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Groundwater Injection Projects: Mitigating the Risk of Emerging Contaminants

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About the Author

Conor Jennings is a second-year student at William & Mary Law School. At William & Mary, he is a fellow with the Virginia Coastal Policy Center, serves as Secretary of the Student Environmental & Animal Law Society, and is on the William & Mary Law Review. After his first year, Conor interned with the Maryland Attorney General's office in the Criminal Division. He graduated in 2011 from the University of Virginia with a double major in Biology and Psychology.

About the Virginia Coastal Policy Center

The Virginia Coastal Policy Center (VCPC) at the College of William & Mary Law School provides science-based legal and policy analysis of ecological issues affecting the state's coastal resources, by offering education and advice to a host of Virginia's decision-makers, from government officials and legal scholars to non-profit and business leaders.

With two nationally prominent science partners – the Virginia Institute of Marine Science and Virginia Sea Grant – VCPC works with scientists, local and state political figures, community leaders, the military, and others to integrate the latest science with legal and policy analysis to solve coastal resource management issues. VCPC activities are inherently interdisciplinary, drawing on scientific, economic, public policy, sociological, and other expertise from within the University and across the country. With access to internationally recognized scientists at VIMS, to Sea Grant's national network of legal and science scholars, and to elected and appointed officials across the nation, VCPC engages in a host of information exchanges and collaborative partnerships.

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VCPC grounds its pedagogical goals in the law school's philosophy of the citizen lawyer. VCPC students' highly diverse interactions beyond the borders of the legal community provide the framework for their efforts in solving the complex coastal resource management issues that currently face Virginia and the nation.

VCPC is especially grateful to the Virginia Environmental Endowment for providing generous funding to support our work as well as to establish the clinic in fall 2012.

I. INTRODUCTION

Eastern Virginia relies on groundwater withdrawals from the Potomac Aquifer to supplement surface water sources.[1] Population increase, especially in the Hampton Roads region, has led to increasing demand, and overuse, of the aquifer.[2] In 2016, 138 million gallons per day (mgd) were pumped out of the aquifer to supply both large, permitted users and individual, unpermitted users.[3] Overuse of the aquifer is leading to severe consequences, including aquifer depletion, land subsidence, and saltwater intrusion.[4] Problems arise because the aquifer is a confined, pressurized system that loses pressure whenever water is withdrawn through a well.[5] As a result, brackish saltwater from the Chesapeake Bay can intrude farther into the aquifer, disturbing the present chemistry of the groundwater.[6] Additionally, the land sinks down into the depressurized aquifer; up to 50% of observed land subsidence in eastern Virginia is due to aquifer depletion.[7] This subsidence, in turn, contributes to coastal flooding observed in the low-lying Hampton Roads region.[8] Combined with sea level rise due to climate change, flooding is a recurrent, costly problem in eastern Virginia, especially for the military.[9]

The Hampton Roads region is one of the fastest growing population centers in Virginia, meaning that demand for clean drinking water is only increasing.[10] In response to this growing problem, the Hampton Roads Sanitation District (HRSD), whose mission is to treat the region's wastewater, has developed and begun to implement the Sustainable Water Initiative for Tomorrow (SWIFT) project to better reclaim treated wastewater by directly injecting it into the aquifer. Currently, HRSD's treated wastewater is simply released into surface waters but this process does not help replenish the aquifer because the natural replenishment of the underground aquifer through surface water seepage is much slower than the rate of withdrawal.[11] Under the SWIFT project, wastewater will be treated with advanced technologies and injected directly back into the aquifer. That way, the recycled wastewater is used to directly recharge the aquifer. HRSD elected to complete an aquifer replenishment system because it would be a more direct form of water recycling (compared to surface water discharge) and would address most of the problems associated with aquifer depletion.[12] First, injection of the treated wastewater would create pressure in the aquifer that would slow down land subsidence. Second, the pressure would also push back on brackish water intruding from the Chesapeake Bay. Third, by injecting the wastewater into the aquifer and not surface waters that empty into the Chesapeake Bay, it will be easier for Virginia

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[1] *See* generally, KURT STEPHENSON & ABT ASSOC.'S. INC., AN INVESTIGATION OF THE ECONOMIC IMPACTS OF COASTAL PLAIN AQUIFER DEPLETION AND ACTIONS THAT MAY BE NEEDED TO MAINTAIN LONG-TERM AVAILABILITY AND PRODUCTIVITY (2014).

[2] *Id.* at 15.

[3] VA. DEP'T. OF ENVTL. QUALITY, ANNUAL STATUS OF VIRGINIA'S WATER RESOURCES at 23 (2017).

[4] STEPHENSON, *supra* note 1, at 4-5.

[5] *Id.* at 2.

[6] *Id.*at 4-5.

[7] HAMPTON ROADS SANITATION DISTRICT, *Sustainable Water Recycling*, slide 5 (2015), https://www.hrpdcva.gov/uploads/docs/Attachment_01D_SustainableWaterRecycling.pdf [hereinafter HRSD Sustainable].

[8] *Id.*

[9] STEPHENSON, *supra* note 1, at 5.

[10] *Id.* at 23.

[11] HRSD Sustainable, *supra* note 7, slide 6.

[12] *Id.* at slide 10.

to meet Environmental Protection Agency (EPA) total maximum daily load (TMDL) requirements regarding pollutant discharges into the Bay. In addition, an aquifer recharge project is less expensive than some other water supply projects, like desalinization, which is comparatively expensive.[13] This paper will look at the costs of SWIFT, the advanced methods SWIFT will use to treat wastewater, and how to approach the risks and benefits of a project of this magnitude, with a special emphasis on emerging contaminants.

II. SWIFT DETAILS

A. Costs

HRSD intends to cover the full capital and operating expenses of SWIFT, subject to the EPA and U.S. Department of Justice accepting the HRSD Integrated Plan/Regional Wet Weather Management Plan (RWWMP).[14] Initial costs to get the project underway as currently planned will primarily consist of constructing seven injection sites around Eastern Virginia, and HRSD estimates that each site will cost approximately 128 million dollars to initiate, with an operating cost of 3.5 million dollars per year per site.[15] However, these plans remain in flux, so the projected costs may change.[16]

B. Advanced Water Treatment

SWIFT will operate by subjecting wastewater to several additional stages of treatment and purification. The treatment process has two simultaneous goals: the injected water must meet human drinking standards and must match the chemistry of the groundwater already in the aquifer.[17] For that reason, HRSD selected a carbon-based advanced treatment process with ozone-biofiltration at its core, because after extensive testing it was best able to both achieve contaminant elimination and match the background chemistry of the Potomac Aquifer.[18] The different treatment techniques and HRSD's choice of this approach are detailed below.

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[13] STEPHENSON, *supra* note 1, at 62-63.

[14] Email from Charles B. Bott, Director of Water Tech. & Res., Hampton Roads Sanitation District, May 22, 2018 (on file with the author). The HRSD is subject to a federal consent decree that settled a case brought by the Virginia Department of Environmental Quality and the EPA, alleging unpermitted discharges of sewage by the HRSD in violation of the Clean Water Act (E.D. Va., Feb. 23, 2010, as modified), https://www.epa.gov/enforcement/consent-decree-and-complaint-hampton-roads. The consent decree required HRSD to develop a RWWMP and install significant system upgrades to address sanitary sewer overflows and any other unpermitted or unauthorized discharges from HRSD sewage treatment plants. *Id*. On Sept. 29, 2017, the HRSD submitted to EPA and DOJ for approval an Integrated Plan/RWWMP incorporating SWIFT and providing an implementation schedule that takes into account SWIFT revenues and expenditures. *See* https://www.hrsd.com/sites/default/files/assets/Documents/pdfs/EPA/RWWMP%20Newsletters/RWWMP_AnnualNewsletterVol10-Issue1.pdf, https://www.hrsd.com/sites/default/files/assets/Documents/pdfs/EPA/Presentations/RWWMP_AnnualPublicMeetingPresentation20180123.pdf.

[15] HRSD Sustainable, *supra* note 7, slides 34-36.

[16] Bott, *supra* note 14.

[17] HRSD Sustainable, *supra* note 7, at slide 30.

[18] Hampton Roads Sanitation District, SWIFT RESEARCH CENTER, SWIFT WATER QUALITY TARGETS at 2-3 (2017) [hereinafter HRSD SWIFT Water Quality].

C. Oversight Committee

Legislation proposed in the Virginia General Assembly this year would have created a Potomac Aquifer Recharge Oversight Committee and Monitoring Lab.[19] The lab would have been run by scientists at Virginia Tech and Old Dominion University, who would have conducted independent tests of the water quality at each SWIFT injection site, along with aquifer sampling.[20] The committee would have ensured that the lab remained independent of HRSD, and would have met four times per year for the first three years of SWIFT operation, and once per year after that.[21] Although the bill failed, HRSD is committed to independent oversight and is working to establish the lab as planned via a Memorandum of Understanding with Old Dominion University, Virginia Tech, and other partners, as well as considering introducing legislation again next year.[22] HRSD is planning on covering the cost of the lab for the first three years, but will need additional funding either from users or the state after that.[23] HRSD is considering a permit withdrawal fee to help cover the costs of the lab once SWIFT is operational.[24]

III. EMERGING CONTAMINANTS

A. Microplastics

Due to society's accelerated use and reliance on plastics in many facets of daily and industrial life, plastic debris is being released into the environment at record high levels.[25] Over 300 million metric tons of plastic per year is produced worldwide, and up to 12 million metric tons are released into the world's oceans.[26] Microplastics are defined as small plastic particles 5 millimeters (mm) or less in diameter and can come from a wide variety of sources, including personal care products (microbeads), clothing (polyester fibers), and industrial cleaning products.[27] Scientists have documented microplastics throughout both terrestrial and aquatic environments, including at the Poles and on remote coastlines.[28] Part of the reason microplastics can so effectively move through the environment is their small size, which is optimal to be absorbed or ingested by animals low on the food chain.[29] The particles can then be dispersed, including into animals farther up the chain.[30]

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[19] H.B. 771, 2018 Sess. (Va. 2018).
[20] *Id.*
[21] *Id.*
[22] Bott, *supra* note 14.
[23] Telephone Interview with Charles Bott (Apr. 16, 2018).
[24] HRSD Sustainable, *supra* note 7, slide 36.
[25] Robert C. Hale, *Analytical Challenges Associated with the Determination of Microplastics in the Environment*, 9 ANALYTICAL METHODS, 1326, 1326 (2017).
[26] Tamara S. Galloway et al., *Interactions of Microplastic Debris Throughout the Marine Ecosystem*, NATURE, ECOLOGY & EVOLUTION, Apr. 2017, at 1.
[27] Yongfeng Deng et al., *Tissue Accumulation of Microplastics in Mice and Biomarker Responses Suggest Widespread Health Risks of Exposure*, SCI. REP., Apr. 2017, at 1.
[28] Robert C. Hale, *Are the Risks from Microplastics Truly Trivial?*, 52 ENVTL. SCI. & TECH., 931, 931 (2018).
[29] Galloway et al., *supra* note 26, at 3-4.
[30] *Id.* at 4.

As researchers continue to study the effects of microplastics in the environment, the question of the exact risks to ecological and human health remain largely unsolved.[31] Microplastics have received increasing attention, not only from scientists but politicians and the public as well.[32] This focus recently led to the Microbead-Free Waters Act, passed by Congress in 2015 to ban microbeads in personal care products.[33] Yet despite this increased attention, the exact risks remain unknown. For example, scientists have found evidence that ingestion and exposure to microplastics by some small aquatic animals hinders their ability to ingest their normal prey, resulting in nutritional shortfalls.[34] Rotifers and mussels are two examples that have evinced this trend.[35] Yet other ocean suspension feeders, including oyster and urchin larvae, show no ill effects.[36] Furthermore, mortality is rarely affected when studying animals of any size in controlled (laboratory) environments with plastic compared to without.[37] And when effects are seen, it is with microplastic concentrations orders of magnitude higher than seen in any real environment.[38] Another risk is that microplastics would make their way up the food chain, with the potential to eventually be ingested by humans. Research is limited in this area, especially in mammals. One study found some limited effects of oxidative stress in mice who were supplied with microplastic tinged water.[39]

Although microplastics have been found in most surface environments as well as the oceans, no data exists currently about the presence or potential effects of microplastics in groundwater aquifers.[40] Thus, the greatest risk is the unknown. Scientists predict that microplastics are present in groundwater because small particles can filter down through the soil when surface water slowly replenishes the aquifer.[41] Additionally, although the HRSD will be treating the injected water with turbidity objectives consistent with the highest quality drinking water, there is the possibility that direct injection of treated wastewater may contaminate the groundwater with any particles left over after the advanced treatment process (as explained below).[42] Scientists are unsure what affect these contaminants might have in the aquifer environment and if there would be any health risk when the water is then drawn out.[43]

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[31] G. ALLEN BURTON, MICROPLASTICS IN AQUATIC SYSTEMS: AN ASSESSMENT OF RISK 5-6 (2017).
[32] Albert A. Koelmans et al., *Risks of Plastic Debris: Unravelling Fact, Opinion, Perception, & Belief*, 51 ENVTL. SCI. & TECH., 11513, 11513.
[33] Microbead-Free Waters Act, 21 U.S.C.A. § 331(ddd) (West Supp. 2016).
[34] Galloway et al., *supra* note 26, at 4.
[35] *Id.* Rotifers are a type of microscopic sea animal.
[36] *Id.*
[37] *Id.*
[38] Burton, *supra* note 31, at 10-11.
[39] Deng et al., *supra* note 27, at 8.
[40] MARGARET MURPHY, EPA OFFICE OF WETLANDS, OCEANS & WATERSHEDS, MICROPLASTICS EXPERT WORKSHOP REPORT 11, 14 (2017).
[41] Interview with Robert C. Hale, Professor of Marine Sci., Va. Inst. for Marine Sci., in Williamsburg, Va. (Jan. 29, 2018).
[42] Murphy, *supra* note 40, at 10.
[43] Hale, *supra* note 41.

B. Pharmaceuticals

Pharmaceuticals include antibiotics, analgesics (anti-inflammatories), mood regulators (SSRI's), and endocrine disrupting chemicals like synthetic hormones.[44] The diversity of chemicals is vast. After the drugs are ingested, most are excreted and thus can make their way into wastewater. From there, they have been detected at varying levels in most aquatic environments, including creeks and rivers.[45] Traces of pharmaceutical residues have even been found in drinking water, although at harmless concentrations.[46] Still, as opposed to microplastics, the risk from pharmaceuticals are more concrete, simply because scientists know how the chemicals react with tissues in the human body. For instance, synthetic hormones can interfere with both female and male sex hormone function, as well as other endocrine pathways like the thyroid gland.[47] The risk of the unknown also remains because the pharmaceutical residues, once in the environment, break down and may interact with other chemicals.

IV. ADVANCED TREATMENT TECHNIQUES

Wastewater treatment proceeds through several stages before the water meets regulatory requirements and can be released into the environment. Primary and secondary treatment focuses on removing large scale contaminants and readies the water for advanced techniques.[48] There are several different major advanced techniques that each have unique characteristics, energy requirements, and costs.

A. Membrane Filtration: Reverse Osmosis and Nanofiltration

Membrane filtration pressurizes the water to move it through a selective filter to remove contaminants.[49] Reverse osmosis (RO) uses a filter that is essentially nonporous and uses solution-diffusion to remove solutes and ions from the water.[50] It is an effective technique for removing a wide range of contaminants, including pharmaceuticals.[51] However, because the membrane is nearly impermeable, it takes a large amount of energy to push the water through, and consequently RO is among the most expensive advanced techniques to install and operate.[52] In addition, HRSD found that RO treated water did not match the existing chemistry of the Potomac Aquifer because, in effect, RO "overcleaned" the water, removing so many impurities and ions (salts) that the treated water needed to be treated with salts to balance and match the pH to the groundwater before

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[44] CARSON O. LEE ET AL., STATE OF KNOWLEDGE OF PHARMACEUTICAL, PERSONAL CARE PRODUCT, & ENDOCRINE DISRUPTING COMPOUND REMOVAL DURING MUNICIPAL WASTEWATER TREATMENT 2 (2009).
[45] Thomas A. Ternes et al., *Removal of Pharmaceuticals During Drinking Water Treatment*, 36 ENVTL. SCI. & TECH. 3855, 3855 (2002).
[46] *Id.*
[47] Lee et al., *supra* note 44, at ES-1.
[48] Primary vs. Secondary: Types of Wastewater Treatment (Jan 22, 2014), http://archive.epi.yale.edu/case-study/primary-vs-secondary-types-wastewater-treatment.
[49] H. K. Shon et al., *Nanofiltration for Water and Wastewater Treatment - A Mini Review*, 6 DRINKING WATER ENGINEERING & SCI. 47, 47 (2013).
[50] *Id.*
[51] Lee et al., *supra* note 44, at 21.
[52] *See* Shon et al., *supra* note 49, at 47.

injection.[53] HRSD estimates that RO would cost about 7.2 million dollars per year per injection site.[54]

Nanofiltration is a newer technique and uses a membrane with a pore size of between one and five nanometers (nm).[55] The membrane operates with a fixed charge, so that the mechanism of action is not only size exclusion, but also some electrostatic action as well.[56] Even though the pores are on the nanometer scale, the pressure required to push water through the membrane is about three times less than needed for RO.[57] It is thus less costly to operate than RO while removing contaminants just as effectively. HRSD estimates that nanofiltration would cost about 6.4 million dollars per year per injection site.[58]

B. Activated Carbon: Biological and Granular Activated Carbon

Activated carbon refers to carbon that has been specially treated to have many microscopic pores, which greatly increase the surface area of the carbon. [59] As water passes over the granules in Granular Activated Carbon (GAC), contaminants are absorbed by the carbon.[60] Biological activated carbon (BAC) simply adds microorganisms to an activated carbon process to aid in the digestion of certain contaminants.[61] Activated carbon is a cost-effective treatment method that requires less energy to operate than a membrane filtration system.[62] Furthermore, studies show that a BAC/GAC system[63] is at least as effective at removing contaminants as a membrane system and, especially when paired with an oxidative process like ozonation, a BAC/GAC system can remove most major pharmaceuticals.[64] The ozonation process oxidizes the contaminants, making biodegradation easier.[65] While in isolation, an uncompromised RO membrane would remove more contaminants than a BAC/GAC filter, when combined with other advanced treatments like ozone and ultraviolet light (UV), BAC/GAC is about equal in contaminant removal.[66] In fact, HRSD ran a two year pilot program to compare the efficacy of RO and BAC/GAC processes that finished in early 2018. For the BAC/GAC process, HRSD treats wastewater with coagulation/flocculation/sedimentation and ozone before, and UV after, the activated carbon filtration.[67] The results of that study indicated that both treatment paradigms were equally effective at removing pathogens and emerging contaminants of concern.[68] In addition, water treated with

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[53] HRSD SWIFT Water Quality, *supra* note 18, at 2-1 to 2-2.
[54] HRSD Sustainable, *supra* note 7, at slide 34.
[55] Shon et al., *supra* note 49, at 48.
[56] *Id.*
[57] *Id.* at 49.
[58] HRSD Sustainable, *supra* note 7, at slide 34.
[59] PENGKANG JIN, BIOLOGICAL ACTIVATED CARBON TREATMENT PROCESS FOR ADVANCED WATER & WASTEWATER TREATMENT 155 (Miodrag D. Matovic ed. 2013).
[60] *Id.*
[61] *Id.*
[62] HRSD SWIFT Water Quality, *supra* note 18, at 2-3.
[63] This paper uses the abbreviated term "BAC/GAC" to refer to the overall process for advanced wastewater treatment because, in modern wastewater filtration systems, they are together because of how well they complement each other. The two processes are separate, and work differently to remove different contaminants.
[64] Ternes et al., *supra* note 45, at 3862.
[65] EPA, Wastewater Technology Factsheet 1 (1999), https://www3.epa.gov/npdes/pubs/ozon.pdf.
[66] JEFFREY J. MOSHER ET AL., POTABLE REUSE RESEARCH COMPILATION: SYNTHESIS OF FINDINGS 106 (2016).
[67] HRSD SWIFT Water Quality, *supra* note 18, at 2-5.
[68] *Id.* at 2-2.

BAC/GAC was a closer match to the existing chemical properties of the Potomac Aquifer and thus did not have to be treated with a salt solution like the effluent from RO.[69] HRSD chose an activated carbon system because it is the cheapest (an estimated 3.5 million dollars per year per injection site), delivers effluent quality on par with both RO and nanofiltration, and, since it uses less energy and chemicals, it is more environmentally friendly.[70] HRSD is continuing to refine the procedure to ensure it meets water quality standards and matches the native groundwater. In April 2018, the SWIFT Research Center came online in association with the recharge well at the Nansemond Treatment Plant in Suffolk.[71] The goal, over the next eighteen months, is to continue to monitor and refine the GAC/BAC process that was selected in the previous parallel pilot program while injecting a nominal amount of water at that well.[72]

V. SURVEY OF WORLDWIDE INJECTION PROJECTS AND THEIR APPROACH TO RISK

A. Texas: El Paso Water Utilities - Hueco Bolson Aquifer

Built in 1985, the Fred Hervey Water Reclamation Plant run by El Paso Water Utilities injects 12.5 millions of gallons of water per day into the Hueco Bolson Aquifer.[73] At thirty-three years old, it is one of the oldest groundwater injection projects in the United States.[74] Its advanced treatment process consists of ozonation followed by granular activated carbon (GAC), making it similar to HRSD's proposed treatment process for SWIFT.[75] With this set-up, the Fred Hervey Plant keeps contaminants 30-80% below Texas state permitting requirements and has won multiple awards from the National Association of Clean Water Agencies.[76] To mitigate risk, treated water is held for a minimum of eight hours where daily lab analysis involves testing the water for any contaminants.[77] Additionally, water at any stage of treatment can be diverted back to the headworks if any contamination problem is detected.[78] The plant recently was upgraded to increase the water output from ten to 12.5 million gallons per day.[79]

B. Australia

The Australian government, facing chronic water shortages due to an arid climate and exacerbated by climate change, has developed a comprehensive risk management strategy to uniformly assess all water recycling projects in the country, including groundwater recharge

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[69] *Id.*
[70] *Id.*
[71] *Id.* at 1-1.
[72] *Id.*
[73] El Paso Water, Fred Hervey Reclamation Plant, https://www.epwater.org/cms/One.aspx?portalId=6843488&pageId=10884159 (last visited Apr. 28, 2018).
[74] *Id.*
[75] *Reclaimed Water Plant Helps Quench El Paso's Thirst*, WATERWORLD, Apr. 1, 2011, http://www.waterworld.com/articles/2011/04/reclaimed-water-plant-helps-quench-el-pasos-thirst.html.
[76] *Id.*
[77] *Id.*
[78] *Id.*
[79] *Id.*

projects.[80] The government's philosophy is to complete a multistep risk analysis as each project is developed and completed. The goal was to identify risks ahead of time as much as possible, while also recognizing that water recycling was critical to maintaining the water supply in such a climate.[81] For example, under this risk management strategy, the injection site becomes just one place where water is tested and analyzed for contaminants: others include wells dug in the aquifer at successively farther distances from the injection site.[82] The theory is that some contaminants, such as those that are naturally biodegradable, will break apart as the water slowly moves through the aquifer, while others such as hazardous heavy metals, need to be fully removed even before the water is injected.[83] Thus, the Australian guidelines recommend different levels of testing at different stages of the water injection process based on the type of contaminant.[84]

HRSD's Research Center in Suffolk that will provide ongoing monitoring of the BAC/GAC filtration system is a good example of the risk management strategy employed by Australia. Now that HRSD has committed to carbon-based advanced treatment, the Nansemond Treatment Plant is continuing to refine the process to ensure the effluent water is fully compatible with the aquifer chemistry. As part of this refinement process, HRSD will also be using monitoring wells located 50, 450, 500, and 550 feet from the test injection well.[85] This is consistent with Australia's risk mitigation strategy of continual evaluation of the program.

C. California: Orange County Water District

A partnership between the Orange County Water District and Orange County Sanitation District operates the world's largest groundwater injection project, operating at one hundred million gallons per day.[86] The facility uses reverse osmosis coupled with ultraviolet treatment for additional disinfection.[87] Like HRSD, Orange County recognizes that no treatment process will be able to remove all contaminants, and that as detection methods improve, new contaminants will continually be found.[88] Thus, Orange County relies on a combination of treatment processes and a detailed risk management strategy based on system resilience. [89] One example of this is early level monitoring of the treated water, where water is tested at several steps along the treatment process instead of just as it is entering the aquifer in order to quickly detect problems.[90] Orange County has a contingency plan for managing "off-spec" water (when some contaminant is

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[80] NATURAL RESOURCE MANAGEMENT MINISTERIAL COUNCIL ET AL., AUSTRALIAN GUIDELINES FOR WATER RECYCLING (2009), http://www.agriculture.gov.au/SiteCollectionDocuments/water/water-recycling-guidelines-health-environmental-21.pdf (last visited Apr. 28, 2018).

[81] *Id.* at 3-4.

[82] *Id.* at 136-38.

[83] *Id.*

[84] *Id.*

[85] Hampton Roads Sanitation District, SWIFT RESEARCH CENTER, AQUIFER MONITORING & CONTINGENCY PLANS FOR MANAGED AQUIFER RECHARGE (2017) [hereinafter HRSD SWIFT Aquifer Monitoring].

[86] Orange County Water District, The Purification Process, https://www.ocwd.com/gwrs/the-process/ (last visited Apr. 29, 2018) (approximately 35 mgd of water are pumped into injection wells to create a seawater intrusion barrier, and 65 mgd are pumped daily to percolation basins to filter through sand and gravel to deep aquifers to increase the drinking water supply).

[87] *Id.*

[88] Mosher et al., *supra* note 66, at 105.

[89] *Id.* at 161.

[90] *Id.* at 164.

discovered) that is based on the time and distance the water is from users.[91] For groundwater injection projects, that time and distance provide more of a buffer than surface water because of how slow the water moves.[92] If a problem is detected, Orange County can divert off-spec water back through it treatment facility before it reaches the aquifer.[93] As described below, HRSD either has or is planning on implementing the same sort of risk management strategies, including the diversion of off-spec water.

VI. BALANCING OF THE RISKS

As with any scientific and engineering endeavor, the potential risks of the SWIFT project must be balanced against the potential rewards. Additionally, the cost of doing nothing to augment the aquifer should be taken into account.

A. Risks & Benefits

Much of the risk associated with an aquifer recharge project stems from the unknown. Microplastics and some pharmaceuticals are both considered emerging contaminants because scientists do not fully understand characteristics fundamental to determining the risk. For example, new drugs are released in the market constantly, so there is no way to know how the chemical byproducts of these new products react to existing treatment strategies. Similarly, the study of microplastics is a relatively nascent field. Techniques for identifying microplastics are struggling to keep up with the increased diversity of plastic products being used.[94] Another hardship facing detection is that microplastics slowly degrade while they are in the environment, eventually shrinking to the nanometer level.[95] The combination of small plastics with a lack of standardized detection technique means that operating a wastewater treatment plant necessarily means accepting the risk of some contaminants getting through the process.

On the other hand, the problems faced by eastern Virginia with depletion of the Potomac Aquifer are known and severe. Land subsidence, partially due to aquifer depletion, coupled with rising seas, means the low-lying Hampton Roads area is at even greater risk for costly and potentially catastrophic flooding. Saltwater intrusion from the Chesapeake Bay into the aquifer as the pressure gradient moves inland means reduced water quality, and the additional treatment measures necessary to treat brackish water are prohibitively expensive for the region.

Thus, the benefits of the SWIFT project are equally clear. Injecting recycled wastewater directly into the aquifer is currently the fiscally feasible way to replenish the aquifer at the speed necessary to keep up with demand. Saltwater intrusion will be kept at bay, and land subsidence would be slowed.

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[91] *Id.* at 167.
[92] *Id.*
[93] *Id.* at 167-68.
[94] Gabriel Erni-Cassola et al., *Lost, but Found With Nile Red: A Novel Method for Detecting and Quantifying Small Microplastics (1 mm to 20 µm) in Environmental Samples*, 51 ENVTL. SCI. & TECH. 13641, 13642 (2017).
[95] Galloway, *supra* note 26, at 1-2.

B. Balancing

While the risks of an unknown contaminant damaging the aquifer are real, so are the risks of doing nothing. Without SWIFT, the current groundwater permitting scheme would have to be limited to decrease overall withdrawals from the aquifer. Yet the population of the region is only increasing, and eventually some businesses that rely on the high-quality water that the aquifer can provide will have to find alternative sources or relocate. Thus, maintaining the status quo could hurt the regional economy and incur just as much expense as the SWIFT project. Other methods of increasing the water supply, like desalination of water from the Chesapeake Bay, would also be much more expensive than SWIFT in the long run.

It is also important to note that surface water sources also face contamination threats and pollution from human sources. In many cases, treated wastewater effluent that is released into surface waters undergoes less treatment than the advanced treatment techniques used in aquifer recharge projects. In early 2017, toxic chemicals were discovered in the Cape Fear River Basin in central North Carolina, the state's largest watershed and a source of drinking water for the area.[96] The toxicants were traced back to wastewater discharge sites in the basin.[97] According to Dr. Detlef Knappe at N.C. State University, who helped discover the source of the pollution in the Cape Fear River, it is impossible to regulate thousands of individual contaminants and track their removal. Instead, he thinks we need to require the installation of advanced treatment techniques that are capable of removing many classes of chemical and biological constituents in wastewater to keep the water safe.[98] For Dr. Knappe, the traditional paradigm of managing risk on a compound-by-compound basis is impractical in a world in which ~100,000 chemicals are on the market.[99] In fact, after researching the Cape Fear incident, Dr. Knappe believes aquifer recharge projects designed with advanced treatment processes for potable reuse on the whole entail less health risk than many unplanned potable reuse scenarios, where drinking water sources of communities are impacted by upstream discharges from wastewater treatment plants without advanced treatment processes.[100]

Similarly, Dr. Carlton Hershner at the Virginia Institute of Marine Science (VIMS) points out that the worst-case scenario from contamination of the aquifer is effectively the same result as doing nothing: an unusable aquifer.[101] But, Dr. Hershner notes that whereas the risk of doing nothing is quite severe, the risk of a worst-case type scenario happening with SWIFT is relatively slim.[102] And, there are many ways to mitigate the risk of contaminants in the aquifer. First, the injection process is quite slow: the water only moves a matter of feet per day when injected. According to HRSD's models, injected water in the Potomac Aquifer will migrate for decades before it reaches the first users.[103] HRSD has a comprehensive contingency plan if contaminated

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[96] Miles O'Brien & Ann Kellan, *Testing the waters: 1,4-Dioxane in North Carolina's Cape Fear River Basin*, NAT'L SCI. FOUND., May 2015, https://www.nsf.gov/news/special_reports/science_nation/capefearwatershed.jsp.
[97] *Id.*
[98] Phone interview with Detlef Knappe, Professor of Civil, Construction, & Envtl. Engineering, N.C. St. U. (Feb. 14, 2018).
[99] *Id.*
[100] *Id.*
[101] Phone interview with Carlton H. Hershner, Professor of Marine Sci., Va. Inst. for Marine Sci. (Mar. 19, 2018).
[102] *Id.*
[103] HRSD SWIFT Water Quality, *supra* note 18, at 2-7.

water is discovered at any point in the process.[104] If discovered early enough, the water can be diverted away from the injection well to receive more treatment.[105] Because of how slow the process is and how often the water is tested, only a small amount of water would make it into the aquifer before HRSD could shut down the injection and discover the cause of the problem.[106] Dr. Robert Hale, VIMS, recommends that treated water be subjected to a routine battery of tests to monitor the effluent.[107] Dr. Hale notes that techniques such as advanced mass spectroscopy not only would monitor the water but also preserve a historical record of the water being injected, so if a contaminant is discovered, scientists could look back to see when it first appeared.[108] SWIFT is employing many of these techniques. The Nansemond Treatment Plant pilot program includes detailed procedures regarding testing of the injected water for a broad spectrum of chemicals and contaminants.[109] Small amounts of effluent will be directed to the SWIFT Research Center where it will be monitored for contaminants including pathogens and pharmaceuticals and, after each test, small samples of the water will be kept as an archive of the water injected.[110] Monitoring the water is part of a broader risk mitigation strategy adopted by other localities, including Orange County, Australia, and El Paso, of intensively screening water up to the time of and shortly after injection. HRSD's monitoring strategies, too, are in line with this approach of careful monitoring.

A second mitigation is that, if a contaminant is discovered later in the process, after the water could effectively be removed from the aquifer, researchers and engineers will have the chance to develop a technique to filter out the contaminant once the groundwater is withdrawn for use, much the same way surface water is monitored and filtered now.[111] Scientists and engineers already must be mindful of emerging contaminants in reference to surface water sources, so adopting the same protocols for groundwater should not be much more burdensome. As Dr. Hershner points out, many scientific advances have been motivated by a need to solve a specific problem, so trust must be placed in the scientific community that they can detect and respond to contaminants as they emerge.[112]

VII. CONCLUSION

Microplastics and other emerging contaminants of concern pose a relatively unknown risk to the environment and human health. HRSD's SWIFT project, like other groundwater injection projects around the country and the world, will have to confront any risks as they are discovered. The advanced treatment techniques used by these projects are incredibly powerful and advanced, removing the vast majority of contaminants from wastewater, leaving it ready to drink and close in chemistry to the aquifer. The techniques, risk mitigation, and contingency plan in place for the SWIFT project are in line with some of the most successful aquifer injection projects in the world, so HRSD should be in an optimal position to deal flexibly with any risks that may be discovered in the future.

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[104] HRSD SWIFT Aquifer Monitoring, *supra* note 85, at 1-9 to 1-10.
[105] *Id.* at 3-3.
[106] *See* HRSD SWIFT Water Quality, *supra* note 18, at 2-7.
[107] Hale, *supra* note 41.
[108] *Id.*
[109] HRSD SWIFT Aquifer Monitoring, *supra* note 85, at 2-3 to 2-17.
[110] *Id.* at 2-29.
[111] Hershner, *supra* note 101.
[112] *Id.*