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October 24, 2025

Triangle Environmental
Onsite Non-potable Water Reuse for Commercial & Residential Buildings

Funding Background

Triangle Environmental (TE) was awarded $200,000 by the Middle Peninsula Planning District Commission (MPPDC) from two sources. The Virginia General Assembly provided funding for an elevated commercial unit installation outside of the floodplain on public property. Growth & Opportunity (GO) Virginia provided funding for a residential unit to be installed at publicly owned home inside the floodplain as part of their initiative to foster innovation and growth in the water economy via an award to Virginia Sea Grant (VASG). Both of these awards were provided to TE through the coastal adaptation and resilience business plan competition, RISE Resilience Innovations Rural Coastal Community Resilience Challenge. These two funding sources allowed for a more comprehensive understanding of both commercial and residential onsite systems.

Program Overview

Both funding opportunities were aimed at addressing the same problem – failing onsite wastewater (i.e., septic) systems in the Middle Peninsula. Two different statewide sources predict that 20,000 onsite systems will fail by 2040 in the Middle Peninsula alone and many more in other Coastal VA regions. Reasons for failure are due to increased flooding and sea level rise causing drainfield inundation. Meanwhile, solutions available in the market remain susceptible to these risks as septic systems and alternative systems are all subgrade systems (at risk of flooding) and drainfield improvements such as mounds are only temporary solutions as sea level rise continues to reduce unsaturated soil depth. Therefore, the need was identified for vertically elevating an onsite wastewater treatment unit above the floodplain and eliminating the drainfield as paramount priorities. Elevating the treatment unit illustrates that critical septic infrastructure can continue to be located in flood prone areas and kept safe from floods. The second priority was to eliminate the dependency on a traditional drainfield in areas with high water tables. Both of these goals are difficult to accomplish in an affordable manner for community members, necessitating the challenge disseminated by RISE to identify potential solutions.

TE is a research and development (R&D) company focused on providing innovative decentralized water and wastewater solutions that proposed a technology that could meet these two needs – elevated treatment that does not need a drainfield for treatment purposes. TE was awarded these funds to install two full-scale prototype pilot systems and demonstrate that is indeed possible to vertically elevate a treatment unit while no longer relying on a drainfield. This goal supported our business plan by providing an opportunity to demonstrate the real-world feasibility of our product and ease the financial difficulty of pushing new technology into a traditional market. Observing system operations in a representative market environment over a longer-term period was deemed necessary for ensuring product success.

The two full-scale pilot units (commercial and residential) were elevated at different vertical heights for different specific reasons. The residential piloting effort was completed in December 2024. However, the commercial pilot location was under construction at that time, so piloting did not start until the summer of 2025. In the meantime, a temporary commercial location was used to operate the second pilot system until the construction of the building for its intended use was completed.

The funding program was an overwhelming success. The funds allowed TE to demonstrate that it is in fact possible to vertically elevate a treatment unit, protected from increasing flood levels, which can then produce a high-quality effluent that does not rely on a drainfield for any treatment. The success of this program has already resulted in property owners reaching out to program stakeholders for inquiries as they have failing systems for which they have not been able to identify a viable solution. Meanwhile, the funds have enabled TE to enter the Coastal VA market and collaborate with stakeholders necessary to enable a successful rollout of this product. The difficulties involved in demonstrating new technologies in this market would have made market entry too expensive for TE to overcome without the funding from the VA General Assembly and GO VA.

High-Level Findings

- Two of TE's pilot systems were installed and operated in Virginia's (VA's) Middle Peninsula.
- The systems demonstrated treatment performance meeting VA's strictest effluent quality requirements.
- The systems were installed elevated above-ground, demonstrating the ability to be installed above flood elevations.
- The two previous features combine to demonstrate TE's technology as a solution that is adaptive and resilient to local conditions of today and tomorrow in that failing systems can be replaced by a solution that does not require a drainfield and can be protected and/or moved per changing climate conditions.
- The piloting process exposed TE to many key stakeholders who supported the steps involved from permitting, installation, long-term operations, and business partnerships.
- Due to the piloting demonstration, TE has received multiple purchasing requests for challenging systems that others have not been able to rectify.

Installation Overview

Site Details

The "RISE-Residential" piloting program took place at a three-bedroom, two-bathroom home in the "Lands End" or "Captain Sinclair" area of Gloucester, near Mobjack Bay. The home was sporadically occupied throughout the trial period with some residents in the home and some residents staying in campers/RVs on the property but using the home's facilities. Meanwhile the office area was used almost daily by at least one person. As such, the total use was still representative of a typical home in terms of total flow and type of wastewater.

The "RISE-Commercial" piloting program took place at a newly-constructed office building in King & Queen County named "HUB33" which houses MPPDC offices as well as a few other local businesses.

Both locations were plumbed to provide greywater separation so that testing could be completed with either septic tank effluent (receiving all wastewater from the building) or raw greywater (i.e., bathroom sinks, showers) to demonstrate the system's performance with both source waters as each has a distinct market application for climate resiliency. However, septic tank effluent treatment was prioritized as the more urgent local demand. Each system was installed for testing purposes only and in an arrangement that could do no harm. As such, existing treatment processes (i.e., drainfields) remained in place while TE's system intercepted wastewater upstream of the drainfield for testing purposes and discharged back into the original drainfield.

The timelines for implementation are provided below.

Table 1. Permitting and installation timelines for the Residential and Commercial systems.

Residential	***Commercial***
October 2023: Construction Permit received	February 2025: Construction Permit received
January 2024: Installation completed	May 2025: Installation completed
March 2024: Operation Permit received	June 2025: Operation Permit received
April – October 2024: Pilot Testing	June 2025 – Present: Pilot Testing
November 2024 – Present: Long-term operation	

Permitting

Each pilot site (Residential, Commercial, and the Temporary site) required a different permitting approach. Though differing approaches introduced some inefficiencies, the exposure to each pathway was a beneficial experience for TE as the company prepares for commercialization. Due to the complexities and nuances, TE had several meetings with Virginia Department of Health (VDH) personnel. The permitting pathways included the following:

- Residential – "Voluntary Upgrade" of an existing conventional septic system to an alternative system which required using VDH waivers that the local department was allowed to use at their discretion
- Commercial – Conversion of a "Conventional" system to an "Alternative" system for new construction which required requesting a permit variance that had to be approved by the State Health Commissioner
- Temporary Commercial – "Minor Modification" of an existing alternative system

Installation Details

Pilot systems were installed above-ground on an elevated platform. At the Residential location, the platform was elevated to three feet above the base flood elevation (BFE) per local building requirements for development in the Federal Emergency Management Agency (FEMA) insured area. At the Commercial location, the system was not elevated as high because of the placement outside of the flood zone, but still approximately one foot off the ground for demonstration purposes.

Figure 1. Pictures of pilot systems installed at their respective locations, Residential (Left) and Commercial (Right). Each system is elevated above ground level to demonstrate flood-proofing potential.

Operation Summary

Treatment Performance

Throughout piloting, samples were taken weekly by TE's local operator who analyzed them in a field lab setup via VASG assistance. Additional samples were occasionally taken to a third-party lab accredited by VDH to provide additional support for the treatment quality. TE's technology was designed to treat various types of domestic wastewater (e.g., septic tank effluent or greywater, residential or commercial strengths) and produce a final effluent meeting the strictest quality standards so that the treated effluent can go to any desired location – surface discharge, sub-surface discharge, and even non-potable reuse. TE combined VA and national standards to determine the strictest requirement for each parameter and ensure that our effluent met that target. Results in Table 2 display that TE's technology met the goal.

Table 2. TE's treatment system final effluent average values for key wastewater parameters and referenced against VDH's highest treatment level requirements. "Internal" values are from TE's operator testing while "3rd Party" results are from an accredited third-party lab.

	Residential Effluent		**Commercial Effluent**		**VA Limits**
Parameter	**Internal**	**3rd Party**	**Internal**	**3rd Party**	**Highest Level**
BOD (mg/L)	9	3	-	1	10
COD (mg/L)	22	10	45	45	-
TSS (mg/L)	0	2.5	0	0	10
E. coli (cfu/100 ml)	-	0	-	0	126

Internally-analyzed samples included multiple points throughout the treatment process and were evaluated to determine each unit process's ability to treat particular parameters and identify areas for future optimization.

A key advantage of how TE's technology operates is it provides consistent treatment despite climate or changing loading rates. In comparison, biological systems do not perform well when cold or under inconsistent use, whether too much or too little flow. The box-and-whisker plots below (Figure 2) demonstrate the wide variability of flow through the system along with feed and effluent characteristics. These results demonstrate that the system always produces high quality effluent, despite the wide variability in feed characteristics.

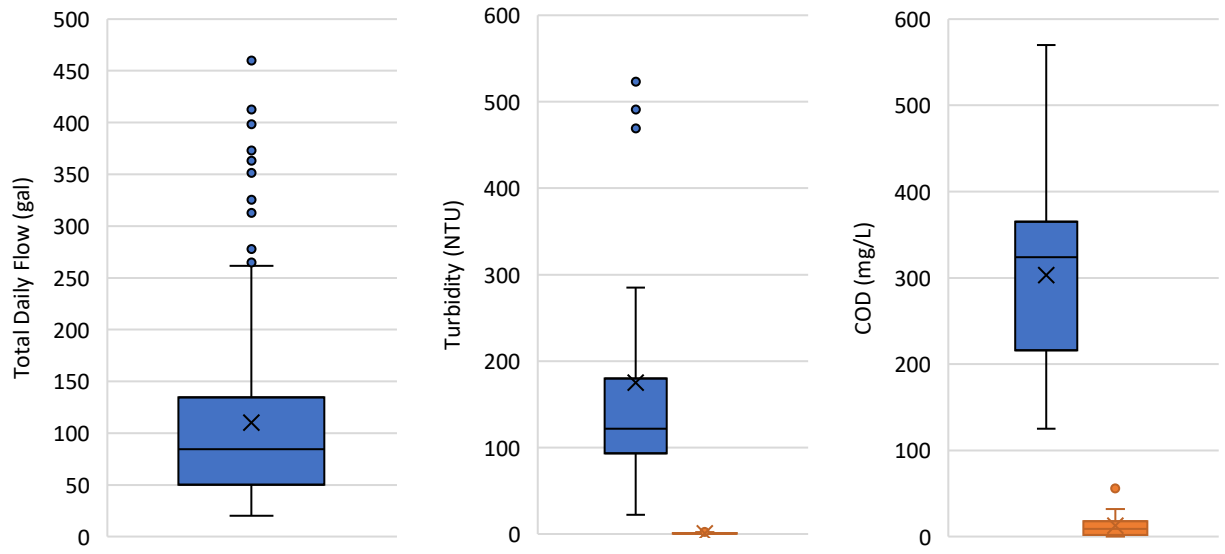

Figure 2. Variability in daily flow (left) along with variability in feed turbidity (middle) and COD (right) compared to effluent quality. Feed characteristics are blue while effluent characteristics are orange.

Operational Performance

The Residential system treated an average of 140 gallons per day while the Commercial system treated an average of 200 gallons per day.

Systems were installed with additional functionality to evaluate operational regimes that produced the highest amount of treated volume at the lowest possible energy. Additional features were also installed for monitoring purposes. Data from the piloting periods has resulted in updated designs that have confirmed conclusions from the trials.

Market Summary

The Virginia Department of Health Three Rivers Health District estimates that there are 79,990 septic systems within their district, which encompasses ten counties on the Middle Peninsula and Northern Neck. Estimates suggest that at least 25% of existing systems on Virginia's Middle Peninsula and Northern Neck will be vulnerable to sea-level rise and minor to moderate flooding by 2040[1]. Several of these counties have water tables that sit less than 25 cm (about 9.84 in) below the surface in large areas[2], and there is evidence of thousands of systems failing in low-lying areas already[3].

Using data on repair and replacement permits from VDH, a hotspot analysis from the Virginia Institute of Marine Science in 2021 estimated there were 1,148 onsite sewage failure hotspots across coastal

[1] Commonwealth Center for Recurrent Flooding Resiliency. (2020). *Future Sea Level and Recurrent Flooding Risk for Coastal Virginia* (CCFR Report 11). https://www.floodingresiliency.org/wp-content/uploads/2020/03/Future-Sea-Level-and-Recurrent-Flooding-Risk-for-Coastal-Virginia-Final-Version.pdf

[2] United States Department of Agriculture (2024). Web Soil Surveys. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

[3] Mitchell M, Isdell RE, Herman J and Tombleson C (2021) Impact Assessment and Management Challenges of Key Rural Human Health Infrastructure Under Sea Level Rise. Front. Mar. Sci. 8:631757. doi: 10.3389/fmars.2021.631757

Virginia[4]. Each hotspot represents a median of 17 houses, so we can infer an estimate of about 19,516 homes possibly associated with these hot spots. They also identified high density failure areas, where 25% or more of onsite sewage systems were failing. Their research identified 72 of these areas, representing roughly 1,224 homes, using the 17 home per grid median. The findings from this analysis imply that there are tens of thousands of homes in coastal Virginia that may already have failing septic systems associated with rising water tables or recurrent flooding.

To attempt to estimate the number of systems that may fail in the future, we used sea-level rise and flood modeling from the Commonwealth Center for Recurrent Flooding Resiliency (CCRFR). According to CCRFR, approximately a quarter of all parcels on the Middle Peninsula and Northern Neck will be inundated by sea-level rise or susceptible to minor to moderate flooding by 2040[5]. Across all coastal Virginia, they estimate 165,387 parcels will be vulnerable to sea-level rise and minor to moderate flooding by 2040. Statewide, 28% of houses are on septic or cesspool systems, and the percentage is undoubtedly higher in rural, coastal Virginia[6]. Still, pairing a conservative estimate of 28% of parcels on septic with CCRFR's modeling implies an estimate of over 45,000 possible vulnerable systems in coastal Virginia by 2040, just 15 years away.

Compared to existing systems on the market, TE's technology has a clear advantage in that it can be elevated above predicted flood levels, protecting the investment while protecting the environment. Meanwhile, its consistent high-quality effluent is not matched by competitors. Commercialization priorities will be ensuring that the system's final price point is similar to if not lower than existing products as well as keeping operational and maintenance concerns minimized. The price point can be difficult for TE to control due to reliance on external manufacturing, distribution, and installation companies along the product pathway; however, the base materials cost along with standard margins found through market research suggest that the final consumer price will be competitive.

Key Challenges & Findings

The pilot program was a resounding success with respect to TE's goals and expectations. The effluent quality being maintained and minimal operation required were significant achievements for the system's first field pilots treating septic tank effluent. However, this program elucidated opportunities to improve system design and operation.

[4] To identify hotspots they used the Emerging Hot Spot Analysis tool in ArcGIS, which examines patterns across both spatial and temporal scales. "It can identify continuous hot spots (where there are constant and high numbers of repair permits) and emerging hot spots (locations representing new, intensifying, or diminishing clusters of repair permits."
Mitchell M, Isdell RE, Herman J and Tombleson C (2021) Impact Assessment and Management Challenges of Key Rural Human Health Infrastructure Under Sea Level Rise. Front. Mar. Sci. 8:631757. doi: 10.3389/fmars.2021.631757

[5] Commonwealth Center for Recurrent Flooding Resiliency. (2020). *Future Sea Level and Recurrent Flooding Risk for Coastal Virginia* (CCFR Report 11). https://www.floodingresiliency.org/wp-content/uploads/2020/03/Future-Sea-Level-and-Recurrent-Flooding-Risk-for-Coastal-Virginia-Final-Version.pdf

[6] Galbraith, J. M., Zipper, C. E., Jr., R.B. Reneau, & Brown, P. J. (n.d.). *On-site sewage treatment alternatives*. Retrieved August 5, 2024, from https://pubs.ext.vt.edu/content/pubs_ext_vt_edu/en/448/448-407/448-407.html

Challenges already addressed

- The pilot system had more complexity than necessary for testing purposes only. Components have been identified to simplify the system and improve reliability and longevity.
- The elevated system is more exposed to cold temperatures, so future systems will be better insulated.

Key challenges to be addressed

- Nitrogen – The system was not designed for nitrogen treatment which will be required for many opportunities in the region. TE has one nitrogen treatment technology recently funded by VA Department of Environmental Quality (DEQ) for piloting demonstrations along with another that also demonstrates preliminary success. Both are easily integrated into the current technology.
- Final price – TE needs to further refine the distribution model to ensure a competitive final price point.
- Third-party certification – TE needs to secure founds to produce a next product version ready for third-party certification, enabling easier market rollout and credibility.

Next Steps

TE have spent the last several months actively engaging partners to support larger scale rollout including with crucial support from a permitting strategist, a manufacturing and distribution company, and a local installation and operation company. Each has provided important guidance on the next steps including an opportunity in which TE is providing designs and costs estimates on a commercial site with a failing system. It is possible that TE has a signed purchase agreement for their first sale at the start of 2026.