Anne Arundel County Managed Aquifer Recharge Pilot Project

Independent Advisory Panel Findings and Recommendations for Meetings 1 and 2 April 27 and May 26, 2022

Prepared for

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About NWRI

The National Water Research Institute is a 501c3 nonprofit organization and Joint Powers Authority, founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment.

We assemble teams of scientific and technical experts that provide credible independent review of water projects, develop recommendations that support investment in water infrastructure and public health, and enable water resource management decisions grounded in science and best practices.

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NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and Metropolitan Water District of Southern California.

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This report was prepared by an Independent Advisory Panel (Panel), which is administered by National Water Research Institute. Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes. For more information, please contact:

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Introduction

National Water Research Institute (NWRI) is pleased to present the findings and recommendations from Meetings 1 and 2 of the Independent Advisory Panel (Panel) to review Anne Arundel County's (AACO) proposed managed aquifer recharge (MAR) project (Project). NWRI convened and facilitated online meetings on April 27, 2022, and May 26, 2022.

Background

Anne Arundel County asked NWRI to organize an Independent Advisory Panel to review the proposed MAR Project under Agreement No. 10797 and Purchase Order No. 182952-000-OO. AACO contracted with NWRI to administer and facilitate this Panel to help guide the County's planning, sampling, pilot testing, and implementation processes.

The Panel review process for the Project is designed to provide feedback and recommendations on scientific, technical, regulatory, and outreach elements of AACO's proposed MAR Project. Members of the Panel include:

- Thomas Missimer, PhD, Florida Gulf Coast University, Panel Chair
- Diana Aga, PhD, University of Buffalo
- Charles Bott, PhD, Hampton Roads Sanitation District
- Scott Fendorf, PhD, Stanford University
- Mehul Patel, PE, Orange County Water District
- Steve Via, MS, American Water Works Association

A brief biography of each Panel member is on the NWRI website at www.nwri-usa.org.

Because the quality of life in Anne Arundel County is closely connected to groundwater supplies and water quality in the Chesapeake Bay, AACO has adopted a One Water approach to protecting and enhancing water resources within its control. This approach, known as the Our wAAter program, has two primary objectives: 1. Enhancing the resiliency of the region's groundwater supply, and 2. Reducing nutrients discharged to the Chesapeake Bay.

The County has evaluated several alternatives to achieve their objectives and has identified indirect potable reuse (IPR) by managed aquifer recharge as a cost- effective alternative. Tertiary effluent from the Patuxent Water Reclamation Facility will be treated using a multi-barrier advanced water treatment (AWT) process configuration consisting of five main steps including coagulation/flocculation and sedimentation, ozonation, biofiltration, granular activated carbon adsorption, and ultraviolet (UV) disinfection. While each step will contribute to greater overall pathogen and organics removal, these AWT processes will also provide treatment for emerging contaminants and will produce finished water that meets drinking water standards. The finished water from the AWT system will be used for groundwater augmentation by injecting the recycled water back into the groundwater aquifers.

The initial research investigations proposed by the County will consist of two parallel studies in aquifer recharge testing and advanced water treatment. The aquifer recharge testing, to be conducted initially with conditioned potable water, will examine hydrogeological compatibility, injection rates and travel times, and develop and expand a monitoring program. The AWT process testing will be performed using a pilot treatment system to identify treatment capability for constituents of concern, establish critical control points, and confirm finished water characteristics.

Purpose of Meetings

The objectives of the first two panel meetings were to:

- Facilitate an opportunity for stakeholders to introduce themselves to the Panel and share their purpose and goals for participating in this effort.
- Establish AACO's drivers and goals for the Our wAAter program, identify milestones, and present integrated planning concepts.
- Introduce the proposed MAR Pilot Project, including well siting, design, and related performance testing and monitoring.
- Introduce the project background and pilot treatment selection process and validation plan.
- Review and discuss the questions submitted by the Maryland Department of the Environment (MDE) staff.

- Solicit recommendations and comments from the Independent Advisory Panel.

Review Materials

Before Meetings 1 and 2, AACO provided the following core review materials to the Panel for review:

- Anne Arundel County Integrated Management Plan: Draft Executive Summary
- Panel Meeting 1 Presentation 1 Introduction and Background
- Questions from Maryland Department of the Environment (MDE) for the NWRI Independent Scientific Advisory Panel on the AACO Our wAAter Project
- Annotated issues letter from AACO to MDE dated March 27, 2019
- MAR Feasibility Study
- Pilot Recharge Siting, Basis of Design, and Testing Plan
- Underground Injection Control (UIC) Test Well Applications
- MDE Comments on MAR Feasibility dated December 12, 2018
- MAR 90 Percent Design Report dated May 26, 2020
- Panel Meeting 2 Pre-read Document Summary dated May 19, 2022
- Advanced Water Treatment Pilot Evaluation dated December 31, 2020
- Advanced Water Treatment Pilot Test Plan dated March 17, 2022
- Aquifer Travel Time Map Estimates dated May 20, 2022

Organization of the Report

The following section summarizes the NWRI Expert Panel's findings and recommendations followed by an Overview of the Anne Arundel County Managed Aquifer Recharge program and general Panel recommendations.

Following the Overview, the Anne Arundel County Project Team gives its technical response to questions that were provided by the Maryland Department of the Environment. The Panel adds additional comments and recommendations, if any, after the AACO Project Team responses.

Appendices provide supplemental information, including Appendix A, References; Appendix B, agendas for meetings 1 and 2; Appendix C, a list of meeting attendees; and Appendix D, supplemental questions from Dr. C. Tien on behalf of the MDE with responses from the Project Team and Panel.

Summary of Findings and Recommendations

The findings and recommendations presented here are derived from a review of the materials provided to the Panel, the presentations by the AACO MAR Project Team, and interactive Panel discussions during the meeting. This brief summary of findings and recommendations is followed by the questions that the Panel considered and its analysis and more detailed recommendations.

Overview

- AACO should take a stepwise, cautious, science-based approach to project development and should make incremental go/no-go decisions as new data are collected and analyzed.
- The Maryland Department of the Environment (MDE) should review the project within the context of sustaining water levels and water quality in the aquifer to support all relevant uses, particularly drinking water.
- The AACO MAR Project should be evaluated within the context of US Geological Survey (USGS) and Maryland Geological Survey groundwater models. This analysis will require a concerted effort by all stakeholders, including the County, the MDE, the Maryland Geological Survey, and the USGS.
- If the initial injection well tests are successful, the Panel recommends that Anne Arundel County, the State of Maryland, and the USGS should expand current groundwater level and aquifer water quality monitoring programs to expand the database that will improve groundwater resource management for future model calibration.

MDE Questions

- For the entire project, the Panel recommends that AACO use aquifer evaluation methods that have been used successfully at other large-scale MAR and aquifer storage and recovery (ASR) projects in the United States.
- After the initial injection well testing is successfully completed, the Panel strongly recommends conducting a detailed inventory of all existing wells within the full area of influence for both the expected capacity of the MAR system and for potential expansion of the system.
- The Panel recommends that a detailed plan for monitoring the advanced treated water to be injected occurs frequently to verify that it meets drinking water standards.
- The Panel recommends that AACO work with MDE to develop a list of Constituents of Emerging Concern (CECs) that require monitoring. In addition, the Panel recommends that CEC data be reviewed regularly to determine if constituents should be added to or removed from the monitoring list.
- The Panel does not recommend rotating injection in MAR wells at 30-day intervals.
- The Panel recommends using wellhead pressure monitoring devices to assess potential for well screen and gravel pack clogging.
- The Panel recommends that existing training for wastewater treatment plant staff should be reviewed. Wastewater treatment plant staff need to understand their role in the advanced treatment system performance and to identify training opportunities.

Aquifer Chemistry

- For recharge pilot testing, AACO should not use hydrogen peroxide to boost the dissolved oxygen (DO) in the potable water before injection.
- Please specify that the surrogate per- and polyfluorinated substances (PFAS) will include short chain PFAS, since these are the ones that typically exhibit decreased capacity for removal by granular activated carbon (GAC) adsorption.

Groundwater Flow

- The Panel recommends the use of nested monitoring wells that are not screened through the full aquifer thickness as in the injection wells.
- During initial testing of the advanced treated water, the Panel recommends detailed and timely sampling and analysis for the compounds of concern.
- The Panel strongly recommends that the initial phase of the project include engaging stakeholders to begin a dialog about issues of mutual concern.

AACO Project Team Questions

- The Panel recommends that the project team begin chemical characterization and modeling on any existing potable supply wells that may be affected in the future.
- The Panel recommends that the monitoring well design should be reconsidered and the monitoring plan should be reviewed based on the modified well design. The monitoring wells should have a nested design so that discrete units of the aquifer can be monitored to increase detection of CECs at the depth where they occur. This recommendation applies to both initial injection well testing and future evaluations.
- The Panel believes that it would be useful to speciate arsenic during the geochemical assessment.
- The Panel suggests that after successful completion of the initial injection well testing, AACO should consider more exploratory drilling to better characterize the aquifer system at key locations. This aquifer characterization should be a collaborative effort with the USGS and the Maryland Geological Survey.
- The Panel suggests that after successful completion of the initial injection well testing. AACO should study some of the drilling cores to assess metals leaching based on an array of experimentally determined pH, Eh, and oxidation-reduction potential.

Overview

The Anne Arundel County (AACO) managed aquifer recharge (MAR) project (Project) is conceived to help address several regionally important issues. Specifically, the MAR Project is designed to augment important regional aquifers and reduce nutrients being discharged into Chesapeake Bay from wastewater treatment plants. The MAR project will also reduce the impact of significant groundwater withdrawal by injecting advanced treated water into two aquifers in the Lower Potomac Aquifer System.

The Upper Patapsco Aquifer (UPAT), Lower Patapsco Aquifer, and the Patuxent Aquifer are the combined primary source of drinking water for Anne Arundel County. Based on aquifer hydraulics and water level reports written by the US Geological Survey (USGS) and the Maryland Geological Survey, the aquifers are subject to saltwater intrusion and land subsidence. These adverse effects to the aquifer system are caused by declines in water levels based on pumping rates. As the population grows in the County and surrounding region, the increased volume of pumping from the aquifer system will exacerbate declining water levels, pumping-induced saltwater intrusion, and land subsidence caused by loss of storage from the confining units. The land subsidence issue, combined with climate-change-induced sea level rise, has the potential to affect coastal regions of the County and the neighboring region.

The local and regional groundwater resource issues and the nutrient balance of Chesapeake Bay need to be addressed collaboratively by Anne Arundel County and the State of Maryland regulators. The AACO MAR Project has the potential to help lessen the impacts on regional groundwater resources and water quality. Fully understanding the Project's potential consists of verifying the science-based Project design by collecting field data and then modeling groundwater flow and solute transport. Collaboration will be important to integrating the Project into regional USGS and Maryland Geological Survey groundwater models.

General Findings and Recommendations

Based on the background information provided and the open discussion at the Panel meeting, the Panel makes the following suggestions and statements about the overall goals of the project.

- AACO should take a stepwise, cautious, science-based approach to project development and make incremental go/no-go decisions as new data are collected and analyzed. This approach also allows the State to review the project incrementally and minimizes long-term financial risk to the County. Examples of no-go decisions would be the discovery of a fatal flaw, such as the inability of the aquifer system to receive and transmit the injected water, or the inability to treat wastewater to an acceptable standard.
- The MDE needs to review the project within the context of sustaining water quantity and quality in the aquifer to support all relevant uses, particularly drinking water. This includes considering potential long-term saltwater intrusion and land subsidence coupled with climate-change-induced sea level rise. In addition, the MDE must be satisfied that the water treatment process will meet regulatory limits now and in the future. The project design does not include treatment of contaminants in the aquifer, so treatment performance criteria must be clearly defined and then monitored for compliance before injection into the aquifer.
- The AACO MAR Project should be evaluated within the context of USGS and Maryland Geological Survey groundwater models. The existing regional groundwater flow model should be expanded to include an analysis of confining bed storage loss, land subsidence, and saltwater intrusion. Increased water levels resulting from the AACO MAR Project should be considered in the model design. This analysis will require a concerted effort by all stakeholders, including the County, the MDE, the Maryland Geological Survey, and the USGS.
- If the initial injection well tests are successful, the Panel recommends that Anne Arundel County, the State of Maryland, and the USGS should expand current groundwater level and aquifer water quality monitoring programs to increase the database that will improve groundwater resource management for future model calibration.

Questions from Maryland Department of the Environment

MDE Regulatory Question 1

Cite similar projects in the United States that are comparable to this proposed project:

- Projects that inject wastewater into a drinking water aquifer without any planned potable withdrawal, like an ASR project.
- Projects that inject non-RO-treated wastewater into a drinking water (COMAR 26.08.02.09 Type I) aquifer.
- Projects that inject wastewater into a drinking water aquifer in a state without potable reuse regulations.
- What are the major public concerns that have been raised during the proposal of previous projects?

AACO Project Team Response

Attachment "Potable Reuse Examples in the United States" (developed by HDR) provides a comprehensive list of indirect and direct potable reuse projects in the United States. This list is not meant to be all inclusive as additional projects are under development; however, it provides a substantial list of the primary operating potable reuse facilities.

While indirect potable reuse has been employed in some form since the 1960s, we acknowledge that a rigorous applied research approach is required to confirm applicability of the proposed treatment and injection methods for application in Anne Arundel County.

Specific answers to the four items in Question 1 are provided below:

- Item 1: Aquifer storage and recovery typically refers to a system that is intentionally used for future removal of the injected water and employs buffer zones to prevent mixing of injected water with native water. There are many projects that inject treated reclaimed water into non-drinking water aquifers, particularly in Florida, Texas, Colorado, and Arizona.

Please note that ASR is not proposed by the County. Rather, the County is evaluating intentional groundwater augmentation of the aquifer system to enhance and increase water supply in the region. Injectate will be conditioned to match aquifer characteristics and thus mix with native groundwater.

- Item 2: Aquifer classification varies by state and primacy agency. Each situation is unique relative to the location of injection into the system and water chemistry at that location.
  - The following projects utilize oxidation and biofiltration treatment, followed by groundwater injection where residents use groundwater as their primary source of domestic water or injectate is pumped after aquifer storage to nearby municipalities: Reno, Nevada (Golden Valley Aquifer Recharge Program) and Aurora, Colorado (Prairie Waters Program).
  - Several other projects are currently evaluating similar scenarios, including Altamonte Springs, Florida (pureALTA Program) and Olympia, Washington (LOTT Clean Water Alliance).
- Item 3: Of the examples provided in Item 2, all the states have implemented or developed potable reuse guidance along with the reuse project mentioned, with the exception of Colorado. Colorado is exploring direct potable reuse (DPR) and evaluates projects on a case-by-case basis. California, Florida, Georgia, and Texas have led development of water criteria for potable reuse. Most other states have some level of reclaimed water/reuse regulation in place. The only states that do not have any regulations in place are Alaska, Maine, New Hampshire, Connecticut, Kentucky, and Louisiana. It would be anticipated that the requirements for a full-scale system would be identified by the State and vetted through third-party arrangements (such as the Independent Scientific Advisory Panel or research laboratories). These requirements would be informed through the applied research testing program being proposed by the County.
- Item 4: Please see Chapter 13 in the Potable Reuse Compendium (EPA, 2017) for Current State of Public Acceptance, Chapter 5 of the Framework for Regulating Direct Potable Reuse

in California (2019 – Note: the proposed project is not direct potable reuse), and "Public Perceptions of Potable Water Reuse, Regional Growth, and Water Resources" (Ormerod, 2019 – Note: Written for Nevada but applicable to other regions).

Primary concerns and their respective mitigation approaches include the following:

- Pathogen and other contaminant occurrence. The mitigation strategies for this risk include redundancy in treatment (multiple barriers) and multiple monitoring locations and risk management responses before water is injected into the aquifer or environmental system. These are referred to as critical control points (CCPs) in the industry, and water that doesn't not meet CCP criteria is diverted from final discharge.
- Industrial and upstream wastewater variability. Mitigation strategies include identifying source water characteristics, implementing source control, CCPs to divert flow, and pretreatment programs to avoid contamination. The addition of an environmental or engineered buffer can help provide a safety factor.
- Meeting water quality requirements. Mitigation strategies include Federal and state guidelines and establishing limits and critical control points.
- Negative public opinion/public perception of potable reuse. Mitigation strategies include: extensive public outreach; public education and awareness; incorporating the ratepayers and stakeholders in the potable reuse decision making process. Communicating and demonstrating improved water quality with pilot or demonstration-scale facilities can help in gaining public trust and obtain potable reuse regulatory permits.

Please note that many of the risks identified above are also intended to be evaluated as part of the applied research testing program proposed by the County.

Panel Response

The Hampton Roads Sanitation District (HRSD) Sustainable Water Initiative for Tomorrow (SWIFT) project in Virginia is a comparable project that has collected an abundance of scientific data. The Underground Injection Control (UIC) Permit application for the HRSD SWIFT injection wells was posted on June 7, 2022, at: https://www.epa.gov/system/files/documents/2022-06/HRSD_Draft_Permit.pdf

MDE Regulatory Question 2

What approach can be deployed to minimize the potential for third-party impacts?

Have similar projects done ongoing, regular monitoring in nearby private wells?

Have agreements been required to ensure mitigation of unanticipated, unintended water quality impacts to aquifer users?

AACO Project Team Response

It is anticipated that a series of monitoring wells with rigorous testing would be employed to monitor water quality in the aquifer. Should the program move forward to full-scale implementation, the County could also consider connecting nearby groundwater users to the public water system if warranted. The applied research testing program would help identify the required monitoring systems and determine evaluation parameters that would inform such a decision.

Panel Response

The Panel recommends aquifer evaluation methods that have been used successfully at other large-scale MAR and ASR projects in the United States.

Everglades ASR System

In the largest capacity ASR system (the Everglades ASR system in southern Florida proposed 127 wells at a capacity of 5 million gallons per day [MGD] each), many long-term aquifer studies assessed the geology, aquifer hydraulic properties, composition of the rock matrix, and regional water levels. Groundwater flow and solute transport modeling studies were used to make decisions on where to locate ASR wells.

Potentially impacted well locations were identified using a geographic information system (GIS) and water quality samples were collected. The system design was based on minimizing impacts on existing wells. A comprehensive operation monitoring network was designed and monitoring started on numerous wells before injection began.

A science advisory panel reviews the ASR Science Plan annually and makes timely data assessments and recommendations. The NWRI Panel for the AACO MAR project recommends that AACO take a similar approach.

Orange County Water District

Orange County Water District (OCWD) in Fountain Valley, California, has maintained a comprehensive groundwater monitoring program throughout the Orange County Groundwater Basin for decades, testing ambient groundwater for various organic, inorganic, and microbiological constituents at OCWD monitoring wells and potable drinking water wells. Since 2008, the OCWD Groundwater Replenishment System (GWRS) Advanced Water Purification Facility (AWPF) has provided advanced treatment consisting of microfiltration, RO, and advanced oxidation using UV light with hydrogen peroxide.

OCWD has two types of direct injection well systems that are applicable to the proposed AACO MAR project. First, the Mid-Basin Injection Project (MBI) directly replenishes a heavily pumped region of the principal aquifer managed by OCWD. The second is an injection well system known as the Talbert Barrier, which prevents seawater intrusion along the coastal portion of the Orange County Groundwater Basin. The Talbert Barrier has operated since the 1970s and began using 100 percent recycled water from the GWRS AWPF in 2010.

The MBI Project most closely resembles the proposed AACO Our wAAter MAR program.

The MBI Project was implemented in two parts: A demonstration (DMBI) Project and the MBI Centennial Park Project. The DMBI Project was intended to provide operational and groundwater quality data to support the engineering design and permitting of a multi-well injection project in the central portion of the Basin. The primary objective of the larger MBI Centennial Park Project is to replenish a heavily pumped region of the principal aquifer with recycled water from the GWRS AWPF. The MBI Centennial Park Project also increases the recharge capacity of the Basin while preserving recharge capacity in the OCWD Forebay Spreading Grounds, which accept Santa Ana River water and imported water flows. Together, the DMBI Project (injection well MBI-

1) and MBI Centennial Park Project (injection wells MBI-2, MBI-3, MBI-4, and MBI-5) comprise the MBI Project.

In the MBI Project area, OCWD began groundwater monitoring activities in 2012 to collect background data before injecting GWRS highly treated recycled water in DMBI Project well MBI-1, which began on April 15, 2015.

Nested monitoring wells SAR-10 and SAR-11 were constructed in late 2011 and 2012 for the DMBI Project and are located approximately 80 and 650 feet, respectively, downgradient from injection well MBI-1. The DMBI Project site is located approximately three miles north of the Talbert Barrier, along the GWRS Pipeline at the Santa Ana River and Edinger Avenue in the city of Santa Ana.

Nested monitoring wells SAR-12 and SAR-13 were constructed during late 2017 approximately one-half mile southeast and downgradient of SAR-10 and SAR-11. Two wells were strategically located downgradient of MBI-1 and the four new MBI wells in Centennial Park, along the flow path toward the nearest drinking water wells operated by the Irvine Ranch Water District, IRWD-12 and IRWD-17. The SAR-12 and SAR-13 wells serve as the two required downgradient monitoring wells (California Code of Regulations, 2018; Regional Water Quality Control Board [RWQCB], 2019) for the five-injection-well MBI project.

The project went online on March 18, 2020. Along with continued injection of GWRS water at MBI-1, it marked the start of a full-scale intrinsic tracer test to comply with requirements (RWQCB 2019) to track the injected GWRS water signal as it migrated to SAR-12 and SAR-13 and farther downgradient to drinking water production wells IRWD-12 and IRWD-17. For the intrinsic tracer test, all five MBI wells were put online on the same day and operated at relatively high and stable injection rates for the remainder of 2020.

The four MBI Project monitoring wells were tested for: 1. An extensive list of inorganic, organic, and radiological parameters, 2. The majority of the US Environmental Protection Agency (EPA) Priority Pollutants, and 3. The compounds 1,4-dioxane and NDMA. During 2020, groundwater quality at SAR-10, SAR-11, SAR-12, and SAR-13 complied with all Federal and State Primary Drinking Water Standards. The water used to feed the MBI wells from the GWRS AWPF is also subject to extensive water quality testing as required by the California Title 22 CCR and specifically the 2014 Groundwater Replenishment Reuse Projects requirements (see Article 5.2 IPR: Groundwater Replenishment - Subsurface Application) from the California State Water Resources Control Board as administered through the California Division of Drinking Water.

HRSD SWIFT Managed Aquifer Recharge Project

For the HRSD SWIFT Research Center, there is a monitoring well with a FLUTe sampling system screened over the same locations as the recharge well, 50 feet away. The purpose of this well is to evaluate the potential for soil aquifer treatment with only a few days travel time. There is also a nest of three monitoring wells located about 400 feet from the recharge well in the upper, middle, and lower Potomac aquifers. The first full-scale SWIFT facility will be configured with 10 recharge wells and 2 nests of monitoring wells. There are no private or public wells near enough to these locations that would warrant monitoring.

The integrity of existing drinking water wells, or wells for other uses, must be protected. Under federal UIC regulations, existing water users in the aquifer are protected. It is our understanding that the operators of a managed aquifer recharge facility are fully responsible for any adverse impacts on existing wells, which includes water levels and water quality. The County should reach out to well owners within the projected area of influence and consider signing a contractual agreement ensuring the quality of water with full agreements for replacement of the water supply if it should become unusable.

The Panel strongly recommends conducting a detailed inventory of all existing wells within the full area of influence for both the expected capacity of the MAR system and for the potential expansion of the system. The construction details of these wells need to be verified and recorded. These wells should be located using GIS and should be sampled to obtain background water quality for all chemical parameters of concern. These wells should be added to the monitoring system for periodic water quality sampling.

The Panel recommends that a detailed plan for monitoring the advanced treated water to be injected occurs frequently to verify that it meets drinking water standards. In addition, AACO should work with MDE to develop a list of CECs that require monitoring. OCWD has a list of

CECs and a groundwater monitoring plan that was developed through the NWRI Independent Advisory Panel for the OCWD GWRS Program.

In addition, the Panel recommends that CEC data be reviewed regularly to determine if constituents should be added to or removed from the monitoring list if they are not detected over time. The Project Team should negotiate the duration of non-occurrence for removal from the list with MDE.

The Panel is not in favor of rotating injection in MAR wells at 30-day increments. Rotating injection could confound monitoring for metals liberation and transport since such releases are likely a temporary phenomenon.

The Panel recommends using wellhead pressure monitoring devices to assess potential for well screen and gravel pack clogging. Commonly, dissolved air impaction requires periodic backflushing (typically 30 minutes to 1 hour each, 12 hours to 7 days average frequency depending on the chemical properties of the injected water). While well clogging is an operational issue important to the success of the project, it is not a regulatory or public health issue and should not be treated as one.

MDE Regulatory Question 3

What proficiencies are required for operators?

What training should be required?

AACO Project Team Response

The Safe Drinking Water Act (SDWA) contains requirements for drinking water plant training and operator certification. These training programs can cover several of the advanced water treatment systems used in potable reuse.

Chapter 10 in the Potable Reuse Compendium (EPA, 2017) outlines some of the relevant requirements for potable reuse implementation and the existing operator training and certification framework that exists within the Clean Water Act (CWA) and the SDWA, and how these existing concepts may apply to advanced water treatment (AWT) facilities. The chapter also covers key operations issues, such as hazard analysis and the establishment and monitoring of critical control points, start-up and commissioning, operation and maintenance (O&M), optimization of plant operations, and other monitoring considerations.

Additionally, the EPA has developed an online resource (2022) to summarize national and state reuse operators guidance and training resources, in fulfillment of Action 9.2 in the EPA Water Reuse Action Plan: https://www.epa.gov/waterreuse/water-reuseadvanced-water-treatment-training-resources

Some states, such as Texas and California, have developed reuse operators guidance that can be used by other states. Additionally, the American Water Works Association is considering development of a potable reuse operations guide and has begun to compile relevant documentation (AWWA G485-20).

Please reference the "Potable Reuse Operator Training and Certification Framework" (California Urban Water Agencies, 2016), the "Development of an Operation and Maintenance Plan and Training and Certification for Direct Potable Reuse (DPR) Systems" (The Water Research Foundation, 2016), and the EPA table linked above for more resources.

Panel Response

The Panel supports the Project Team's approach to training requirements for operators at the AWT plant, which is based on the SDWA requirements for drinking water plant operator certification.

The non-membrane-based process being proposed by AACO is not vastly different from technologies used in conventional water treatment plants. Finding qualified operators should not be a major issue for AACO.

For example, California requires operators to have a state water or wastewater operator certification license. In addition, the California Division of Drinking Water is starting to regulate new IPR facilities by requiring that the chief plant operator and one person per operating shift obtain the new Advanced Water Treatment Operator (AWTO) certification. The AWTO can only be obtained by a licensed operator with a minimum Grade 3 license in water or wastewater treatment. California water and wastewater treatment operator licensing has five grades and operators with a Grade 3 license or above are eligible to obtain AWTO certification.

In addition, the Panel recommends reviewing the existing training for wastewater treatment plant (WWTP) staff to make sure it addresses how operation of the WWTP affects AWT plant performance and to identify training opportunities for WWTP staff. Successful performance of the AWT plant will depend on close cooperation and coordination between AWT plant and WWTP operations staff.

MDE Regulatory Question 4

Where regulations have been developed for IPR, what requirements are put in place to protect groundwater as a potable resource?

- Primary and secondary drinking water standards?
- Specific treatment technologies?
- Proper conditioning of water for pH and alkalinity?
- Nearby monitoring wells?

AACO Project Team Response

Although there are currently no federal regulations for potable water reuse, there are several federal guidance documents that address certain aspects of potable reuse systems. Federal guidance documents that have been developed include:

- EPA Guidelines for Water Reuse (2012)
- EPA Potable Reuse Compendium (2017)
- EPA National Water Reuse Action Plan (2019) (https://www.epa.gov/waterreuse/water-reuse-action-plan)

The 2012 guidelines and 2017 compendium both provide resources on potable reuse treatment technologies and goals for treatment. None of these documents provide regulations, however, the 2019 Action Plan provides the initial stages of federal support for research and development for utilities for potable reuse. Additionally, there are some states that have regulations, policies, and guidelines in place. States including California, Florida, Georgia, and Texas have implemented certain state regulations for water criteria for potable reuse.

When evaluating criteria for potable reuse development, utilities have a baseline goal of producing water that meets primary and secondary drinking water standards. This includes meeting all applicable SDWA, CWA, and state-specific requirements. See Table 3-1 in the Potable Reuse Alternatives Evaluation TM Excerpt. Additionally, please see Chapter 3 for regulation and Chapter 7 for treatment technologies in the EPA Potable Reuse Compendium (EPA, 2017) and Chapter 4 in the Guidelines for Water Reuse (EPA, 2012) for more resources.

Treatment technology implementation varies by state and discharge location requirements. Generally, most potable reuse systems employ an oxidation step (contaminant destruction, pathogen removal), a filtration step (pathogen reduction), and sometimes a biological step (contaminant destruction) with multiple barriers in place to ensure several levels of treatment. Two treatment trains are commonly employed: the ozone-biofiltration treatment system and the reverse osmosis treatment system.

Although not specific to potable reuse injection, EPA guidance provided to the Florida Department of Environmental Quality (formerly Florida Department of Environmental Protection) allows for arsenic mobilization as a result of public water system recharge. In particular, arsenic concentrations above the primary drinking water standard are permitted in drinking water aquifers as long as water violating the arsenic standard is not accessible by the public.

As noted, finished water conditioning is important for groundwater injection. This conditioning may be contradictory to secondary drinking water standards (e.g., total dissolved solids) but is imperative to prevent metals mobilization in the aquifer. This approach will be evaluated in the applied research testing program recommended by the County.

Lastly, demonstration of compliance differs with jurisdiction. Florida and Arizona permit compliance with some water quality standards at a control boundary, requiring monitoring well installation and sampling, while other parameters must be met at the wellhead. California permits lower pathogen removal in the treatment process with field demonstration of minimum travel time to the compliance point.

Panel Response

The County and State are already familiar with the national programs for protecting potable groundwater resources pertinent to this project, the SDWA and the UIC Program. Federal UIC program guidance is available at https://www.epa.gov/uic/uic-program-guidance. The UIC guidance is extensive, but much of it is not directly relevant to this project. There are recurring themes in the guidance that warrant consideration:

- Appropriate well design, placement, and operation to both assure reliable performance and to protect the aquifer.
- Adequate financial capacity to assure regulatory responsibilities are met.
- Identification of potentially impacted parties.
- Adequate community outreach.

Various states regulate IPR depending on the type of project, for example, soil-aquifer treatment for infiltration basins, aquifer storage, and recovery of stormwater or wastewater. Under UIC regulation in Florida, managed aquifer recharge projects using injection wells require that the injected water must meet primary drinking water quality standards at the wellhead. Project owners may apply for an exemption for secondary standards, but exemptions are not easy to obtain. In some states, an underground zone of mixing is allowed with points of compliance, such as monitoring wells. Low concentrations of compounds that do not have drinking water standards are not regulated.

California Title 22 from the California Code of Regulations Division 4, Chapter 3 has detailed information as part of the amended 2014 Article 5.2 titled Indirect Potable Reuse: Groundwater Replenishment - Subsurface Application.

MDE Regulatory Question 5

For the HRSD SWIFT project:

- Please describe the aquifer chemistry with respect to primary and secondary drinking water standards

- What is the required water chemistry of the injectate (primary and secondary standards, pH, alkalinity, TOC, PFAS, etc.)?
- Please list nearby water withdrawals, both distance, quantity and purpose
- Please describe the extent of aquifer depletion, both the spatial extent and the severity
- What management outcomes are being pursued and how will these be measured?
- Describe monitoring required under the full-scale injection program
- How does this receiving aquifer in this project differ from the aquifer used by the HRSD SWIFT project?

AACO Project Team Response

The SWIFT injectate met all the primary and secondary drinking water standards except for TDS since TDS in the aquifer is already high. The TDS levels in the aquifer ranged from 1,500 mg/L in the upper aquifer zone to 4,500 mg/L in the lower aquifer zone. The initial test well analysis identified a target recharge pH of 7.8 and a conditioning program prior to recharge consisting of an aluminum chloride solution to stabilize the clays around the well. Other finished water requirements are summarized in Tables 1, 2, and 3 of HRSD SWIFT's quarterly water quality report (October - December 2021).

The aquifers at HRSD and the aquifers in Maryland are both part of the Atlantic Coastal Plain Aquifer system. The major difference is in the salinity of the receiving zones. As noted above, the TDS levels where HRSD is injecting range from 1,500 to 4,500 mg/L, whereas the aquifers in Anne Arundel County specifically are expected to have TDS concentrations less than 50 mg/L.

Panel Response

More information about the HRSD injection wells and the aquifers are contained in the UIC Permit on the EPA website at:

https://www.epa.gov/system/files/documents/2022-06/HRSD_Draft_Permit.pdf

MDE Aquifer Chemistry Question 1

The injectate will need to be conditioned to match the groundwater. What concentrations of the following constituents need to be maintained?

- Dissolved oxygen
- Total dissolved solids
- pH
- Alkalinity
- Chlorine/chlorine residual

AACO Project Team Response

In order to test the aquifer response to recharge of future AWT injectate, adjusted to improve geochemical compatibility, bench-scale evaluations were completed using Patuxent Water Reclamation Facility laboratory tap water. The water samples were conditioned to approximate expected values of key injectate parameters prior to recharge. The specific objectives of the water quality conditioning bench-scale testing were to conduct bench-scale testing for water quality conditioning of potable water to represent expected pH, total dissolved solids (TDS), dissolved oxygen (DO) and alkalinity of potential future injectate. See Table 6 from the Bench Scale Water Conditioning Technical Memorandum Excerpt (HDR, 2019) for the target water quality parameter values.

Given the anticipated high DO in the injectate (8-12 mg/L) alkalinity will be maintained between 80-120 mg/L (as $CaCO_3$) and pH will be maintained between 8-8.5 to control possible arsenic mobilization. The ionic strength of the injectate is anticipated to closely approximate that of the receiving zones so no clay stabilization is proposed prior to recharge testing. Residual chlorine levels in the recharge water will remain close to that of potable water in the AACO distribution system.

The effectiveness of the proposed water quality adjustments in controlling metals mobilization will be verified by conducting an initial injection cycle of 1.5 million gallons (MG) in each aquifer unit and analyzing for arsenic, cadmium, and other metals in the recovered water. Samples will be collected at 5, 25, 75, 150, and 300 percent of the total injection volume is produced. The relatively large purge volume is intended to remove water with elevated metals concentrations before laboratory analyses can verify compliance with SDWA standards.

Panel Response

Establishing ideal geochemistry goals for the AWT treated water is important. This includes setting goals for DO, TDS, pH, alkalinity, and chlorine residual. Optimizing the individual treatment process steps will be key.

The control of DO is based on local aquifer conditions. In some projects, DO is fully removed to reduce the potential for arsenic liberation from pyrite, for example, in Florida. In other cases, high levels of DO are allowed to remain in the injectate.

The Panel notes that the AACO MAR storage aquifers are anoxic. The Panel recommends measuring DO after successful completion of the initial injection well tests. In the second phase, DO should be measured during the first injection tests using advanced treated water. Perhaps the DO values could be varied during the testing phase to assess metals concentrations at a nearby monitoring well. With the injection of high levels of DO, it is important to ensure that the advanced treated water is appropriately amended to have a sufficiently high pH and alkalinity to allow the oxidation and precipitation of hydrous ferric oxide, to create stable passivating surfaces that can sorb and immobilize arsenic.

It will be hard to remove DO from the advanced treated water that will be injected and it will be difficult to ensure that DO is always near zero. A more common approach is to acknowledge that DO is high, keep it positive (greater than zero) and stable, and match the needed pH and alkalinity to ensure hydrous ferric oxide production and stability in the aquifer. The Panel recommends adjusting pH and alkalinity during the demonstration phase and during the initial injection well tests with advanced treated water. It may be beneficial to start injection with finished water with higher pH and alkalinity for a short time while the aquifer oxidation-reduction potential is increasing around the well. After this period, the finished water pH and alkalinity could be slowly decreased to a steady-state target for long-term MAR. The actual values should be based on geochemical modeling and monitoring. It is important to avoid pH values that are so high that calcium carbonate precipitation occurs, leading to potential well clogging.

For the recharge pilot testing using the Patuxent Water Reclamation Facility laboratory tap water, the Panel recommends that AACO should not use hydrogen peroxide to boost the DO in the tap water before injection. Pure oxygen injection should be considered here.

The Panel understands that the TDS concentration in the two aquifers is considerably lower than the advanced treated water. We do not believe that this is an issue as long as the mixed water in the aquifer maintains a concentration of less than 500 mg/L.

The Panel understands that many MAR systems purposely add chlorine to the injectate to lessen the potential for biofilm formation in the well screens and gravel packs in the MAR wells. State regulatory bodies have assessed the regulated concentration byproducts at the wellhead and not in the aquifer. Most disinfection byproducts are degraded in the aquifer, so chlorine addition has been approved.

MDE Aquifer Chemistry Question 2

How do we handle the risk of currently-unregulated contaminants being injected into the aquifer in the absence of reverse osmosis?

- Total organic carbon limits?
- Conduct bioassays?

AACO Project Team Response

The proposed AWT train consists of a multi-barrier approach for contaminant removal: Coagulation/Flocculation/Sedimentation→Ozone→Biofiltration→GAC Adsorption→UV Disinfection. This treatment system was chosen due to its robust treatment capabilities with minimal waste generation (and subsequent treatment requirements).

These treatment processes have the ability to remove different contaminants as estimated in Table 3-2 of the HDR report titled *Advanced Water Treatment Pilot Technical Memorandum*.

Different risk mitigation strategies will be implemented such as source control, critical control point monitoring, surrogate monitoring, and optimizing the AWT treatment train.

During the pilot operation, CCPs will be monitored and in the event the CCP exceeds the threshold limit, corrective actions such as diverting the flow will be implemented for full-scale AWT. During pilot operation hundreds of different contaminants including emerging contaminants, microbial contaminants, primary and secondary drinking water standards will be monitored throughout the AWT train. Additionally, the County is investigating water quality surrogates that could be useful for tracking and treatment emerging contaminants. A few examples of surrogates under consideration include: UV254 (aromatic hydrocarbons), sucralose (wastewater marker), and total oxidizable precursor (PFAS indicator).

Panel Response

The Panel agrees that an AWT system with a multi-barrier treatment train will mitigate the negative effects of unregulated contaminants on aquifer water quality. Water quality testing during the advanced treatment pilot operation will further inform AACO on the potential for CEC breakthrough. A surrogate approach is a very common method to address this issue as proposed in the AWT Pilot Test Plan and AWT Pilot technical memos.

Please specify that the surrogate PFAS will include short chain PFAS, since these are the ones that typically exhibit decreased capacity for removal by GAC adsorption.

MDE Aquifer Chemistry Question 3

What elements are possible to be mobilized as a result of DO-induced reactions in the aquifer?

- Can aquifer heterogeneity lead to mobilization of different elements along a flow path?
- Will certain ions in the subsurface geology be exchanged with ions from the injectate?

AACO Project Team Response

Given the anticipated high DO in the injectate (8-12 mg/L) arsenic could be mobilized through oxidation of pyrite or siderite. Pyrite and siderite are known to be associated with the Arundel Clay which separates the lower Patapsco and Patuxent aquifers.

Clay fragmentation is related to ion exchange between the clay and injected water. This can occur when a fresh water is injected into a brackish or saline aquifers. Larger bivalent ions can replace smaller sodium or potassium ions in the clay minerals causing the structure to disaggregate. The more mobile clay particles can collect in pore spaces, causing plugging.

Besides dissolution of metals, we are not aware of any other significant ion exchange problems. The applied research testing program will evaluate the potential for arsenic mobilization and clay fragmentation and provide recommendations for mitigation, if needed.

Panel Response

A number of elements have the potential to be mobilized when advanced treated water is injected into an aquifer. Other aquifer recharge projects in the region have some experience with such mobilization. The elements of concern, in order of importance, are arsenic, iron, manganese, uranium, molybdenum, and perhaps chromium.

The Panel believes that the issue of aquifer heterogeneity is not a controlling factor in the mobilization of various metals. The composition of the aquifer matrix, the oxidation state of the aquifer water, and the oxidation state of the advanced treated water that is injected are the predominant factors that control the potential for metals release and reattachment within the aquifer.

MDE Aquifer Chemistry Question 4

Provide physical and mineralogical characteristics of the receiving aquifers, describing heterogeneity, anisotropy and the nature of connectivity of individual sand units within the formation.

- What potential chemical or physical changes could occur in these aquifers with the injection of highly-treated wastewater?
- How can the test wells be used to identify potential problems and minimize the potential for unanticipated consequences in the full-scale project?

AACO Project Team Response

The physical characteristics of the receiving zones will be defined in the applied research testing program by performing aquifer pumping tests in each of the MAR zones while monitoring the hydraulic response in the related monitoring well and in the vertically adjacent aquifers. The mineralogical makeup of the aquifer system will be determined through analyses of up to 21 total core samples from the MAR zones and intervening confining units. Indications of heterogeneity, anisotropy and the nature of connectivity of individual sand units will be provided by data collected from the six proposed borings at the site. Data from the onsite monitoring wells will be used to estimate MAR zone effective porosity and storativity. If dissolved metals levels in recharge water detected at the monitor wells remain below EPA primary drinking water standards, the risk of future MAR activities causing metal concentrations above the related MCLs off-site is greatly reduced.

Panel Response

Please see the aquifer characterization discussion in Question 3, above.

MDE Aquifer Chemistry Question 5

Should it be anticipated that trace constituents that have made it through the wastewater treatment process will be highly mobile in the groundwater setting?

AACO Project Team Response

We would suggest further discussion with respect to the fate of trace constituents in the groundwater and would appreciate thoughts from the Panel with respect to constituents to be monitored.

Panel Response

The Panel believes that metals contained in the advanced treated water would not pose a water quality problem when injected into the aquifers being used for the MAR project. Metals would be mobile initially, but as the DO is consumed within the anoxic water of the aquifer, they would likely be deposited on the surface of the various minerals that constitute the aquifer matrix.

The Panel understands that AACO has not proposed that injected water quality rely on aquifer treatment of compounds contained in the advanced treated water. The project goal is to remove compounds, such as PFAS and/or 1,4 dioxane, before injection. Even if very small concentrations of these compounds were to enter the aquifer, the internal dilution would be so great that it is unlikely that they could be detected using current analytical methods. As discussed later in the report, the Patuxent Water Reclamation Facility laboratory tap water used in the initial test phase should be analyzed to determine if it contributes any critical trace organic compounds.

MDE Aquifer Chemistry Question 6

Will certain ions from the wastewater "replace" other ions in the aquifer geology resulting in changes in ionic composition?

AACO Project Team Response

Please refer to the response to Question 3 above.

Panel Response

Please refer to the AACO Project Team Response and Panel Response to Aquifer Chemistry Questions 3 and 4.

MDE Aquifer Chemistry Question 7

What timeline should be used to estimate pathogen microorganism survival/degradation in the aquifer?

Panel Response

The project does not include an aquifer treatment component. If the MDE wants information on this subject, please see the Lisle, J.T., et al. reference in Appendix A.

MDE Groundwater Flow Question 1

How will aquifer heterogeneity, anisotropy, and connectivity affect the flow and will it affect the integrity of the aquifer?

- How can these impacts be best predicted?
- Will the chemical composition of injected water vary both temporally and spatially?

AACO Project Team Response

The potential for fracturing adjacent confining units as a result of excessive recharge pressures is very low given the greatest anticipated recharge pressure (assuming 1 year of continuous recharge and minimal plugging due to solids accumulation) is 2 psi at the UPAT MAR. Assuming a fracture gradient of 1/4 psi per foot of depth to the top of the injection zone (based on Texas Railroad Commission guidance document for Gulf Coast injection wells with casing depths less than 2,000 feet below land surface), and the estimated fracture pressure of 25 psi in the UPAT at the Patuxent Water Reclamation Facility. The resulting hydraulic fracturing safety factor is greater than 10. The other two zones have significantly higher estimated fracture pressures and lower maximum recharge pressures.

The risk of aquifer contamination as a result of future recharge activities is best assessed using water quality data collected from monitoring wells (MWs) close by the MAR wells during the applied research testing. Because the proposed test MAR wells and corresponding MWs will be completed across all permeable zones of each MAR zone, and the MWs are relatively close to the MAR wells (between 80 and 132 feet), it is anticipated that a much higher concentration of recharged water will be detected in the proposed MWs than will ever occur at points further from the pilot MAR wells.

Sediments comprising the upper and lower Patapsco and Patuxent aquifers in Anne Arundel County were deposited in a fluvio-deltaic environment resulting in discontinuous sand and gravel lenses interfingered with silts and clays. Therefore, the potential for preferential flow paths extending for significant distances within these aquifers is very low and recharge plumes will tend to disperse vertically and horizontally over relatively short distances.

Confining units separate the three MAR zones. The Magothy-Patapsco confining unit separates the Upper Patapsco aquifer system from the overlying Magothy aquifer. The unit is estimated to be less than 40 feet thick in the area of the Patuxent Water Reclamation Facility but is absent in portions of east-central Anne Arundel County. As such, the confining unit does not provide effective hydraulic isolation.

The Patapsco Clay separates the Upper and Lower Patapsco aquifers. This unit is approximately 80 feet thick in the area of the Patuxent Water Reclamation Facility, continuous in AACO, and thickens in the down gradient direction. Clay beds that comprise the unit tend to be laterally discontinuous so hydraulic isolation may not be regionally effective.

The Arundel Clay separates the Lower Patapsco and Patuxent aquifers. This unit is approximately 200 feet thick in the area of the Patuxent Water Reclamation Facility, continuous in AACO, and thickens in the downgradient direction. This unit provides substantial hydraulic isolation regionally.

Panel Response

The Panel agrees with this response based on the materials provided on the aquifer characteristics.

MDE Groundwater Flow Question 2

How do other programs determine the integrity of the aquifer is not compromised?

AACO Project Team Response

The projects that we are aware of monitor recharge water quality before it is injected and conduct applied research prior to full-scale implementation to ensure that there are no adverse water quality impacts. We look forward to hearing the input of the Panel relative to this question.

Panel Response

Please see earlier Panel response in MDE Aquifer Chemistry Question 2.

MDE Groundwater Flow Question 3

Wells built in this geology contain multiple screened intervals. The aquifer is so heterogeneous that even over short distances, there are dramatic changes to the sand lenses that are screened; therefore, there is potential for the hydraulic connection to not be well established.

- What is an appropriate number of monitoring wells?
- Should the monitoring wells be constructed for one screened interval per well or screen all sand lenses?
- What is the appropriate distance from injection site and number of screened intervals?

AACO Project Team Response

Given the very similar density of the native groundwater and anticipated recharge water, the proposed monitoring wells (that fully will screen the same zones as the adjacent MAR well) should provide direct connection to the MAR well recharge strata.

Panel Response

The Panel recommends using nested monitoring wells that are not screened through the full aquifer thickness, like the injection wells. The nested well design allows for sampling advanced treated water at various depths without dilution, which could prevent detection of CECs.

MDE Groundwater Flow Question 4

What are typical monitoring well requirements for these projects?

AACO Project Team Response

We are proposing one monitoring well in each confined aquifer (including the Magothy aquifer, which will not have any injection). The monitoring wells are relatively close to the MAR wells (between 80 and 132 feet) to detect the presence of recharge water relatively quickly. We look forward to hearing the input of the Panel relative to this question.

Panel Response

The Panel recommends constructing three nested monitoring wells at varying distances downgradient from each injection well before starting the initial injection well testing. The Panel also recommends that the Project Team should use the outcomes of the initial injection testing program and associated groundwater modeling conducted during the second phase testing to determine the number and placement of monitoring wells for the full-scale MAR project.

The OCWD GWRS 2020 Annual Report is a useful reference that gives detailed information on monitoring well requirements for IPR projects in California and includes specific monitoring well design schematics used for the GWRS project.

MDE Groundwater Flow Question 5

What are the best approaches for evaluating residence time and time of travel prior to the project implementation?

- How to estimate blending with native water?
- Are tracers effective? If so, what tracers are commonly used? Is it common to add a tracer or use an existing constituent already present in the injectate?

AACO Project Team Response

We anticipate using the proposed monitoring wells and existing water constituents to evaluate travel time. An increasing trend in conductivity and chloride concentration will be the primary indicators of the arrival of recharge water. Although the values of pH, DO, oxidation-reduction potential (ORP), and alkalinity are dramatically higher in the recharge water compared to the native groundwater (NGW), these parameters may decrease due to chemical and biological processes in the aquifer and may not be accurate predictors of the absence of recharge water. Because the pilot recharge water is chemically similar to the NGW at the test site, a conservative tracer may be useful in evaluating blending in the MAR zones. We look forward to hearing the input of the Panel relative to this question.

Panel Response

The Panel notes that OCWD has used chloride and electrical conductivity as an effective tracer for tracking recycled water travel time for decades. Using an existing constituent in the injectate is far more common than adding a tracer. For example, fluoride in the advanced treated water, since the water is originally derived from drinking water, can serve as an effective tracer, depending on background concentrations in the aquifer.

MDE Groundwater Flow Question 6

What monitoring plan should be in place to track the movement of the plume?

- Locations of wells, direction and distance from injection point
- Parameters monitored
- Should regular monitoring be conducted in nearby private wells?
- Test project vs full scale project?

AACO Project Team Response

Please refer to the response to Groundwater Flow Question 4 for location of monitoring wells for the test wells. Proposed monitoring well water quality analysis is provided in Table 6 of the Recharge Testing Plan (documents provided with Presentation 3). For the test wells, we do not anticipate the recharge water reaching any local private wells. If the initial test results confirm feasibility and the County moves forward with a Demonstration Facility, additional monitoring plans and testing protocols will be developed. We look forward to hearing the input of the Panel relative to this question.

Panel Response

Please see the response to Groundwater Flow Question 4.

MDE Groundwater Flow Question 7

What timeline should be used to estimate pathogen microorganism survival/degradation in the aquifer?

AACO Project Team Response

From previous discussions with MDE, the County is not planning to rely on pathogen treatment through the aquifer, although this approach has been taken by other utilities investigating groundwater injection. This approach is referred to as Soil Aquifer Treatment (SAT), a natural treatment process in which water is treated as it percolates through the aquifer.

California grants 1 log reduction credit for viruses, *Cryptosporidium* and *Giardia* per month of travel time in the aquifer up to a total of six months of travel time (Titles 22 and 17 California Code of Regulations, State Board, Division of Drinking Water, Recycled Water Regulation).

SAT has been studied widely in potable reuse applications for degradation and removal of pathogens, total organic carbon, nitrogen species, emerging contaminants and disinfection byproducts (see references: Fox, 2006; Trussell, 2015; and Trussell 2020 in Appendix A). SAT can be validated at the pilot-scale using soil column experiments as shown in Figure ES.1 (WRF 4600 report), to study attenuation of different pathogens and contaminants. The County intends to keep abreast of ongoing research related to soil aquifer treatment but is not planning on initiating these types of experiments at this time.

Panel Response

Extensive work on this issue has been performed by the US Geological Survey on the North Lake Okeechobee ASR project in Florida. California IPR regulations generally offer a 1-log virus reduction credit for each month of proven underground residence. For more information, see Lisle, J.T., et al., in Appendix A.

MDE Groundwater Flow Question 8

To what extent are organic constituents degraded in the aquifer?

AACO Project Team Response

The rate of attenuation and/or degradation of organic constituents in recharge water depends on the constituents present, recharge water temperature, redox conditions, chlorine residual as well as the composition of the aquifer matrix. In general, organic constituents degrade rapidly with time after biological communities that metabolize the organics become established in the vicinity of the recharge well. It can take many months for colonization to reach a maximum level.

As noted earlier, the County is not planning to rely on soil aquifer treatment as part of its overall treatment strategy. This applies for organic constituents as well.

Panel Response

AACO plans to remove trace organic compounds of concern (PFAS and 1,4 dioxane, for example) from the water before it is injected into the aquifer. The compounds to be tested for should be approved by AACO and MDE during project permitting. During initial testing of the advanced treated water, the Panel recommends detailed and timely sampling and analysis for the compounds of concern. If these compounds are found in the advanced treated water, then the water already injected into the aquifer could be pumped out and treated during initial testing.

The Panel strongly recommends that AACO engage stakeholders in the initial phase of the project to begin a dialog about issues of mutual concern, including water quality parameters, monitoring frequency and methods, and to jointly review current literature on the degradation rates of organic compounds in anoxic groundwater systems.

MDE Groundwater Flow Question 9

What water characteristics need to be maintained to prevent clogging around the well?

AACO Project Team Response

Recharge well clogging is typically caused by precipitation of solids, mobilization of clay minerals as a result of ion exchange, accumulation of solids entrained in the recharge water, or accumulation of biomass related to metabolism of organics, iron, manganese, or other metals. Analyses using the groundwater quality and anticipated recharge water quality suggest that precipitation and mobilization of clay minerals will not cause significant clogging. However, clogging due to elevated suspended solids levels or dissolved organic content in the AWT effluent may require operational procedures to control. As the pilot water should have very low suspended solids and dissolved organic concentrations, clogging is not anticipated to be observed during the initial pilot testing.

Potential for clogging of the MAR wells will be quantified using effluent from a future pilot demonstration system. A second MAR well recharge pilot program will be required to test clogging and verify there are no adverse impacts to the aquifer. By design, proposed injection rates for the pilot MAR wells will likely be limited to no more than 80 percent of proposed recharge rates to ensure backflushing is effective in restoring injection capacity. Requirements for chlorine residual will be determined during this demonstration testing. If clogging due to excessive levels of dissolved carbon is observed, treatment train modifications may be explored during this demonstration phase.

Panel Response

Increases in injection pressure at the wellhead are most commonly caused by an accumulation of entrained gases during the injection phase and are corrected by periodic backflushing for 30 minutes to 1 hour. Biofilms can develop, which most commonly occurs in wastewater ASR systems (in Australia, for example). Biofilms can be remediated by adding residual chlorine and/or periodically backflushing the injection wells.

Standard operating practices (SOPs) to recognize and address clogging are an important part of ongoing MAR facility operation. Appropriate SOPs should be established and amended as necessary based on experience over time. Preventing clogging is an important operational concern, but it is not a regulatory issue that the Project Team will need to address.

Questions from the AACO MAR Project Team following Meeting 1

Question 1

Please expand on comments during the panel session related to the short-term test.

- Should the testing plan be modified, or the monitoring extended, to capture changes in metals formation and re-adsorption?
- If the test period was lengthened, would the Panel be comfortable not purging the entire volume but instead take into account the metals concentration as long as it is lower than the MCL?

Panel Response

The Panel understands that the use of tap water for the short-term test is not ideal, but it is not practical to generate the volume of advanced treated water needed to conduct the first phase of injection testing.

The Panel believes that using tap water for the first phase of testing can accomplish some of the testing goals, but a complete chemical characterization of the tap water should be done before and during testing. It is important to establish if the tap water contains any trace CECs that could affect the results of aquifer water quality testing.

The Panel recommends that chemical characterization and modeling begin on any existing potable supply wells that may be affected in the future. The purpose of this characterization would be to establish background concentrations of dissolved metals and other chemical parameters in each aquifer. Some of these wells may be located in the shallower part of the aquifer system in areas that could have been impacted by past downward movement of water that contains trace CECs.

During the short-term test, the Panel suggests using a Speece Cone and injecting pure oxygen to boost the DO content of the tap water before injection, rather than hydrogen peroxide. Hydrogen peroxide may act as a stronger oxidant than DO in the aquifer matrix.

The Panel has concerns regarding the length of the initial test period to evaluate metals release. The current approach seems likely to overestimate trace metals release compared to longer term operation and monitoring. The testing period will need to continue until it reasonably simulates actual operation of the MAR treatment system. Perhaps adding 30 to 60 days of injection would project a more realistic result.

Question 2

Please comment on the Test Well Plan. Is it a sound plan? Are there any fatal flaws?

Panel Response

The Panel recommends that the monitoring well design should be reconsidered and the monitoring plan should be reviewed based on the modified well design. The monitoring wells should not be screened over the full aquifer thickness, based on the design of the injection wells. The heterogeneity of the aquifers makes this design change necessary.

Small amounts of water that contain low concentrations of trace metals, synthetic organic compounds, or other analytes would be diluted by water allowed into the well by the full screen, which may result in false non-detects. The monitoring wells should have a nested design so that discrete units of the aquifer can be monitored to increase detection of CECs at the depth where they occur.

The Panel also believes that the design of the MAR wells needs to meet a higher materials standard than drinking water production wells to prevent casing corrosion. Despite their projected use for a shorter time period, corrosion could affect water quality observations. The Underground Injection Control (UIC) well materials standard is a more appropriate basis. Steps should be taken to ensure that corrosion is considered and does not become a permitting issue for the MAR wells.

The Panel also suggests that cathodic corrosion be analyzed, based on the TDS and dissolved chloride differential between the aquifer water and the injected advanced treated water. The electrical potential across the stainless-steel casing should be evaluated to assess enhanced corrosion potential that would cause pitting and shorten the functional life of the well.

Question 3

There were some comments from Panel members and MDE staff regarding the speciation of arsenic. Should modifications be made with respect to the test plan related to the analysis of arsenic?

Panel Response

The Panel believes that it would be useful to speciate arsenic during the geochemical assessment. Arsenic speciation will yield information on what chemical reactions are occurring in the MAR aquifers, which will be useful in predicting other trace metals reactions. The geochemical characterization of the aquifer should include pre-injection testing of all aquifer injection and monitoring wells. The potable water and the treated water should also be tested regularly during pilot testing and operation.

Question 4

Comments were made from MDE related to the anisotropic nature of the aquifer.

- Does the Panel feel that the current testing plan will adequately define storage zone variability?
- Will the current overall plan, between the core sampling and the monitoring wells adequately define storage zone variability?

Panel Response

The Panel believes that the aquifer system is highly heterogeneous, and that small numbers of MAR and monitoring wells will not fully define the groundwater flow system. The Panel recommends constructing three nested monitoring wells downgradient from each test injection well before starting the initial testing program. The Panel also recommends that the Project

Team should consider more exploratory drilling to better characterize the aquifer system at key locations during the second phase testing. This exploratory research could be used to assess heterogeneity and to design new monitoring wells within the area of MAR influence (see Question 2 Panel Response on monitoring well design).

The Panel believes that the plan presented is a good start in the aquifer characterization process. More exploratory test drilling in the aquifer system would improve the database and the AACO MAR Project Team's understanding of aquifer hydraulic properties. This aquifer characterization should be a collaborative effort with the USGS and the Maryland Geological Survey, which may be eligible for funding under the EPA's innovative water resources management planning program. Also, if the MAR system is approved for construction and operation, more monitoring wells could be installed over time to continuously improve aquifer characterization and to assess possible new MAR well locations.

The Panel suggests that some of the cores be studied to assess metals leaching based on an array of experimentally determined pH, Eh, and ORP. The core matrix should be analyzed using a hand-held XRF (x-ray fluorescence) unit to provide quantitative background concentrations for the chemical composition of the aquifer matrix and the presence of trace metals of concern.

Question 5

MDE staff indicated concerns related to maintaining the integrity of existing confining units above and below the storage zones.

- Are there guidelines or limitations for maximum allowable injection pressures?
- Has there been a need in other programs to compare and contrast managed aquifer recharge with hydraulic fracturing from either a regulatory or public information standpoint?

Panel Response

The Panel does not believe that the MAR project, as defined, would create integrity issues for aquifer confinement. However, during the aquifer testing program, particularly in the Upper Patapsco Aquifer, pumping tests should be conducted at a sufficient pumping rate and duration to measure aquifer leakance. This would better define any potential impacts of advanced treated water leaving the aquifer via leakance either up or down.

The Panel is aware that the issue of aquifer matrix fracturing was raised by the National Research Council on the Everglades ASR project in southern Florida. The US Army Corps of Engineers and the South Florida Water Management District thoroughly investigated this issue and set a conservative maximum wellhead pressure to avoid any potential for fracturing the limestones and dolostones of the aquifer matrix. Since the aquifer confining unit at the top of the system was a mud, it could not be fractured, but only compressed. Based on the geology of the Potomac Aquifer System, it is highly unlikely that aquifer fracturing could occur based on the lithology and recommended pumping rates.

Questions from the AACO MAR Project Team following Meeting 2

Based on conversations at the two Panel meetings as well as previous correspondence, the Anne Arundel County team feels that MDE has two overarching concerns: the compatibility of the injectate into the aquifer and the use of a non-membrane-based treatment system. The previous questions submitted to the Panel and the responses to previous MDE questions attempt to address these issues. Additional questions to the Panel based on Panel Meeting No. 2 are provided below. It may be beneficial to develop a subcommittee for each of these issues to reach consensus. The subcommittee would include appropriate members of the Panel, MDE, and the County team. We look forward to the Panel's input into these matters.

Question 1

At the May 26 Panel meeting, MDE suggested that effluent from the future AWT plant be conditioned to match the native groundwater pH and DO to avoid oxidizing iron-bearing minerals rather than injecting water with high DO (8 mg/l to 12 mg/L) and controlling metals mobilization by increasing pH to 8.0 to 8.5 and alkalinity to between 80 mg/L and 140 mg/L, as proposed in the testing plan. MDE was concerned the high pH and DO proposed by the County could result in dissolution of iron and other trace metals, causing well screen and formation clogging similar to that observed at a recharge project in Worcester County, which recharged tertiary treated wastewater into the surficial aquifer.

Although the information related to the Worcester recharge test is sparse, it is likely that the significant and persistent loss of recharge capacity observed may have been related to clay fragmentation related to recharging fresher water into a brackish zone. The resulting ion exchange can cause the clays to destabilize, clogging pores in the sand intervals. This is not the situation at the Patuxent Water Reclamation Facility where the recharge water injection zones have very similar ionic characteristics. We welcome an opportunity to review any data MDE may have related to native groundwater and recharge water salinity.

What is the Panel's opinion on the efficacy and cost related to attempting to replicate the native groundwater pH and DO as an alternative to the simply boosting the pH and native groundwater pH and alkalinity to counter the elevated DO? Is this strategy being applied at any other MAR projects using ozone in the recharge water treatment train?

Panel Response

The project team can test DO and pH during the first injection test using tap water to assess the potential for metals liberation and to help determine if DO and pH need to be modified. An economic analysis could also be prepared based on the tap water evaluation test results.

It will be hard to remove DO from the advanced treated water and it will be difficult to ensure the DO is always near zero. A more common approach is to acknowledge that DO is high, keep it positive (above zero) and stable, and match the needed pH and alkalinity to ensure hydrous ferric oxides production and stability in the aquifer. It may be beneficial to inject finished water with higher pH and alkalinity for a short time while the aquifer ORP is increasing near the well. The pH and alkalinity could slowly be decreased to a steady state target for long-term MAR. The actual values should be based on geochemical modeling and monitoring.

Question 2

Final total organic carbon (TOC) limits for managed aquifer recharge vary by state and regulatory drivers. For example, California stipulates a TOC limit of 0.5 mg/L while other states, such as Florida, have higher TOC limits (3 mg/L) or no TOC limits and evaluate on a case-by-case basis (Arizona). California's TOC limit is based on the performance of a required advanced water treatment process – reverse osmosis (RO).

Since RO has the capability of reducing TOC concentrations below 0.5 mg/L, if values exceed that concentration, it may indicate an RO performance issue and require maintenance or membrane replacement. Non-RO treatment (e.g., biofiltration and granular activated carbon [GAC] based treatment) do not remove total dissolved solids and result in higher TOC in finished waters when compared to RO-based trains.

WRF 4771 completed a comparative analysis to determine the characteristics of the remaining TOC after RO or non-RO treatment. The remaining TOC quality was also compared to TOC levels found after drinking water treatment. Results of the study found that TOC concentrations as high as 4 mg/L are acceptable by drinking water regulators and that similar levels in potable reuse applications may also be safe, provided that sufficient monitoring of select indicators (such as CECs), disinfection byproducts, and CEC surrogates like iohexol, sucralose, and sulfamethoxazole) is completed. The approach outlined in WRF 4771 has been followed by other non-RO treatment systems performing indirect potable reuse and MAR (UOSA, Gwinnett County, GA, HRSD SWIFT) and is proposed for the Anne Arundel County, MD MAR pilot.

Furthermore, the Anne Arundel County team is proposing to simultaneous test multiple GACs at bench-scale using rapid small scale column testing (RSSCT) while performing pilot testing to obtain additional CEC removal data. The RSSCT will measure CEC breakthrough and correlate carbon type and characteristics to removal capability. This data will be used in conjunction with pilot testing data to inform carbon selection, carbon life cycle, and optimal carbon performance should the project proceed to later phases (demonstration scale).

Does the Panel agree with an initial TOC goal of 4 mg/L, with an understanding that TOC/CEC removal will be evaluated further with the pilot and RSSCT testing? Are there other tests that should be performed to inform the ultimate TOC goal?

Panel Response

The Panel believes that the test program proposed by the County is adequate to affirm the 4 mg/L TOC goal or to revise the target TOC performance criterion. The Panel agrees that TOC and CEC/disinfection byproduct (DBP) removal data collected during pilot testing should further inform Anne Arundel County on the validity of the TOC goal of 4 mg/L. The RSSCT for various GAC media during pilot testing should further validate the TOC goal to show the proposed treatment process adequately addresses CEC removal.

The Water Research Foundation report *Characterizing and Controlling Organics in Direct Potable Reuse Projects* (WRF 4771) specifically focuses on controlling organics in potable reuse applications. The report documents a comparative analysis to determine the TOC remaining in water after RO or non-RO treatment, which was then compared to TOC levels after drinking water treatment. The study found that TOC concentrations as high as 4 mg/L are a valid indicator that CECs are at low levels (see Figure 1).

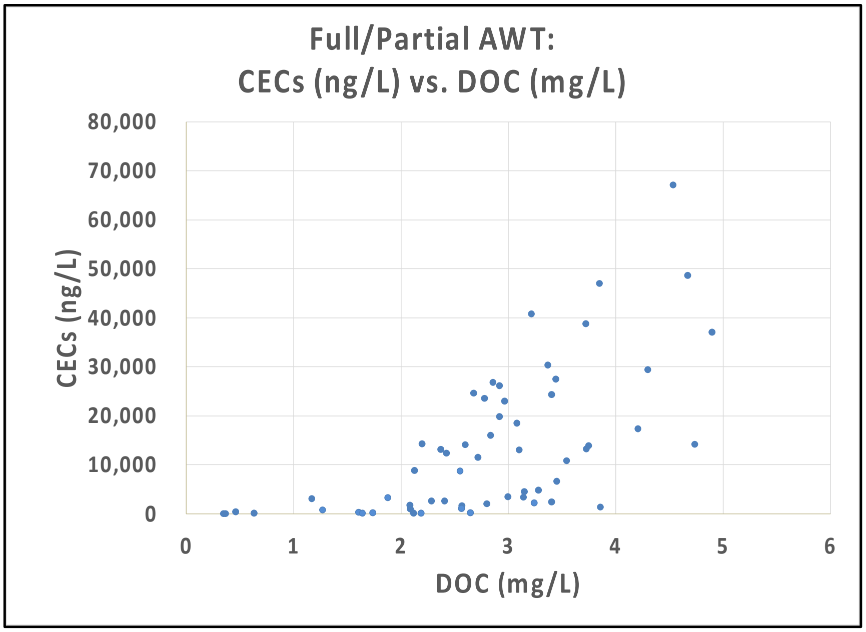

Figure 1: Relationship between Total Trace Organic Chemicals and DOC in Advanced Treated Water.[1]

TOC can be used in combination with other surrogates to look for manmade compounds in wastewater. Complementary surrogates include iohexol, sucralose, and sulfamethoxazole. The approach to controlling organic contaminants, including those that are problematic at low concentrations, is outlined in WRF 4771 and has been followed by other organizations that use non-RO treatment systems for IPR (including Gwinnett County, Georgia, the Hampton Roads Sanitation District, and the Upper Occuquan Service Authority [UOSA] in Virginia.) The proposed AACO MAR pilot is also based on this framework.

In addition to using an established framework to control organics, the Anne Arundel County team is proposing to simultaneously test multiple GACs at bench scale using RSSCT during pilot

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[1] Source: Figure 5.2 from Schimmoller, L. 2020. *Characterizing and Controlling Organics in Direct Potable Reuse Projects*. The Water Research Foundation Project No. 4771, Alexandria, VA.

testing to obtain additional CEC removal data. The RSSCT will measure CEC breakthrough and will correlate carbon type and characteristics to removal capability. This data will be used with pilot test data to inform carbon selection, carbon life cycle, and optimal carbon performance if the project proceeds to demonstration scale. The RSSCT method is good for evaluating specific contaminant removal capacity on GAC (PFAS, for example), but is only a partial TOC removal assessment, given the potential for TOC to be partly removed on GAC through biological treatment, particularly as the GAC ages. The RSSCT measures adsorption capacity but not biological treatment potential. Fully characterizing TOC removal is addressed through longer term AWT pilot testing.

Additional MDE Questions

Additional Question 1

High levels of TDS are typical in ENR effluent due to the need for the coagulants to be fast-dissolving and reactive. How should the treatment process be designed to prevent exceedances of primary and secondary drinking water standards relating to TDS? These include TDS (secondary) = 500 mg/L, chloride (secondary) = 250 mg/L and sulfate (secondary): 250 mg/L.

AACO Project Team Response

At the Patuxent Water Reclamation Facility, we expect to be below the MCLs for TDS, chloride, and sulfate. The TDS of the treated wastewater during our recent sampling event averaged approximately 250 mg/L, and was always lower than 350 mg/L. Previous chloride levels were measured below 50 mg/L and sulfate levels were below 40 mg/L. We will monitor these parameters during the pilot test to confirm compliance with the secondary MCL.

Panel Response

The Panel agrees that the monitoring of these parameters during testing will provide evidence of concentrations that will occur during system operation in the future.

Additional Question 2

What concentration of TDS is achievable in a treatment process like this (high-level treatment w/o RO)?

AACO Project Team Response

We do not expect to provide any removal of TDS from the treated wastewater. We also do not expect to add significant TDS from the advanced treatment system. Cation and anion contribution from AWT chemicals will be monitored to ensure SDWA compliance and aquifer compatibility.

Panel Response

The Panel agrees with this response.

Additional Question 3

EPA's SDWA health advisory level for combined PFOA/PFOS is 70 ppt. EPA will revisit this number in late 2022 and is also scheduled to release a draft MCL for combined PFOA/PFOS by the end of the year, with a final rule coming in 2023. These values are expected to be lower than 70 ppt. EPA will also be starting monitoring for its Fifth Unregulated Contaminant Monitoring Rule (UCMR5) in 2023, which will look at 29 PFAS species. Basically, the trend is toward increasing regulation of more PFAS species to lower concentrations. PFAS species that are not regulated under the SDWA today may not be allowed next year, and it seems likely that PFAS certain species that are not yet being monitored may be regulated to very low concentrations by the end of the decade. What treatment approaches should this facility employ to ensure that future SDWA standard will be achievable, and to limit the potential for any currently-unmonitored organic pollutants from being introduced to the aquifer.

AACO Project Team Response

It is recognized that additional PFAS regulatory action is likely in the near future. Anne Arundel County is taking a multi-prong approach to PFAS in potential AWT water:

A robust suite of PFAS and PFAS surrogates will be measured with multiple methods and will be monitored throughout the pilot test. We do expect the pilot treatment train, particularly the GAC system, will be able to remove a substantial portion of PFAS and we will report on results. We will also utilize RSSCT to test multiple GAC media simultaneously so the optimal media may be selected.

The County continues to look at source water control for PFAS to limit those that come to the wastewater treatment plant.

While we cannot guarantee performance for future unknown regulatory limits with any treatment process, we are proposing to monitor a suite of other CECs during the pilot test and to identify potential surrogates that can be used as critical control points for monitoring. All data collected will be shared with MDE and the PANEL for interpretation.

Panel Response

EPA's 2016 SDWA health advisory level for PFOA and/or PFOS was 70 ng/L. In June 2022, EPA released new interim advisory health advisories for PFOA and PFOS, as well as final health advisories for GenX and PFBS. All four of these values are lifetime health advisories. The values are:

PFOA = 0.004 ng/L

PFOS = 0.02 ng/L

GenX = 10 ng/L

PFBS = 2000 ng/L

Importantly, EPA is pointing to 4 ng/L as the method reporting level for PFOA and PFOS and is focused on framing management of PFAS in a drinking water rule proposal scheduled to be released late this year. A final drinking water standard is planned for 2023. As part of that rulemaking, EPA will set maximum contaminant level goals, which, like health advisories, are not enforceable but serve as a reference point for regulatory requirements. Under SDWA, drinking water treatment requirements are set as close to the MCL goal as feasible, where feasibility takes into account a water utility's ability to measure a contaminant, available treatment technologies, and the benefit of treatment given the costs. Water utilities will begin monitoring for 29 PFAS species under the Fifth Unregulated Contaminant Monitoring Rule (UCMR5) in 2023. That monitoring effort will not be complete in time to inform EPA's rulemaking. The SDWA gives water utilities three years to make necessary improvements to assure compliance. If EPA completes its rulemaking as planned in 2023, then compliance will be required in 2026.

Given the project timeline, the Project Team will have the opportunity to incorporate the direction that EPA sets in this SDWA rulemaking into its alternatives evaluation.

Additional Question 4

What TOC concentrations can realistically be achieved with the proposed treatment process?

AACO Project Team Response

Generally, TOC concentration goals in potable reuse are based on achievable TOC reduction from the treatment system (performance-based criteria) and minimization of trace organics (water-quality-based criteria). We are targeting a TOC concentration of below 4 mg/L with the proposed treatment process. This level is based on the HRSD SWIFT pilot treatment goals which were developed after a comprehensive study completed by the Water Research Foundation (WRF 4771: Characterizing and Controlling Organics in Direct Potable Reuse).

As described in Water Research Foundation Study 4771, this level is based on the achievable removal through an ozone-BAF-GAC treatment process that optimizes trace organics removal without being cost prohibitive (i.e., GAC media replacement). The study evaluated effective methods for measuring organics such as TOC and dissolved organic carbon (DOC) and correlation of those organics with trace constituents. These results were compared to organic characteristics found in drinking water as well. The results suggested that the nature of the TOC remaining after an ozone-BAF-GAC has been found to be inert organic material and further noted that several ozone-BAF drinking water systems were found to have TOC concentrations ranging from below 1 mg/L to above 4 mg/L and maintained safe drinking water that did not correlate with greater presence of trace organics. More information can be found in the WRF 4771 study.

Panel Response

Please see the Panel response to Question 2 in Questions from the AACO MAR Project Team following Meeting 2.

Additional Question 5

Do MAR discharges typically include any disinfectant residual? What approach is recommended for limiting ammonia and disinfection byproducts accumulating in the aquifer?

AACO Project Team Response

There may need to be a small chlorine residual to prevent biofouling at the wellhead. The ideal scenario is to provide a small amount of residual that is consumed by the end of the injection well, thus minimizing any residual that would enter the aquifer.

With any disinfectant application, there is the potential for disinfection byproduct formation. During AWT piloting, we will simulate disinfection byproduct formation potential with a test called simulated distribution system (SDS) testing. This test involves setting up small bench-scale reactors where AWT pilot finished water is spiked with disinfectant residual and incubated for the anticipated contact time of the injection well. After incubation, DBPs are measured and dosing is optimized in subsequent SDS tests.

Panel Response

The issue of disinfection byproducts should be assessed during pilot test monitoring of the advanced treated water.

Additional Question 6

Are there any recommendations relating to limiting DO concentrations in the injectate?

AACO Project Team Response

There may be methods to reduce DO in the injectate. The results of the well pilot testing will inform if such reduction is necessary.

Panel Response

See responses above. Removal of DO from the advanced treated water is not recommended at this site.

Appendix A · References

Fox, P. 2006. *Investigation of Soil-Aquifer Treatment for Sustainable Water Reuse*. The Water Research Foundation Project No. 487.

Lisle, J.T. 2014. *Survival of bacterial indicators and the functional diversity of native microbial communities in the Floridan aquifer system, South Florida.* United States Geological Survey Open-File Report 2014-1011. 70 pp.

Lisle, J.T. 2020. *Nutrient removal and uptake by native planktonic and biofilm bacterial communities in an anaerobic aquifer.* Frontiers in Microbiology 11(1765). 13 pp.

Lisle, J.T. and G. Lukasik. 2022. *Natural inactivation of MS2, poliovirus type 1 and Cryptosporidium parvum in an anaerobic and reduced aquifer.* Journal of Applied Microbiology 132(3): 2464-2474. Additional scientific on bacteria and virus survival is being conducted on the North Lake Okeechobee ASR project by the South Florida Water Management District. This information can be accessed via their ASR website.

Lohman, S. W. 1972. *Ground-water hydraulics.* U. S. Geological Survey Professional Paper 1972, Washington, DC, 69 pp.

Schimmoller, L. 2020. *Characterizing and Controlling Organics in Direct Potable Reuse Projects.* The Water Research Foundation Project No. 4771, Alexandria, VA.

Trussell, R.S. 2015. *Enhancing the Soil Aquifer Treatment Process for Potable Reuse*. The Water Research Foundation Project No. 1699.

Trussell, R.S. 2020. *Soil Aquifer Treatment Characterization with Soil Columns for Groundwater Recharge in the San Fernando Valley*. The Water Research Foundation Project No. 4600.

Appendix B · Meeting Agenda

NWRI
NATIONAL WATER RESEARCH INSTITUTE

Independent Scientific Advisory Panel Supporting the
Anne Arundel County OurwAAter Program
Managed Aquifer Recharge Pilot Project

April 27, 2022 • Meeting No. 1

Location

Zoom. See Outlook invitation for login information.

Contacts

Suzanne Sharkey, NWRI: (949) 258-2093
George Heiner, AACO: (410) 222-4128

Meeting Objectives

- Facilitate an opportunity for stakeholders to introduce themselves to the Panel and share their purpose and goals for participating in this effort.
- Establish AACO's drivers and goals for the OurwAAter Program, identify milestones, and present integrated planning concepts.
- Introduce the proposed Managed Aquifer Recharge (MAR) Pilot Project including well siting, design, and related performance testing and monitoring.
- Review and discuss the questions submitted by Maryland Department of the Environment (MDE) staff.

Agenda

11:00 am EDT	Welcome, Agenda Review, and Meeting Logistics	Kevin M. Hardy, JD Executive Director, NWRI
11:10 am EDT	Panel, Project Team, Stakeholder, and NWRI Self-Introductions	
11:25 am EDT	Review Panel Charge, Processes, and Work Product	Tom Missimer, PhD Panel Chair

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Anne Arundel County Managed Aquifer Recharge Pilot Project: Panel Meeting 1 Agenda

11:30 am EDT	Introduction to the Anne Arundel County OurwAAter Program/Background on Integrated Planning Effort Reference Documents: • Draft Executive Summary of the Anne Arundel County Integrated Management Plan.	AACO Project Team
12:15 pm EDT	Panel Q & A	Kevin Hardy
12:30 pm EDT	Managed Aquifer Recharge Research Program: Planned Approach and Schedule Reference Documents: • Annotated issue letter to MDE (Apr 27, 2019) • Managed Aquifer Recharge Concept Feasibility Study (Apr 25, 2018) Key Regulatory Questions: • The injectate will need to be conditioned to match the groundwater. What concentrations of the following constituents need to be maintained: DO, TDS, pH, alkalinity, chlorine residual? • Discussion of which states have regulations in place and the process for developing a program.	AACO Project Team
1:15 pm EDT	Panel Q & A	Kevin Hardy
1:30 pm EDT	Break	
1:45 pm EDT	Managed Aquifer Recharge Research Program: Planned Approach to MAR Test Well Siting and Design Reference Documents: • Pilot Recharge Siting+Zone Selection (May 3, 2019) • Pilot Recharge Well Basis of Design (Jul 25, 2019) • Recharge Testing Plan (May 10, 2021) Key Regulatory Questions: • What elements are possible to be mobilized as a result of DO-induced reactions in the aquifer? • Provide physical and mineralogical characteristics of the receiving aquifers, describing heterogeneity, anisotropy, and the nature of connectivity of individual sand units within the formation.	AACO Project Team
2:30 pm EDT	Panel Q & A	Kevin Hardy

2 National Water Research Institute

2:45 pm EDT	Discuss and Review MDE Questions Reference Documents: • MDE Comments on AACO MAR Concept Feasibility Study (Dec 2018) • Questions from MDE (Apr 2022)	
3:15 pm EDT	Stakeholder Questions	Kevin Hardy
3:30 pm EDT	Panel Closed Working Session	Tom Missimer
5:00 pm EDT	Adjourn Panel Closed Working Session	

NWRI
NATIONAL WATER RESEARCH INSTITUTE

Independent Scientific Advisory Panel Supporting the
Anne Arundel County OurwAAter Program
Managed Aquifer Recharge Pilot Project

May 26, 2022 • Meeting No. 2

Location

Zoom. See Outlook invitation for login information.

Contacts

Suzanne Sharkey, NWRI: (949) 258-2093
George Heiner, AACO: (410) 222-4128

Meeting Objectives

- Facilitate an opportunity for stakeholders to introduce themselves to the Panel and share their purpose and goals for participating in this effort.
- Introduce the project background and Pilot treatment selection process and validation plan.
- Review and discuss the questions submitted by MDE staff.

Agenda

11:00 am EDT	Welcome, Agenda Review, and Meeting Logistics	Kevin M. Hardy, JD Executive Director, NWRI
11:10 am EDT	Panel, Project Team, Stakeholder, and NWRI Self-Introductions	
11:25 am EDT	Review Panel Charge, Processes, and Work Product	Tom Missimer, PhD Panel Chair
11:30 am EDT	Project Background and Process Selection • Review of the Anne Arundel County OurwAAter Managed Aquifer Recharge (MAR) Project • History of Potable Reuse • Overview of Regulations • MAR Implementation Nationwide	AACO Project Team

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Anne Arundel County Managed Aquifer Recharge Pilot Project: Panel Meeting 2 Agenda

12:15 pm EDT	Panel Q & A	Kevin Hardy
12:30 pm EDT	Pilot Treatment Process Selection • Advanced Water Treatment Evaluation • Sampling Program and Results • Process Selection Considerations Reference Documents: • Advanced Water Treatment Pilot Technical Memorandum (Dec 30, 2020)	AACO Project Team
1:15 pm EDT	Panel Q & A	Kevin Hardy
1:30 pm EDT	Break	
1:45 pm EDT	Pilot Testing & Validation • Pilot Design • Pilot Test Plan • Risk Mitigation (CCPs, Surrogates, Online monitoring) Reference Documents: • Draft AWT Pilot Test Plan (Mar 17, 2022)	AACO Project Team
2:30 pm EDT	Panel Q & A	Kevin Hardy
2:45 pm EDT	Discuss and Review MDE Questions • SWIFT Program Highlights • Travel time estimates • Review of MDE Questions • Next Steps Reference Documents: • Questions from MDE (Apr and May 2022)	
3:15 pm EDT	Stakeholder Questions	Kevin Hardy
3:30 pm EDT	Panel Closed Working Session	Tom Missimer
5:00 pm EDT	Adjourn Panel Closed Working Session	

Appendix C · Attendees

Panel Members

Chair: Tom Missimer

Diana Aga

Charles Bott

Scott Fendorf

Mehul Patel

Steve Via

AACO Project Team

Christina Alito, HDR

Noelle Anuszkiewicz, AACO

Brian Balchunas, HDR

Sharon Cole, AACO

James Dwyer, HDR

George Heiner, AACO

Karen Henry, HDR

Larry Hentz, HDR

Chris Murphy, AACO

Beth O'Connel, AACO

Chris Phipps, AACO

Ben Thompson, AACO

Maryland Department of the Environment

Greg Busch

Mary Dewa

Robert Peoples

Tracy Rocca-Weikart

Ching Tien

NWRI

Kevin Hardy

Mary Collins

Suzanne Sharkey

Appendix D · Questions from Dr. C. Tien

Question 1

As shown in the water quality table shown, below (source: AA County DPW slides titled "Integrated Planning MAR Approach"), the dissolved oxygen (DO) concentration of 8-12 mg/l in the aquifer recharge water is much higher than the anoxic DO level of less than 1 mg/l. Section 4.1,4.2 (Mineral Precipitation) of the MAR final report dated 4/25/2018 indicated mineral precipitation typically occurs when the injectate contains DO at concentrations exceeding anoxic (DO < 1.0 mg/L) levels, but can also occur if the pH of the injectate exceeds 9.0. The high DO concentration will enhance the oxidation of pyrite (FeS_2), arsenic pyrite (FeS2-xAsx) and siderite ($FeCO_3$) in the aquifer resulting in release of ferric oxide precipitants, As (III) and As (V). Ferric precipitants can clog the well screen and aquifer media. Clogging problems at the two injection well facilities in Worcester County caused well replacement and relocation. Although As (III) is more toxic than As (V), both arsenite (As (III)) and arsenate (AS(V)) are harmful to humans and

Parameter	Patuxent WRF Tap Water	Range of AWT Effluent Water Quality Values*
pH	8.5 S.U.	8.0 - 8.5 S.U.
Temp	16.3 °C	5 - 25 °C
DO	9.5	8 - 12 mg/L
TDS	51 mg/L	200 - 300 mg/L (Sodium = 50 mg/L Calcium = 15 mg/L Magnesium = 5 mg/L)
Alkalinity	30 mg/L	80 -140 mg/L
*Finished water quality for an ozone biofiltration AWT process.		

overall arsenic shall not exceed the 0.01 mg/l drinking water standards.

AACO Project Team Response

We anticipate being able to monitor the situation described during the test well operations. Recharging water with DO near saturation in combination with an alkaline pH oxidizes reduced metal bearing minerals, releasing iron and manganese and promoting precipitation of highly adsorptive hydrous ferric oxides and manganese oxide surfaces on the reactive mineral surfaces. Promoting the precipitation of metal oxide surfaces benefits MAR operations by removing nuisance and harmful metals from the migrating recharge water.

Reactive iron and manganese bearing minerals often strongly influence natural groundwater chemistry, or if the proper measures are not implemented, the chemistry of water migrating in the MAR aquifer. However, the actual amount of reactive metal bearing minerals rarely exceeds one percent of the whole rock matrix. Precipitating hydrous ferric oxides or other oxide coatings on these minerals also represent a miniscule percentage of the aquifer pore space.

Under normal operations, recharge water will not be recovered, limiting potential accumulation of iron precipitation. Therefore, iron precipitation due to oxidation by recharge water will only occur once at the recharge water/groundwater interface. As iron concentrations in the recharge water are relatively low, screen clogging due to iron precipitation should not be a problem.

Total suspended solids entrained in the recharge water represent a far greater concern for clogging a MAR well. This may be the cause of clogging issues at previous well injection sites in Maryland, as we understand those facilities were not of the same level of treatment as the expected Advanced Water Treatment facility for Anne Arundel County MAR operation. Clay mobilization may also have been an issue at the previous injection sites.

Panel Response

As previously stated, the Panel does not believe that the issue of well screen and/or gravel pack clogging is a regulatory or public health issue. AACO needs to decide what measures are required to keep wells operational during injection. This issue will be revisited in time as more data are collected during pilot testing of the AWT water and perhaps during future operation.

Question 2

Section 4.2.3.1 of the MAR report suggests using KOH to raise pH of recharge water to control reactive metal-bearing minerals in the aquifer environment during MAR operations. Similar to NaOH, KOH is a strong base which will raise pH higher than 9 and may enhance the release of As (III), As (V) and ferric precipitants in the aquifer and cause adverse impacts in water quality and well screen and aquifer clogging. It is suggested to use chemicals, if available, to decrease pH and DO of the recharge water to minimize the aquifer mineral oxidation and clogging. One of the projects in Worcester County used a chlorine and acid mix to dissolve well screen clogging in the past as a temporary fix. The clogged wells were replaced or relocated.

AACO Project Team Response

We understand the reference to be from the Feasibility Study. Ultimate pH adjustment of the AWT water will be evaluated as part of the pilot process and the future Demonstration Facility, should the project proceed to that phase. For the Conditioned Potable Water Test Wells, we anticipate minimal pH adjustment will be required. Should pH modification be necessary, we have included chemicals to adjust pH as necessary to meet our targeted ranges for geochemical stability (H_2SO_4 and NaOH). Any pH adjustment will be modified iteratively while monitoring pH to ensure that the targeted pH range is maintained.

Well clogging is discussed further in Question 1, Appendix D.

Panel Response

Please see the Panel response in Question 1, Appendix D.

Question 3

Research into monitoring conducted at other groundwater injection systems has suggested multiple groundwater monitoring wells (located both upgradient and downgradient) be installed in the recharge aquifer for each injection well system. The upgradient well would be installed outside the area of influence caused by injection to monitor the background groundwater quality. Given the anisotropy of the receiving aquifer, it could be necessary to include more monitoring wells due to the uncertainty of flow paths. It is being considered to have monitoring wells installed in each cardinal direction, in each aquifer surrounding each injection well.

AACO Project Team Response

We are proposing one monitoring well in each confined aquifer (including the Magothy aquifer, which will not have any injection). The monitoring wells are relatively close to the MAR wells (between 80 and 132 feet) to detect the presence of recharge water relatively quickly. With less than 30-day travel time to the monitoring wells at the 0.5 MGD recharge rate, regional groundwater movement will have a negligible effect on recharge water migration so we would consider additional monitoring wells to be unnecessary to define the extent of recharge water in any direction.

We anticipate using the proposed monitoring wells and existing water constituents to evaluate travel time. An increasing trend in conductivity and chloride concentration will be the primary indicators of the arrival of recharge water. Although the values of pH, DO, ORP, and alkalinity are dramatically higher in the recharge water compared to the native groundwater (NGW), these parameters may decrease due to chemical and biological processes in the aquifer and may not be accurate predictors of the absence of recharge water.

We would anticipate additional monitoring wells for long-term MAR operation and injection and location of those additional monitoring wells can be discussed at a later date.

Panel Response

Please see the Panel's responses to MDE Regulatory Question 2 and MDE Groundwater Question 3 for the Panel's recommendations related to the design and number of monitoring wells.