, volatile organic compounds, metals, and pesticides. These data are available from NWIS.[24] More information about the well network and data collection is available in USGS Data Series Report 1124, *Groundwater-quality and select quality-control data from the National Water-Quality Assessment Project, January through December 2016, and previously unpublished data from 2013 to 2015.*[25] The data are also available in a USGS data release: doi.org/10.5066/P9W4RR74.

[24] nwis.waterdata.usgs.gov/md/nwis/qwdata

[25] pubs.er.usgs.gov/publication/ds1124

Residents affected by groundwater contamination

Dredge Materials Containment Areas

Dredge Material Containment Areas (DMCA) have the potential to negatively impact the water quality of nearby wells if effective confining units are not present to create impermeable boundaries to groundwater flow. For instance, an USGS report from 2013[26] documented that the Pearce Creek DMCA impacted the water supply of a community in Earleville (Cecil County) that utilized individual domestic wells. Use of the DMCA, combined with pre-existing natural conditions, degraded nearby groundwater quality. The DMCA is the source of high total dissolved solids and is the driver of geochemical processes that enhance the mobilization and transport of metals and release of radionuclides, which are often elevated above the applicable regulatory thresholds (primary MCL, secondary MCL, or health advisory levels). Public water had to be provided to the community as an alternative water supply. Multiple other DMCAs exist in Maryland. Many are located near areas that may have individual domestic wells nearby. Most sites have not been evaluated to determine the extent of impact to groundwater quality that sources the wells.

Trichloroethylene: Salisbury-Morris Mill Site, Wicomico County

A collaboration of state and local agencies worked to address the discovery of trichloroethylene (TCE) in private wells in Wicomico County. The affected area is located in a rural residential area, three miles south of Salisbury. TCE is a chlorinated solvent not found in the natural environment. It is used in a variety of industrial applications, most commonly as an extractant and metal degreaser.

The affected groundwater wells are located in the Salisbury aquifer, a shallow, unconfined aquifer, which is recharged rapidly from precipitation and is susceptible to both point and nonpoint source pollution and contamination. To determine the source of contamination, a subsurface investigation was performed. Review of historic documentation and results of sample analyses indicate the most probable cause of the TCE contamination to be the historic septage disposal and spreading area. Septage at this site along Morris Mill Road was spread on farm fields from the early 1950s until mid-1980. It is suspected that TCE was used in or dumped into septic systems, from which waste was pumped for use as field fertilizer.

A Removal Action under the CERCLA was implemented by the EPA as part of their emergency response protocol. Thirty-eight residences received granular activated carbon water treatment systems installed by EPA as an interim measure. Public water service connection was identified as the best long-term solution to provide these homes with clean drinking water. The City of Fruitland received a $3 million grant from MDE and $5 million in U.S. Department of Agriculture (USDA)-Rural Development funding ($3 million grant and $2 million loan) to provide municipal water to the area.

[26] pubs.er.usgs.gov/publication/sir20125263

Environmental Justice Implementation

Consideration needs to be given to the management of groundwater in regard to Environmental Justice. Environmental justice[27] (EJ) means that all people, regardless of their race, color, national origin or income, are able to enjoy equally high levels of environmental protection. Sensitive sub-populations, including low-income and minority communities, are most vulnerable to EJ issues. Often these communities do not have an organized community group that can serve as a point of contact. Additionally, these communities may house a disproportionate number of polluting facilities putting residents at a much higher risk for health problems from environmental exposures.

MDE's mission[28] in regard to EJ, is to emphasize improvements in quality of life, economic development, and environmental protection for all communities. Implementation efforts of EJ at MDE include the following: integrate and incorporate EJ activities into state operations; continue the education of state regulators on environmental justice and sustainable communities, with specialized focus given to marginalized and disenfranchised communities; strengthen government infrastructure at local levels to support marginalized communities; efficiently build a network of people who are knowledgeable about the issues of concern to share expertise and advance the EJ initiatives; and collaborate with the Commission on Environmental Justice and Sustainable Communities. EJ solutions could appear in the form of increased public participation and education, public-private partnerships, innovative outreach advertising, and strategic enforcement.

MDE has created a website that lists EJ web tools.[29] Also, the University of Maryland School of Public Health has developed the Maryland EJScreen Mapper.[30] These resources allow users to explore factors of environmental justice concern at community relevant scales, determine a score for different census tracts, and view context layers relevant to the area of concern. Information such as exposure, environmental effect, socioeconomic factors, and sensitive populations are available in the application. These tools are available to assist state agencies in managing groundwater resources.

From a drinking water perspective, EJ does not exist with CWSs except when it comes to rate structure. Within a CWS, rates may represent different proportions of household income. The same rate for everyone is not really the same rate when systemic income inequalities exist. This issue is prevalent in communities like Baltimore City. However, there have been a number of EJ cases involving private wells. These communities are often outside of a municipal corporate boundary and lack a centralized or reliable water supply. The private wells they rely on may be contaminated due to the adjacent municipal practices (i.e., discharge, landfill, industrial releases, etc.). These communities often lack the ability to demand greater resources and accountability to protect their vital groundwater resource. Over the years, WSP has worked with state and federal funding agencies to construct reliable and affordable CWSs for them.

[27] mde.maryland.gov/programs/Crossmedia/EnvironmentalJustice/Pages/WhatisEJ.aspx
[28] mde.maryland.gov/programs/Crossmedia/EnvironmentalJustice/Pages/index.aspx
[29] mde.maryland.gov/programs/Crossmedia/EnvironmentalJustice/Pages/resources.aspx
[30] p1.cgis.umd.edu/mdejscreen/

Groundwater Remediation and Restoration

Contaminated Sites

MDE's Land Restoration Program (LRP) administers a "Superfund" program, which assesses suspected hazardous waste sites, including federal facilities, to control and remove environmental and public health threats through site cleanups and remedial actions. The Voluntary Cleanup Program (VCP) provides a streamlined process for the remediation and redevelopment of former industrial or commercial properties that are contaminated or perceived to be contaminated with controlled hazardous substances.

Consistent with the requirements of the Controlled Hazardous Substance Act, LRP maintains a Brownfield Master Inventory (BMI) list,[31] which serves as a tool for tracking new and closed sites. There are 871 active sites and 974 archived sites on the BMI list, which includes VCP sites, sites assessed using federal grant money, formerly used defense facilities, assessment and cleanup activities at sites subject to the Controlled Hazardous Substance Response Plan, and sites identified as being impacted by hazardous substances, but subject to other regulatory authorities such as the federal Corrective Action Program, the federal Toxic Substances Control Act or Maryland's Solid Waste Management Program.

Additionally, since the inception of the VCP in 1997, 1,138 applications have been received for 705 properties. Six hundred forty applications have been accepted into the program. Since 1997, the VCP has issued 246 Certificates of Completion (COC) and issued 410 No Further Requirements Determinations (NFRD), and only nine of these closures were issued without restrictions on the use of groundwater.

Oil Pollution Control and Tank Management

The Oil Control Program (OCP),[32] within MDE's Land and Materials Administration, is the unit responsible for the implementation of the underground storage tank (UST), leaking underground storage tank (LUST), and aboveground storage tank (AST) regulations. OCP implements and enforces the regulations so that petroleum can safely be transported, handled, stored, and used in a manner that minimizes groundwater and surface water pollution. Additionally, OCP oversees the safe removal of USTs and corrective actions to mitigate petroleum releases when they occur.

USTs are a potential source of groundwater contamination. OCP has established stringent regulations and provides strict oversight of tank operations within Maryland. Releases from USTs are required to be investigated and those with groundwater impacts are required to define the vertical and horizontal extent of the contamination. Once defined, a corrective action plan is implemented to mitigate the impact of the contamination. The effectiveness of remediation systems is normally evaluated through groundwater monitoring.

[31] mde.maryland.gov/programs/Land/MarylandBrownfieldVCP/Pages/BrownfieldMasterInventory.aspx
[32] mde.maryland.gov/programs/LAND/OilControl/Pages/index.aspx

OCP has enacted a specialized tank inspection program to ensure the protection of groundwater resources and public health from the release of chemicals stored in UST systems. An owner of a UST system in Maryland is required to have the system inspected by a MDE certified underground storage system inspector. Inspectors visit the UST facilities and complete detailed site inspection reports. The inspector evaluates tank and piping release detection, overfill/spill prevention, system corrosion protection, as well as facility housekeeping and other compliance concerns. After the initial inspection, follow-up inspections occur at least every 3 years to confirm continued compliance with Maryland regulations. OCP requires additional testing requirements for gasoline UST facilities operating within the high-risk groundwater use and wellhead protection areas of Baltimore, Carroll, Cecil, Frederick and Harford County. Facilities that fail to perform these tests face MDE enforcement actions and the issuance of a fuel delivery ban.

OCP Compliance Division is responsible for tracking compliance of approximately 9,200 federal or state regulated USTs in Maryland. The federally regulated tanks (approximately 7,200) are inspected at a minimum every 3 years by MDE Certified Underground Storage System Inspectors. Over the past year, OCP provided oversight for the removal of over 300 USTs. OCP Remediation Division continues to maintain a very strong petroleum release cleanup program. On average, the division manages more than 800 long- and short-term cleanups annually. The majority of these cleanups are completed within 2 to 3 years.

Emergency Response

MDE's Emergency Response Division (ERD)[33] conducts immediate removals of oil and hazardous materials that threaten both surface and groundwater sources. Annually, ERD responds to approximately 500 oil spills and hazardous materials incidents throughout the state, both on land and on the water. If a spill occurs within a known source water protection area, ERD will notify the MDE Water Sciences Administration duty officer, who will notify the appropriate PWS, so that monitoring of potential impacts to drinking water can begin. WSP engineers are on call 24-hours per day to provide technical assistance during any water supply emergency.

On-site Sewage Disposal Systems

MDE’s Wastewater Permits Program[34] has delegated the authority for administering on-site sewage disposal (OSDS), land subdivision and well construction programs either to county health departments, which are part of the MDH, or to a local county permitting agency. MDE personnel oversee the delegated programs, provide technical support, investigate potential public health threats, and perform on-site evaluations of innovative and alternative sewage disposal system applications. A strong field presence and ongoing training are vital to the implementation of these important public health laws.

MDE actively promotes the use of advanced OSDSs. As a rule, advanced OSDSs better protect

[33] mde.maryland.gov/programs/crossmedia/emergencyresponse/pages/erhome.aspx
[34] mde.maryland.gov/programs/Water/wwp/Pages/index.aspx

groundwater resources than conventional systems. Advanced systems used in Maryland include: recirculating sand filters, advanced waste treatment units, sand mounds, waterless toilets and at-grade systems. Research on emerging on-site sewage disposal technologies continues, with emphasis on those technologies that reduce discharges of nitrogen.

In 2004, Maryland established a dedicated fund for projects to reduce nutrient pollution to the Chesapeake Bay. Known as the Bay Restoration Fund (BRF), it contains two separate funding streams: a wastewater fund, paid for by WWTP users and directed toward wastewater plant upgrades, and an OSDS fund, paid for by OSDS users and directed toward OSDS upgrades and agricultural cover crops. OSDS may be upgraded either by adding best available technology (BAT) or, subject to limitations, may be connected to sewage treatment plants achieving enhanced nutrient removal. The OSDS program evaluates and approves proprietary technologies as grant eligible BATs for removing nitrogen. All these technologies must also undergo field verification of performance in Maryland. Twelve Maryland installations of each technology must be sampled on a quarterly basis for four quarters. The results of this sampling must indicate a minimum of 50 percent nitrogen removal to successfully complete field verification.

Through June 2020, septic systems serving greater than 11,000 homes have been upgraded to remove nitrogen with BRF grants, reducing the load of nitrogen discharged to groundwater by over 86,000 pounds per year. (As of 6/30/2020: BAT 11,098, Public Sewer Connections 932, Drain fields 131, Holding tanks 183). Currently, nine proprietary technologies have been approved as grant eligible BATs for removing nitrogen.

<u>Sustainable Growth and Agricultural Preservation Act of 2012</u>

The Sustainable Growth and Agricultural Preservation Act limits the spread of septic systems on large-lot residential development to reduce the last unchecked major source of nitrogen pollution[35]. The purpose of the legislation is to decrease future nutrient pollution to the waters of the state and to reduce the amount of forest and agricultural land developed by large lot developments. It does this by limiting major residential subdivisions served by OSDS.

The law provides counties and municipalities the option to adopt a growth tier map that identifies where residential major and minor subdivisions may be located in their jurisdiction and what type of sewerage system will serve them. Without an adopted tier map, a local jurisdiction may not authorize a major residential subdivision served by OSDS. The four tiers described in law are as follows:

- Tier I areas are currently served by sewerage systems.
- Tier II areas are planned to be served by sewerage systems.
- Tier III areas are not planned to be served by sewerage systems. These are areas where growth on septic systems can occur.
- Tier IV areas are planned for preservation and conservation and prohibit residential major subdivisions.

MDP estimated that between 2012 and 2015, this bill will reduce the number of new homes served by OSDS by approximately 50,000, preventing a nitrogen load to groundwater of

[35] planning.maryland.gov/pages/ourwork/SB236Implementation.aspx

approximately 580,000 pounds per year.

Permit Programs

MDE issues many types of permits for activities that can have a negative impact on groundwater quality. Permits can establish limits for specific chemicals or groups of pollutants or can require BMPs that reduce releases to the environment. All the described permitting programs serve to protect groundwater in some capacity, either by regulating legal discharges to groundwater or by preventing pollutants from reaching groundwater.

Groundwater Discharge

The MDE Wastewater Permits Program[36] issues municipal groundwater discharge permits and industrial groundwater discharge permits. In FY21, MDE issued 24 municipal groundwater discharge permits and 10 industrial groundwater discharge permits.

Currently, there are 32 municipal groundwater facilities permitted for water reuse via spray irrigation. Four of facilities are permitted for rapid infiltration systems. Ten facilities are permitted for drip irrigation, of which five are in operation. One facility is permitted to reuse treated wastewater for fire protection, toilet flushing, lawn irrigation, and replenishing their stormwater management pond under permitted conditions.

In 2016, MDE created an exemption from a groundwater discharge permit for land application of food process wastewater for small, on-farm operations such as wineries, breweries, creameries, etc. Food process wastewater from on-farm operations can be beneficially reused via land application provided the wastewater is registered as a soil conditioner through the Maryland State Chemist and the operator complies with the MDA's Nutrient Management regulations. MDE has issued 15 exemptions, with two being issued in FY21.

Underground Injection Control

In 1984, EPA delegated authority for the Underground Injection Control (UIC) program[37] to Maryland. There are six classes of UIC wells, but Maryland currently has primacy for five classes of wells. Class VI wells are a new class of wells for sequestering carbon dioxide. Currently, Maryland has no plans to proceed with applying for primacy for Class VI UIC wells. There has been no industry interest in Maryland to inject carbon dioxide into UIC wells. If industry interest is expressed, Maryland will reconsider applying for Class VI primacy.

In FY21, 421 UIC inspections were conducted by one MDE inspector. The inspector issued 24 Notices of Corrective Action. In FY21, 23 facilities were returned to compliance.

Inquiries have been made to Maryland's UIC program regarding aquifer storage and recovery (ASR) wells. ASR wells are being considered in several locations in Maryland to store water in an aquifer for later withdrawal and use during periods of peak demand. These types of wells are regulated differently across our country. Since ASR wells were not classified as high risk in the federal Phase I Class V Rule, states have regulatory discretion to require a permit or rule to

[36] mde.maryland.gov/programs/Permits/WaterManagementPermits/Pages/waterpermits.aspx
[37] mde.maryland.gov/programs/Water/wwp/Pages/UIC.aspx

authorize ASR wells. Nationwide UIC regulating authorities use both rule authorization and require discharge permits. In Maryland, we will most likely require a UIC permit for ASR wells.

For industrial groundwater permits, including UIC permits, MDE is planning to send a survey to permittees to gather information to determine whether they will be subject to PFAS monitoring requirements. The survey was initiated in 2021 and is planned to be completed in early 2022.

<u>Hazardous Waste</u>

MDE's Land and Materials Administration (LMA) supervises hazardous waste generators, treatment, storage and disposal facilities through both state regulations and a federally mandated permit program.[38] LMA manages the hazardous waste permit program and implements the requirements of the federal RCRA as well as the requirements of state law. To be regulated as hazardous waste, a substance must meet specific requirements as defined by COMAR 26.13.

LMA also maintains a "cradle-to-grave" tracking system for all hazardous waste generated. Proper management and pollution prevention techniques ensure against contamination of groundwater. Furthermore, LMA oversees the enforcement of hazardous waste requirements. If there is improper management of hazardous waste, the program requires that actions be taken to remedy the situation and to restore, to the extent possible, the quality of the affected groundwater. A strong oversight and enforcement effort is maintained to provide high visibility as a deterrent against future violations.

Permitted hazardous waste treatment, storage, and disposal facilities whose operations will present a greater potential for groundwater contamination if an unforeseen incident occurs are placed under more stringent permit conditions. Permit conditions in this case would include the requirement that a groundwater monitoring system be deployed. LMA is charged with inspecting these systems and initiating enforcement action should the need arise. Permit requirements are tailored to address the potential for contamination presented by each facility using requirements for groundwater protection defined in state regulations. At a minimum, semi-annual reports are submitted by facilities required to monitor groundwater. Failure to meet permit requirements results in an enforcement action designed to both bring the facility into compliance and to remediate any contamination.

Within LMA, the Land Restoration Program is responsible for supporting cleanup at federal facilities under the CERCLA, or the federal “Superfund” program. MDE maintains a U.S. Department of Defense/State of Maryland Memorandum of Agreement (DSMOA), which provides federal funding to support the section’s activities. The focus of the section’s activities at U.S. Department of Defense sites is on groundwater contamination. Evaluation of the extent of contamination, remedial alternatives, and ultimate cleanup criteria is conducted through the CERCLA process. The federal IRP Support Section directly supports EPA Region III in the CERCLA cleanups.

[38] mde.maryland.gov/programs/land/hazardouswaste/pages/index.aspx

Solid Waste

The Solid Waste Program, within MDE's LMA,[39] regulates through permitting, monitoring, and compliance activities, the management and disposal of non- hazardous waste such as municipal solid waste, industrial waste, construction and demolition waste, land-clearing debris and natural wood waste, and also performs enforcement activities for scrap tires, sewage sludge, composting Controlled Hazardous Substances, and Coal Combustion Byproduct (CCB) facilities. In FY20, the program reviewed environmental monitoring data for 23 municipal solid waste landfills, four permitted industrial waste landfills plus four regulated under consent orders, and five construction and demolition waste landfills. Currently, the program evaluates environmental monitoring data for three former or operating sewage sludge storage or treatment facilities and approximately 60 closed landfills.

Resource Management Program

The Resource Management Program[40], within LMA, regulates several activities to ensure the protection of public health and the environment. These include but are not limited to: Regulating the discharges from animal feeding operations (AFO); regulating composting facilities; regulating the utilization of sewage sludge (biosolids); regulating the clean-up, storage, collection, transferring, hauling, recycling, and processing of scrap tires; and regulating the treatment, storage, and disposal of hazardous waste. All of which may represent a serious source of pollution to groundwater and surface water. By regulating nutrient applications, composting operations, scrap tire end-of-life management, processes that can cause a serious source of pollution to groundwater and surface water can be controlled.

Regulations for AFOs became effective Jan. 12, 2009. AFO regulations and the General Discharge (GD) Permit are designed to control nutrients from Maryland's largest agricultural animal operations and are a significant step forward in protecting the Chesapeake Bay, local waterways, and our groundwater.

On May 26, 2014, revised Sewage Sludge Management Regulations went into effect. The regulations incorporated MDA's updated nutrient management requirements, EPA's regulations relating to treatment and land application standards, and streamlined the Sewage Sludge Utilization Permit application review process.

On June 12, 2015, a Notice of Final Action was published adopting new composting facility regulations effective July 1, 2015. The action adopted the regulations as proposed in December 2014, with several minor non-substantive changes. The regulations are designed to promote composting and ensure their safe operation to prevent harm to surface and groundwater.

[39] mde.maryland.gov/programs/LAND/SolidWaste/Pages/index.aspx
[40] mde.maryland.gov/programs/LAND/RMP/Pages/index.aspx

Mining

Mining has the potential to impact groundwater from both quality and quantity perspectives. The mission of MDE's Mining Program[41] is to protect the public and the environment from the potential impacts of active mining; and promote the restoration and enhancement of active and abandoned mine lands and water resources. The program oversees the reclamation of mine sites to ensure that no adverse impacts to public health or the environment occur. The Mining Program is comprised of three divisions: Minerals, Oil & Gas (Non-coal), Maryland Bureau of Mines (Coal), and the Abandoned Mine Lands and Acid Mine Drainage Division. The Maryland Bureau of Mines regulates and oversees coal mining, its associated impacts (e.g., acid mine drainage), and abandoned mine sites. The Minerals, Oil & Gas Division regulates non-coal mining. The Abandoned Mine Lands and Acid Mine Drainage Division reclaims pre-1977 (pre-law) coal mines and restores streams impacted by acid coal mine drainage in Allegany & Garrett counties.

Stormwater Management

The Stormwater Management Act became effective Oct. 1, 2007. MDE's Stormwater Management Program is responsible for implementing this act and its provisions for improving stormwater management in Maryland. Stormwater runoff contributes to surface and groundwater pollution, flooding, stream channel erosion, sedimentation, wildlife habitat deterioration, and lower stream base-flows. The goal of MDE's Stormwater Management Program[42] is to maintain after development, pre-development runoff characteristics. The program achieves this through Environmental Site Design (ESD) requirements, BMPs, and implementation of the MS4 permit program under the federal National Pollutant Discharge Elimination System (NPDES).

MDE issues NPDES Phase I permits to large (populations of greater than 250,000) and medium (populations between 100,000 and 250,000) municipalities. Baltimore City and four counties are covered by large Phase I MS4 permits, while five counties are covered by medium Phase I MS4 permits. MDOT SHA is also covered by a Phase I MS4 permit. Municipalities with less than 100,000 people, as well as state and federally owned facilities, are handled separately by Phase II general MS4 permits. Maryland's MS4 permits include a restoration requirement, requiring municipalities to retrofit a portion of their respective impervious area not already treated with a stormwater BMPs. This requirement, also called the impervious area restoration requirement, can be met through practices such as bioretention, enhanced filters, forest planting and riparian buffering. These practices, in addition to providing benefits to surface water quality, should also benefit groundwater levels. Many of the practices that counties use to meet the restoration requirement can promote the recharge of groundwater. ESD and structural stormwater practices are being implemented according to these permits to address Waste load Allocations associated with the Chesapeake Bay Total Maximum Daily Loads (TMDLs).

Maryland's 11 Phase I MS4 permittees, through 2020 MS4 permit implementation, have established themselves as national leaders in reducing stormwater pollution by collectively investing $685 million in clean water infrastructure and restoring 35,000 impervious acres. This

[41] mde.maryland.gov/programs/LAND/mining/Pages/index.aspx
[42] mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/index.aspx

restoration work continues to advance innovations such as pay-for-performance contracting, public-private partnerships, and new technologies. The permits also include incentives for climate resiliency and green infrastructure projects.

To help support this work, in the fiscal year beginning in July 2019, MDE's Water Quality Finance Administration guaranteed $108.3 million in low interest loans to counties and local governments for stormwater restoration projects, and another $213.2 million in low interest loans are pending for planned projects. The Chesapeake and Atlantic Coastal Bays Trust Fund awarded an additional $36.5 million in grants to stormwater programs for restoration projects. Maryland continues to push for additional federal funding for local stormwater projects, especially for those that increase climate resiliency in underserved communities and for those that help sustain Chesapeake Bay restoration and groundwater protection efforts for decades to come.

Water Well Construction

The On-Site Systems Division of the Wastewater Permits Program regulates the permitting and installation of water wells within Maryland.[43] Responsibility for permitting well construction is delegated by MDE to local county health officers or other county environmental officials. MDE directs this delegated program and provides technical assistance to county personnel as well as the well drilling community. In 2015, COMAR 26.04.04 was fully repealed and amended.

Pesticides and Herbicide Management

The MDA Pesticide Regulation Section is the state's lead agency[44] for implementing the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The EPA, in cooperation with the states, has developed a *State Pesticides of Interest* list. Pesticides of interest (including their degradants) are pesticides that have been identified by the states as having the *potential* to occur in ground or surface water at concentrations approaching or exceeding a human health or ecological reference point. These pesticides are to be periodically evaluated to determine whether a human health or environmental reference point is likely to be approached or exceeded. If an evaluated pesticide is found to pose a risk to water quality, then that pesticide must be actively managed. To date, no evaluated pesticide on the *State Pesticides of Interest* list has exceeded human health or ecological reference points that would require active management.

Since 1983, MDA, in cooperation with the USDA National Agricultural Statistics Service (NASS), has conducted statewide pesticide use surveys. NASS is currently conducting a survey for the 2020 calendar year. Past surveys can be found on MDA's website. Once released, the 2020 report will be available on the Pesticide Information for Consumers website.[45]

MDA, in cooperation with local government and private industry, inspects, stores, and ships clean, empty pesticide containers that have been offered for recycling. Collection centers are maintained in seven counties with the assistance of county government agencies. A total of 24 collection days are held during June through September. In addition, 16 pesticide dealers/custom applicators are participating in inspection and collection of containers at their own facilities. The

[43]mde.maryland.gov/programs/Water/BayRestorationFund/OnsiteDisposalSystems/Pages/WellConstruction.aspx
[44] mda.maryland.gov/plants-pests/Pages/pesticide_regulation.aspx
[45] mda.maryland.gov/plants-pests/Pages/Pesticide-Information-for-Consumers.aspx

program has been well received by different interest groups, including the agricultural community, EPA's Chesapeake Bay Program, and environmental organizations. More than 1 million empty pesticide containers have been collected and recycled since 1993, taking more than 500 tons of plastic out of Maryland's waste stream.

Wastewater Reuse

MDE began reinvigorating its efforts for water re-use[46] in 2017. As part of a strategic restructuring, capacity was directed towards a water reuse initiative. This initiative includes setting goals and evaluating progress, helping raise awareness by providing general information about water reuse, improving business certainty via clear reuse guidelines, offering help with financial and technical resources, incorporating water reuse into long range planning, and building strategic partnerships.

Maryland's primary law addressing water reuse, Environment Article 9-303.1, directs MDE to encourage the reuse of reclaimed wastewater effluent and identifies setbacks. Maryland's primary regulation on water reuse, COMAR 26.08.02.09 (Groundwater Quality Standards), incorporate guidelines on land application by reference. State and local plumbing codes are also part of the governance framework of water reuse.

PUREWater Westminster

The City of Westminster relies on both surface and groundwater sources; however, for the past 15 years, the city has been challenged with increasing growth and not being able to find an adequate and sustainable groundwater source. This challenge has affected its ability to grow and support development within its corporate limits. MDE and the city have been working together to establish the first indirect potable water reuse in Maryland. The city has hired an engineering firm to design a system that would augment their existing source water Cranberry Reservoir with purified effluent from their WWTP. The project is currently testing a pilot system and plans to start construction in 2023.

Anne Arundel County Managed Aquifer Recharge

Anne Arundel County relies on groundwater from confined aquifers to supply water to its residents. Anne Arundel County is working with MDE to explore options for injecting highly treated wastewater into confined aquifers through a Managed Aquifer Recharge (MAR) program. This process would take highly treated wastewater and inject it into three different confined aquifers. This project is currently being evaluated to ensure that all the potential risks to these highly pristine aquifers are evaluated and eliminated.

[46] mde.maryland.gov/programs/Water/waterconservation/Pages/reuse_initiative.aspx

Protection of groundwater wells

In Maryland, there are no state regulations that require individual domestic well owners to maintain their well or test their drinking water, unless the property is a rental property (HB 1069). Many contaminants cannot be seen, smelled, or tasted, but are naturally present or have been anthropogenically introduced into groundwater. Poorly maintained wells can also act as direct pathways for contaminants to enter a drinking water supply. It is recommended that private well owners have their water tested by a certified laboratory every year. Local health departments or University of Maryland Extension educators may be able to advise on contaminants of concern in particular areas. MGS has an informational website[47] on suggested testing. The testing results need to be compared to state drinking water standards as not all levels of contaminants present a health concern. Well owners should also inspect their wells to detect any cracks, holes, or corrosion in the casing. A sanitary well cap should be installed to keep out insects, small mammals, and other surface contamination. Backflow prevention devices are good to have installed, if not already present. Fertilizers and pesticides should not be spread near the well.

Addressing climate change

MDE's Water and Science Administration[48] has adopted priority climate adaptation goals and strategies.[49] Climate change is water change. As related to PWSs, the strategies include identifying drought vulnerable systems, developing, and implementing timely corrective actions for those vulnerable systems, and ensuring that system operators are alert to water quality changes due to climate change so they can respond promptly to treatment adjustment. Establishing a robust water reuse program in Maryland, would be another great tool in dealing with climate change.

Groundwater systems are dependent on recharge. Changes in the amount of precipitation, intensity and distribution of rainfall will impact the sustainability of our water resources. Published scientific investigations are relied upon by WSP to make technical evaluations for Water Appropriation and Use permitting decisions. Water balance studies that have been done in the distant past to measure the amount of infiltration, overland flow and evapotranspiration need to be re-evaluated to account for the change in weather patterns. For instance, the most widely used publication to evaluate the sustainability of unconfined aquifers on the Eastern Shore was published in 1959.[50]

[47].mgs.md.gov/groundwater/well_information.html
[48] mde.maryland.gov/programs/Water/Pages/WSA_Climate_Change.aspx
[49] mde.maryland.gov/programs/Water/Documents/WSA_Climate_Adaptation_Goals.pdf
[50] Geologic Survey Water Supply Paper 1472

Recommendations

Water Withdrawal Measurement
The ability to accurately measure permitted water use provides a tremendous amount of data toward the determination of long-term sustainability of the state water resources. Maryland could benefit from the formation of a workgroup to examine the accuracy of water withdrawal estimation techniques that do not utilize flow meters and to assess the benefits of metering against potential costs.

Establish Water Quality Reporting Requirements at Property Transfer
No state requirements ensure a safe drinking water supply from private wells at the time of property transfer. New Jersey has testing and reporting requirements for individual wells at property transfer. There are various other programs in Oregon, Rhode Island, Minnesota, Iowa, and Maine that have different means and requirements as to how to fund their specific programs. Maryland could benefit from the creation of a workgroup to make recommendations on water quality testing requirements at the time of property transfer.

Sustainable Funding
More detailed monitoring and analysis of the state's groundwater resources is needed to assess the long-term viability of many of the state's aquifers in the face of existing and increasing demands for water and changing rainfall patterns. Maryland could benefit from the establishment of a workgroup to study long term sustainable funding to study and manage groundwater.

Coordination Improvements
MDE and MDH are working to improve data sharing between their two agencies and local health departments. One option being investigated is an integrated database that would organize interagency business processes. This project would streamline workflow between agencies and provide the relevant agencies with real-time access to permit status. The database could house well construction data including results of any raw water quality sampling.

Source Water Protection
Source water assessments were mandated by the 1996 amendments of the SDWA. Assessments have not been updated since their completion. It is recommended to require water utilities of a specified size to review and update their source water assessment plans periodically. Counties and municipalities should review and update their source water protection strategies to be consistent with the water utilities' source water assessment plans.

Groundwater Report
This report attempts to collect and organize key information about Maryland's groundwater resources from a variety of sources. While this information may not change substantially from year to year, it could be useful to have updated on a triennial basis.

Administrative Penalties
Maryland state law Section 5-514 of the Environment Article authorizes MDE to impose civil penalties for violations related to water appropriation rules, regulations, order or permits.

However, few penalties have been imposed as they must be adjudicated in Circuit Court. The penalty process could be revised to include administrative penalties for violations related to water appropriation and use laws, regulations and permits. These are adjudicated at the Office of Administrative Hearings.

CONCLUSION

Our knowledge of groundwater has improved over the years as our policies and programs have evolved. However, there is more work ahead of us that requires financial, technical, and staffing support. The emergence of new natural and manmade contaminants, which were unknown until a couple of years ago, acceleration of climate variability, population growth, and alteration of the natural landscape are all concerns that highlight the urgency for the state to be ready and vigilant. Our water supply sources are finite, and we cannot afford to have any of them compromised. While the programs described in this report have a strong track record of success in protecting our groundwater resources, there is still much work that needs to be done. When it comes to drinking water, our strategy is to be preventive; otherwise, public health could be compromised. To face these challenges and be ready for any potential adverse scenario, we need to continue conducting additional investigations, update our outdated technology, improve data collection and monitoring networks, and implement comprehensive planning. These are the basic ingredients for holistically managing state water resources. Water is often taken for granted, and its value is not realized until a crisis occurs. Maryland has enjoyed a robust water resource management program dating back to 1933; however, it is important and urgent that this continues.