Climate Change and Onsite Wastewater Treatment Systems in the Coastal Carolinas: Perspectives from Wastewater Managers

Photo: Septic System Maintenance by Degler Waste Services, Ridgeland, South Carolina

Photo (left): Exposed septic tank in Folly Beach, S.C. (Wade Spees/The Post and Courier)
Photo (right): Ocean meeting home in Rodanthe, N.C. (Chicamacomico Banks Water Rescue)

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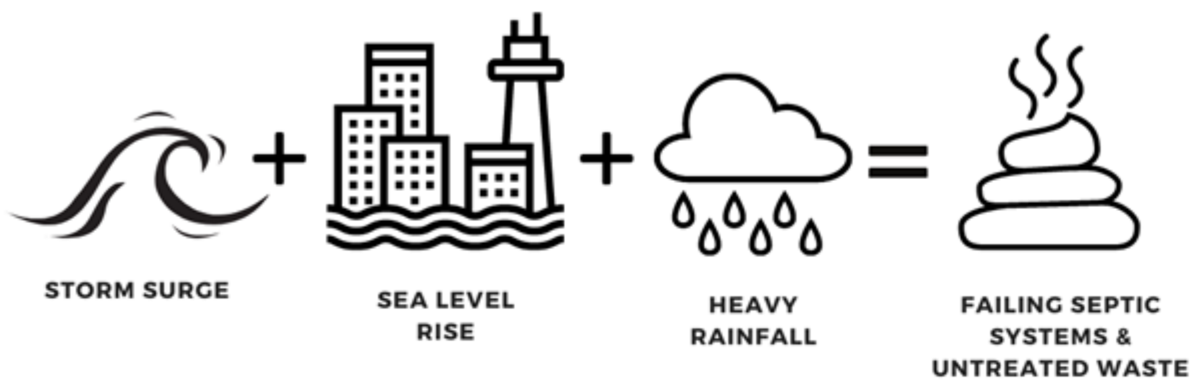
EXECUTIVE SUMMARY

Climate change is already being felt in the coastal Carolinas, and it will continue to pose a significant challenge for the foreseeable future. A warmer and wetter climate will impact many elements of our lives, some more visible than others. One less visible impact are the effects on decentralized, that is, onsite wastewater treatment systems (OWTS). These systems are used in areas without centralized wastewater treatment plants. They are generally out of sight and out of mind, even for the property owners who rely on them.

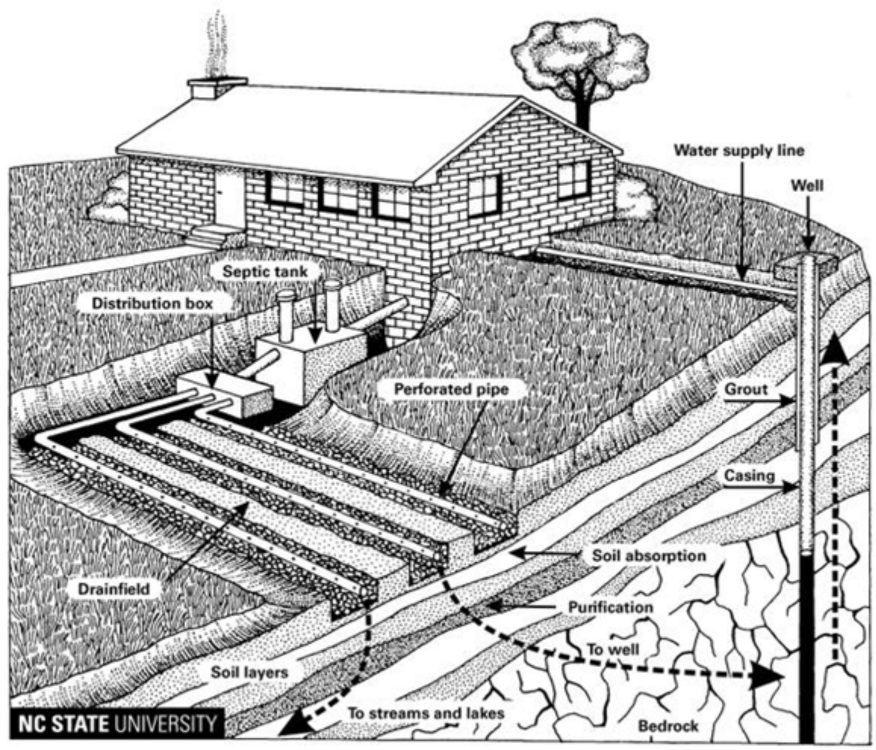
Almost half of residents in North and South Carolina have OWTS, either individual onsite septic systems or small community cluster systems. As climate changes, coastal communities relying on decentralized wastewater are particularly vulnerable. These systems can malfunction or even fail if exposed to storm surges, sea level rise, and heavy rainfall – disruptive weather events that are expected to increase in frequency and severity with climate change. Figure 1 depicts how climate change may impact septic systems in coastal areas.

Figure 1. Potential climate change impacts on septic systems.



Residents with OWTS have a variety of options to choose from, including conventional systems that treat less than 1,500 gallons of water per day and package treatment plants that treat effluent from a group of properties. A conventional system has three main parts: the septic tank, the drainfield, and the soil beneath the drainfield. The primary treatment of wastewater occurs in the soil beneath the drainfield. As sewage effluent enters and flows through the ground, soil particles filter out many of the bacteria that can cause diseases. The soil absorbs smaller germs like viruses and can retain chemicals like phosphorus and nitrogen. Figure 2 depicts a typical conventional system.

Figure 2. Wastewater treatment and disposal in the soil.[1]



This report documents the results of a study that was conducted to better understand the climate change impacts on OWTS. The intent was to learn from wastewater managers -- those who permit, regulate, select, install and maintain these systems. Surveys and interviews were conducted with 28 OWTS managers in the coastal Carolinas. Managers are from the private and public sectors, and included onsite wastewater operators and installers and county and state health officials charged with OWTS permitting and regulations.

Managers interviewed said that conventional systems are the cheapest and simplest option available but are not always sufficient depending on site conditions. There are numerous advanced treatment components that can be added for additional pretreatment and dispersal.

The managers described how saturated soils combined with disruptive weather events like heavy rain and king tides can cause conventional systems to malfunction. System operators and health regulators were provided with weather scenarios and asked if a system would malfunction. Dry conditions and heavy rain would not cause malfunction whereas wet soils and a disruptive event could according to the majority of experts interviewed.

Disruptive weather events like heavy rainfall have a negative impact on systems where traditional site variables are undesirable. Site conditions like drainage, soil type, elevation, groundwater height and slope are key to determining whether a weather event or shift in climate

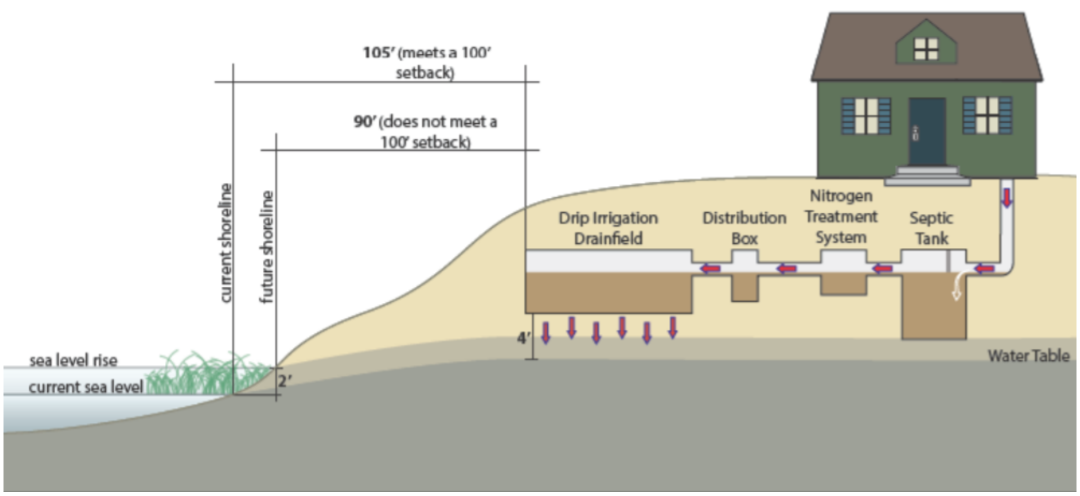
[1] NC State University Extension. 2016. Septic systems and their maintenance. https://content.ces.ncsu.edu/septic-systems-and-their-maintenance

will have an impact on system functionality. Site conditions in some coastal areas are already undesirable, leading to failing systems and constraining development in new areas. Disruptive weather events only worsen the condition of these sites.

Weather and climate however do not directly impact site approval or system selection. Rather, system installers and health regulators evaluate sites with a snapshot view of a single day. They measure vertical separation distance, i.e., the distance between the bottom of the drainfield and groundwater. They examine soil morphology which refers to soil texture, structure, clay mineralogy, and organic composition. They take into account issues like lot size and topography, number of bedrooms, and strength of wastewater. They consider horizontal setbacks to water bodies.

Although weather and climate are not factors considered directly in site or system evaluation, many system operators and health regulators are aware of how weather and climate may impact the variables they do evaluate. For example some managers mentioned that rising sea levels and hurricanes can impact soil conditions, and conditions such as the depth of the groundwater table and the height of the mean high water mark on ocean side lots can all impact setbacks. Figure 3 depicts the impact of rising sea levels on meeting setback requirements as well as the groundwater level beneath a septic system.[23]

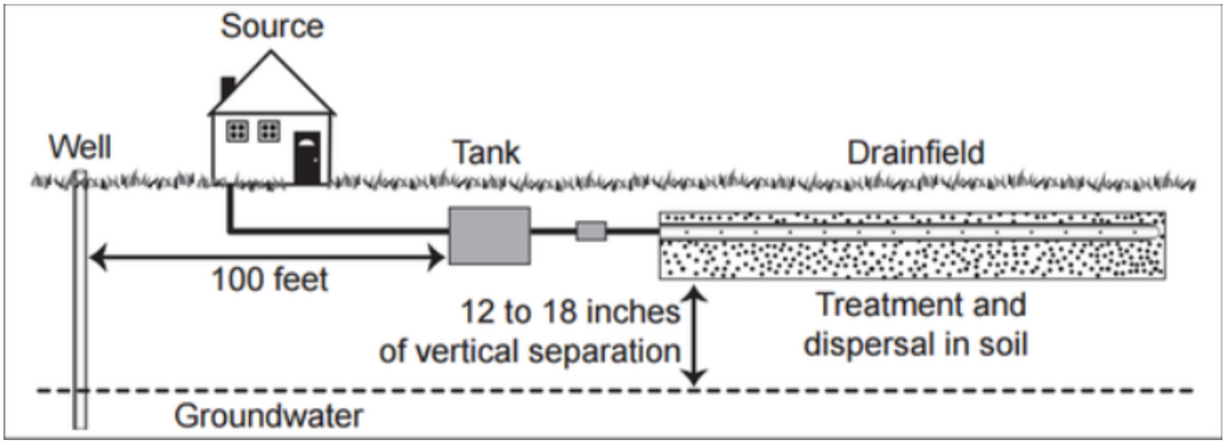
Figure 3. Impacts of rising sea level on septic systems and setback distances.[4]



[2] The North Carolina Sea Level Rise Assessment Report released in 2010 concludes that a 1 meter (39 inch rise) in sea level is considered likely along the NC coast within the 21st century. A 2’ rise is used in this diagram as an example scenario to illustrate the impact sea level rise could have on a septic system in the coming decades.
[3] The North Carolina Onsite Wastewater Rules (Section .1900 - Sewage Treatment and Disposal Systems) provides horizontal separation distances that are required between OWTS and various features, which vary from 5 feet to 100 feet. A 100 foot horizontal setback distance is used in this diagram as an example of how setbacks may be impacted by sea level rise.
[4] U.S. Environmental Protection Agency Office of Wastewater Management. 2013. A Model Program for Onsite Management in the Chesapeake Bay Watershed. *U.S. Environmental Protection Agency.*

In both states, a 12-18 inch vertical separation distance is required for conventional systems and up to 24 inches for package treatment plants.[56] This minimum vertical separation distance is determined by the measurement taken on the day of the site evaluation. Regulations do not require a buffer for rising groundwater table conditions, but some system operators and health regulators add some buffer just in case. Figure 4 depicts the vertical separation distance requirement.

Figure 4. Vertical separation distance required for conventional systems.[7]



Inspections of conventional septic systems are rare which means we have little data about how these systems are performing over time and before and after disruptive weather events. In North Carolina, conventional systems are not required to be inspected unless there is an obvious problem that needs to be investigated (e.g. bad smell or unsightly mess that prompts a complaint), whereas engineered systems do require regular inspections. The frequency of inspections for advanced systems depends on system type and varies by state. If a system fails an inspection in N.C., a notice of violation is sent to the homeowner, after which homeowners are to bring their systems back into compliance to avoid further regulatory action. There are no inspection requirements for conventional or engineered systems in South Carolina.

Communications with property owners about system regulations and requirements are limited, indicating a need for consistent information on system maintenance and causes of malfunction. Information is provided to owners when the system is installed, but after that, communication between regulators and owners varies depending on the local health departments and municipalities. There are some operators and realtors who will provide information on the

[5] 15A NCAC 18A .1956 - Modifications to Septic Tank Systems. Chapter 18 - Environmental Health. Subchapter 18A - Sanitation. Section .1900 - Sewage Treatment and Disposal Systems. Effective April 4, 1990.

[6] SC Regulation 61-56, Onsite Wastewater Systems. Statutory Authority: 1976 Code Sections 44-1-140 (11), 44-1-150, and 48-1-10 et seq.61-56. Onsite Wastewater Systems Department of Health and Environmental Control. Approved May 11, 2016.

[7] NC State University Extension. 2014. Why do septic systems fail? https://content.ces.ncsu.edu/why-do-septic-systems-fail

specifics of the septic system at a property when a house gets a new owner, but this is not universal.

While there are many educational materials available for system owners, the homeowner generally has to be proactive to gather such information. For example, information on septic system use after a flood could be useful but the owner usually has to seek it out. There is a need for targeted education to homeowners so that they can prepare for and recover their systems from disruptive weather events.

System adaptation is taking place in response to weather and climate shifts, despite no regulatory requirements to do so. The majority of septic installers interviewed are preemptively making adaptations. They are raising septic tanks and drainfields, using conservative installation measurements, and adding greater tank capacity. They are also installing advanced systems with pretreatment, drip irrigation, modified chamber features, and pressure. Additionally they are adding curtain drains, fill caps, silt application, and for package treatment plants, installing rain guards for manhole covers, membranes and bypasses. See the Appendix for a description of these features.

An easy solution to disruptive weather events is simply to let the system dry out -- to avoid use for a few days and/or pump the system if an issue is suspected. Long-term options include installing advanced rather than conventional systems. Advanced systems for an average home can cost between $25,000 and $30,000 whereas a conventional system generally costs under $10,000. Thus, this technological fix will only be available to those with sufficient financial means.

Ultimately, there is much variability in how OWTS managers perceive climate change and weather impacts on these systems. About half of the wastewater installers and operators said that repeated malfunctions caused by weather events have little to no impact on the system's overall life expectancy. Just as many said the opposite. Additional studies are needed to systematically test how OWTS perform under different weather conditions.[8]

[8] Parallel research to this study is being undertaken to evaluate performance of OWTS in the coastal Carolinas under different weather conditions.

INTRODUCTION

Almost half of residents in North Carolina (48%) and South Carolina (40%) rely on onsite wastewater treatment systems (OWTS), either individual onsite septic systems or small community cluster systems.[9] Most of these systems require a soil treatment area or drainfield to remove contaminants from the wastewater. As climate changes, coastal communities relying on decentralized wastewater are particularly vulnerable, as the effectiveness of drainfields are highly vulnerable to exposure from storm surges, sea level rise, and heavy rainfall. When drainfields are inundated by water, contaminant removal becomes less efficient, leading to negative water quality impacts for both ecosystems and human health.

We seek to better understand the climate change impacts on OWTS, and in this study, learn from coastal septic operators/installers (O/Is) and health officials charged with regulating and permitting these systems. Towards these ends, we survey and interview septic experts and professionals who service and regulate systems in the coastal Carolinas. The intent is to catalog the OWTS technologies used, how they function and are regulated, the potential impact that climate change may have on these systems, and the potential measures that may help coastal communities adapt onsite wastewater infrastructure to changes in climate and weather in the coming decades. Additionally, we gather cost data associated with installation and maintenance of these systems. This understanding will illuminate ways to move forward for coastal municipalities and government entities in developing adaptation strategies for onsite wastewater treatment systems in the face of rising sea levels and changing climate.

STUDY AREA

The study area is defined as the Atlantic Coastal Plain delineated by the U.S. Geological Survey, which includes three physiographic provinces: the Sandhills, Inner Coastal Plain, and Outer Coastal Plain (Figure 1). Counties that overlap with these provinces were identified for North and South Carolina to create a list of counties applicable to this study. Those counties are listed in Table 1.

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[9] Environmental Protection Agency. 2018. Septic Systems Overview. Retrieved from http://www.epa.gov/septic/septic-systems-overview.

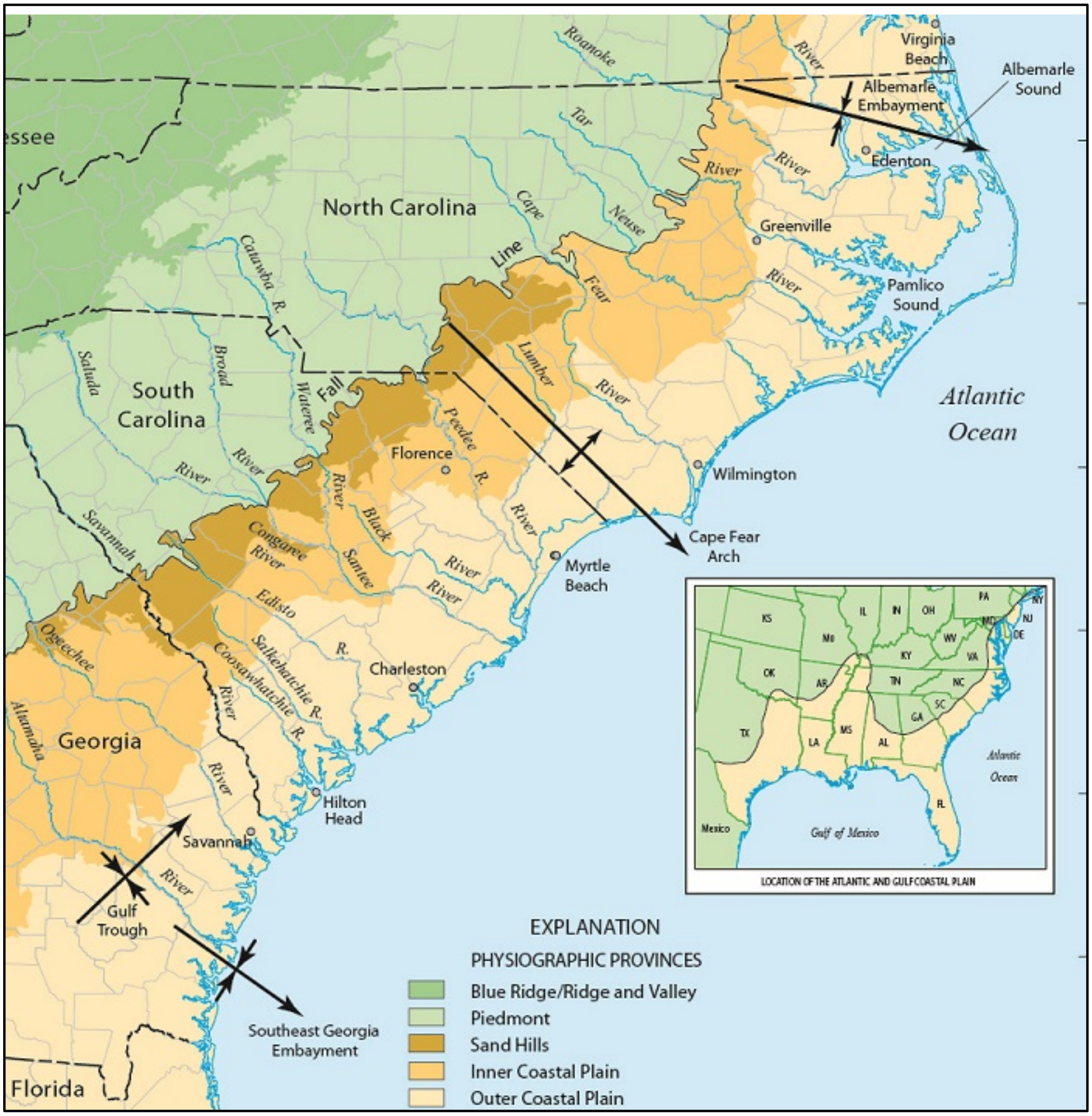

Figure 1. The Atlantic Coastal Plain along the Atlantic Coast of North and South Carolina and parts of northern Florida, Georgia, Virginia, and Maryland (U.S. Geological Survey. 1:100,000 scale).

Table 1. North and South Carolina counties included in the study area.

	Outer Coastal Plain		Inner Coastal Plain		Sandhills
North Carolina	Beaufort	Hertford	Bladen	Martin	Moore
	Bertie	Hyde	Columbus	Nash	Richmond
	Brunswick	New Hanover	Cumberland	Northampton	Lee
	Camden	Onslow	Duplin	Pitt	Hoke
	Carteret	Pamlico	Edgecombe	Robeson	Harnett
	Chowan	Pasquotank	Greene	Sampson	
	Craven	Pender	Halifax	Scotland	
	Currituck	Perquimans	Johnston	Wayne	
	Dare	Tyrrell	Jones	Wilson	
	Gates	Washington	Lenoir		
South Carolina	Florence	Berkeley	Calhoun	Sumter	Chesterfield
	Georgetown	Charleston	Clarendon	Allendale	Kershaw
	Horry	Colleton	Darlington	Orangeburg	Lexington
	Marion	Dorchester	Dillon		Richland
	Williamsburg	Hampton	Lee		Aiken
	Bamberg	Jasper	Marlboro		Barnwell
	Beaufort				

STUDY PARTICIPANTS

Study participants included 28 OWTS experts in coastal counties in North and South Carolina who completed an online survey and follow-up phone interview. The group consisted of 20 onsite wastewater O/Is and 8 county and state health officials. Wastewater O/Is were identified from publicly available lists, such as a list available on the North Carolina Septic Tank Association website. The North Carolina Septic Association provides the names, locations, and contact information for installers, inspectors, and subsurface operators in North Carolina. For South Carolina wastewater O/Is, we used a list provided by the South Carolina Department of Environmental Quality of subsurface operators.

Only wastewater O/Is who service the coastal counties of our sample area were eligible to participate in this study. Hence, we excluded O/Is whose business address was outside of the study area. We divided the coastal counties into northern counties and southern counties within both North and South Carolina. We randomly chose 4-5 potential participants from each of those four regions. In addition, we included three potential participants (randomly chosen) from each of the four counties (Craven County, N.C.; Dare County, N.C.; Pitt County, N.C.; Charleston County, S.C.) where long-term water quality research is being conducted with regards to onsite wastewater treatment.

Health officials were identified by referrals and snowball sampling as well as from the North Carolina Septic Association list, which includes environmental health specialists, program managers, and engineers in the state. Health officials charged with OWTS permitting and regulations in North Carolina include personnel from county health departments as well as the North Carolina Department of Health and Human Services (NCDHHS). Health officials charged with these tasks in South Carolina work for the South Carolina Department of Health and Environmental Control (SCDHEC).

Once potential study participants were identified, we called the professional to ask if they would be willing to participate in the study. They were then informed about the purpose of the study and the type of data being collected. If they agreed to participate, a web URL link to an online consent form was provided to the participant. Once the participant completed the online consent form, a phone interview was conducted. Wastewater operators also completed an online survey prior to the phone interview. Table 2 displays the county locations and occupation of the study participants.

Table 2. Number of study participants from counties in the coastal Carolinas

County, State	Wastewater Operator/Installer	Health Official
Beaufort County, N.C.	1	
Craven County, N.C.	2	1
Currituck County, N.C.	2	
Dare County, N.C.	2	1
Hyde County, N.C.	1	
Jones County, N.C.	1	
New Hanover County, N.C.	1	
Onslow County, N.C.	1	
Pasquotank County, N.C.	1	

Pender County, N.C.		1
Pitt County, N.C.	3	
State of N.C. (NCDHHS)		3
Beaufort County, S.C.	1	
Berkeley County, S.C.	1	
Charleston County, S.C.	1	
Chesterfield County, S.C.	2	
State of S.C. (SCDHEC)		2
TOTAL	**20**	**8**

SURVEY & INTERVIEW DESIGN: OPERATORS & INSTALLERS

An online survey was developed for wastewater O/Is and deployed via the online Qualtrics platform. The intent was to survey them about their experience with small- and large-flow systems and ask about their perception of effectiveness of various technologies. They were asked to describe how effective each system was at reducing nitrogen and phosphorus pollution, as well as fecal coliform bacteria. They were also asked about the required maintenance and life expectancy, resilience to flooding and extreme weather events like hurricanes, and the commonness of various systems.

An interview instrument was designed for wastewater O/Is to determine how they perceive extreme weather events to affect OWTS, potential adaptation measures, and costs of system installation and maintenance. Initial interview questions related to site conditions that determine how OWTS handle a heavy rain event or frequent rainfall, visible signs of failure, and the factors that influence system replacement decisions. Next, O/Is were asked about three hypothetical weather scenarios and how they would expect a conventional septic system to handle the conditions. They were then asked to describe the impacts of weather-related malfunctions, high groundwater tables and seasonal occupancy on system functionality and life expectancy. They were also asked to describe measures they are using to adapt septic systems to more extreme weather events. Next, they were provided with a description of four hypothetical properties in the coastal region and asked to identify an appropriate OWTS for the site and the costs of installation and management. Finally, they were asked about the availability of grants and loans for system replacement and repair in their region.

A handout was provided to all study participants to define the types of treatment, dispersal, and collection/conveyance systems they would be asked about in both the online survey and during the interview (Appendix 1).

RESULTS: OPERATORS AND INSTALLERS

Survey Results

Of the 20 total wastewater O/I who participated in the study, only 17 completed the online survey. Three O/I participated in an interview but not a survey. Some key survey results from the 17 participants are reported in this section, while the rest of the survey results are contained in Appendix 2.

Professional experience with OWTS

Of the 17 survey respondents, 13 work as operators or installers in North Carolina and four work as operators or installers in South Carolina (Figure 2). When asked what ecoregion they work in, they were provided with the map displayed in Figure 1 to identify their region(s), which delineates the Outer Coastal Plain, the Inner Coastal Plain, and the Sandhills region. Almost all respondents (16) said they work in the Outer Coastal Plain, three in the Inner Coastal Plain, and one in the Sandhills (Figure 3). Some participants work in more than one region. Ten participants (out of 17) work with OWTS on barrier islands like the Outer Banks or sea islands like Hilton Head (Figure 4). Most respondents (14) have more than a decade of experience working with OWTS in the coastal regions of the Carolinas (Figure 5).

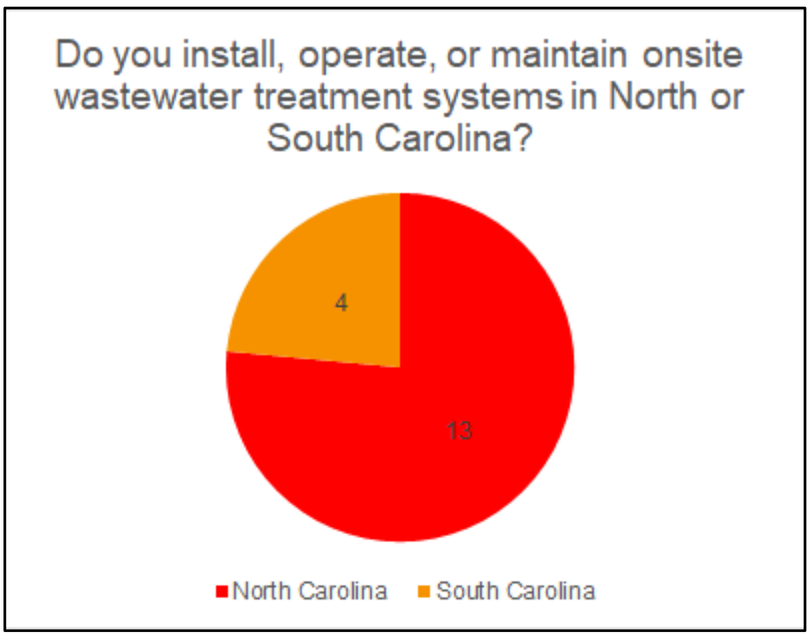

Figure 2. Number of survey participants in North Carolina vs. South Carolina.

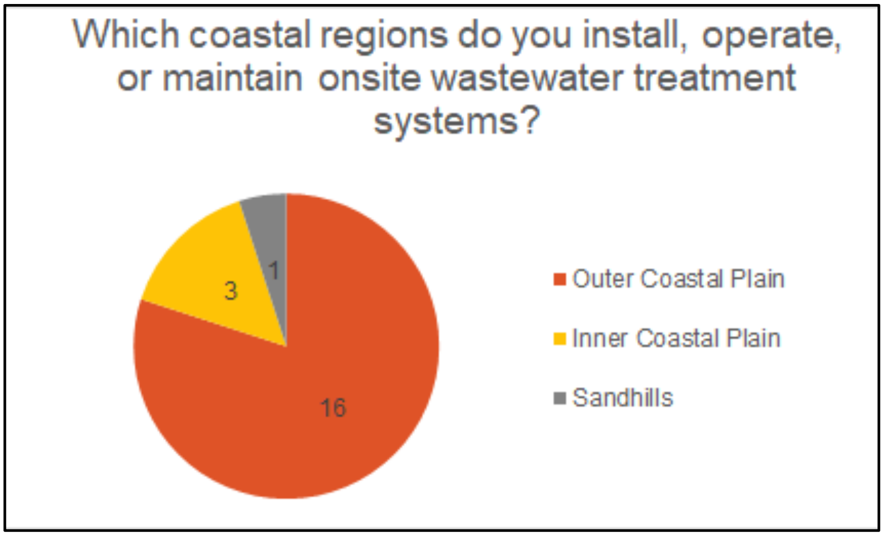

Figure 3. Number of survey participants who work in each coastal ecoregion.

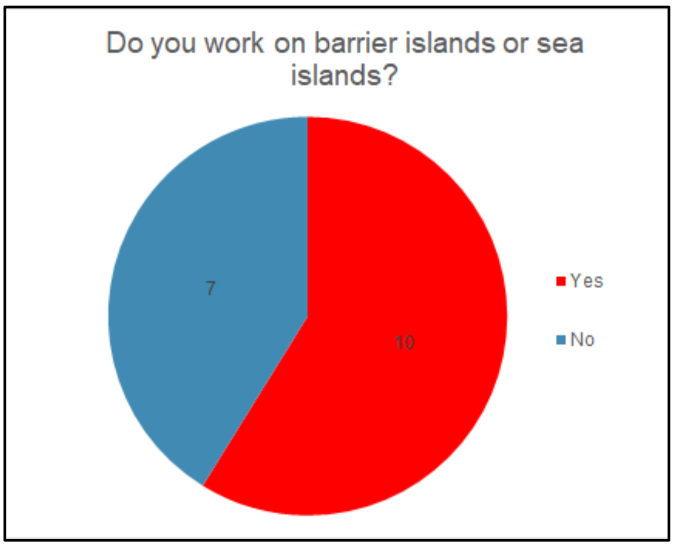

Figure 4. Number of survey participants who install, operate, or maintain OWTS on barrier islands like the Outer Banks or sea islands like Hilton Head.

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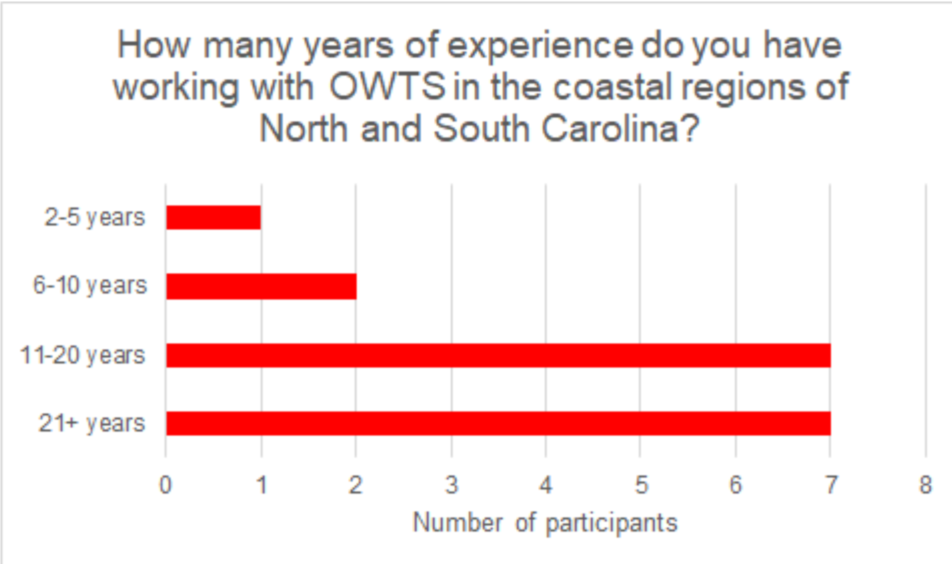

Figure 5. Participants' years of experience working with OWTS in the coastal regions of the Carolinas.

Small-flow systems

Almost all respondents (16) currently install, operate, or maintain small-flow (defined as treating less than 1,500 gallons per day) OWTS (Figure 6). Among those, most respondents (13) have more than a decade of experience working with small-flow systems (Figure 7).

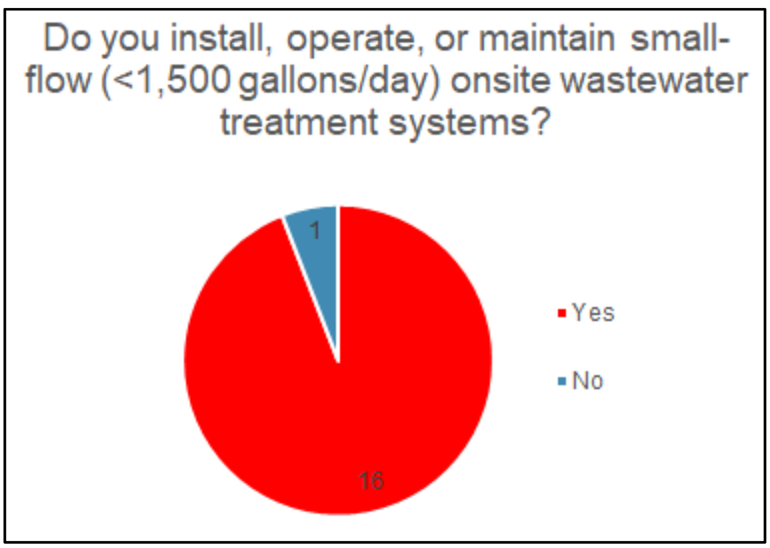

Figure 6. Participants who currently work with small-flow (<1,500 gallons/day) systems.

Figure 7. Participants' years of experience working with small-flow (<1,500 gallons/day) septic systems.

Large-flow systems

About half of respondents (9) currently install, operate, or maintain large-flow (defined as treating more than 1,500 gallons per day, including package treatment plants), OWTS (Figure 4). Among those, half (5) have between 11 and 20 years of experience working with large-flow systems (Figure 5).

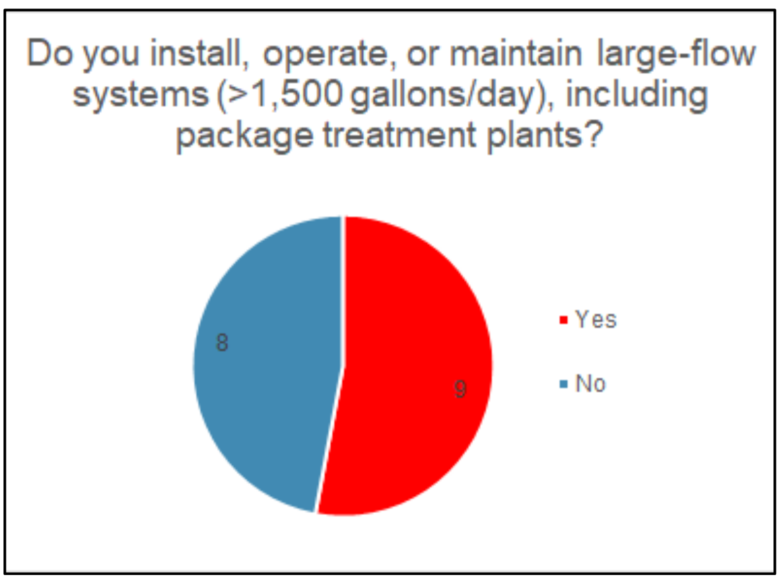

Figure 4. Participants who currently work with large-flow (>1,500 gallons/day) systems.

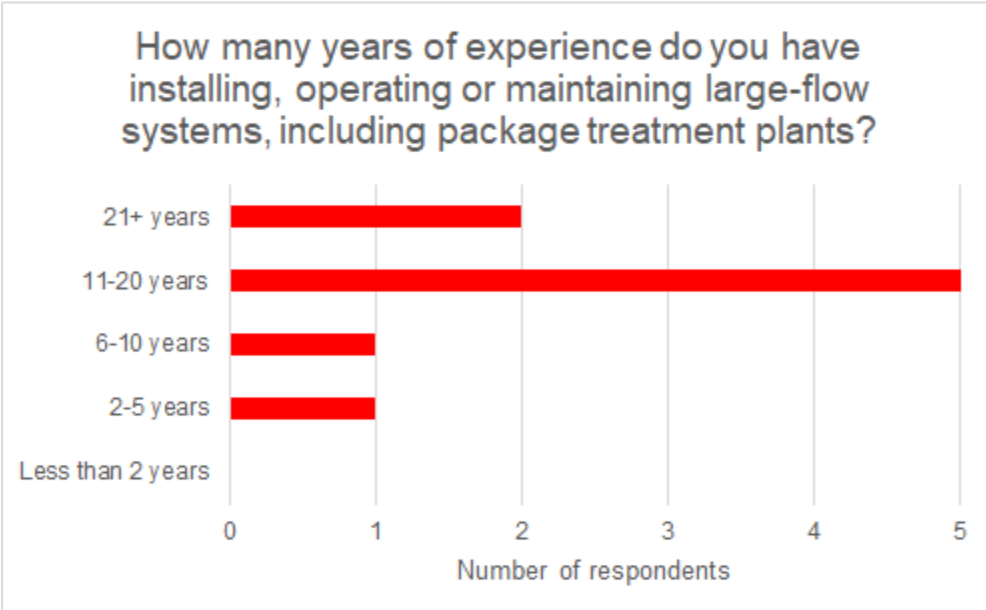

Figure 5. Participants' years of experience working with large-flow >1,500 gallons/day) septic systems.

Interview Results - Operators & Installers

Site Conditions

Wastewater operators and installers were asked about the site variables that determine how an individual/small-flow septic system handles a heavy rain event. The most important site condition variable was reported to be drainage: the rate at which a site can dispose of water or drain water away from the system and allow the dispersal field to dry out. Ten out of 20 respondents reported drainage as the most important factor. Specific aspects of drainage were also common responses including soil type (also referred to soil percolation rate, soil absorption, or soil texture), and elevation, and slope (Figure 1).

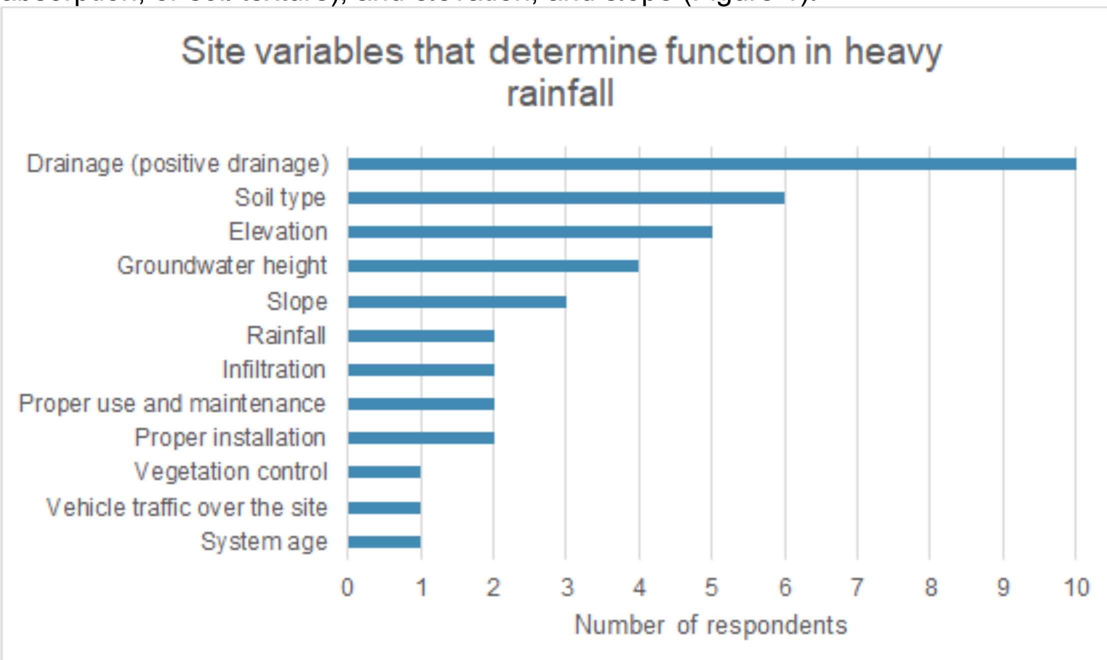

Figure 1. Site variables that determine how an individual septic system functions during extreme weather conditions.

Similar responses were given to which site variables determine how well a small-flow system responds to frequent rainfall events, with the three most common responses (each noted by 7 respondents) being positive drainage on the site, elevation, and groundwater table height/proximity to the water table (Figure 2).

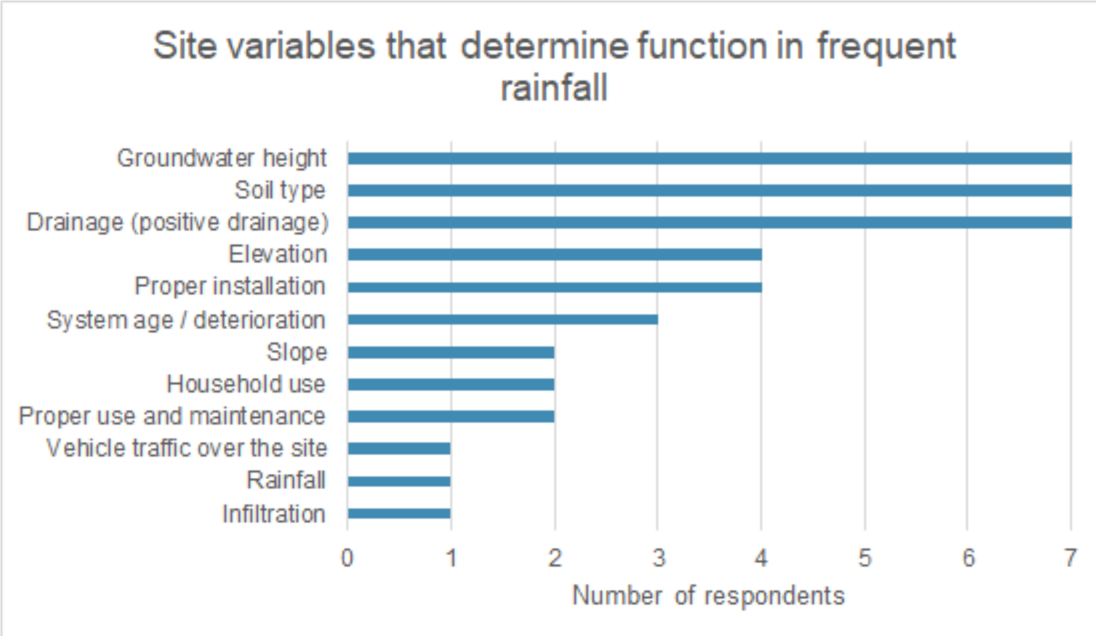

Figure 2. Site variables that determine how an individual septic system functions during frequent rainfall.

When an individual septic system is failing, the most frequently reported sign of failure was ponding of septic tank effluent over the drainfield, noted by 17 respondents. They also described this issue as visible water, surfacing water, or standing water. Also frequently seen when a system is failing is backing up of the plumbing system inside the house, which was noted by 6 respondents (Figure 3).

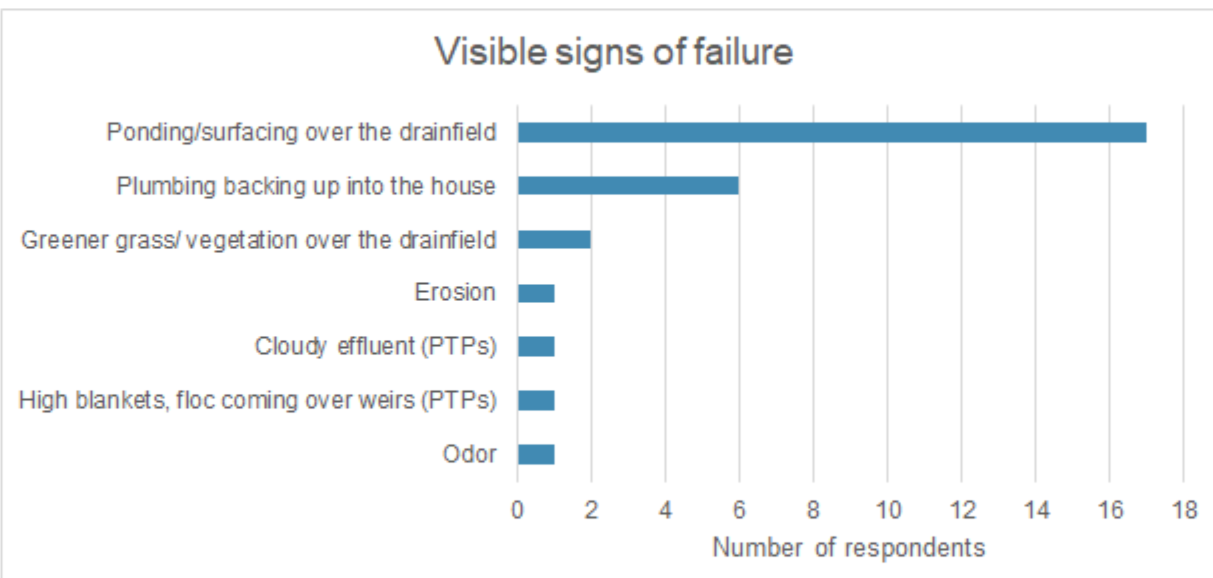

Figure 3. Visible signs of failure in small-flow and large-flow septic systems.

System replacement factors

About half of respondents (10) reported that ponding or surfacing water above the tank or drainfield is a key indicator that a septic system needs replacement. An additional 5 respondents said if the plumbing in a house is backing up, then the system likely needs to be replaced. Four respondents reported that if the system starts to require frequent pumping (every 1-2 months), that is also a good indication of system failure. The following indicators of septic system failure were each noted by two respondents:

- Green patches growing on top of the drainfield;
- Damage to the septic system from a vehicle driving over it or from tree roots growing into the inlet and/or outlet,;
- Damage to the drainfield by tree roots or vehicles compacting the soil; and
- An order by the local or state health department or a complaint by a neighbor

A total of one respondent reported that the following were key indicators that a system is failing and needs to be replaced:

- Solid waste builds up in a package treatment plant and there is insufficient cubic feet for proper treatment of the wastewater;
- Water quality testing of the effluent in a system consistently indicates poor treatment;
- If a package treatment plant is no longer safe to operate; and
- A package treatment plant is spilling or dumping out untreated wastewater in the surrounding environment.

One additional respondent explained that a system should be replaced at whatever point the homeowner is able to afford it, indicating that cost is a major prohibiting factor for homeowners.

Weather Scenarios

Participants were asked about three hypothetical weather scenarios and how they would expect a conventional septic system to handle the conditions. The first scenario was dry conditions for a long enough time to create very dry soils, after which there is an intense rainfall event that produces 2” of rain in one day. The second scenario describes an inland coastal area that is more than 1 mile from the ocean. Soils are saturated from prior rainfall, and then there is a heavy rainfall event that produces 2” of rain in a day. The third scenario describes a coastal area within 1 mile from the ocean. Again, soils are saturated from prior rainfall, and then the area experiences a high tide/King Tide event that causes a high tide that is 12” above average.

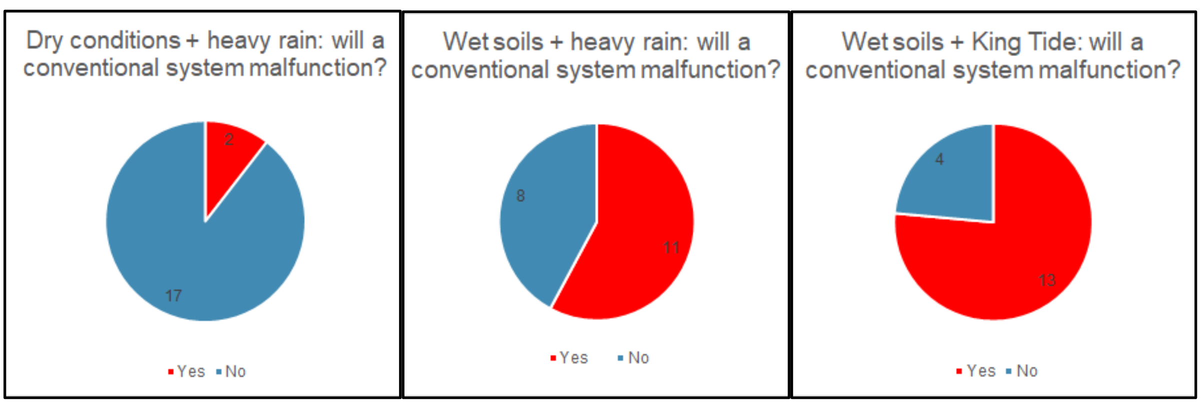

Figure 4. Comparison of whether or not a conventional system would be expected to fail under three hypothetical weather scenarios.

Scenario 1: Dry conditions + 2” rainfall

When asked whether or not they would expect a septic system to malfunction in these conditions, 17 out of 19 respondents said no, while two said yes (Figure 4). The two participants who responded “yes” estimated the length of time it would take for a system to recover after such an event. One respondent said it should recover within 24 hours and the other said, while it depends on many variables, it may take between 3 and 7 days.

Six respondents reported that there is no amount of rainfall that should cause a system to fail in well-draining soils, provided the system was working properly beforehand. Four respondents said that several days of consecutive days of rain would likely cause a system to fail, and an additional four participants said that it would take multiple weeks of wet conditions (slow rain) followed by a 2” rain event to cause a system to fail. Three respondents said a system would likely fail if there were high water table conditions present and the area then experienced a 2” rainfall event. Another three respondents said that it would take quantities of rainfall that are typical during a hurricane (7-8” of rain) for a system to fail from rainfall. Two participants reported that poor drainage would cause a failure from a rain event, either because the property is in a low-lying area or due to improper installation, and one participant said a system malfunction would likely happen if the water table has been high for a long period of time, perhaps for 1-2 months.

If a system were to fail under dry conditions followed by a 2” rainfall, 8 respondents reported that there is no maintenance needed to regain function – the system will recover on its own given sufficient time to dry out. Seven people said that the tank and/or distribution box should be pumped out in such a scenario in order to give the drainfield time to rest and dry out. Four respondents said that after a malfunction in these conditions, the homeowners would need to allow the system to rest by reducing the water use in the house. Three respondents said that in order to regain function after a weather-related failure, the drainage and runoff on the site would need to be checked to ensure that the drainage pathways are moving. And another 3 respondents said that it is likely that part of or all of the drainfield would need to be replaced after a system malfunction from this weather event. One respondent recommended adding more dirt and grass seed on top of the drainfield to repair erosion by the rainfall event after a malfunction.

According to about half of the respondents (9), there is no difference in the maintenance required to regain function in a conventional system compared to an advanced system after a malfunction from a heavy rain event. More specifically, if the malfunction is caused by a hydraulic failure, then both conventional and advanced systems will need the same thing in order to recover: time to rest. Five respondents said that advanced systems tend to malfunction less frequently than conventional systems because they are usually designed to withstand adverse conditions (weather, high tides, etc.). Respondents further explained that many advanced systems are installed with two 1,000-gallon tanks, so they have a greater capacity to hold the water before it enters the drainfield. Four people explained that the difference between maintenance needed for a conventional system versus an advanced system after a weather-related malfunction is that different parts of the systems will likely need to be replaced. Specifically, part or all of the drainfield may need to be replaced in a conventional system, whereas in an advanced system, individual parts may need to be replaced such as wood chips, textile filters, peat filters, etc. The same concept is true in package treatment plants as well: in traditional PTP systems, solids may need to be removed and hydraulics may need to be adjusted, but in non-traditional systems, any moving part or filter can fail and need to be replaced. Three respondents said that advanced systems will need more maintenance than a conventional system after a weather-related malfunction, which may include checking the pumps, reconfiguring drainlines, adding an extra pump to the system, installing a mound in the drainfield, etc. One respondent for each of the following reported the difference between conventional and advanced treatment systems in terms of what maintenance is required to regain function after an extreme weather event:

- a conventional system needs to be pumped after a weather-related malfunction, and

- in advanced systems, all valves should be shut off prior to a flooding event so that the system fills with water beforehand, which protects it from being inundated by saltwater and sand.

When comparing what maintenance would be needed to regain function in small-flow systems versus large-flow systems, some respondents (4) reported that large-flow systems perform better in extreme weather events because they are designed to withstand large amounts of water, including from adverse weather conditions. Large-flow systems also have fail-safes that prevent pollution, so water can be treated more than once if necessary and can also be discharged out into the environment if the system is overwhelmed with volume. Three respondents said that there is no difference in the maintenance needs of the two types of systems – both large and small need time to rest and dry out to regain function. Two respondents for each of the following reported the difference between small-flow and large-flow systems in terms of what maintenance is required to regain function after an extreme weather event:

- large-flow systems typically need more time and work to regain function, and
- large-flow systems have problems when they have large quantities of water from infiltration through manhole covers, so it is important to identify any infiltration that is overloading the system.

Scenario 2: Wet conditions + 2" rainfall

When asked whether or not they would expect a septic system to malfunction in wet conditions followed by a heavy rainfall, about half of respondents (11) said "yes," while eight said "no" (Figure 4). The eleven participants who responded "yes" estimated the length of time it would take for a system to recover after such an event. Most participants commented that the length of time would vary greatly depending on many factors (i.e., soil type, drainage, proximity to surface waters, system use, etc.). In fact, one respondent said it was impossible to guess because the length of time is completely dependent on environmental factors (i.e., amount of sun, wind, and runoff). However, many respondents (7) estimated it would take between 2 and 7 days. Two respondents estimated between 10 and 14 days to recover. One respondent said it could take up to 30 days, which happened after Hurricane Matthew.

A handful of respondents (3) said that there is no amount of rainfall that should cause a system to fail in well-draining soils, provided the system was working properly beforehand. Two respondents said that several consecutive days of rainfall on top of saturated soils would likely cause a malfunction, and another two respondents reported that high water table conditions plus a prolonged slow rain in the area would likely cause a malfunction. A total of one respondent said that each of the following conditions would cause a system to malfunction:

- if there is enough rain to cause ponding/surfacing above the drainfield,
- if there are multiple weeks of wet conditions (slow rain) and then a 2" rain event in addition to that, and
- in areas that cannot drain effectively, either because it is in a low-lying area or due to improper installation.

If a septic system were to malfunction in this type of scenario, most respondents (17) explained that giving the system time to rest in some capacity is the only action that is required to get the system functioning again. To that end, some people (8) explained that no action is required – simply waiting for the system to dry out will allow the system to start functioning again on its own. Along the same theme, five respondents explained that a system should be given time to rest by reducing the water consumption coming from the house so that the drainfield can dry out. Four respondents said that the system should be given time to rest by pumping the tank and/or distribution box. A handful (3) said that in order to regain function after a weather-related malfunction, the drainage in the drainfield should be improved by checking the runoff on the site to ensure drainage pathways are moving properly or by raising the system with dirt/fill in order to create positive drainage. A total of one respondent said the following actions would be required to resume function in a septic system that malfunctioned as a result of this type of weather scenario:

- check the drainage and runoff on the site to ensure drainage pathways are moving properly;
- replace part or all of the drainfield;
- in a traditional package treatment plant, get the hydraulics in the system working again by removing the solids or change the way the water is moving in the system to create more backwashes; and
- in a non-traditional package treatment plant, there are a lot of moving parts that can fail or become overloaded, so replace these parts to get the system working again.

Scenario 3: Wet conditions + high tide/King tide event

When asked whether or not they would expect a septic system to malfunction in wet conditions followed by a high tide/King Tide event, most (13) respondents said "yes," while eight said "no" (Figure 4). The thirteen participants who responded "yes" estimated the length of time it would take for a system to recover after such an event. Some participants (5) said it should take 1-2 days after the water recedes, and another three participants estimated 3-7 days. Two respondents estimated 7 days, and two more estimated 10-14 days. One respondent explained that the length is dependent on many factors, so it could take as little as 4 days or as many as 20-30 days.

The third scenario asked respondents to consider saturated soil conditions from prior rainfall, after which the area experiences a high tide/King Tide event. A couple of respondents (2) said that there is no high tide scenario that would cause a malfunction in sandy soils, provided the system was working properly beforehand. A total of one respondent said each of the following conditions would cause a system to malfunction under saturated soils plus a King Tide event:

- old systems with poor site conditions (e.g., on low-lying sites) and systems that are already experiencing problems prior to the high tide event;
- high water table conditions plus a prolonged rain or 2" rain event in addition to the high tide event; and
- loss of power for a long period, which often occurs during a hurricane.

If a septic system were to malfunction in this type of scenario, most respondents (16) explained that giving the system time to rest in some capacity is the only action that is required to get the system functioning again. To that end, about half of respondents (10) explained that no action is required – simply waiting for the system to dry out will allow the system to start functioning again on its own. Along the same theme, four respondents said that the system should be given time to rest by pumping the tank and/or distribution box. Two respondents explained that a system should be given rest by reducing the water consumption coming from the house so that the drainfield can dry out. Another two respondents said that adding more dirt and grass seed on top of the drainfield to repair erosion caused by the rain event is the only maintenance that would be needed after a malfunction in these conditions. A total of one respondent said the following maintenance actions would be needed to regain function in a system that malfunctioned during a high tide event:

- replace all or part of the drainfield; and
- in traditional package treatment plants, change how the water is flowing through the system to get rid of as much water as possible, such as bypassing the filters.

Weather-related malfunctions & system life expectancy

Just under half of respondents (8) said that repeated malfunctions caused by weather events have little to no impact on the system's overall life expectancy because the soil would not be damaged by those events. Some explained further that rainfall does not impact a system as much as the flow coming out of the house. However, others (7) said that repeated weather-related malfunctions would likely shorten the lifespan of a system because the system would not be getting the rest it needs to function properly. Specifically, if the drainlines stay wet for an extended period, a biomat begins to form along the walls of the trenches and clogs up the drainlines. Two respondents said that the impact of repeated malfunctions on a system depends on how that system was functioning before the rain event and what the site conditions are for that system. These respondents explained that other variables have a greater impact on life expectancy, such as tree roots growing in the drainfield or a rising groundwater table. One respondent for each of the following said that repeated weather-related malfunctions would have these impacts on a septic system:

- for systems that are near the beach, septic systems can be pushed out of the ground and sometimes be washed away, and
- in package treatment plants, repeated power problems will cause parts of the plant to break and need replacing.

High groundwater tables

Most people interviewed (12) said that they have observed more problems with OWTS in areas where the groundwater table is high (Figure 5). Among those, 5 respondents said that there would be an overall decrease in functionality of the systems in areas with high water table conditions. Another 5 respondents said water backing up into the house and four respondents said ponding/surfacing water over the system were the most typical problems seen in such areas. A total of two respondents said the following were the types of problems seen in areas with high water table conditions:

- more green vegetation growing on top of the drainfield,
- premature failure in systems that had pre-existing issues, and
- biomat formation that clogs drainlines.

Finally, one respondent explained that systems in high groundwater table conditions often need to be pumped quite frequently, such as once per year.

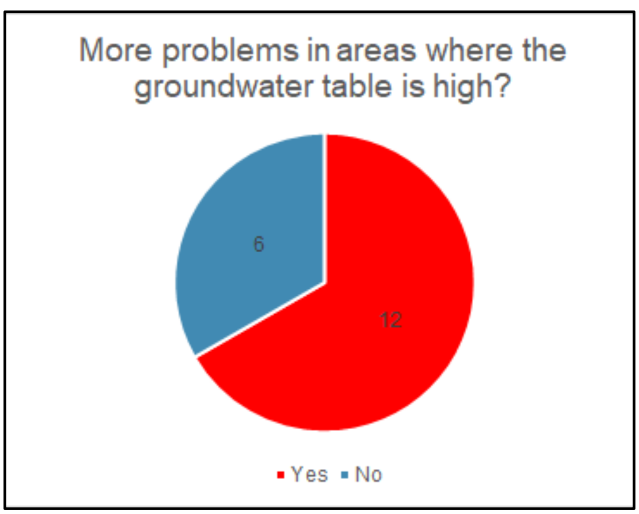

Figure 5. Portion of operator and installer participants who have noticed more problems with OWTS

functioning in areas with high groundwater table conditions.

Vacation homes

Nearly half (9) of respondents reported that seasonal occupancy at vacation home sites impacts the septic systems on those sites negatively. This can be attributed to higher than permitted occupancy at vacation homes during the tourism season, meaning the daily flow exceeds the design flow and the system is likely to be overloaded. Septic systems at seasonally occupied homes can also be negatively impacted by vacancy during the off-season, which causes biological activity to slow down, thus reducing the system's treatment capacity when it is in use again. However, some (5) respondents reported that seasonal occupancy impacts the septic systems positively because vacancies during the off-season allows the system to rest, so that it can handle more water during the occupied months. Another 4 respondents said that seasonal occupancy would have no impact on the septic systems. One respondent reported that the impact would be variable, meaning some system types perform better during high occupancy times, such as trickle filter systems and traditional package treatment plants, while others perform better during vacant periods, such as SBR package plants and biological sand filter systems.

Adaptation measures

More than half of the operators and installers (11) are implementing measures to adapt septic systems to more extreme weather events (Figure 6). Among those, 8 respondents are raising septic tanks up with fill to be partially or completely above ground and raising the drainfield to be shallower or above the ground. Raising the system up creates a greater vertical distance to the groundwater table. Another four respondents said they are being more conservative with installation measurements and recommendations for depth and loading rate for systems. This could mean installing the drainfield shallower or the dispersal area larger than required, increasing the width of the trenches in the drainfield to increase their water capacity, and installing greater tank capacity – either one 1,500-gallon tank or two 1,000-gallon tank instead of the standard one 1,000-gallon tank. After that, three respondents said that more advanced systems are being recommended and installed now because they discharge cleaner effluent. More chamber systems are also being installed instead of traditional gravel systems. A few respondents (2) are installing additional measures to adapt to more extreme weather, such as fill caps that provide an additional layer of soil on top of the drainfield and curtain drains to divert groundwater and rainwater away from the drainfield. One respondent said that system installation and recommendations have changed over time but could not provide specific changes that have occurred.

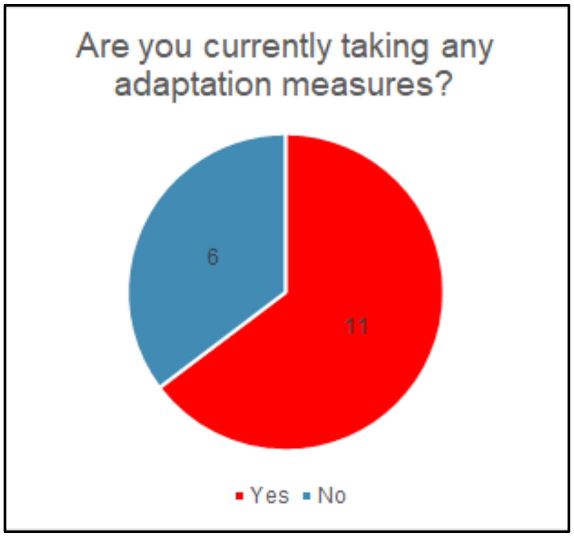

Figure 6. Portion of participants who are currently taking adaptive measures to improve OWTS functioning during extreme weather events.

Close to half (7) of respondents who said there have been adaptations and changes in system installations and recommendations said they do not know what prompted the change(s) because site decisions are up to engineers, county regulators, and state regulators. A handful of respondents (3) explained that the regulations issued by the state or county health departments have changed over time regarding how high the tanks need to be above the water table and there have been new disposal laws and new setback laws as well. Two respondents said that changes are prompted by changing use of the property and system (e.g., increased/ decreased water flow from the house, what is put down the pipes, etc.) or higher groundwater conditions. Another two said that they personally started making changes when they saw the improvements in function in the systems after such changes were implemented. A total of one respondent said that the following changes in installations or recommendations were prompted by:

- an increase in awareness and interest in water quality issues in coastal areas by the people living in the local communities, and
- there are fewer suitable sites available for traditional gravel trench systems than there used to be, so chamber systems are becoming more popular.

Respondents provided a list of many technologies that are improving or could improve the function of septic systems during extreme weather, higher sea level, and/or shallower water table conditions. Three respondents said that system elevation improves the functioning of systems in extreme weather – either raising the tank up with fill to be partially or completely above ground and/or raising the drainfield to be shallower or above the ground. Another three participants explained that more advanced systems such as those with pretreatments and drip irrigation systems are being used in environmentally sensitive areas such as near beaches. Modified systems are also being used more, specifically chamber systems are being installed instead of traditional gravel trench systems. Two respondents suggested pressure systems because they are able to handle large amounts of water, and another two recommended curtain drains to improve functioning of systems because curtain drains divert both groundwater and rain water away from the drainfield. A total of one respondent recommended the following to improve individual septic system function in extreme weather:

- Advantex systems;

- hurricane valves that allow a system to be shut off so it can fill up with water prior to a flooding event so that salt water and sand cannot enter the system and damage it or wash the tank away;
- silt cloth applications over trenches to prevent silt from going into the rock beds,
- fill caps that provide additional soil depth on top of the drainfield; and
- increased water capacity of the system which can be achieved by installing two pipes per trench instead of one and using a type of rock that can handle more water.

A total of one respondent recommended the following technologies to improve the functioning of package treatment plants during extreme weather events:

- spray irrigation technology for disposal of the water because they can dispose of large amounts of water;
- membrane technology because it allows the systems to generate reuse-quality wastewater;
- bypasses for filters that allow the system to get rid of water during extreme events;
- technologies that allow an operator to return water to the other side of a PTP system and change solid levels quickly; and
- rain guards for manhole covers to prevent infiltration into PTP systems.

An additional two respondents said they did not know of a technology or system that could help in extreme weather events, and another respondent said there is no technology that can help if the system is in a low-lying area with a shallow water table.

Respondents provided a wide variety of advanced treatment recommendations to improve septic system functioning during extreme weather events like the ones provided in the hypothetical scenarios (e.g., heavy rainfall, high tide/King tides, etc.) (Figure 7). Many respondents (7) recommended elevating the system, which includes installing shallow or above-ground systems or installing a mound with a single-pass or recirculating media filter or with an Aerobic Treatment Unit (ATU). Six respondents suggested pump systems for handling extreme weather conditions. These participants explained that installing two or three pump tanks and pumping to a low pressure manifold, LPP, or distribution box would increase the treatment distance to allow the system to handle more water. Another option they said is to pump the effluent to another site for treatment.

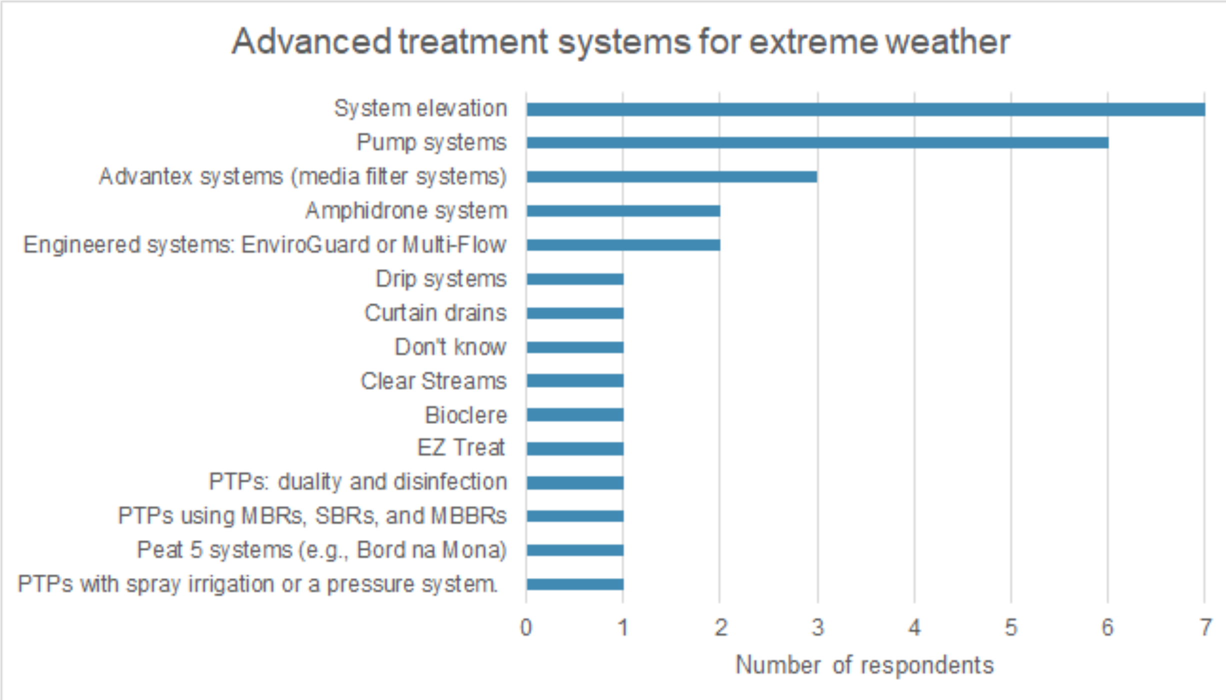

Figure 7. Recommendations for advanced treatment system options for handling extreme weather and large quantities of water.

Many respondents (8) reported that they would recommend advanced treatment for septic systems in areas where there are poor soils, meaning soils with low percolation rates (e.g., sandy loam soils and clay soils). Some (5) said they would recommend advanced treatment in high water table conditions, such as from a high groundwater table, high stream levels, or high sea level. Another four participants said they would recommend advanced treatment at sites with drainage problems such as those with elevation problems that prevent water from draining effectively away from the system. Three respondents said they would recommend advanced treatment when there are large quantities of water coming into the system from the house or surrounding areas and another three participants recommended advanced treatment when a system is going to be installed for a large house on a small lot. Finally, three respondents said they would recommend advanced treatment at all sites where a septic system was to be installed.

Costs of system installation and maintenance

Descriptions of four hypothetical properties in the coastal region were provided to respondents, who were then asked to think about the costs associated with installing OWTS on these properties. The first property described was intended to be an example of a standard home site: a 2,000 square foot home with four bedrooms on a ¼ acre lot, requiring a 480-foot drainfield. Just over half of respondents (11) recommended a conventional system for this property, among which four participants said they would install additions such as installing four trenches instead of three in the drainfield, adding a 12-inch fill cap on top, or installing a curtain drain on the property. A couple of respondents (2) said they would install a chamber system (specifically a 6” infiltrator), while another two said they would install a modified conventional system/gravelless trench because they require less square footage for treatment. Finally, two participants said they would install an advanced treatment system because of the small lot size (Figure 8). The specific type of advanced treatment would depend on the soils, elevation, and drainage on the site.

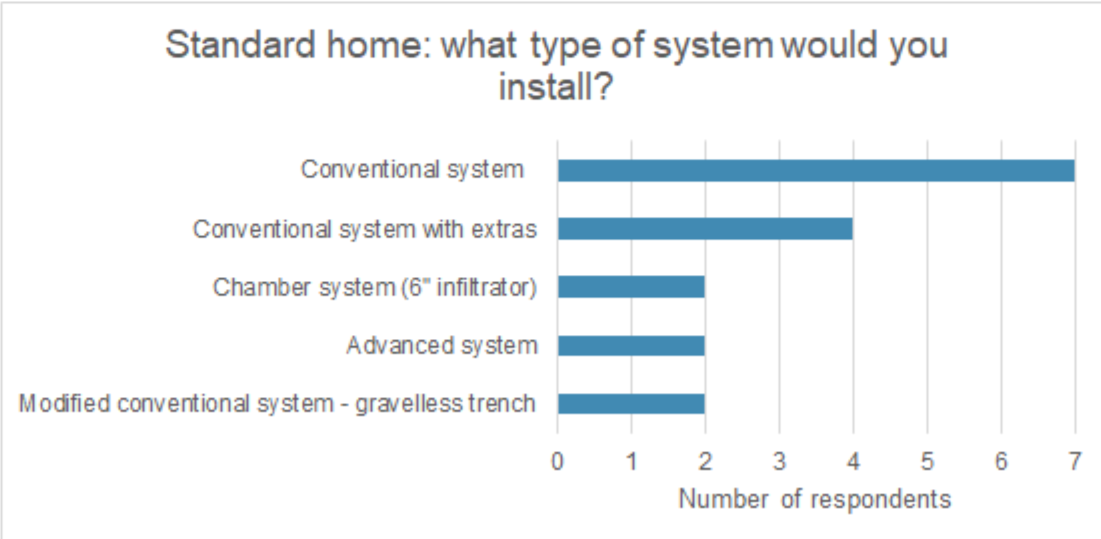

Figure 8. The type of septic systems recommended to be installed at a hypothetical standard home example site.

Estimations of installation cost for systems being installed at this standard home site varied depending on the type of system recommended (Figure 9). Almost half of respondents (9) estimated between $5,000 and $10,000 to install a conventional system, a conventional system with extra treatment capability, or a chamber system.

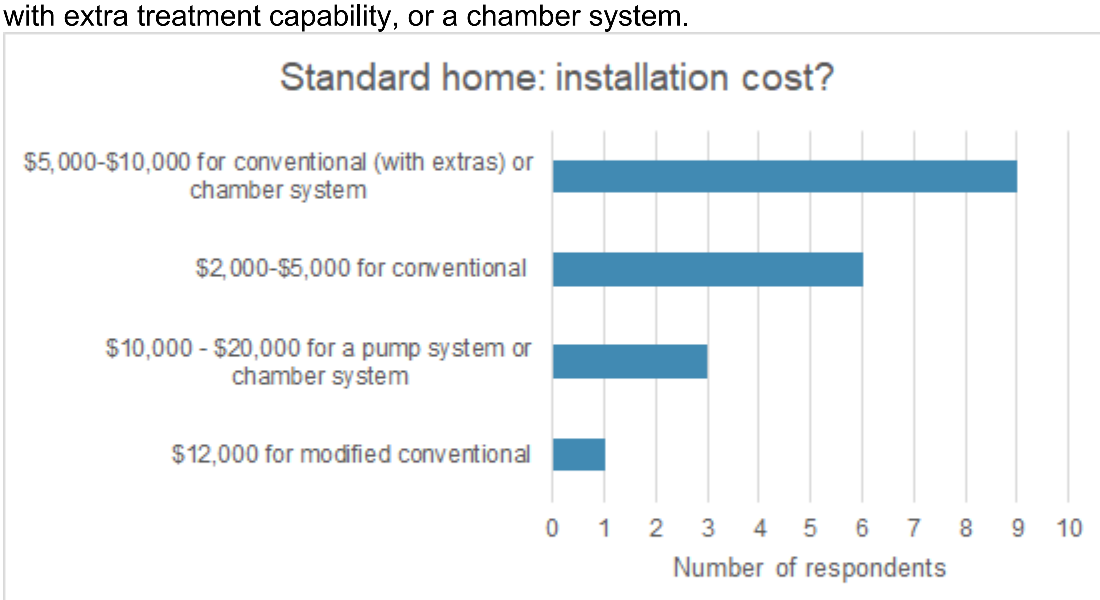

Figure 9. Estimated cost to install an onsite wastewater treatment system at a hypothetical standard home site.

The annual operational cost estimations also varied among interviewees (Figure 10).The majority of respondents (14) said that a conventional system should not cost anything in maintenance each year until it needs to be pumped (every 3-5 years). The cost of pumping a conventional system is between $150 and $500, which ends up being between $50 and $100 each year. One respondent remarked that "if it's put in the way it's supposed to and it's designed to, it shouldn't need any maintenance. I just tell them to put buttermilk in there once a month and leave it alone."

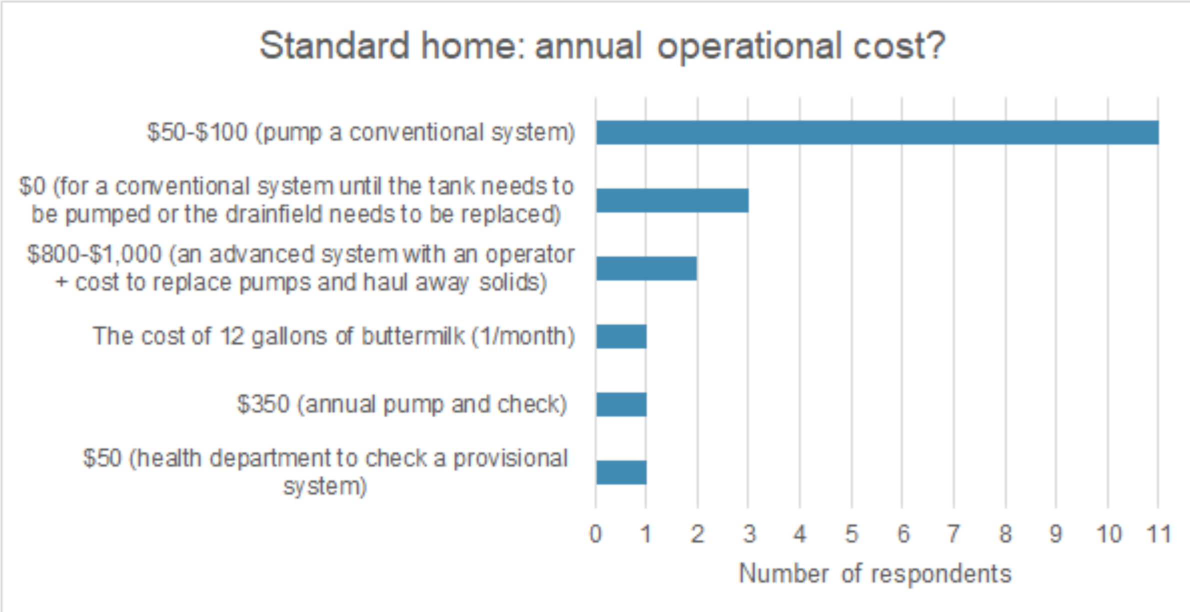

Figure 10. Estimated annual cost to maintain a septic system at a hypothetical standard home site.

The second property described to respondents was a vacation home site: a 4,000 square foot home with eight bedrooms on a ½ acre lot, requiring a 960-foot drainfield. The vacation home is assumed to have seasonal occupancy and thus seasonal fluctuations in use. Many respondents (7) recommended an advanced system with pretreatment for this property, such as media filter systems (e.g. Advantex), ATUs, peat systems or a Moving Bed Biofilm Reactors (MMBR) package treatment plant. Four participants said they would install a conventional system on this example site. Three participants said they would install a chamber system and another three said they would install an LPP system with pods and mulch chips. A few respondents provided a variety of other recommendations as well (Figure 11).

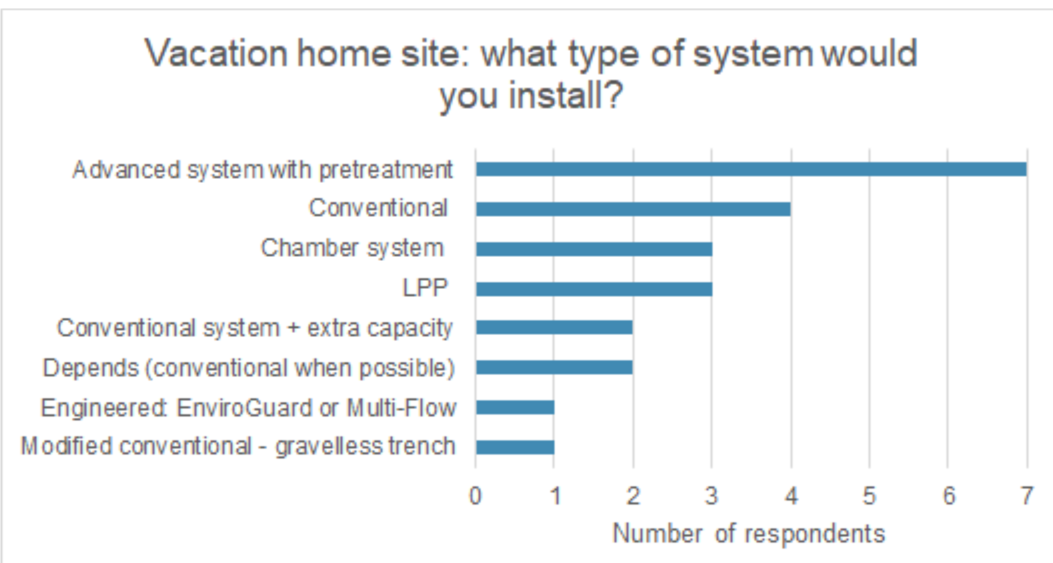

Figure 11. The type of septic systems recommended to be installed at a hypothetical vacation home example site.

Estimates of system cost at the vacation home site varied depending on the type of system recommended (Figure 12). Six respondents estimated between $25,000 and $30,000 to install an LPP system or an advanced system with pretreatment. Five respondents who recommended conventional treatment for this site estimated the installation cost between $4,500 and $9,000.

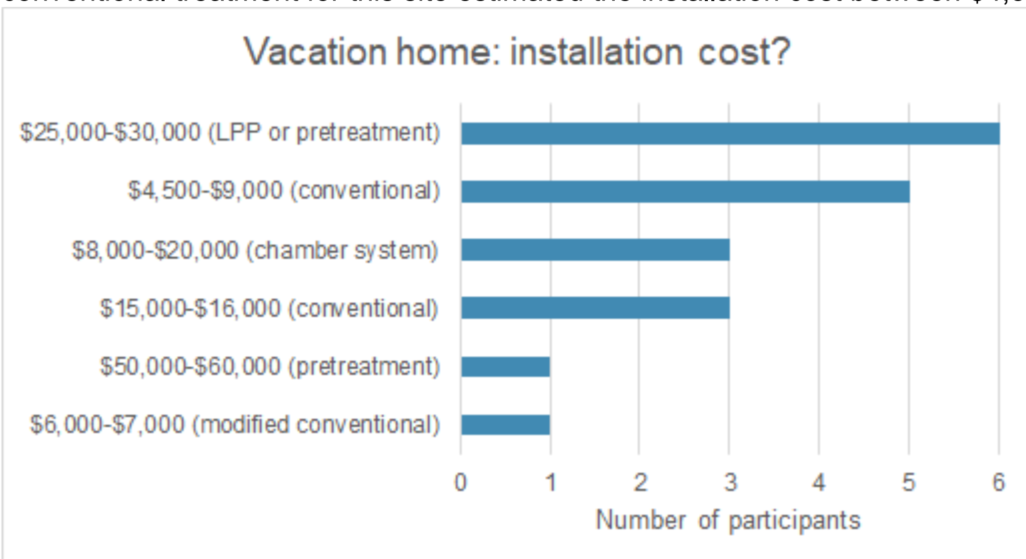

Figure 12. Estimated cost to install an onsite wastewater treatment system at a hypothetical vacation home site.

Annual operational cost estimates also varied among respondents (Figure 13). Five respondents said that a conventional system would cost between $100 and $1,000 each year for pumping, depending on the frequency of pumping that is needed. The cost of pumping a conventional system was calculated to be between $50 and $100 each year. Four additional respondents agreed that pumping a conventional system would be the only cost for maintaining the system until it needs to be replaced.

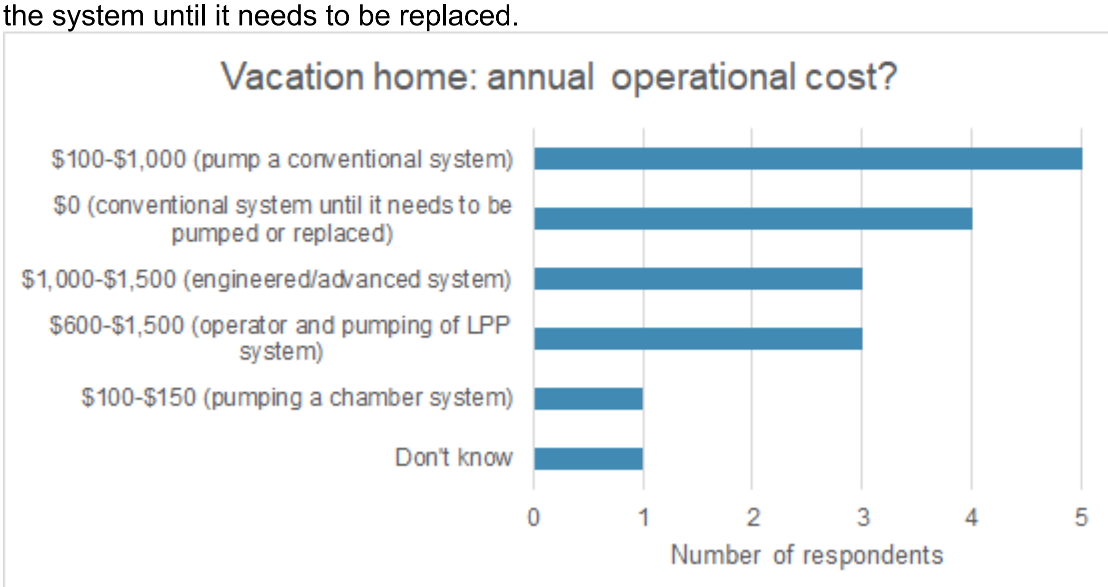

Figure 13. Estimated annual cost to maintain a septic system at a hypothetical vacation home site.

The third property described was a commercial property with an average wastewater flow of 1,200 gallons per day. The wastewater is assumed to be high-strength. More than half of respondents (10) recommended an advanced treatment system with pretreatment for such a property, such as a media filter system or ATU with some kind of pressure system (LPP or drip distribution). Other advanced treatment systems suggested by these ten respondents were TS2 systems like an Amphidrome system or TS1 systems like Advantex or Bioclere. Grease traps and a lagoon may be necessary as well, or an MMDR package treatment plant system. Other responses by the remaining respondents are listed in Figure 14.

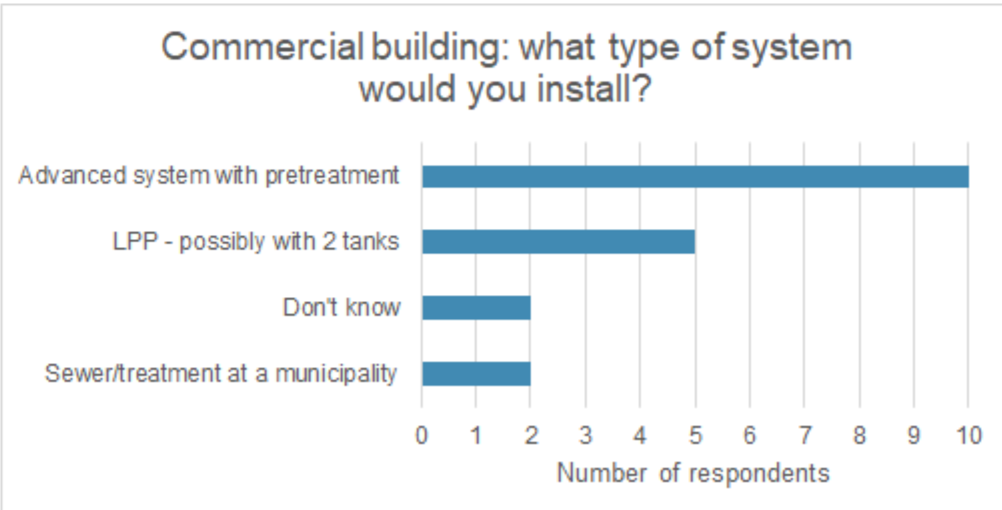

Figure 14. The type of septic systems recommended to be installed at a hypothetical commercial building site.

Estimates of installation cost for systems being installed at the vacation home site varied depending on the type of system recommended (Figure 15). Five respondents estimated between $12,000 and $30,000 to install an LPP system or a drip distribution system. Three respondents estimated between $35,000 and $60,000 for an advanced system.

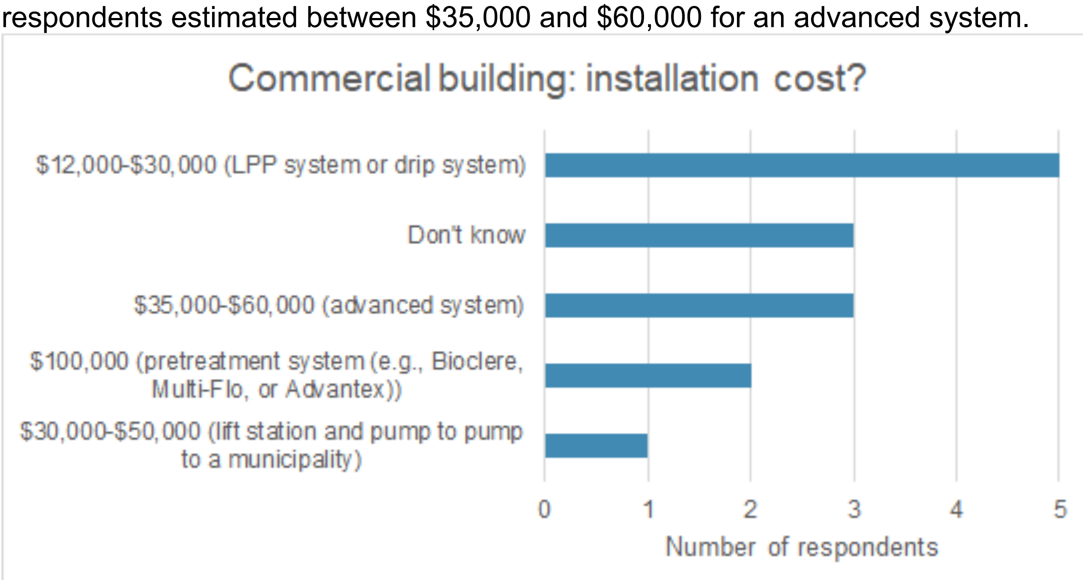

Figure 15. Estimated cost to install an onsite wastewater treatment system at a hypothetical vacation home site.

Four respondents who thought an LPP system would be best at a commercial building property estimated that annual operational cost for a commercial building property to be between $300 and $600 for an operator of that system. Another four participants estimated the annual maintenance cost to be higher because an advanced system with pretreatment would be necessary, which would likely cost between $1,200 and $5,000 each year (Figure 16).

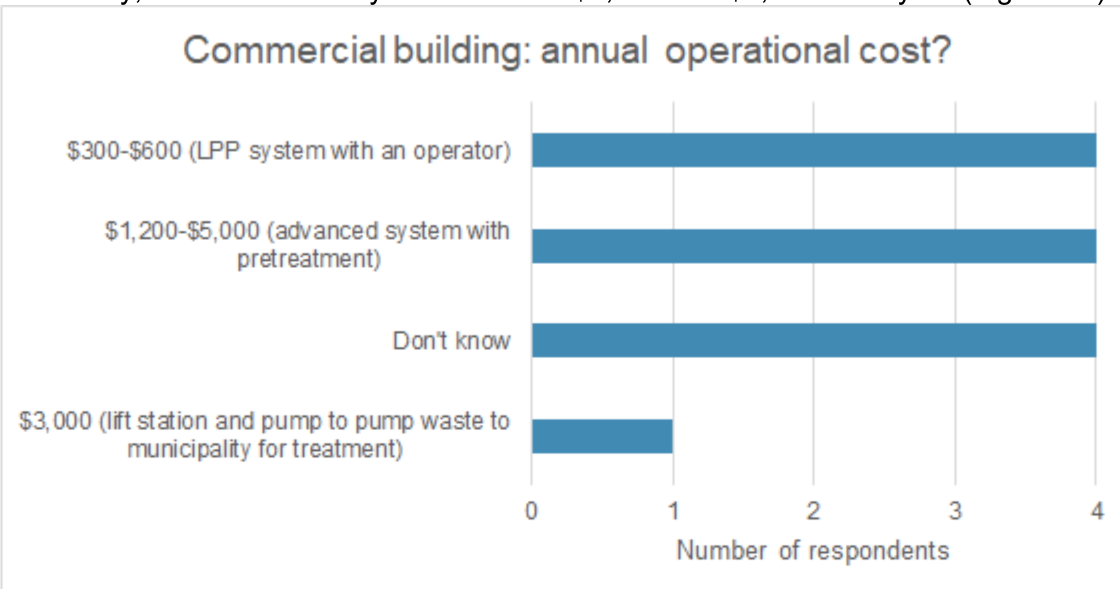

Figure 16. Estimated annual cost to maintain a septic system at a hypothetical commercial building site.

The fourth property described was a housing development serving 100 homes which uses a package treatment plant. The development requires treatment of 45,000 gallons per day. Respondents recommended a large variety of systems to install and types of components to include. Their recommendations are shown in Table 3.

Table 3. The type of advanced treatment systems recommended to be included in a hypothetical package treatment plant installation.

PTP: what type of advanced treatment components should be used?	Number of respondents
Don't know	4
If there are good soils and 2-3 acres of disposal field: a typical standard air plant or activated sludge plant. If only 1/2 an acre is available for the entire system: MBR system.	2
This system would need to be connected to a sewer.	1
Dissolved oxygen controls	1
Sensors hooked to the air supply	1
Telemetry	1

Plugs and lights accessible and numerous	1
Overflows and bypasses	1
TS2 system like Amphidrome with some kind of membrane filter and UV disinfection	1
Drip irrigation system with clarifiers, digesters, and grease separators	1
Activated system using enzymes like Liquid Fire	1
Elevated system - either ultra-shallow or above-ground	1
Large sand filter bed	1

Estimations of installation cost for this package treatment plant example varied but ranged between $50,000 and over $2 million (Figure 17).

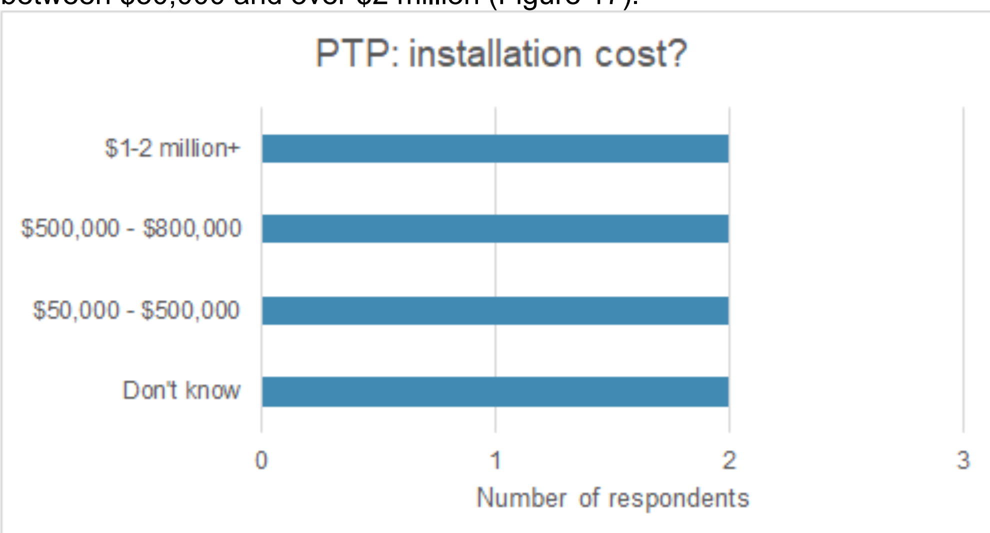

Figure 17. Estimated cost to install a hypothetical package treatment plant that would serve 100 homes and treat up to 45,000 gallons per day.

The annual operational cost estimations also varied among interviewees (Figure 18), but the cost estimations ranged from $7,000 to $100,000.

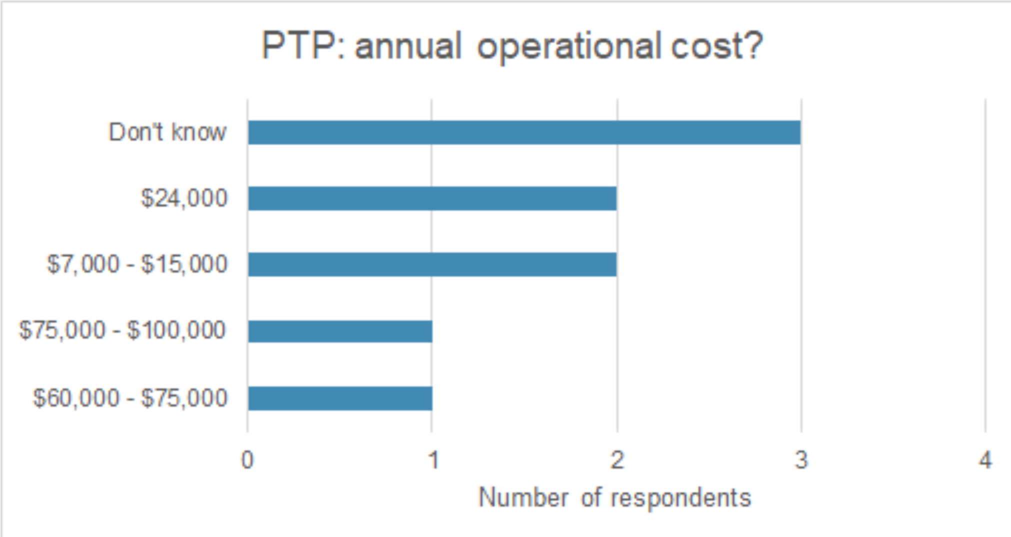

Figure 18. Estimated annual cost to maintain a package treatment plant that serves 100 homes and treats up to 45,000 gallons per day.

Respondents were asked what it would cost to add a pretreatment component to a system that is already installed on a given site. Responses varied depending on the type of component that would/could be added, but the largest number of participants estimated that it would cost between $9,000 and $15,000 to add some kind of pretreatment component, such as a pump tank, to a gravity-fed system (Figure 19). All respondents who felt they could answer this question (14) said that it would cost more to add a pretreatment later (after the initial installation) than if the pretreatment was included in the initial installation because the system would need to be altered to accommodate for the additional pretreatment component.

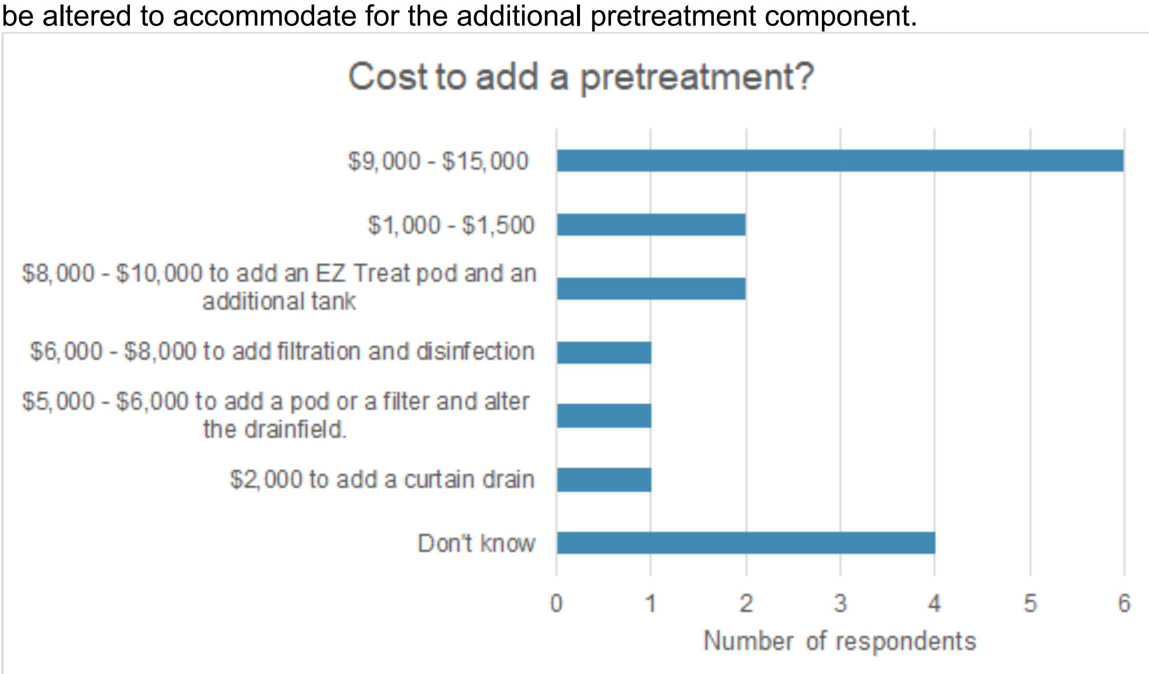

Figure 19. Estimated cost to add a pretreatment component to an existing septic system.

Availability of grants and loans for system replacement and repair
Nearly half of respondents (10) were not aware of any grants or loans available for installing or repairing small-flow septic systems. A handful (3) said they know grants or loans exist for that purpose, but they are few and far between. Another three respondents reported that most of the grants they are aware of run through the counties. Pitt County was provided as an example county that offers grants occasionally. One respondent said the Health Department had a program many years ago in which people with septic systems could apply to get a new system for free if their income qualified them. Another respondent described the septic health program, known as the Todd Kraft Program, in the Town of Nags Head, which allows people to get their tank checked and filters cleaned for free. The program also offers loans up to $8,000 with low interest to repair a failed septic system. One respondent said there are certain utilities, such as Berkeley Electric Charleston, SC, that offer free septic systems if the applicant's income does not exceed a certain amount, and one participant said that there are companies that offer the same. Finally, one respondent said that a few years ago, the state of South Carolina was offering to pay 70% of the cost if a homeowner replaced his/her drainlines, with the goal of protecting the rivers in the surrounding area.

Like with small-flow systems, the majority of respondents interviewed (13) were not aware of any grants or loans available for installing or repairing large-flow septic systems. One respondent said they know such programs exist, but they are few and far between, and another respondent said that people can apply for help through the state of North Carolina. Finally, one participant explained there was a Bright Leaf Grant that was given to small municipalities in areas with wastewater treatment problems.

CONCLUSIONS: OPERATOR & INSTALLER SURVEYS

Small-flow systems
Operators and installers who participated in the survey perceived advanced treatment systems to be effective at reducing nitrogen pollution and between effective and somewhat effective at reducing phosphorus pollution and fecal coliform bacteria in small-flow systems. Participants claimed that advanced systems would either increase or not change the resilience of a system to flooding or an extreme weather event. Advanced treatment systems require a moderate amount of maintenance and generally last between 11 and 20 years. These systems were said to be not at all common in the localities of the survey participants.

The responses for effectiveness of dispersal systems to reduce pollutants in small-flow systems varied widely, such that no conclusions could be drawn from them. However, most survey participants believed that all types of dispersal systems asked about were either very resilient or somewhat resilient to flooding and extreme weather events like hurricanes.

Conventional systems are very common across the coastal regions of North and South Carolina. Survey participants say they generally last between 21-30 years or beyond. Shallow conventional systems were said to be common and have slightly shorter lifespans. Gravelless trenches/chamber systems were said to be somewhat common and last between 11 and 30 years. Low-pressure pipe systems, drip distribution systems, and mound systems are somewhat common in some areas and not at all common in other areas. LPP systems and mound systems tend to have longer life spans than drip systems (11-30 years vs. 0-20 years, respectively).

Large-flow systems

In large-flow systems, most participants responded that the collection systems available (vacuum, gravity, and pressure) are highly vulnerable to flooding and extreme weather events, with infiltration and surface water and lack of maintenance presenting the greatest risk of malfunction and pipe leaks presenting moderate risk of malfunction to these collection systems.

Advanced treatment in large-flow systems were generally perceived to be very effective at reducing nitrogen pollution and fecal bacteria, while the results for the systems' ability to reduce phosphorus was inconclusive. Generally, large-flow systems require a moderate amount of maintenance. Most advanced treatment components for large-flow systems are perceived to be very resilient or somewhat resilient to flooding and extreme weather.

Dispersal systems in large-flow septic systems are mostly perceived by the survey participants to be somewhat effective at removing pollutants and somewhat resilient to flooding and extreme weather events.

CONCLUSIONS: OPERATOR & INSTALLER INTERVIEWS

Site conditions

The most important site condition variable that will determine how well a small-flow septic system will handle a heavy rainfall event or frequent rainfall events was reported to be drainage: the rate at which a site can dispose of water or drain water away from the system and allow the dispersal field to dry out. If a system is failing and needs repair or replacement, the most common visible sign is ponding of septic tank effluent over the drainfield, although backing up of plumbing fixtures in the house is also commonly seen.

Weather scenarios

In dry soil conditions, operators and installers said a 2” rainfall event is very unlikely to cause a malfunction in a small-flow system. In fact, in sandy well-draining soils, some said there is no amount of rainfall that should cause a system to fail, provided the system was working properly beforehand. Others said that a slow, prolonged rain would be much more likely to cause malfunction in systems than a quick 2” rain, and that hurricane-type conditions (7-8” of rain) are very likely to cause malfunctions. High water table conditions would also make it more likely that a system would malfunction from a 2” rainfall.

However, in wet soil conditions, a 2” rainfall event is slightly more likely than not to cause a malfunction. Along the beach, wet soil conditions with an additional high tide or King Tide event is very likely to cause malfunctions. Similar to the dry soil scenario, conditions that would increase the likelihood of malfunction in these two scenarios are prolonged rain for several consecutive days or weeks, high water table conditions, and large downpours of rain of 7-8” such as seen during hurricanes. In any weather event scenario, systems that are located on sites with poor drainage features are generally more prone to malfunction than those on well-drained sites.

If a malfunction occurs in a conventional system that is well-maintained and does not have any physical damage to it, it would generally be expected to recover on its own given time to rest and the soils to dry out. Given dry weather after the malfunction, that usually occurs within a week of the malfunction, but can sometimes take up to 14 days, and rarely as many as 30 days.

Sometimes pumping of the septic tank and/or distribution box and reduction of water use from the house is needed to help the system recover and soils to dry out.

In advanced systems, a weather-related malfunction caused by a hydraulic failure would require the same as a conventional system: time to rest. Some operators and installers interviewed believe that advanced systems are less likely to malfunction from weather conditions because they are usually designed to withstand adverse conditions, including weather, high tides, etc. Package treatment plants are also believed to be more resilient to extreme weather because they were designed to withstand large amounts of water, including from adverse weather conditions. However, in the case that an advanced small-flow septic system or a package treatment plant does malfunction from a weather event, they may need more maintenance than a conventional system to regain function because both types of systems have many components, including electrical, that would need repair if damaged during a weather event.

The operators and installers who were interviewed were split about whether or not repeated weather-related malfunctions would impact a system's overall lifespan. About half said that repeated malfunctions would have little to no impact on life expectancy because the soil would not be damaged by those events so the system would be able to fully recover after each event. On the other hand, the other half though repeated malfunctions would shorten the lifespan of a system because the system would not be getting the rest it needs to function properly so a biomat would be likely to form along the walls of the trenches and clog the drainlines. The deciding factor between these two responses could be the amount of time between rainfall events, which would determine whether or not the soils are able to dry out completely before the next saturation event.

High groundwater tables

More problems with onsite wastewater treatment systems are seen in areas where the groundwater table is high, with water backing up into the house, ponding/surfacing water over the drainfield, and premature failure being some of the most common problems observed.

Vacation homes

Opinions varied in regards to how seasonal occupancy impacted septic systems at vacation homes. While most said it impacts septic systems negatively because vacation homes are often occupied by more people than the system is permitted for and because little to no use during the off-season decreases biological activity so it has less treatment capacity when occupancy begins again. However, others said little to no use during the off-season affects the system positively because it has time to rest. Some believe seasonal occupancy has no impact. The impact seen on systems may simply vary depending on the type of system installed at each site.

Adaptation measures

More than half of the operators and installers interviewed are implementing measures to adapt septic systems to more extreme weather events and rising groundwater levels, such as raising septic tanks and drainfields to be shallower or above ground, building in more water capacity into the system design than is required, recommending advanced systems more frequently since they disperse cleaner effluent and some can handle larger amounts of water, and adding fill caps or curtain drains to increase the water capacity on the site. Participants offered many other potential technology and advanced treatment solutions for adapting septic systems to handle extreme weather and rising groundwater levels as well. In general, advanced treatment systems are recommended for sites with poor-draining soils, elevation problems that limit drainage, a high groundwater table, high sea levels, or are located on a lot too small to allow for the needed drainfield size.

Cost of system installation and maintenance

Conventional systems are typically installed whenever the site conditions permit due to the higher costs associated with advanced treatment systems. The installation of a conventional system at a standard home in the coastal Carolinas would be expected to cost between $2,000 and $10,000, varying depending on whether or not any extra features are added (an additional trench, a 12” fill cap, etc.). There is no required annual maintenance or associated costs with conventional systems, but it is recommended that the tank be pumped every 3-5 years, which will cost the homeowner between $150 and $500 for each pump.

At a vacation home, advanced systems are typically recommended because it is common for large homes to be built on small lots, although conventional ones are installed whenever possible. Advanced pretreatment systems can cost anywhere from $25,000 to $60,000 for the installation and between $600-$1,500 per year for its operation. Advanced systems are often recommended for commercial buildings as well.

A package treatment plant was estimated to cost anywhere between $50,000 and over $2 million for the installation and between $7,000 and $100,000 for annual operation costs.

Availability of grants and loans for system replacement and repair

Availability of grants and loans for replacement and repair of small-flow systems do not seem to be widely known about among operators and installers. Some knew that grants and loans exist and are typically targeted toward people below a certain income level. Most of the grants interviewees were aware of are run through the counties and small municipalities such as the Town of Nags Head. Grants and loans for large-flow system replacement or repair seem to be even less common, or at least known of by operators and installers.

INTERVIEW DESIGN: HEALTH OFFICIALS

An interview instrument was designed for wastewater health regulators to determine how they perceive extreme weather events to affect OWTS, potential adaptation measures, and costs of system installation and maintenance. A total of 8 health regulators were interviewed. Initial interview questions related to current onsite wastewater technology regulation, including questions about site conditions and permitting, inspections, and communications of regulations and system requirements to homeowners.

Next, health regulators were asked how elements of climate and weather are taken into consideration in the permitting and regulatory process for septic systems. Questions in this section related to flooding risk, rising groundwater, communication with homeowners about extreme weather events, the impact of extreme events on systems, and response of regulatory agencies after these events. Then participants were given three hypothetical weather scenarios and asked how they would expect a conventional septic system to handle the conditions. They were asked to describe the impacts of weather-related malfunctions, high groundwater tables, and seasonal occupancy on system functionality and life expectancy.

In the next section, health regulators were asked to describe regulatory measures being used to adapt septic systems to more extreme weather events, what leaders in the onsite wastewater sector are doing to adapt, and what technologies or siting strategies are improving OWTS function during extreme weather. They were also asked what weather or climate data/tools for OWTS planning and/or decision making (if at all) and what public education or training options are available for homeowners and/or septic system operators/installers to learn about improving resilience of systems to extreme weather.

In the final section, regulators were asked questions about the availability of public financing options for owners of septic systems to build or repair their systems in their region.

RESULTS: HEALTH OFFICIALS

Professional experience with OWTS

Of the 8 interview respondents, 5 work at the state level (3 in North Carolina and 2 in South Carolina) and 3 work at the county level in North Carolina (Figure 20). Of the state employees, 3 people work at the North Carolina Department of Health and Human Services in the Onsite Wastewater Protection Branch, and 2 people work at the South Carolina Department of Health and Environmental Control in the Division of Onsite Wastewater (Figure 21). Of the 3 county employees, participants work at the Dare County Health Department (1), Craven County Health Department (1), and Pender County Health Department (1) (Figure 21). Position titles of participants include Environmental Health Supervisor/Director (3), Program Manager (2), Engineer (2), and Environmental Senior Specialist (1) (Figure 22). All (8) participants regulate small-flow-systems. Half (4) of participants have 21+ years of experience, 3 have 11-20 years, and 1 has 2-5 years (Figure 23). As for large-flow systems or package treatment plants, more than half (5) participants regulate those, while 3 do not. Of the 5 participants who regulate large-flow systems, most (4) have 11-20 years of experience and 1 participant has 21+ years (Figure 23).

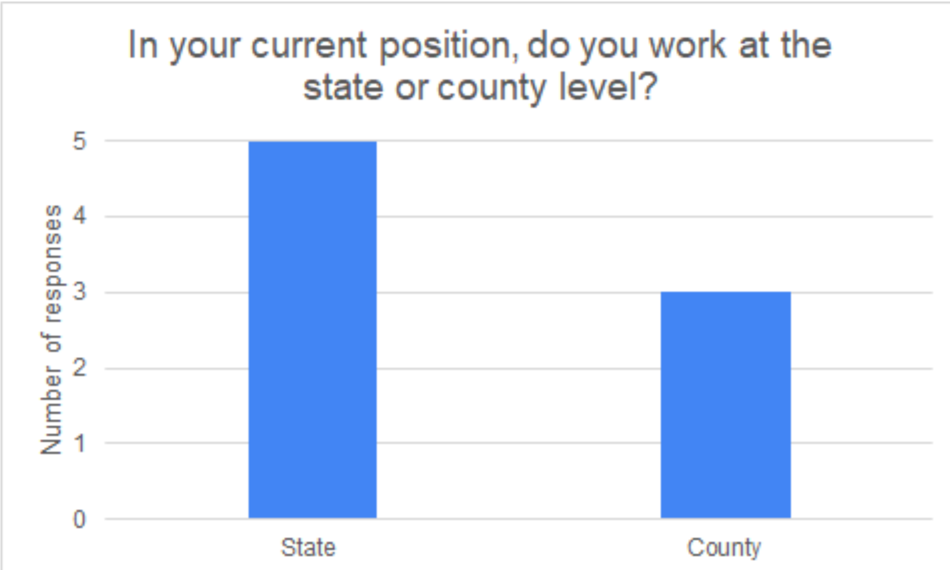

Figure 20. The number of participants who work at the state vs county level.

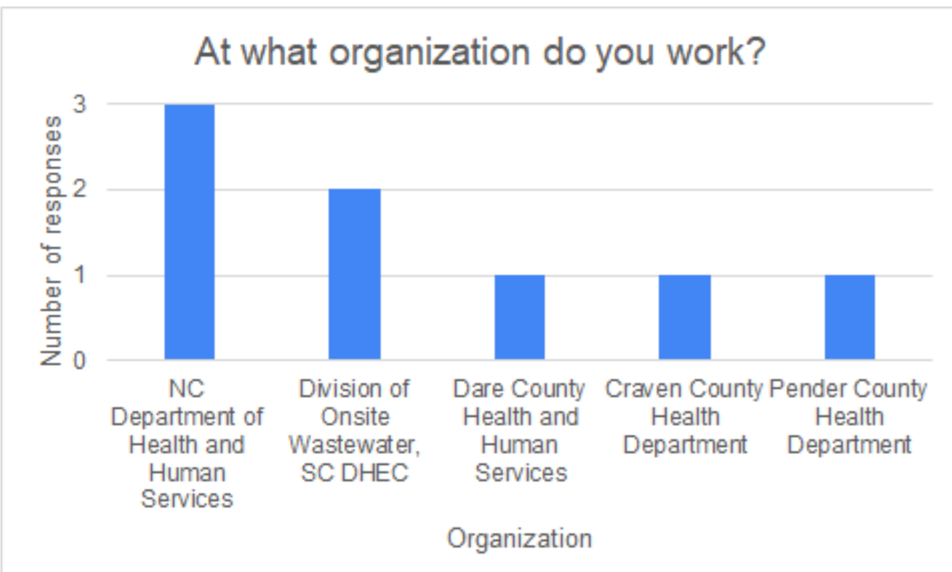

Figure 21. The organization at which each participant works regulating some aspect of OWTS in their state.

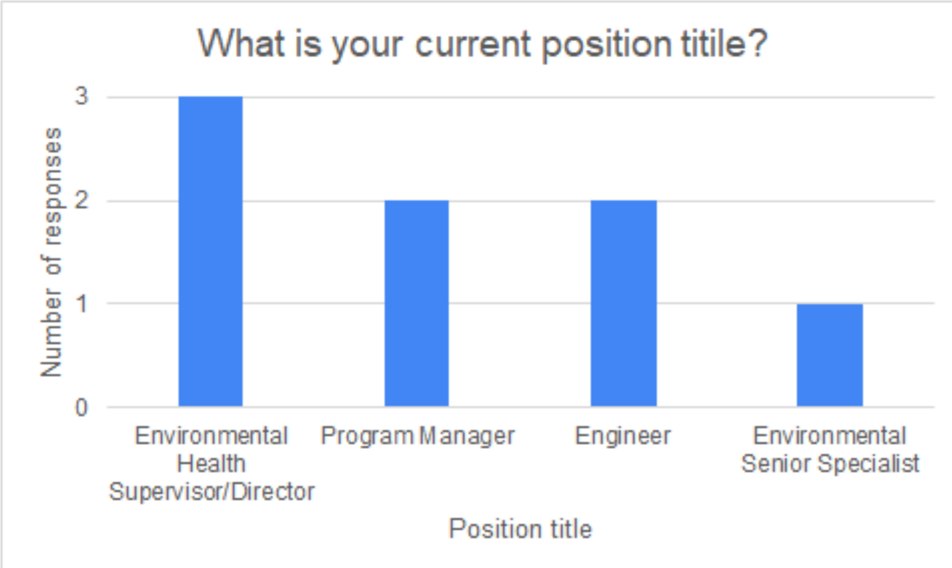

Figure 22. The position title each participant currently holds working with OWTS.

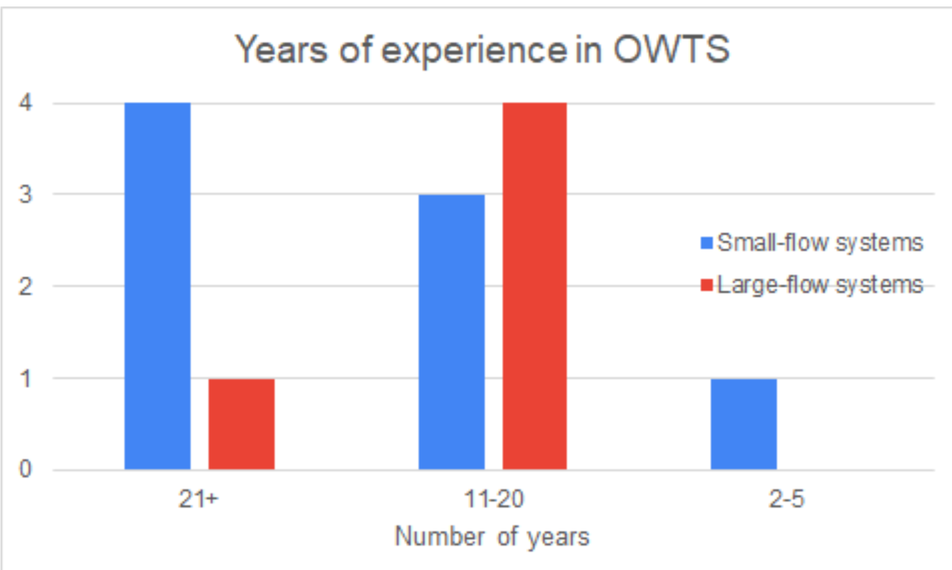

Figure 23. Length of professional experience of each participant working with OWTS.

When asked what ecoregion they work in, almost all respondents (7) said they work in the Outer Coastal Plain (both in the Estuarine/Inner Banks and the Outer Banks), more than half (5) in the Inner Coastal Plain, and a few (3) in the Sandhills (Figure 24). Many participants work in more than one region. Almost all participants (7) have more than a decade of experience working with OWTS in the coastal regions of the Carolinas (Figure 25).

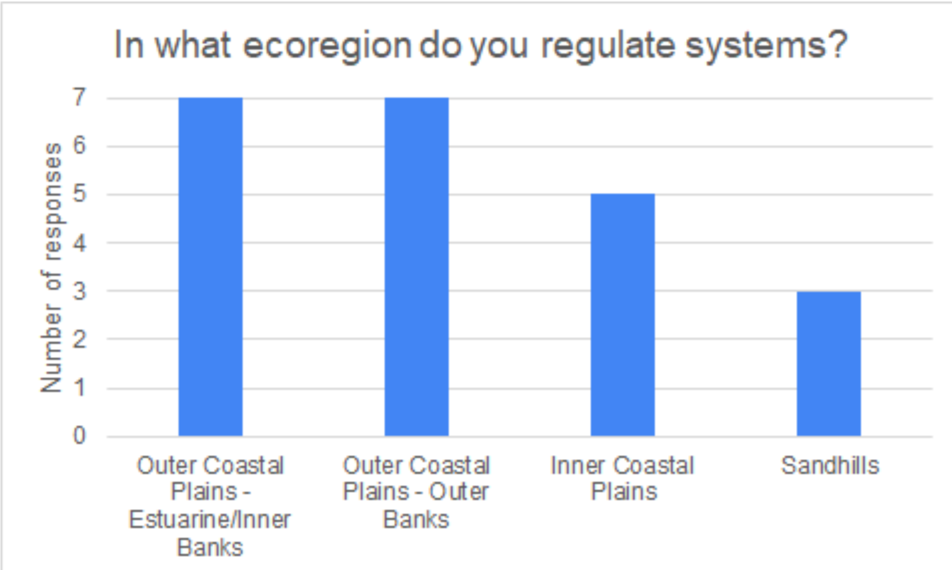

Figure 24. The ecoregion in which participants work regulating onsite wastewater treatment systems.

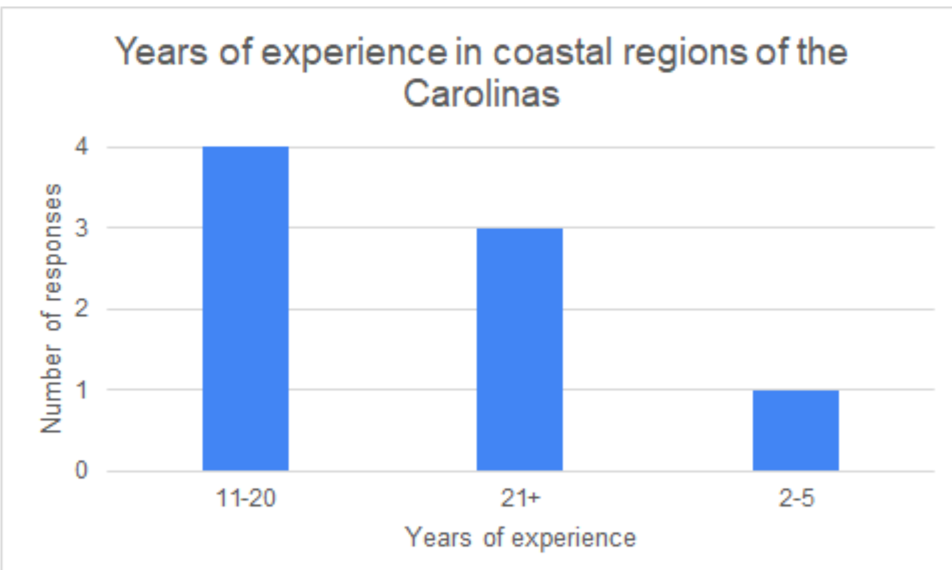

Figure 25. The number of years of experience working in the coastal regions of North and South Carolina of each participant.

Challenges to OWTS

Near the beginning of each interview with health officials, the participant was asked what he/she believes is the biggest challenge for onsite wastewater treatment systems in coastal communities. More than half of the participants (5) said that rising water table conditions is the greatest concern, explaining that if the water table is too high, it does not allow for the required vertical separation distance between the seasonal high water table and the bottom of the drainfield for proper functioning. Another four participants said that the biggest challenge is that there is limited space available for lots with septic systems because of the rapid growth occurring along the coast. The largest lots with the best soils have already been built on, so the lots remaining are smaller with less ideal soils. Developers often want to build as much house square footage on the smallest lot possible, which results in very little space to dispose of wastewater effectively in a septic system. Two participants said that saltwater intrusion from flooding events, hurricanes, storm surges, etc. is the biggest problem facing OWTS along the coast. And one participant cited insufficient regulations as the biggest problem, explaining that there is a lack of sustainable programs of operation and maintenance for systems in municipalities that are needed to keep onsite systems up-to-date and working properly in the long term.

Site permitting

The type of system to be installed on a site is always done on a case-by-case basis. When asked how it is determined what type of system will be installed on a given site, most respondents (6) referenced vertical separation as the determining factor, referring to the vertical distance between the zone of saturation/seasonal high water table and the bottom of the drainfield. Soil morphology (4) is another key determining factor for the type of system to be installed. Soil morphology refers to soil texture, structure, clay mineralogy, organic composition, and presence of constrictive horizons. How much space is available for a septic system for wastewater treatment on a given lot as well as how many bedrooms are in the house that will feed into that system must be taken into consideration as well (3). In order to determine the type of system to install on a given site, it is also important to consider horizontal setbacks (e.g., setbacks to county wetlands, Army Corps wetlands, bodies of water, water lines, property lines) (2), the topography of the lot and positioning of the system (1), and the strength of the wastewater going into the system (domestic vs. high strength) (1).

When asked how environmental factors impact system design, similar answers were given, with the most common response being horizontal setbacks (6). The more marginal a site or system is, the greater the required setback will be. Three people discussed available space again being a key consideration: lot size relative to the house size and the size of usable land on the lot. Two respondents mentioned vertical separation and one stated topography as key environmental factors that are considered for system design on a particular lot.

Respondents were asked to approximate the average depth to the water table at the coastal sites where they work. Most of the respondents (5) in North Carolina said it varies by location, and can be anywhere between 1 foot and 19 feet. A couple of respondents (2) in N.C. said that the depths are greater in the dunes, with a range between 2 and 10 feet. Another couple of respondents (2), one in Pender County, N.C. and one in S.C., estimated the range to be 12-30 inches in their regions. A respondent (1) in Dare County estimated 36 inches, a respondent in N.C. estimated between 24 and 30 inches to the water table in their prospective regions, and a respondent in S.C. (1) estimated between 18 and 22 inches. One respondent who said the average depth varies by location estimated the water table depth at multiple locations (Table 4).

Table 4. Estimated depth to the water table in various locations in North Carolina, according to one participant.

County	Depth to water table (feet)
Craven	1 - 3.2
Carteret	1.8 - 13
Currituck	2.1 - 14.7
Dare	3.5 - 13.5

Pender	2 - 12
Pitt	2.5 - 13.5
Martin	17 - 19

The participants were then asked what their role is in making permitting decisions, half of whom (4) said they do site evaluations, which includes the soil evaluations used to determine the vertical location of the water table on that site. Three participants are involved in issuing permits for approval for subsurface wastewater systems. Of those, two work at the local health department level in North Carolina, and one works at the state level at DHEC in South Carolina. Two participants perform final inspections after a system is installed and before it is covered up and put into operation to ensure proper functioning and compliance with regulations. Two participants, both of whom work at the state level, said they provide expertise for the local health departments (technical/engineering advice). To that end, they review system design information for more complex systems or for systems that require engineers to design. One participant provides programmatic oversight for onsite wastewater treatment in the state of South Carolina, while another participant is involved in product review. There are products that require state approval, so engineers are involved in reviewing manufacturer products before they are approved by the state. One participant is also involved in rule development as regulations come up for updates, particularly the technical aspects of the rules: treatment standards, requirements for different systems, etc.

When asked how common are advanced systems at coastal sites, most respondents (5) said common, some (3) said very common, and 1 person said not common at all (Figure 26). Participants explained that advanced systems are recommended when there is limited space (6), when the water table is high and is restricting the treatment area (4), when the wastewater is high strength (2) and when the wastewater is at risk of contaminating the surrounding environment with organics, nitrogen, ammonia, or metals. Other reasons for recommending advanced systems on a site are if the site evaluation reveals that there are no conventional system options within the regulations that will work on the site (1) or the owner has a preference for an engineered system and opts to hire an engineer on their own (1). One participant also mentioned that when the number of applications coming into the DHEC office is high, they will sometimes encourage property owners to hire a soil scientist or engineer on their own to reduce the workload in their office.

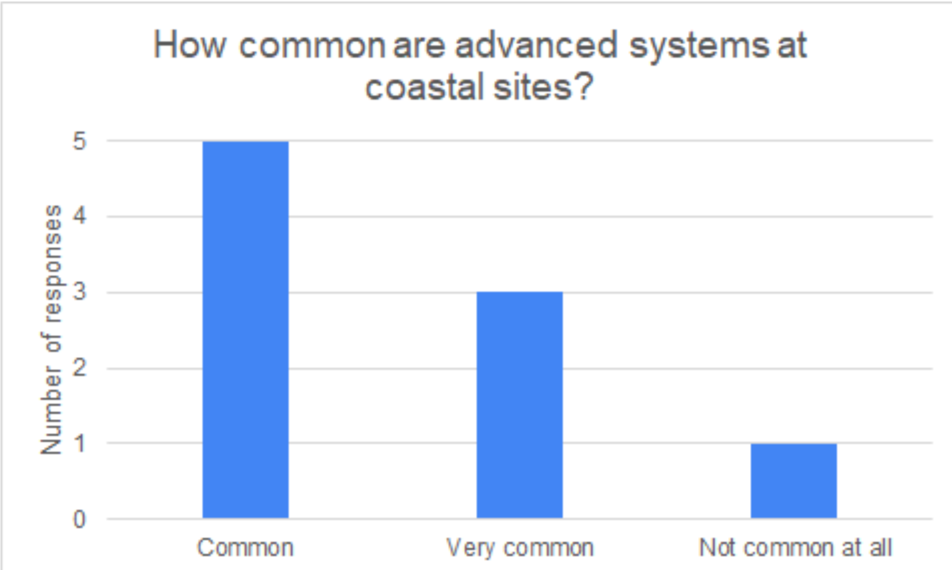

Figure 26. How common advanced systems are said to be by each participant in their respective locations.

Site permitting: weather and climate

Health regulator participants were asked how weather and climate go into permitting a system at a given site. Responses varied but the consensus was that weather and climate are not directly taken into account when permitting a system. Two participants explained that climate and weather conditions are not in the regulations and so are not used at all as criteria for permitting a system. During an inspection, they are looking at a snapshot of what is there the day of the evaluation for permitting a site. Two participants mentioned that the Mean High Water Mark (MHWM) is used on ocean side lots, where there is significant erosion. MHWM indirectly relates to climate and weather because it is influenced by sea level height and tides. There is a 50-foot setback requirement from the MHWM to permit a site. Two participants explained that climate could impact soil conditions, particularly rising seawater and big storm events like hurricanes because saturated soils would prevent a permit from being issued. Another two respondents said that horizontal setbacks are impacted by weather and climate because the water level would change in nearby bodies of water. Two people said that weather and climate are taken into consideration via the CAMA line, as it shifts depending on the amount of dune erosion that occurs. One participant said the depth of the groundwater table could be impacted by climate changes, particularly rising seawater and big storm events like hurricanes. Finally, one participant explained that climate influences site decisions indirectly because the climate of the area 50,000 years ago when the soils were being deposited in the Coastal Plain had a direct impact on the soil formation that is present today - in essence, historical climate has an impact on the soil and thus on the type of system that is permitted at a site.

When asked if flooding risk is taken into consideration when making a site decision, most participants (5) said systems cannot be installed in areas that flood frequently/flood zones. Flood zone maps are sometimes used, and occasionally, a property needs to be delineated. Anything that is to be permitted must be above the 100 year flood level, although components that are watertight can be put in areas susceptible to flooding. Two participants said that flooding risk is taken into account in horizontal setback rules in that there is a required distance from areas that could potentially flood (i.e., bodies of water). However, another two participants said that flooding is not necessarily considered when making a site decision. The fact that a site floods does not in itself impact if a site gets permitted because permitting is based on the zone of saturation and soil texture on that site. One respondent said that flooding risk is taken into account indirectly in the minimum vertical depth to the groundwater that is required.

All the health regulators interviewed (8) said that the water table height after heavy rain events is included in making a site decision during the initial soil evaluation. Soil scientists determine the water table height and potential flooding conditions when they do the soil evaluation by looking at soil color to determine where the water table is and soil texture, which indicates how quickly the soil will move water and effluent. If soils are saturated during the site evaluation, that would prohibit a permit from being issued until the soils dry up.

Participants were then asked if the current requirements for drainfield depth provide any buffer for rising groundwater tables. Most respondents (5) said no; the 12" vertical setback is the only requirement and permitting is solely based on the current conditions on a site. Rule .1956 of the North Carolina Sewage Treatment and Disposal Systems Rules & Regulations stipulate how much vertical distance is required for various soil and site conditions/limitations.[10] One respondent said that in his experience, it is common for inspectors to add a little bit of buffer onto the 12" vertical setback to allow for changes in groundwater table height as well as human error when digging the trenches.

When asked if flood forecasting is used in septic system permitting, most interviewees (5) said it was not (Figure 27). For those that said it is used (3), most (2) said they were used in the site evaluation, during which soil scientists and engineers use flood maps to make a siting decision. The rules used for site evaluations include those referencing 10 or 100 year floodplain levels, among others. One person also said the planning department uses flood maps to determine if a site is located in a flood plain, and in the case that a system is, they will inform the homeowner of that and the owner will need to buy flood insurance to reflect that.

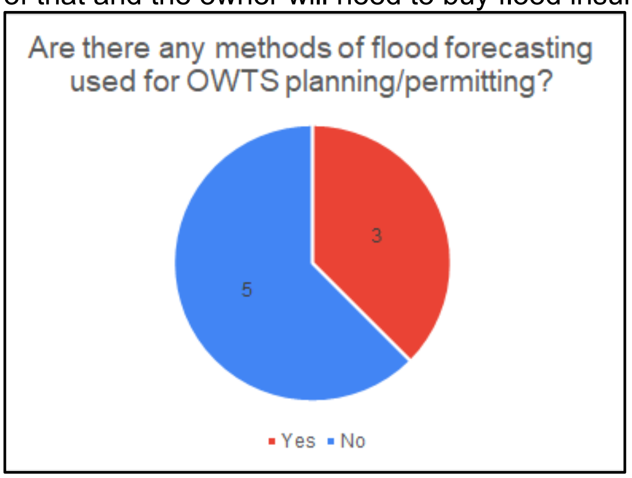

Figure 27. The number of participating health regulators who say methods of flood forecasting are used for onsite wastewater treatment planning and/or permitting in their locality.

Inspections

Almost all participants (7) said they play a role in inspecting onsite wastewater treatment systems before, during, or after installation (Figure 27). Most respondents (6) said they were involved in the final inspection once a system is installed to ensure the system is in compliance

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[10] 15A NCAC 18A .1956 - Modifications to Septic Tank Systems. Chapter 18 - Environmental Health. Subchapter 18A - Sanitation. Section .1900 - Sewage Treatment and Disposal Systems. Effective April 4, 1990.

with regulations before it is put into operation. Some (3) perform investigative inspections, which are done when there is a problem with a system, often prompted by a complaint such as water on the ground surface. A few (2) said they perform initial site evaluations, including soil evaluations. Another two said they perform compliance inspections, which is required for some types of systems to ensure compliance with regulations. The frequency of inspections depends on the type of system (e.g., Type III b systems[11] every 5 years, LPP systems are inspected every 3 years, engineered systems every year). One participant is involved in keeping records of septic system permits once they are issued through a soil scientist or engineer.

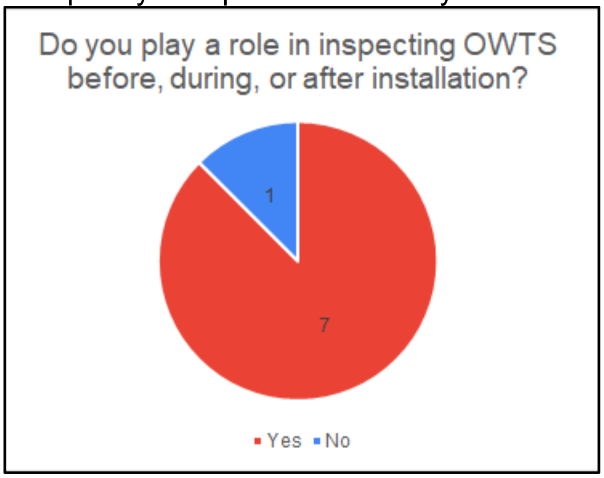

Figure 27. The number of participants who play a role in inspecting onsite wastewater treatment systems at some point before, during, or after the installation of the systems.

If a system fails an inspection, the majority of participants (5) said the first thing that would happen would be to contact the contractor/installer and tell him/her what changes need to be made before putting the system into use. Participants (4) also said the homeowner would be contacted to inform them of what changes need to be made. Two participants from NC said a notice of violation may need to be sent out, which is a legal letter stating that the homeowner must bring the system back into compliance with the permit within 30 days and lists the potential penalties. Three participants, two from NC and one from SC, said it is possible that legal action would need to be taken if the system is not brought back into compliance after the notice of violation. In SC, it may be sent to the enforcement branch of DHEC in that case.

When asked if property owners are required to have their systems regularly inspected, many (5) participants from NC said only engineered systems require regular inspections. The interval depends on the type of system it is, whether it is every 5 years, 3 years, annual, or biannual. Conventional systems are not required to be inspected unless there is a complaint or problem with the system that needs to be investigated. Both SC participants answered “no,” explaining that the regulations in SC do not currently dictate any inspection requirements for homeowners. Two respondents, one from NC and one from SC, said that there are some local requirements in both states that have restrictive covenants requiring a management entity to inspect systems. There are also some voluntary inspection programs, such as in the Town of Nags Head.

Participants were then asked what are the repercussions for owners who do not maintain their system properly. Most participants (6) said that a notice of violation is usually the first step. One

[11] Type III b systems: septic systems with single effluent pump or siphon. Chapter 18 - Environmental Health. Subchapter 18A - Sanitation. Section .1900 - Sewage Treatment and Disposal Systems. Effective April 4, 1990.

of those respondents said that probably 90-95% of homeowners bring their system into compliance after that. If the homeowner does not comply with the notice of violation, they are sent a letter of intent (3) to suspend their operations permit so they will not be able to use the house until the system is brought back into compliance. Alternatively, the homeowner may be issued a financial penalty or be charged criminal penalties (2) if they do not comply with the notice of violation. Very rarely, a judge may need to get involved and give the homeowner a deadline to perform repairs (2). In SC, there are some cases when they would need to send the case to the enforcement section of DHEC, but they try to get the problem corrected without going through enforcement if at all possible. One participant explained that there are some counties that do an excellent job at enforcement (e.g., Carteret County, N.C.), but a number of counties do not have a robust inspection program or the funds to implement the legal tools they have. As a result, most of the attention goes to new systems being installed.

Communications

Half of the participants (4) said that regulations and system requirements are communicated to property owners via the local health departments and districts. How that communication is done depends on the locality. Another four participants said property owners get information on all system requirements (annual maintenance, etc.) in the installation permit when the system is initially installed. One respondent explained that if it's a non-compliance issue, a certified letter is sent to the owner. A certified letter is also sent out if a home changes owners and the new owner is not aware that he/she has an operator for the septic system. Another person said in the case of a house changing hands, if the system has an operator, the operator will usually inform the new owner of the system requirements. One respondent said it is up to the realtor or previous property owner to inform a new owner of the system requirements.

As for educational materials that are given to homeowners, half of participants (4) said there is a fair amount of information available on state and local health department websites about system maintenance, what to do for a system when there is flooding or impending flooding, etc. Other participants (4) said that it is up to the local health departments to provide educational documents. In North Carolina, the Non-Point Source Pollution Program Coordinator in the Onsite Water Protection Branch of the Department of Health and Human Services (DHHS) produces educational materials for homeowners such as door hangers and factsheets. However, it is up to the health departments to provide those documents to homeowners. Two participants said that operations permits and approvals for innovations/advanced system technology installations that are issued by the state specify the operational requirements of the system. Another two participants said that a guide produced by NC Cooperative Extension is sent out to homeowners. The document is called Soil Facts: Septic System Owners Guide and is intended to help owners understand the basic function of their system and how to extend its life. Finally, two participants said there are no educational materials sent to homeowners.

The majority of health regulators who were interviewed (5) said that county health departments do not inform owners of potential flooding risk of their systems, but three regulators said they do (Figure 28). When asked how homeowners are informed of flooding risk to their system, there was no consensus, with a variety of responses being provided. Two participants, one in N.C. and one in S.C., said there is some pre-storm guidance provided through public service announcements to high-risk areas. The announcements are provided for owners of well and septic systems on what steps the owners can take to prepare their systems. One participant in S.C. said there is post-storm guidance provided, also in the form of public service announcements, warning residents about flooded septic systems and the potential danger of wading through standing water as there may be contaminants. Another participant from N.C. said that there is direct communication with the property owner to inform them that the system may have been compromised. If the compromised property is a rental property (which is typically the case), the rental company is called immediately to inform them that it may be compromised and that the house cannot be rented until it is resolved. If it is not a rental property, a certified letter will be sent to the property owner. Another participant in N.C. said that, after a storm, inspectors at county health departments are likely to know where the high-impact zones are and which systems are susceptible to damage, so they will typically do a routine inspection on those sites. Other times, compromised systems are brought to attention by complaints from neighbors (1).

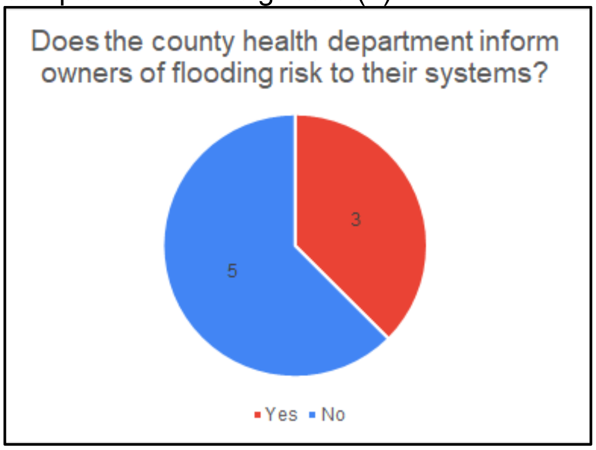

Figure 28. The number of participants who say the county health department in their locality inform OWTS owners of flooding risk to their systems.

For those who responded that homeowners are not informed of flooding risk, they were then asked what would be needed to provide timely advice to system owners. Two participants said direct communication would be needed; there are online resources and materials available on the NC DEQ website and the NC State Extension website of what to do before, during, and after a flooding event. One participant said that septic rules do not address flooding as part of the permitting process, so informing residents would need to come through local and state planning departments. Another said that realtors would need to be informing homeowners when they bought the property that the home was at high risk of flooding. However, in high rental areas, it would be the rental agencies who would need to spearhead informing owners of the rental properties of flooding risk to their systems (1).

Extreme weather conditions and events

All (8) of the health regulators interviewed said that regulations have not changed in response to any changes in frequency or intensity of weather events over time. Almost all (7) of the respondents also said that they have not noticed any changes in terms of weather impacts on the functioning of septic systems over time. However, one respondent said that erosion has become more of a problem from hurricanes hitting the coastal areas, particularly the barrier islands. As a result, the respondent has seen a lot of systems located on the ocean side being torn up and uncovered because those systems are installed in sand, which means any amount of beach erosion can unearth the system, tank, and piping.

The majority of participants (5) agree that they see higher numbers of malfunction complaints or applications for repair permits after an extreme weather event (Figure 29). Of those, most (4) see the problems arise after periods of heavy rain or over a long period of on-and-off heavy rain. One participant continued that it would definitely be seen after a 10” rainfall event. Three participants said that hurricane conditions with high wind and water, especially weather systems that stall and stay over an area for a while, often result in higher numbers of septic problems.

Another condition to cause more complaints is any type of flooding (2), in which the system is completely covered by water and cannot function. One person noted that decentralized systems (individual systems and/or package treatment plants) can potentially handle extreme weather conditions better than centralized wastewater treatment plants. However, one participant said they do not receive more calls after an extreme weather event, explaining that usually when systems are impacted by extreme weather events, there is enough flooding that the homeowner has to evacuate the house, and thus stop using their system. By the time the owner can occupy the house again, the system has usually started working again.

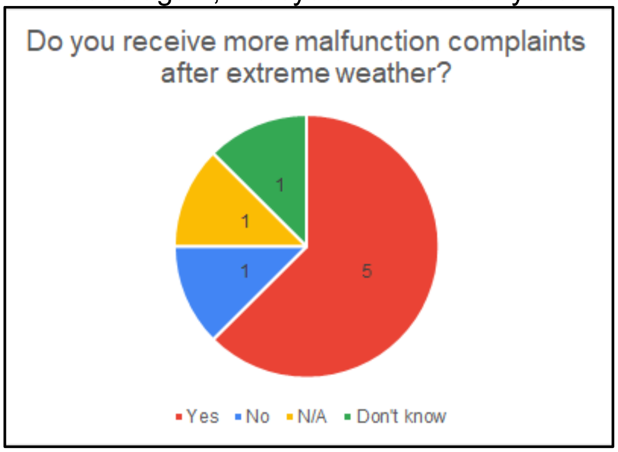

Figure 29. The number of participants who see higher numbers of malfunction complaints or applications for repair permits in their prospective offices and localities after an extreme weather event.

Of the respondents who see higher numbers of malfunction complaints after extreme weather conditions, four people said that generally, the system recovers on its own once the flooding is gone, unless there is damage to the system from the event. Two people said a common complaint after such an event is that the homeowner's system is backing up, meaning toilets are not flushing well, fixtures are draining slowly, etc. Two other respondents said damage is a fairly common complaint after extreme weather events. Trees sometimes fall over due to the saturated soil and strong wind, which can damage the system by pulling up parts of the system with the tree roots. Occasionally, a system will overload and cannot recover after an extreme weather event and will have to be replaced (1). In beachfront properties, a common problem is erosion so the system gets uncovered and inundated with salt water (1).

Vacation sites

When asked about the differences in installation requirements at vacation home sites, all (8) participants said there are no different considerations that are made for vacation homes. Three respondents said that it all goes back to the amount of available space - how large the house is, how many bedrooms it has, and how much space is available on the lot for the drainfield. The size of the drainfield is based on gallons per day coming out of the house and the number of bedrooms in the house. One participant explained that most vacation homes are used by more people than the house and system were designed for, so that should be taken into account when designing a system, but it is not required. One participant said that in the past, there has been coordination with realtors to ensure the capacity of systems is not exceeded by the occupancy in vacation homes. If there is a realtor involved in a rental, the realtor risks losing his/her license if it is advertised that the occupancy limit is higher than the system is permitted for.

Package Treatment Plants

When asked how permitting requirements differ for PTPs compared to individual systems, two participants said that PTPs have to go to the state engineer for review and the state will often stipulate nitrogen levels that are permitted to be discharged based on 1970 rules.[12] Another two participants said that PTPs typically have more frequent inspection requirements from operators and the health departments. One respondent said a difference is that PTPs typically require an operator, and another respondent said a difference is that hydraulic studies need to be done deeper (9-10 feet) for PTPs as opposed to 3-4 feet that is required for individual septic systems. One participant in South Carolina said that PTPs require joint permitting between the S.C. Bureau of Environmental Health Services, which permits the drainfield and performs site evaluations, and the S.C. Bureau of Water, which permits the wastewater collection.

Reuse systems

Participants were asked about systems that reuse wastewater (spray or drip irrigation). Half of respondents (4) said that is not within the purview of their office. Those types of systems are regulated through the Department of Environmental Quality (DEQ) in North Carolina and through the Bureau of Water in South Carolina. When asked if the irrigate is tested for contamination, three participants said yes, two said no, and one said probably but did not know for certain. The three people who responded "yes" explained that the frequency of testing for contaminants depends on the size of the system. Some plants have to be tested every month, some every 3 months, some every 4 months, and a couple of them twice per year.

None of the participants play a role in ensuring people do not come in contact with effluent being dispersed from reuse systems.

Reuse wastewater systems (spray or drip) are used when the wastewater is to be used for watering the landscape or flushing toilets (2). One participant said that reuse wastewater systems are used when the homeowner or owner of the plant and the engineer involved have a preference for it. Some people prefer working with the local health departments and others prefer to work with DEQ, so that is the deciding factor according to that participant. One participant explained that anything discharged above ground is regulated by DEQ.

Weather scenarios

As with the operator and installer participants, health regulator participants were asked about three hypothetical weather scenarios and how they would expect a conventional septic system to handle the conditions. The first scenario was dry conditions for a long enough time to create very dry soils, after which there is an intense rainfall event that produces 2" of rain in one day. The second scenario describes an inland coastal area that is more than 1 mile from the ocean. Soils are saturated from prior rainfall, and then there is a heavy rainfall event that produces 2" of rain in a day. The third scenario describes a coastal area within 1 mile from the ocean. Again, soils are saturated from prior rainfall, and then the area experiences a high tide/King Tide event that causes a high tide that is 12" above average.

Scenario 1: Dry conditions + 2" rainfall

When asked whether or not they would expect a septic system to malfunction in these conditions, almost all (7) said no, while only one said sometimes (Figure 30). Two participants estimated the length of time it would take for a system to recover after such an event would be condition-dependent. So the length of time would depend on the soil type, drainage features,

[12] Chapter 18 - Environmental Health. Subchapter 18A - Sanitation. Section .1900 - Sewage Treatment and Disposal Systems. Effective April 4, 1990.

lateral flow, how high the water was to begin with, and what materials were used for the drainfield (gravel/rock, chambers, etc.).

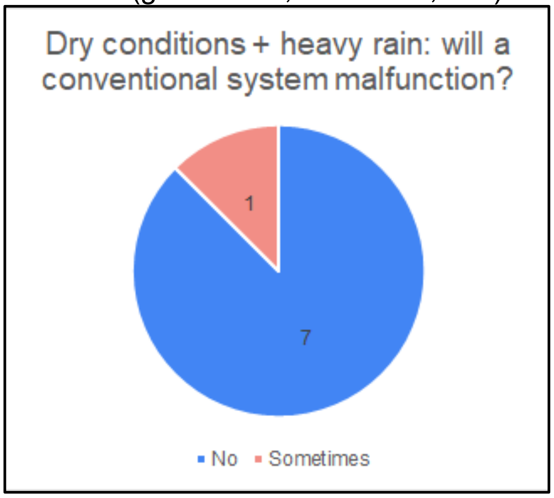

Figure 30. The number of respondents who would predict a conventional system to malfunction in dry soil conditions after receiving a 2" rain event.

Half of the respondents (4) said that prolonged rainfall, meaning multiple weeks of wet conditions (slow rain), followed by a heavy rain, would likely cause a system to fail. Hurricane conditions, with high winds and precipitation amounts of 8-10", would also likely cause system malfunction (2). Some participants (3) said that a system would likely malfunction in areas that cannot drain effectively, either because it is a low-lying area or due to improper installation. A system would also be likely to malfunction if there was any physical damage to the system that occurred during the weather event (1).

If a system were to fail under dry conditions followed by a 2" rainfall, some respondents (3) reported that there is no maintenance needed to regain function – the system will recover on its own given sufficient time to dry out. A few (2) said that the tank and/or distribution box should be pumped out in such a scenario in order to give the drainfield time to rest and dry out. One respondent said that after a malfunction in these conditions, the homeowners would need to allow the system to rest by reducing the water use in the house. Another respondent said that repair of the drainage and runoff on the site would likely be needed to ensure drainage pathways are moving properly, such as redirecting gutter water away from the system into a drainage. However, if there is a long term problem of too little separation distance in the drainfield, it might require an elevated system, shallow system, or fill system to be put in in order to make the system functional again.

Half of the respondents (4) said there is no difference in the maintenance required to regain function of a conventional system compared to an advanced system after a malfunction from a heavy rain event. More specifically, if the malfunction is caused by a hydraulic failure, then both conventional and advanced systems will need the same thing in order to recover: time to rest. One respondent said the main difference in conventional versus advanced systems is that most advanced systems require electrical power, so if the power is lost to the system during a weather event, it will need to be restored for the system to start working again. Another respondent said the biggest concern with an advanced system is the control components. Those systems will have an operator, who would need to fix any components that have malfunctioned from the event. Another difference has to do with site conditions (1): in the case of a conventional system, there might be a separation distance problem or the drainfield might be damaged from a storm event, but in the case of an advanced system, there would likely be more drainage problems after a rain event because advanced systems tend to be installed on sites with marginal conditions (poor draining soils, small lot size, etc.). One respondent in South Carolina did not have knowledge of advanced systems because advanced system repairs are dealt with primarily by engineers in that state.

When comparing what maintenance would be needed to regain function in small-flow systems versus large-flow systems (also referred to as package treatment plants (PTPs)), responses were spread evenly among participants. One participant said there is no difference - if the malfunction is caused by a hydraulic failure, both small-flow and large-flow systems will need time to rest for recovery. However, one participant said small-flow and large-flow systems have different conditions to consider in repairs: large-flow systems have many components and basins for removing solids and nutrients. In addition, PTPs are open to the air while small systems are underground and enclosed, so the impact on the surrounding environment is different. Another participant said that with larger flows in PTPs, the soil must have more regional capability to handle the large flow without backing up or contaminating surrounding areas, so that needs to be considered for repairing the function of large-flow systems. One respondent said a key difference between large and small-flow systems is that PTPs need power, so if the power is lost to the system, it will need to be restored for the system to start working again. Finally, one person reported that PTPs tend to perform better in extreme weather conditions because they have more control of the wastewater than in small systems. Operators are able to slow down the flow if they need to or remove excess waste. PTPs can also discharge water into the environment once the water is treated, so there is more control over water volume than in small-flow systems.

Scenario 2: Wet conditions + 2” rainfall

When asked whether or not they would expect a septic system to malfunction in wet conditions followed by a heavy rainfall, most respondents (5) said “yes,” while two said “no,” and one said “sometimes” (Figure 31). The six participants who responded yes or sometimes estimated the length of time it would take for a system to recover after such an event. The majority (5) commented that the length of time would vary greatly depending on the conditions (i.e., soil type, drainage features, lateral flow, how high the water was prior to the rain, etc.). Some respondents (3) said the system should return to functioning as soon as the water recedes and the soils are able to dry out. One participant estimated it would take between 2 and 3 days on average but up to 7 days.

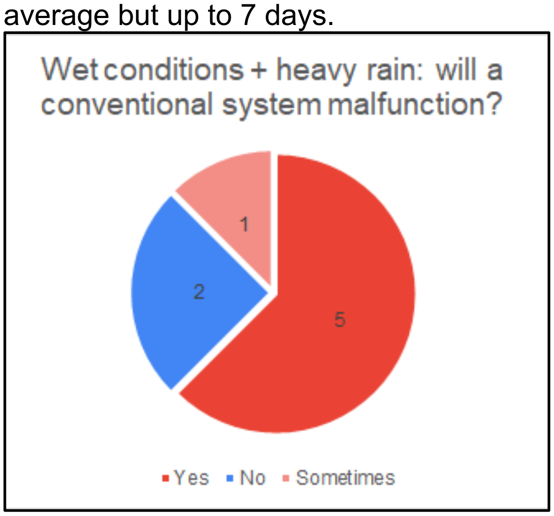

Figure 31. The number of participants who predict a conventional system to malfunction in wet soil conditions followed by a 2” rain event.

Those who said a system would not malfunction under these conditions were then asked under what conditions they would expect a system to malfunction. Some respondents (3) said inland areas with clay soils are at risk of malfunction if the soils are already saturated and then there is a heavy rain event. Another participant said a multiple day rain event, meaning several consecutive days of rainfall, with residents using the system during that time would likely cause a septic system malfunction. And one respondent said malfunction depends on the site and system conditions, such as what type of soils the system is in, if there is a biomat building up, how the system is used and maintained by the homeowners, how much water is going into the system, etc.

If a septic system were to malfunction in this type of scenario, almost all respondents (7) explained that giving the system time to rest in some capacity is the only action that is required to get the system functioning again. To that end, some people (3) explained that no action is required – simply waiting for the system to dry out will allow the system to start functioning again on its own. Along the same theme, two respondents explained that a system should be given time to rest by reducing the water consumption coming from the house so that the drainfield can dry out. Another two respondents said that the system should be given rest by pumping the tank and/or distribution box.

Scenario 3: Wet conditions + high tide/King tide event
When asked whether or not they would expect a septic system to malfunction in wet conditions followed by a high tide/King Tide event, all (8) respondents said “yes” (Figure 32). They were then asked to estimate the length of time it would take for a system to recover after such an event. Half of the participants (4) said it should recover as soon as the water recedes and the soils are able to dry out. Some participants (3) explained that it would be dependent on the conditions (soil type, drainage, etc.). A few (2) estimated 2-3 days, possibly up to a week, in sandy soils. One respondent said it could take anywhere between a week and a month, depending on the conditions.

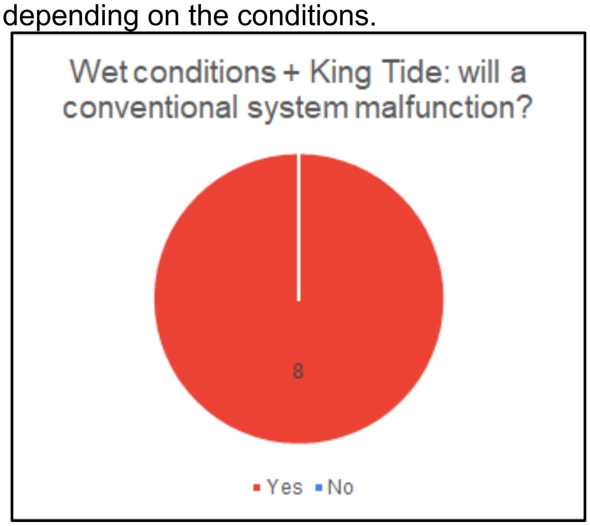

Figure 32. The number of participants who predict a conventional system will malfunction in wet soil conditions followed by a high tide/King Tide event.

If a septic system were to malfunction in this type of scenario, almost all respondents (7) explained that giving the system time to rest in some capacity is the only action that is required to get the system functioning again. To that end, some respondents (3) explained that no action is required – simply waiting for the system to dry out will allow the system to start functioning again on its own. Along the same theme, a few (2)said that the system should be given time to rest by pumping the tank and/or distribution box. Two respondents explained that a system should be given rest by reducing the water consumption coming from the house so that the drainfield can dry out.

Weather-related malfunctions & system life expectancy

A majority of respondents (5) said that repeated malfunctions caused by weather events could shorten the life of the system, probably damaging the drainfield. Repeated flooding events would cause a biomat buildup in the trenches, and saltwater intrusions could impact the pH of the soil or reduce the aerobic environment in the soil, which would impact treatment of the effluent and thus shorten the life expectancy of the system. Systems in clay soils are more likely to be negatively impacted by repeated malfunctions from weather events. Some respondents (3) said malfunctions from weather would have little to no impact on the system's overall life expectancy because the soil would not be damaged by those events. Some explained further that systems are usually able to fully recover after a rainfall or flooding event, especially in sandy soils. Another respondent agreed that, generally, rainfall should not have much of an impact on the general life of a system but added that if a system sustains damage from a hurricane, it could fail prematurely. One respondent said that the bigger issue is not extreme weather events but the rising water table. He continued that there is not a large margin of error in some of their systems; with a 12-18" separation, a 3-6" rise in the water table will start causing problems.

High groundwater tables

Half of the health regulators interviewed (4) said that they have observed more problems with OWTS in areas where the groundwater table is high, while the rest (4) said they have not (Figure 33). When asked what types of problems result from a higher groundwater table, a majority (5) said that many systems experience problems over time because there is no longer the required separation distance and enough vertical separation to treat the wastewater effectively. This is true in the initial installations now as well, where the water table height prohibits permitting of onsite systems. One respondent said ponding or surfacing water over the system is a common issue seen in areas with higher groundwater table conditions, and another said water backing up into the house or filling the drainlines and backing up into the septic tank is commonly seen. Finally, one respondent would expect a higher groundwater table to cause more problems in general to the systems but has not seen that in his experience.

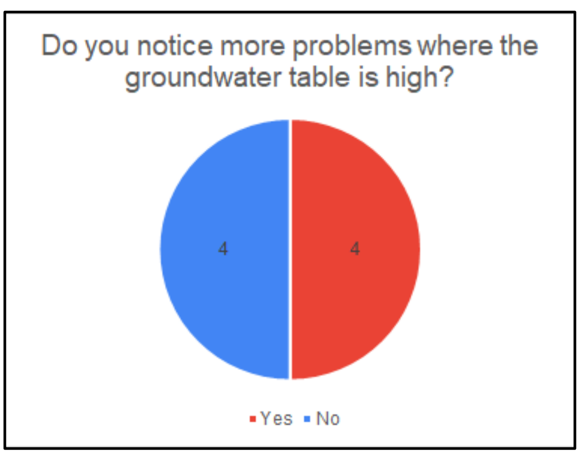

Figure 33. The number of participants who have noticed more problems with onsite wastewater treatment systems in areas where the groundwater table is high.

When asked if those problems observed in areas with higher groundwater table conditions were more chronic or acute, most people who responded to this question said they were more chronic, while one person said the problems were observed in both acute situations and as chronic issues (Figure 34).

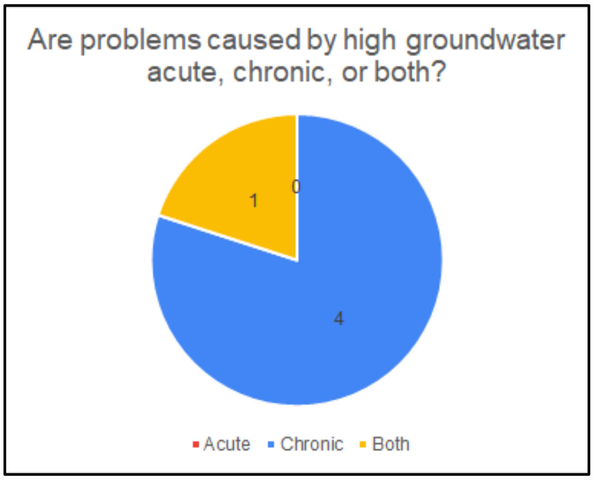

Figure 34. The number of participants who say the problems caused by higher groundwater levels to onsite wastewater treatment systems are more chronic, acute (event-based), or both.

Adaptation measures

Half of the health regulators (4) said that current regulations include measures to adapt septic systems to more extreme weather events, while the rest (4) said they do not (Figure 35). Among those who said they do, three respondents described the individual site evaluations that are required in both N.C. and S.C. as the adaptation measures that are taken. Vertical setbacks from the water table are measured at each site at the time of initial evaluation and for any repair, which could be impacted by higher water tables and thus less vertical separation from extreme weather events. In S.C., it used to be that a developer would receive approval for an entire subdivision to put in onsite wastewater systems. Today, each site is evaluated individually and must stand on its own merit. One participant responded that as climate changes occur, they adapt by making sure what is installed still complies with the water table depths, soil wetness conditions, and setbacks that are required. In one regulator's opinion, the biggest improvement that could be made would be to find better ways of sustainable management of systems, both inspections and maintenance programs, to ensure ongoing operation and maintenance is occurring.

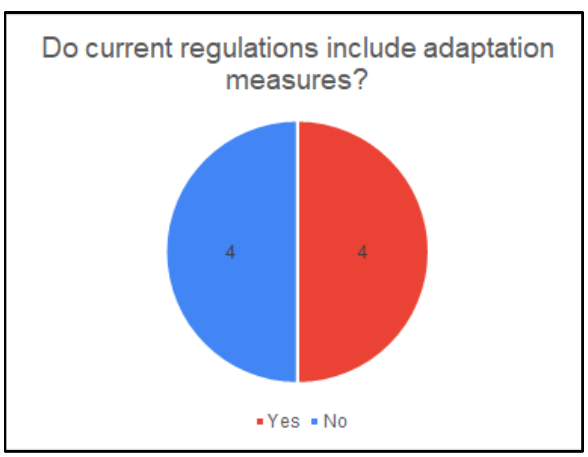

Figure 35. The number of participants who say adaptation measures are included in current onsite wastewater treatment system regulations in their locality.

When asked what prompted the implementation of adaptation measures, most (7) participants did not know, but one participant explained that they have a review of regulations every five years in South Carolina, when they go through the regulations to see if there are any major changes they need to make and if there are system types they need to have increased setbacks for, based on research that has come out.

Respondents were asked what leaders in OWTS are doing to adapt to weather extremes and climate change. Most (5) said they do not know of any technologies that are meant to address climate change effects on systems. However, two people talked about changes in what materials are used in systems now. Traditional materials are concrete, gravel, and stone for septic systems and the components. Now, a lot of manufacturers are using recycled plastics like thermoplastics (polypropylene) and corrosion resistant materials as well as the ability to install systems in shallower soils. They are using more advanced pretreatments to allow for a smaller required area for the dispersal field as well. One respondent explained that East Carolina University and North Carolina State University are researching systems that improve function in extreme weather conditions.

According to two participants, there is no technology available that they are aware of that improves the function of septic systems in extreme weather. They further explained that everything they do is based on gallons per day and how much space is available, so weather events do not factor into any decision. However, other respondents provided a list of many technologies that are improving or could improve the function of septic systems during extreme weather, higher sea level, and/or shallower water table conditions. Two participants discussed advanced systems, which are becoming more robust and sustainable. In S.C., they are starting to be used more frequently. Another two people discussed the change in materials that has taken place as manufacturers move toward more recycled plastics and corrosion resistant materials. One participant said drip irrigation is one of the most recent innovations, but it does require a fair amount of operation and maintenance. Another participant said that evaluation techniques for soil evaluation and others have improved and another said that reuse systems are being used more. Reuse systems are systems that are NSF Standard 350[13] and produce water for reuse, which is close to potable water. This participant believes reuse systems are the future of septic systems because they produce clean water, which can be released freely into the environment without risking contamination in the surrounding areas.

When asked what the limitations are to the technologies described above, each participant provided a different response. One participant stated that limited available space was a key limitation. The amount of usable land available is diminishing as more construction takes place, and the sites with the best soils have already been built on. As such, the areas with better soils for septic systems are diminishing as well. Another respondent explained that the current rules allow for adaptation of design by engineers and soil scientists, so a potential limiting factor is that engineers must be willing to take responsibility for a design that includes adaptations. Lack of research on non-traditional materials and how they work in extreme weather is another limitation (1). Some advanced treatment systems require a fair amount of operation and maintenance, particularly drip systems, which can be another limitation (1). Advanced pretreatment systems also are limited to a specific gallons/day rate, which means they can only

[13] NSF/ANSI Standard 350: On-site Residential and Commercial Water Reuse Treatment Systems sets guidelines for water reuse treatment systems. National Sanitation Foundation. Released July 2011. https://d2evkimvhatqav.cloudfront.net/documents/ww_nsf_ansi350_qa_insert.pdf?mtime=20200420102259&focal=none.

put out a certain amount of effluent each day (1). In extreme weather events with saturated soil conditions, those types of systems will be very limited. Finally, cost is a key limitation for many people to install advanced pretreatment systems, which can cost between $10,000 and $15,000 just for the unit.

Weather and climate data/tools

Half (4) of the health regulators interviewed said they are not using any type of weather or climate data or tools, while some (3) are using some, and one (1) is unsure (Figure 36). Of the participants using data/tools related to climate and weather, two people said they are using rainfall data. If there is rainfall to monitor on the site, the data are used in conjunction with groundwater monitoring to model the rainfall for the year to determine if it has been a normal rainfall year at that site. Also, when a site is being evaluated, precipitation data from the state climate office (NC), including precipitation levels, rainfall data, DrainMod (a model out of NC State University) is used to evaluate water levels in relation to rainfall data. Two participants, both in S.C., said they use flood maps when they are applicable to see if a site is in a potential flood area, depending on the type of system being evaluated. High water marks are sometimes used to determine freshwater setback distances (1), and critical lines are used to determine beachfront setback distances (1). One participant who works at the state level in N.C. said they look at the U.S. Geological Service (USGS) for climate information when they act as consultants to local health departments. The same participant said they also look at projections from the National Weather Service (NWS) in those cases. One of the S.C. participants also said they sometimes use the U.S. Department of Agriculture's Web Soil Survey to look at soil classes in certain areas to compare what they see on the site and what has been recorded in the survey for that area.

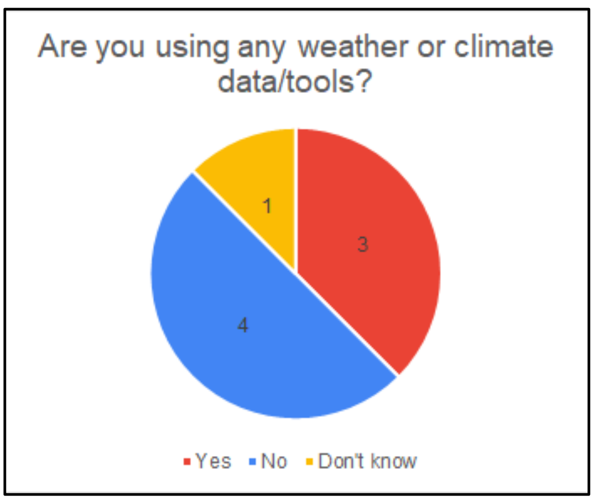

Figure 36. The number of participants who are using some kind of weather or climate data/tools in the regulatory process for onsite wastewater treatment systems.

When asked how the interviewees are using the data and tools described, two people (both in S.C.) said that the flood maps are used when they are evaluating a site to determine if a system is in a flood zone. Another N.C. participant said that the USGS and NWS data are used after flooding during an event like a hurricane to identify areas that are vulnerable to issues from flooding and thus what areas repairs may be needed.

The participants who are using climate data/tools were then asked what recommendations would improve their accessibility and use. Only two people, both in N.C., answered this question. One of those participants said that having GPS locations of every private well, every public well field, every subsurface system, and every water treatment plant would be an ideal situation. They could then use those GPS locations to look at weather path projections to see what areas have been impacted and what systems may have been adversely affected. The other participant who responded said that there used to be a site index that was very useful. It was a tool that enabled them to look up any site, find the date, and then find the 30 year record of rainfall in that area.[14] That tool was eliminated when there were cutbacks to the climate tools available. This participant believes there needs to be continued support of good climate and weather data being available to regulatory agencies.

The participants who are not using any climate data/tools were asked if they are aware that climate tools exist that show coastal flooding projections. A couple (2) of participants responded that yes, they are aware tools exist, while one (1) did not (Figure 37). Those participants were also asked if they see any benefits in having climate or weather data/tools for use in onsite wastewater treatment planning, a couple (2) of which said yes, and a couple (2) said no (Figure 38). When asked if they would know where to go/who to contact to get information about climate or weather data/tools for OWTS planning, both participants (two) who answered this question said no, they do not know.

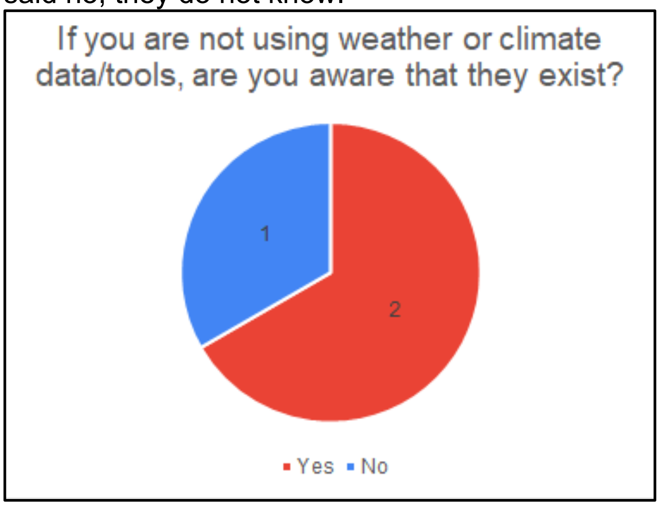

Figure 37. The number of participants who do not use weather or climate data/tools for onsite wastewater treatment regulation and whether they are or are not aware that climate tools exist that show coastal flooding projections.

[14] Possibly referring to the NOAA 30-year climate normals found at: https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals or the NOAA precipitation frequency data server found at: https://hdsc.nws.noaa.gov/hdsc/pfds/.

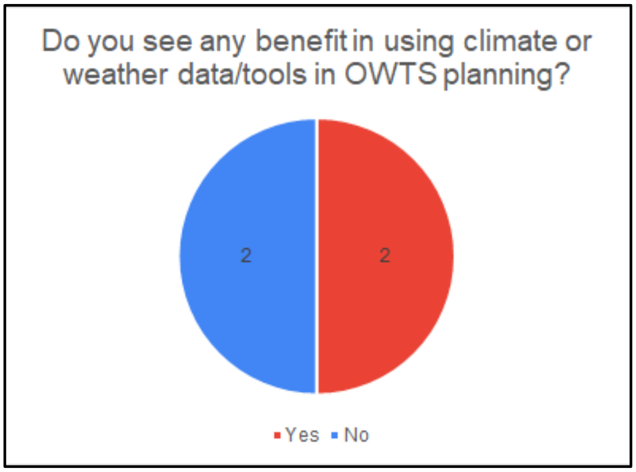

Figure 38. The number of participants who do not use weather or climate data/tools for onsite wastewater treatment regulation and whether they see the benefits of having such data/tools available for OWTS planning.

Public education and training

Participating health regulators were asked what public education or training options are available for property owners to learn about preventing septic system malfunction in the face of extreme weather, rising sea levels, and rising groundwater levels. Three respondents said none - they are not aware of any education or training opportunities that relate to extreme weather, rising sea levels, and rising groundwater levels. One person continued, explaining that money for education in the local health departments has run out, so there is not the same level of education available from the health department as there was 5-6 years ago. Counties used to provide classes as well as “meet and greets” for real estate agents and homeowners who wanted to learn about septic systems. Another three participants said that there is a lot of information on the state websites (NC and SC) about maintenance, how systems work, and information related to flooding. Two respondents (NC) said that the local health departments are available any time to answer people’s questions about their systems, and they also do some outreach. In NC, information on general maintenance of systems (cleaning the tank out, cleaning the filter, harmful actions for systems, etc.) is provided to homeowners during the permitting process (1). Maintenance is also explained to the general contractor when a house is being built. One participant said that a lot of manufacturers have information on their websites as well regarding their systems, and some offer free webinars. The EPA has information on their website as well, and they also have an annual Septic Smart Week to help educate people on their systems (1). Finally, one participant discussed education coming from University Extension programs. East Carolina University has done a lot of research[15] and outreach on septic systems. Also, the NC State University Soil Science Extension program and the Crop & Soil Sciences Department have been very involved in the regulation of septic systems,[16] and they have a lot of information available and do outreach as well.

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[15] Drs. Charles Humphrey and Michael O’Driscoll have produced numerous publications on septic systems out of East Carolina University: https://scholars.ecu.edu/display/F48961432, https://rede.ecu.edu/clusters/natural-resources-environment/michael-odriscoll/.

[16] Dr. Mike Hoover at NCSU in the Crop and Soil Sciences Department conducted research on advanced treatment technology in septic systems in the early 2000s. His research may have been used as research backing for the approval of use of advanced treatment technologies in septic systems. Links to Crop and Soil Sciences Publications and resources: https://cals.ncsu.edu/crop-and-soil-sciences/extension/publications/

When asked what education or training options are available for installers or operators to learn about taking sea level rise, increasing groundwater tables, and flooding into consideration when making site decisions, most (6) participants discussed the continuing education units (CEUs) that are required for installers and operators each year to maintain their licenses. CEUs are required in both North and South Carolina, and the number of hours that are required depends on the person's tier of certification. CEUs can be obtained at N.C.'s onsite wastewater protection conference every year, from opportunities through NC State University, through the North Carolina Rural Water Association,[17] and others. However, the continuing education currently available likely does not address weather and climate.[18] Three participants said there are no education opportunities available that are related to weather or climate.

Availability of Grants and Loans for System Replacement and Repair

When asked what grants or loans are available for small-flow systems, half of respondents (4) described the USDA Rural Development Loan/Grant Program,[19] which has been available for repairing onsite systems fairly consistently over the years. It provides funding for clean and reliable drinking water systems, sanitary sewage disposal, sanitary solid waste disposal, and stormwater drainage to households and businesses in eligible areas. Homeowners can also apply for a low-interest loan for repairing their system through the new Farm Bill.[20] Three participants said there are some funds available through the U.S. Environmental Protection Agency (EPA) as well, specifically through the Rural Life Wastewater Loan Program, but the EPA also provides a list of financing options for people to reference.[21] There are also some funds available through the states (3). According to those participants, some states use their state revolving fund to make funds available to individual homeowners needing to repair their septic systems. The N.C. Housing Finance Agency has urgent repair programs for elderly and low-income individuals. Another three participants said some councils of government sponsor programs to do septic system repairs, but those funds are very limited right now. One of those programs is the Western Piedmont Council of Government,[22] which offers no interest revolving loans for qualifying homeowners to repair systems, but it was limited to four counties: Caldwell, Catava, Burke, and Alexander. That program is administered by the Clean Water Trust Fund. One respondent said the Town of Nags Head offers some low-interest or no-interest financing to encourage homeowners to repair or replace their drainfields who cannot afford to do so on their own.[23] Finally, one person mentioned that there was money for grants/loans from the NC State Extension,[24] but he is unsure if there is currently any money available through there.

Participants were also asked what grants or loans are available for large-flow systems. Most (6) respondents said they did not know of any. Participants further explained that those types of systems have to either be owned by public service entities that have assurance bonding for making septic system repair, or by a private service entity. If it is a private entity, they have to show assurance that they can financially make those repairs. However, three participants said the USDA has a waste disposal program through which state and local entities as well as some

[17] https://www.ncrwa.org/
[18] Erik Severson at the NCSU Extension offered a training webinar in February 2021 entitled "Impact of Sea Level Rise on Septic Systems in Coastal Communities." The training was designed for soil scientists and designers.
[19] https://www.rd.usda.gov/page/all-programs
[20] https://www.usda.gov/farmbill
[21] https://www.epa.gov/septic/programs-related-septic-systems
[22] https://www.wpcog.org/
[23] https://www.nagsheadnc.gov/280/Septic-Health-Initiative-Water-Quality
[24] No record of funding from NCSU Extension was found to corroborate this statement.

private nonprofit organizations and recognized tribes can apply for loans. In North Carolina, two people said that local governments run the Clean Water State Revolving Loan Program,[25] which offers funds for repair of any wastewater infrastructure including package treatment plants, municipal sewage, and septic systems. One respondent mentioned the Southeastern Rural Community Action Project (SERCAP), which does some work with small communities on wastewater issues that could include rehabilitation/repair of package treatment plants.[26] That program would likely use USDA funding.

CONCLUSIONS: HEALTH REGULATOR INTERVIEWS

Challenges to OWTS

Challenges noted by health regulators included:

- Rising water table conditions: If the water table is too high, it does not allow for the required vertical separation distance between the seasonal high water mark and the bottom of the drainfield for proper functioning.
- Limited space available for lots with septic systems because of the rapid growth occurring along the coast. The largest lots with the best soils have already been built on, so the lots remaining are smaller with less ideal soils. Developers often want to build as much house square footage on the smallest lot possible, which results in very little space to dispose of wastewater effectively in a septic system.
- Saltwater intrusion from flooding events, hurricanes, and storm surges
- Insufficient regulations: There is a lack of sustainable programs of operation and maintenance for systems in municipalities that are needed to keep onsite systems up-to-date and working properly in the long term.

Site permitting

Determination of what type of system will be installed on a site is done on a case-by-case basis. Health regulators noted the following factors for determining which type of system is installed:

- Vertical separation and zone of saturation;
- Soil morphology (texture, structure, clay mineralogy, organic composition, and presence of constrictive horizons);
- Available space on the lot; and
- Horizontal setbacks (environmental factors).

Advanced systems are quite common in many areas of the Carolinas and are becoming more so due to declining numbers of sites with ideal conditions. Advanced systems are needed when site conditions are poor, whether that's because there is limited space on the site for wastewater treatment, the soil and landscape has poor drainage capacity, or the water table is high in that area and is restricting the treatment area.

While there are some indirect ways in which weather and climate are taken into account when making a site decision, such as mean high water marks along beaches, the clear consensus among regulators who were interviewed is that weather and climate are not taken into account directly. When evaluating a site, they are looking at a snapshot of the site on the day of the evaluation, and that is the information used to permit a site for wastewater treatment. This is

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[25] https://www.epa.gov/cwsrf

[26] http://sercap.org/get-assistance/for-individuals

true in terms of flooding risk as well. The fact that a site floods does not in itself impact if a site gets permitted because permitting is based on the zone of saturation and soil texture on the site. However, systems are not permitted to be installed in areas designated as flood zones.

Water table height and potential flooding conditions are determined by a soil scientist during the soil evaluation by looking at soil color to determine where the water table is and soil texture, which indicates how quickly the soil will move water and effluent. A 12" vertical setback is required, which is determined by the measurement taken on the day of the evaluation. Regulations do not require a buffer for rising groundwater table conditions, but some inspectors add some buffer to allow for it and for human error during installation.

Inspections

In North Carolina, conventional systems are not required to be inspected unless there is a problem that needs to be investigated, whereas engineered systems do require regular inspections. The frequency of those inspections depends on the type of system. If a system fails an inspection in N.C., a notice of violation is sent to the homeowner, after which homeowners almost always bring their systems back into compliance, so further regulatory action is usually not necessary. There are no inspection requirements for conventional or engineered systems in South Carolina.

Communications

Communications with property owners about regulations and requirements related to their septic systems are limited and are not consistent across either state. Health regulators reported that information is provided to owners when the system is installed, but after that, communication between regulators and owners varies as it depends on the practices and funding of the local health departments and districts. Regulators noted that some operators and realtors provide information on a property's septic system when the property is sold, but this is not universal. Educational materials on OWTS are provided by local health departments and districts, but generally have to be sought after by the property owner (i.e. via an educational website) and are not directly provided to every homeowner. Similarly, flooding risk is not communicated directly to homeowners with septic systems, but there are alerts to flooding risks in the form of public service announcements to the entire community. Again, there is information on publicly available websites on how to care for septic systems before, during, and after flooding events, but use of that information requires that homeowners seek it out. Direct communication with homeowners of this information would ensure everyone received the information and could potentially help homeowners prepare and recover their systems from flooding events.

Extreme weather conditions and events

All of the health regulators interviewed said that regulations have not changed in response to any changes in frequency or intensity of weather events over time, and almost all of them also said that they have not noticed any changes in terms of weather impacts on the functioning of septic systems over time. However, there are often higher numbers of malfunctions noticed by regulators after extreme weather, such as hurricanes or prolonged rain events. Some regulators noted that decentralized systems (individual systems and/or package treatment plants) may potentially be able to handle extreme weather conditions better than centralized wastewater treatment plants. They explained how systems are able to recover on their own after a weather-related malfunction given time for water to recede and soils to dry out.

Vacation sites

There are no special considerations made for vacation homes. Like any other type of site, system type is chosen based on site conditions, including available space and soil conditions, and the number of bedrooms in the house. A common problem seen at vacation homes is over-occupancy of the house, which can overload the septic system.

PTPs

PTPs typically have more inspection requirements, pollutant restrictions, and operator requirements.

Weather scenarios

In dry soil conditions, a 2" rainfall is not likely to cause a conventional system to malfunction, unless the site had drainage issues prior to the event. However, in wet soils conditions, a 2" rainfall is more likely to cause a malfunction in a conventional system, especially if the lot has poor drainage features. Malfunction is more likely in inland areas with clay soils because they have a slower drainage rate. The condition of the septic system also plays a significant role in whether or not a system malfunctions from weather events. If there is a biomat building up along the drainlines or the system is not maintained properly, the system is more likely to malfunction. If a malfunction does occur in a conventional system that is well-maintained and does not have any physical damage to it, it would be expected to recover on its own given time to rest and the soils to dry out. Given dry weather conditions, that usually occurs within a week of the malfunction.

Along the coast, a high tide or King Tide event that occurs in an area with saturated soils is highly likely to cause conventional systems to malfunction. While the amount of time it would take for a conventional system to recover would again vary depending on the site conditions, it would be expected to recover within a few days to a week after the water recedes and the soils are given an opportunity to dry out.

If an advanced system were to malfunction from hydraulic failure from a weather event, it would need time to rest and dry out the soils in order to recover, just as conventional systems would. However, if there was an electrical or component failure from the water inundation, there would need to be a repair to the system to get it functioning again. The same is true of package treatment plants: with a hydraulic failure, time to dry the soils in the drainfield would be all that is needed, but a component failure would need a repair. Package treatment plants have many components that could potentially malfunction from inundation.

Repeated weather-related malfunctions to septic systems could have a long-term impact on the life of the system and shorten its lifespan if those events result in biomat buildup in the trenches of the drainfield or if the aerobic environment of the soil deteriorates. A reduction in the soil's treatment capacity over time will inevitably lead to system malfunction down the road. However, repeated weather-related malfunctions would not impact the life expectancy of the system if it is able to fully recover after each rainfall or flooding event and does not sustain any physical damage from the event.

High groundwater tables

Higher groundwater table conditions were acknowledged to be a real concern for onsite wastewater treatment systems, although most of the regulators had not personally observed these issues. Higher groundwater tables can cause chronic problems if the rising water results in a vertical separation distance less than is required. If that occurs, homeowners will likely observe water backing up in the house and ponding over the system drainfield.

Adaptation measures

While some health regulators reported that current regulations include measures to adapt septic systems to more extreme weather conditions, measures described did not go beyond the required individual site evaluations and methods of ensuring a system complies with the site permit. One health regulator said he believed the most important adaptation that could be implemented for onsite wastewater systems would be sustainable management of systems. This would mean an ongoing program in which inspections and maintenance of systems is tracked to ensure systems remain well-maintained and compliant with regulations. As it stands currently, older systems often fall through the cracks and are not tracked to ensure they remain maintained and properly functioning. Another regulator stated that having GPS locations of every private well, public well field, subsurface system, and water treatment plant would enable them to track each system and ensure proper functionality over time, as well as to identify problem areas and potential solutions.

Most health regulators interviewed were not aware of any technologies that are meant to address climate change effects on septic systems. The only technological changes mentioned were non-traditional materials used for lining trenches and the use of advanced pretreatment systems to adapt to changes in weather and climate. The need for advanced pretreatment systems is increasing as the amount of usable land available is diminishing as more construction takes place, and the sites with the best soils for septic systems have already been built on. However, a key limitation for many people to install advanced systems is cost, as the cost for installing them is often between $10,000 and $15,000 just for the unit.

Public education and training

Health regulators were not aware of any education or training opportunities that relate specifically to extreme weather, rising sea levels, and rising groundwater levels. According to one interviewee, money for education in the local health departments has run out in recent years, so there is not the same level of education available from the health department as there was 5-6 years ago.

APPENDIX 1: Handout provided to participating operators and installers for reference.

Small-flow systems (<1,500 gallons/day)

Advanced treatment systems - pretreatment components

- **Aerobic Treatment Unit (ATU):** Injects oxygen into treatment tanks to increase natural bacterial activity.
- **Single-pass media filters**: Effluent from the septic tank is pressure dosed over a media filter (often PVC-lined or a concrete box filled with sand or other media) and is treated as it filters down once through the media, then is diverted to the drainfield discharge basin for final dispersal.
- **Recirculating media filter system:** Effluent from the septic tank is pressure dosed over a media filter (often PVC-lined or a concrete box filled with sand or other media) and is treated as it filters down through the media, then is recirculated back to the septic tank for further treatment. The effluent may be recirculated several times over the media filter before being diverted to the drainfield discharge basin for final dispersal.
- **Constructed wetland systems:** Effluent flows from the septic tank to the wetland cell where it passes through media and is treated by microbes, plants, and other media that remove pathogens and nutrients before flowing into a drainfield.

Dispersal Systems

- **Conventional Systems:** gravel trench/drainfield
- **Modified Conventional Systems:**
    - Shallow conventional: May go in shallower soil but has the same components as a conventional system.
    - Gravelless trench/chamber system: Plastic louvered chambers, polystyrene aggregate, tire chip aggregate, or large diameter pipes are used in place of gravel aggregate.
- **Low-pressure pipe system (LPP):** Used where suitable or provisionally suitable soil depth inhibits the use of a conventional system. It consists of a series of small diameter pipes that require a pump to pressure-dose the system.
- **Drip distribution system:** Timed dose delivery of wastewater to a drip absorption area.
- **Mound system:** Effluent from the septic tank is pumped in prescribed doses into a constructed sand mound that contains a drainfield trench where it filters through the sand.

Large-flow systems (>1,500 gallons/day)

Package wastewater treatment plant (PTP) system: treats effluent from a group of properties in a small sewage treatment plant that contains a combination of treatment components. Types include: extended aeration, sequence batch reactors, oxidation ditches, contact stabilization plants, rotating biological contactors, and physical/chemical processes.

Collection/Conveyance Systems

- **Pressure system:** Uses pressurized piping to move effluent from each septic tank to the drainfield. Includes both low pressure grinder pump systems and STEP pressure systems
- **Gravity system:** Uses gravity to move effluent from each septic tank to the drainfield.
- **Vacuum system:** Uses vacuum pressure to move effluent from each septic tank to the drainfield.

Advanced Treatment Components

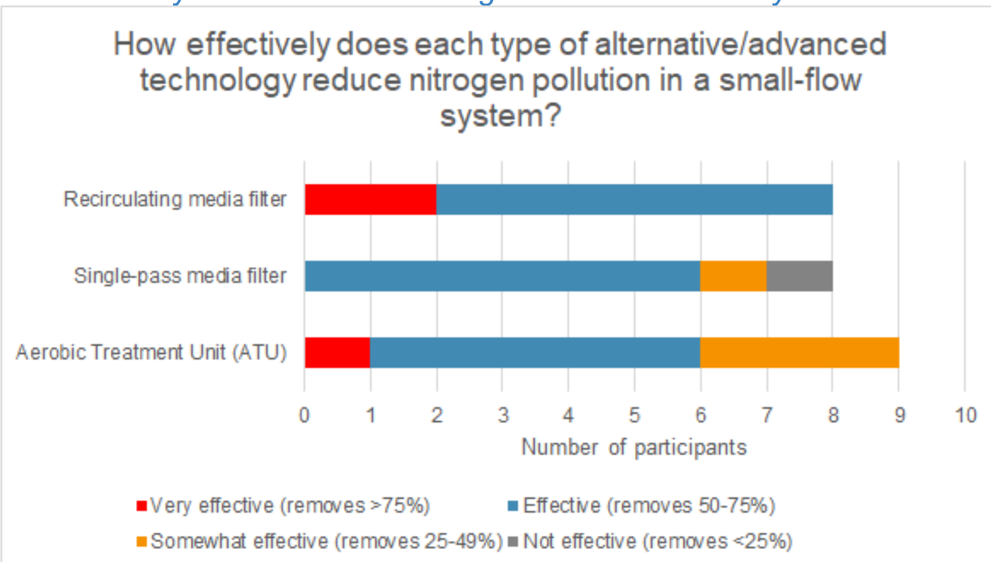
- **Activated Sludge Aeration:** Treatment using aeration and a biological floc composed of bacteria and protozoa.
- **Membrane bioreactors (MBR):** wastewater treatment that combines conventional biological treatment (e.g. activated sludge) processes with membrane filtration to provide an advanced level of organic and suspended solids removal.
- **Oxidation ditch:** a modified activated sludge biological treatment process that utilizes long solids retention times (SRTs) to remove biodegradable organics.
- **Sequencing batch reactors (SBR):** a fill-and-draw activated sludge system in which wastewater is added to a single “batch” reactor, treated to remove undesirable components, and then discharged. A SBR contains two or more reactor tanks that are operated in parallel, or one equalization tank and one reactor tank.
- **Trickling filters:** a fixed bed of rocks, coke, gravel, slag, polyurethane foam, sphagnum peat moss, ceramic, or plastic media over which wastewater flows downward and causes a layer of biofilm to grow, covering the media.
- **Disinfection pretreatment technologies**
    - **Ultraviolet disinfection:** Neutralizes microorganisms as they pass by UV lamps submerged in the effluent.
    - **Chlorination and Dechlorination:** Chlorine is added into the effluent for disinfection, then is removed from wastewater prior to discharge into the drainfield.
    - **Ozone Disinfection Unit:** Ozone is injected into the effluent for disinfection.

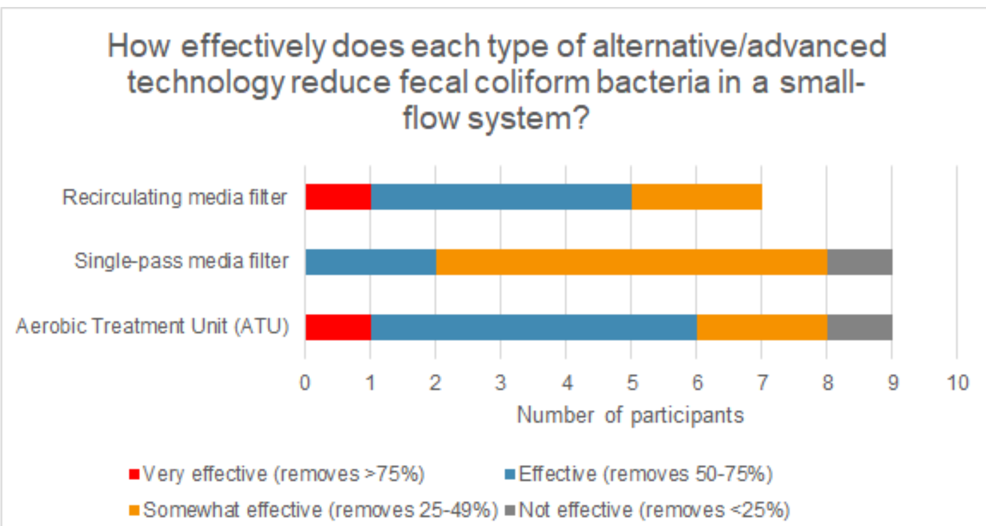
Dispersal Systems (subsurface)

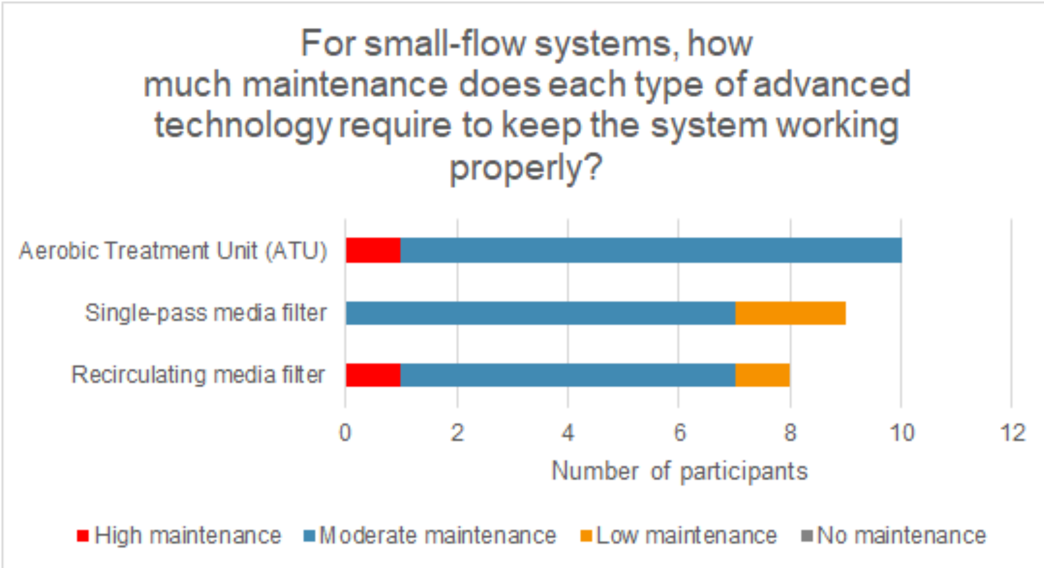
- **Conventional Systems:** gravel trench/drainfield
- **Modified Conventional Systems:**
    - Shallow conventional: May go in shallower soil but has the same components as a conventional system.
    - Gravelless trench/chamber system: Plastic louvered chambers, polystyrene aggregate, tire chip aggregate, or large diameter pipes are used in place of gravel aggregate.
- **Low-pressure pipe system (LPP):** Used where suitable or provisionally suitable soil depth inhibits the use of a conventional system. It consists of a series of small diameter pipes that require a pump to pressure-dose the system.
- **Drip distribution system:** Timed dose delivery of wastewater to a drip absorption area.
- **Mound system:** Effluent from the septic tank is pumped in prescribed doses into a constructed sand mound that contains a drainfield trench where it filters through the sand.

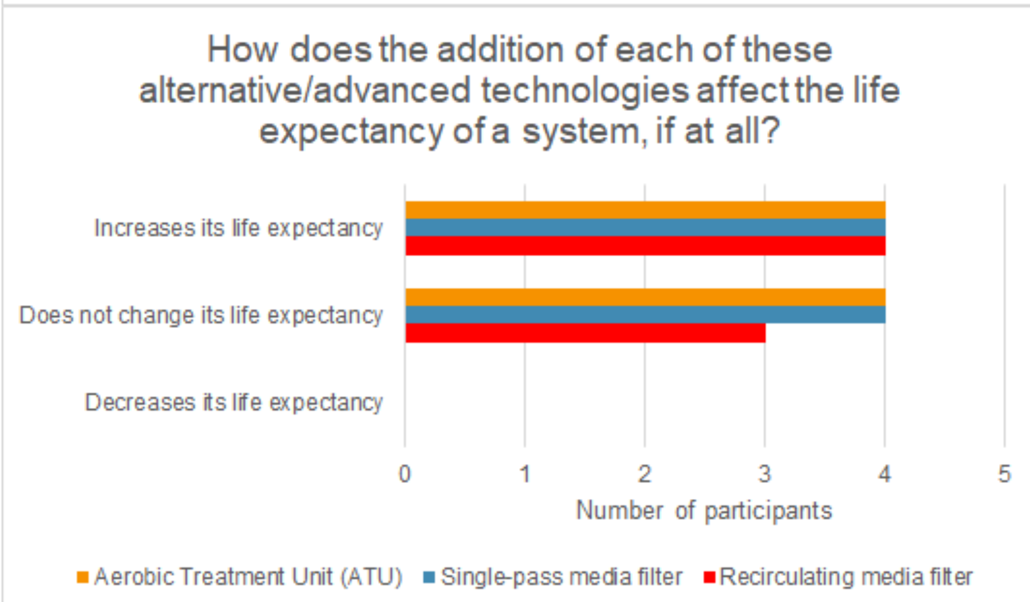
APPENDIX 2: Survey results of the effectiveness of each type of small and large flow OWTS system.

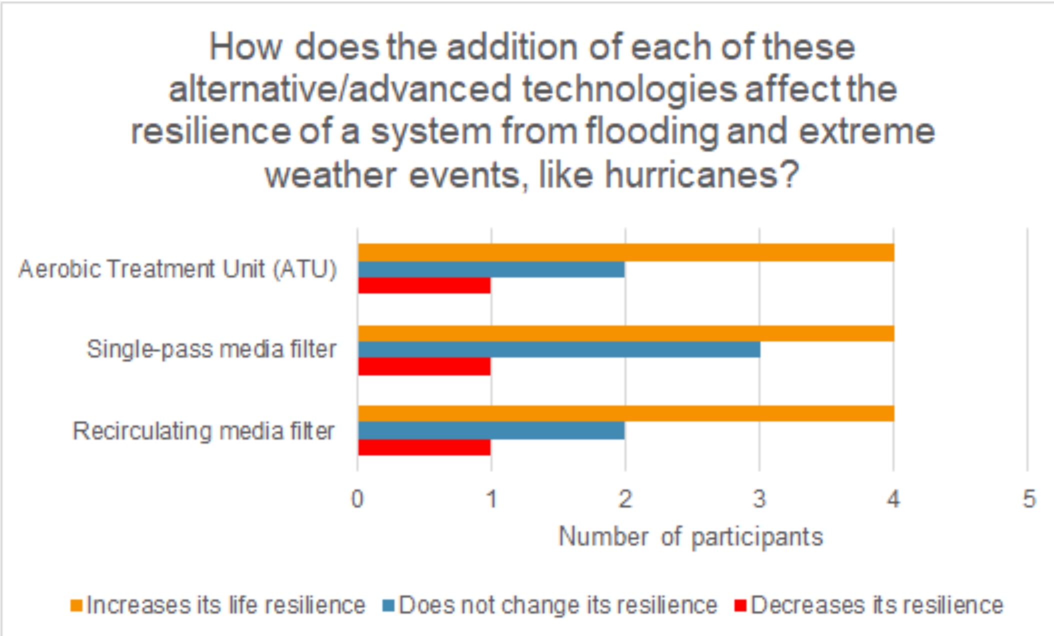
Small-flow systems: Advanced/engineered treatment systems

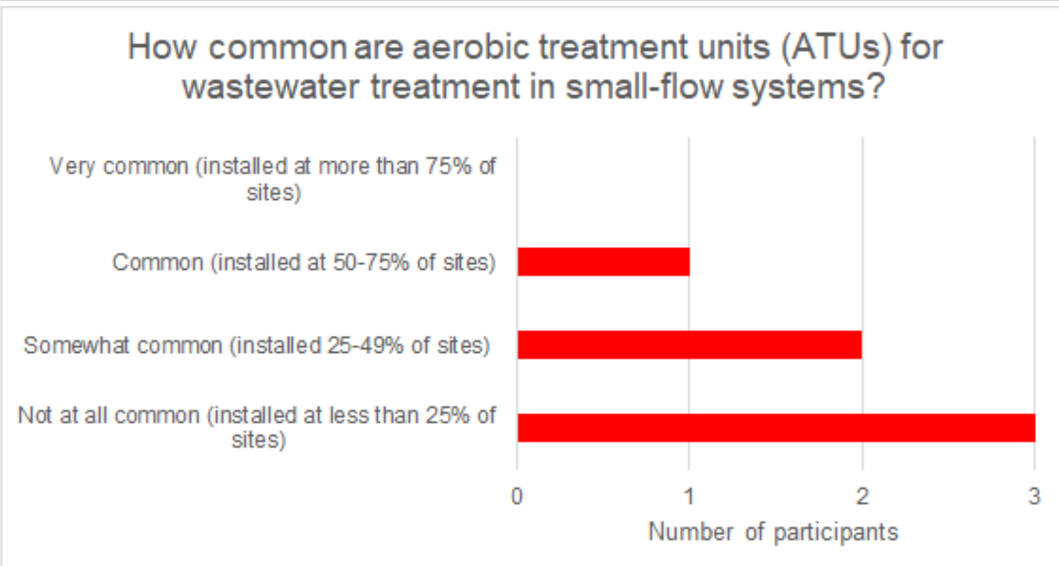


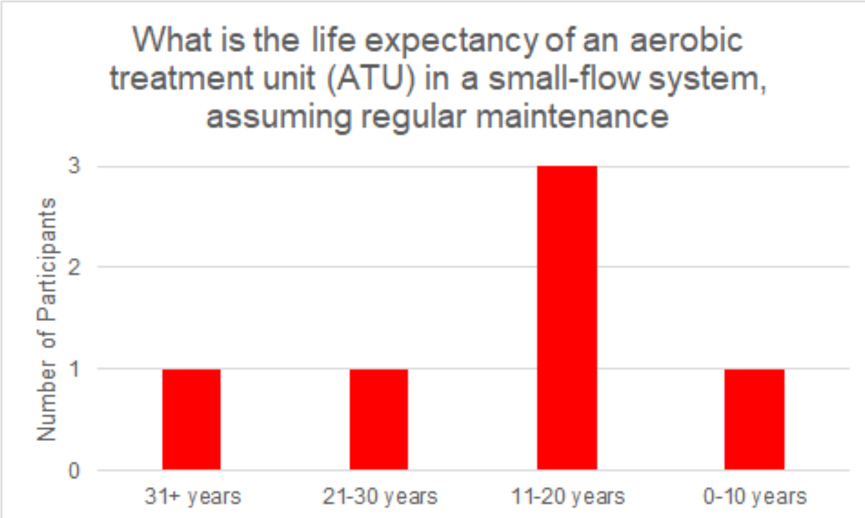


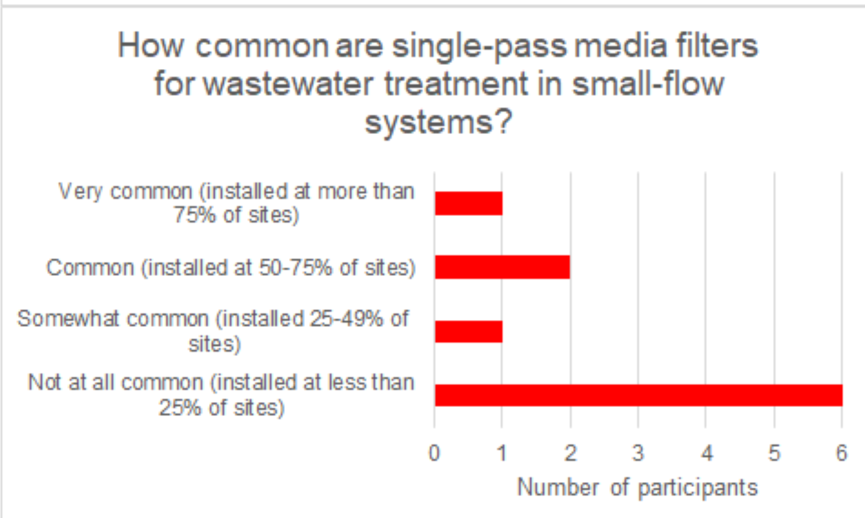

For small-flow systems, how much maintenance does each type of advanced technology require to keep the system working properly?
Aerobic Treatment Unit (ATU)
Single-pass media filter
Recirculating media filter
0
2
4
6
8
10
12
Number of participants
High maintenance
Moderate maintenance
Low maintenance
No maintenance

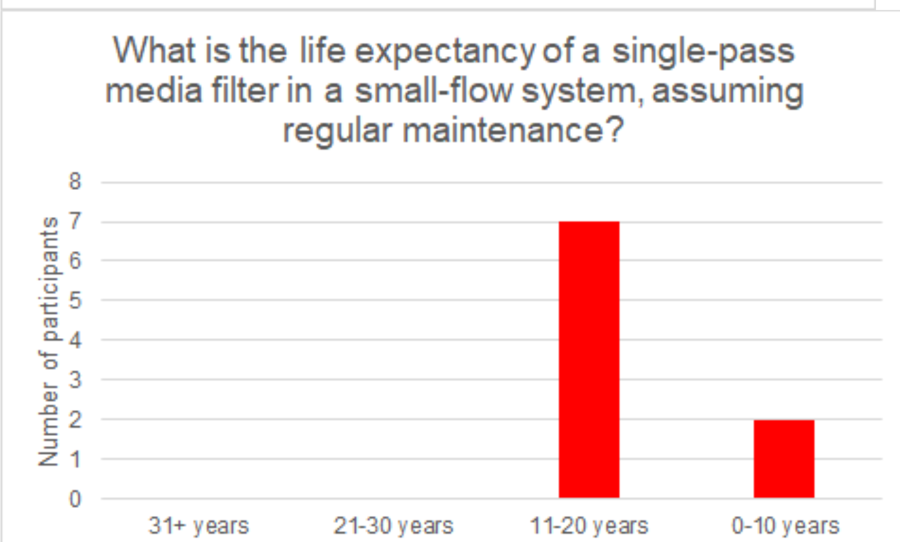

How does the addition of each of these alternative/advanced technologies affect the life expectancy of a system, if at all?
Increases its life expectancy
Does not change its life expectancy
Decreases its life expectancy
0
1
2
3
4
5
Number of participants
Aerobic Treatment Unit (ATU)
Single-pass media filter
Recirculating media filter

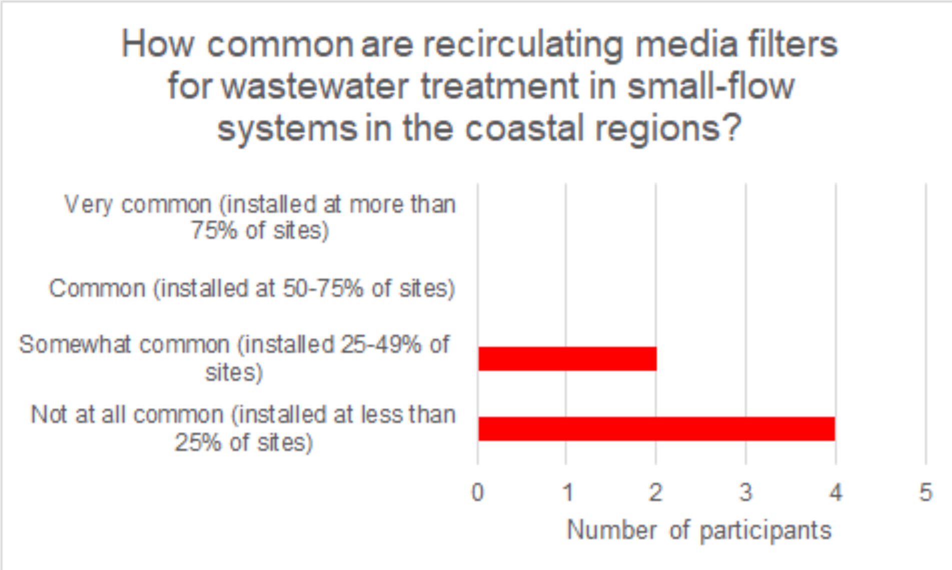

How does the addition of each of these alternative/advanced technologies affect the resilience of a system from flooding and extreme weather events, like hurricanes?
Aerobic Treatment Unit (ATU)
Single-pass media filter
Recirculating media filter
0
1
2
3
4
5
Number of participants
Increases its life resilience
Does not change its resilience
Decreases its resilience

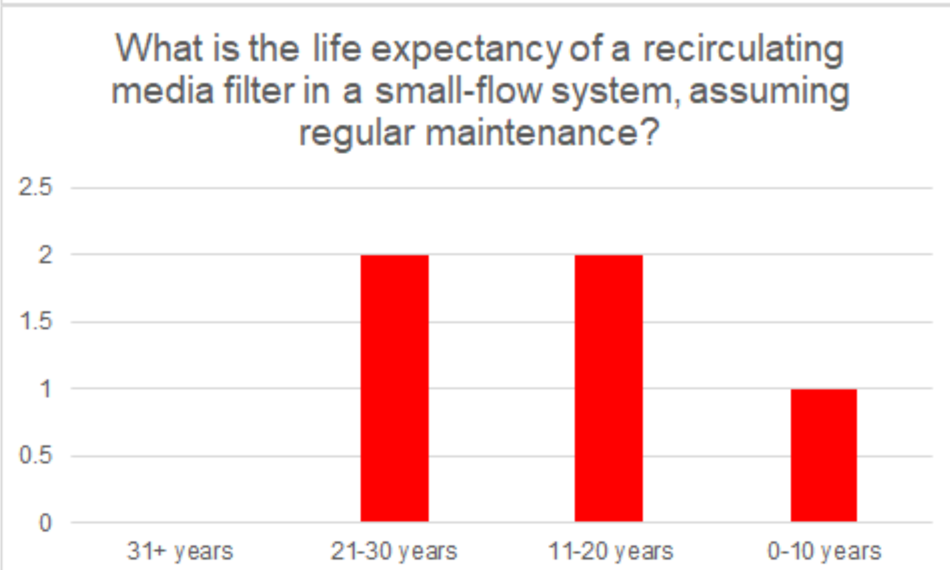

How common are aerobic treatment units (ATUs) for wastewater treatment in small-flow systems?
Very common (installed at more than 75% of sites)
Common (installed at 50-75% of sites)
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)
0
1
2
3
Number of participants


What is the life expectancy of an aerobic treatment unit (ATU) in a small-flow system, assuming regular maintenance
Number of Participants
0
1
2
3
31+ years
21-30 years
11-20 years
0-10 years

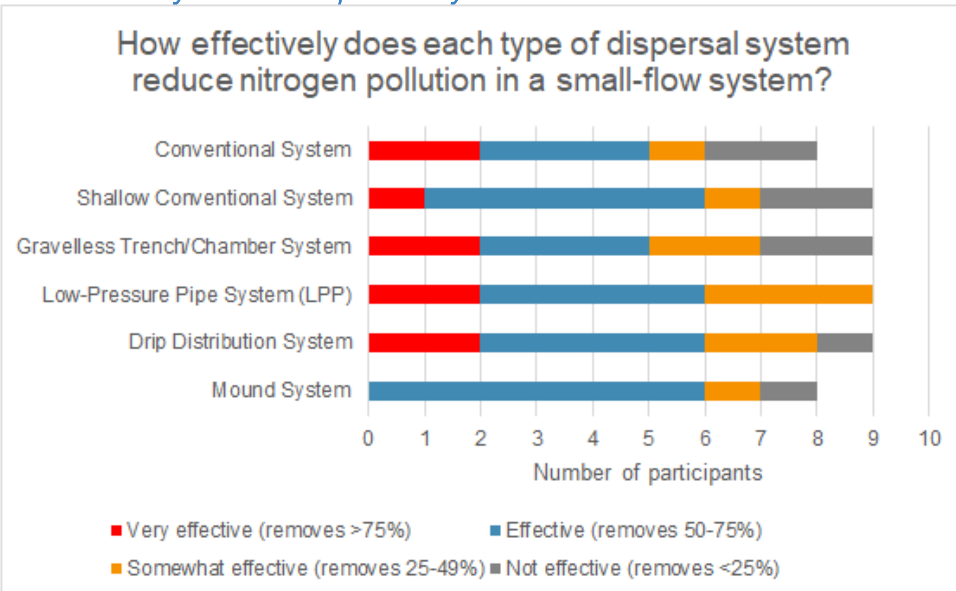

How common are single-pass media filters for wastewater treatment in small-flow systems?
Very common (installed at more than 75% of sites)
Common (installed at 50-75% of sites)
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)
0 1 2 3 4 5 6
Number of participants

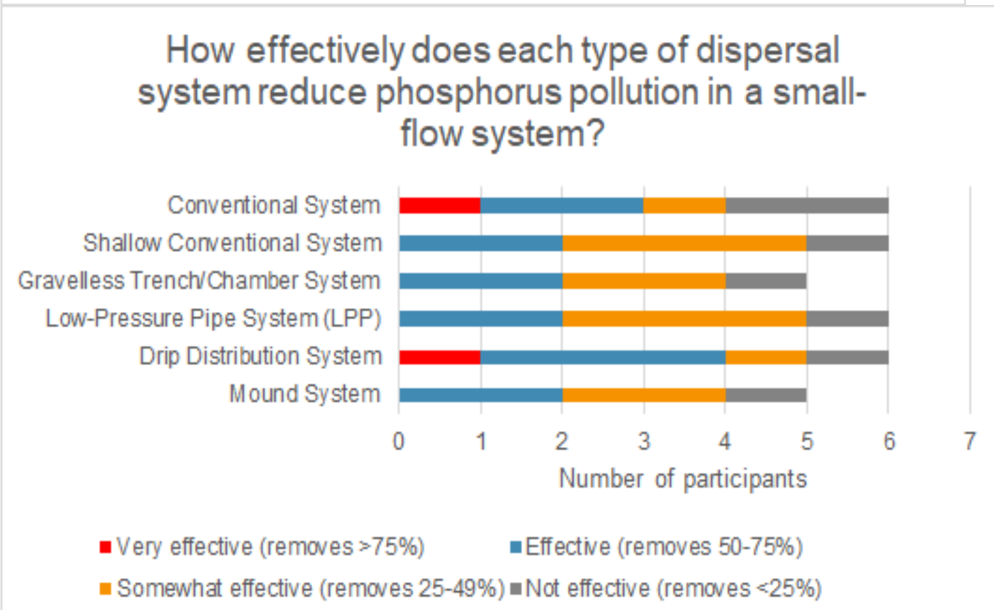

What is the life expectancy of a single-pass media filter in a small-flow system, assuming regular maintenance?
Number of participants
0
1
2
3
4
5
6
7
8
31+ years
21-30 years
11-20 years
0-10 years

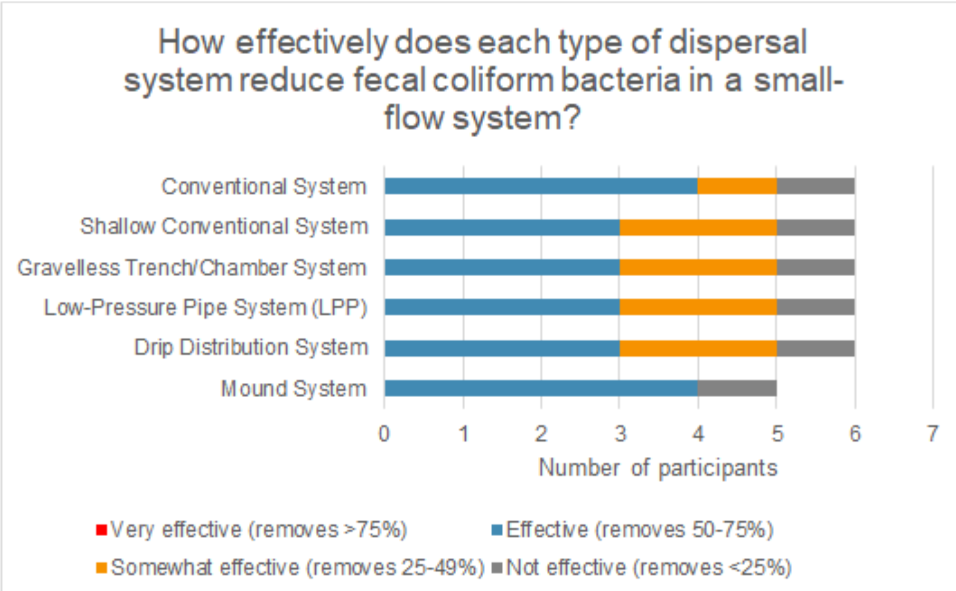

How common are recirculating media filters for wastewater treatment in small-flow systems in the coastal regions?
Very common (installed at more than 75% of sites)
Common (installed at 50-75% of sites)
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)
0
1
2
3
4
5
Number of participants

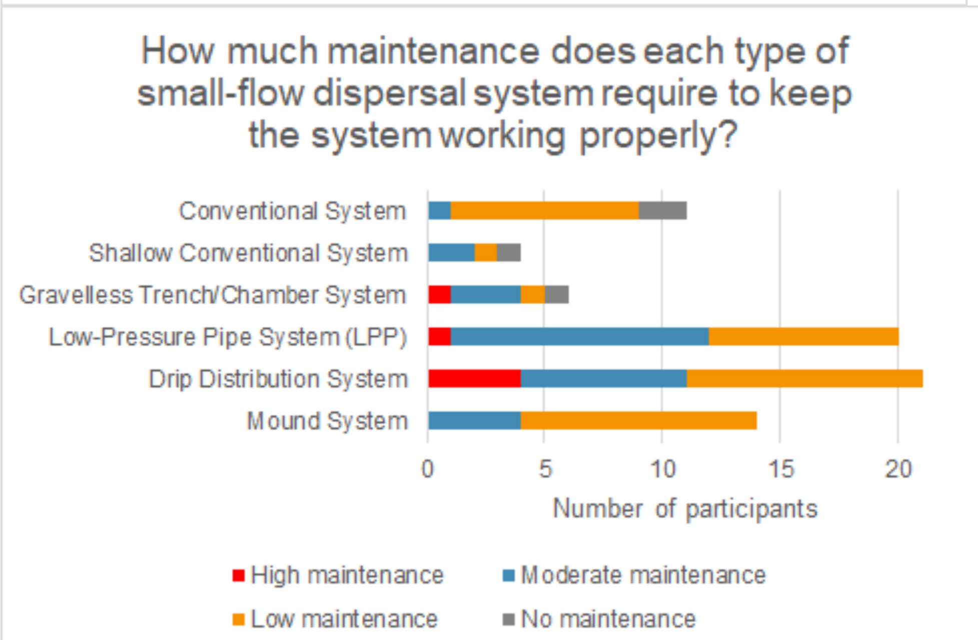

What is the life expectancy of a recirculating media filter in a small-flow system, assuming regular maintenance?
2.5
2
1.5
1
0.5
0
31+ years
21-30 years
11-20 years
0-10 years

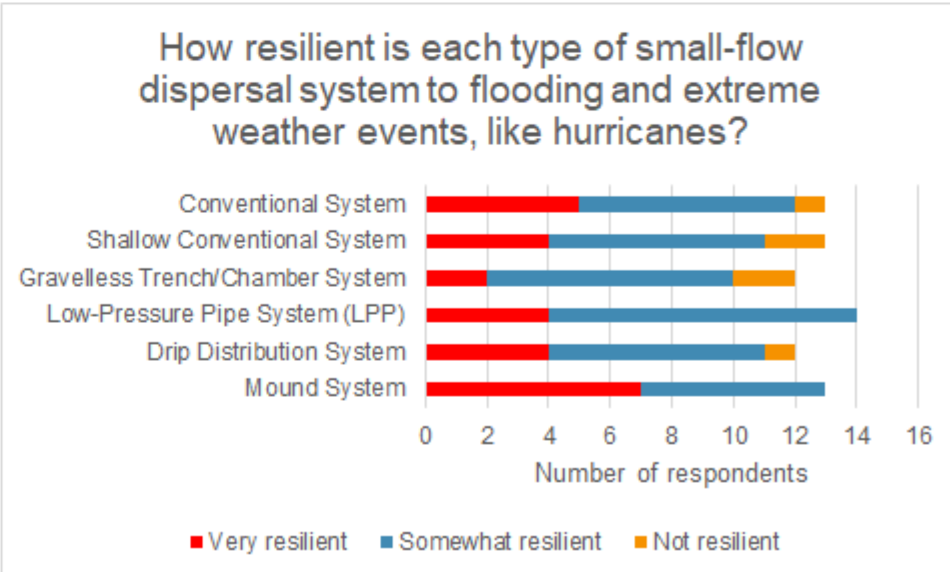
Small-flow systems: Dispersal systems

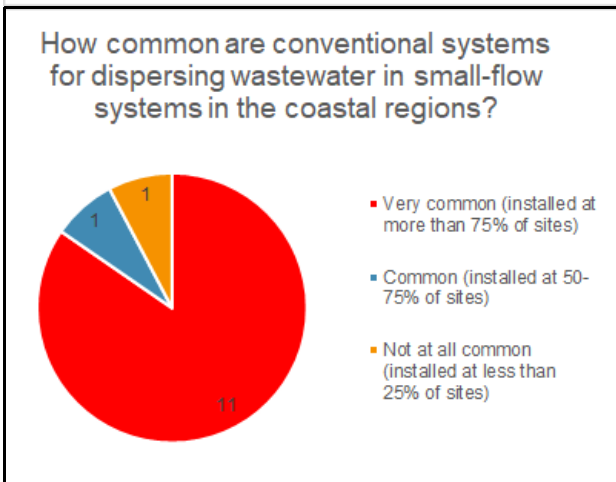


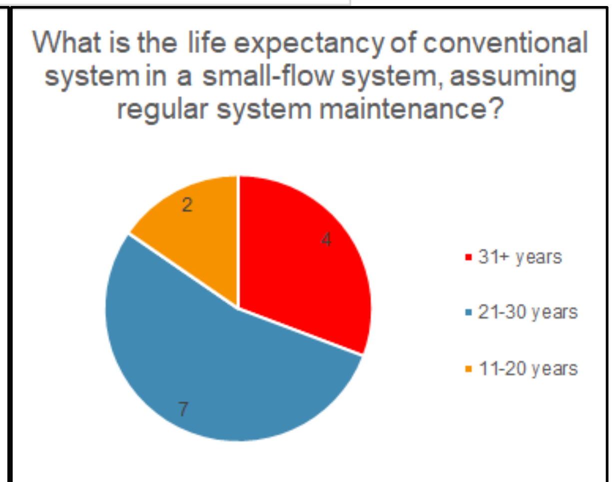


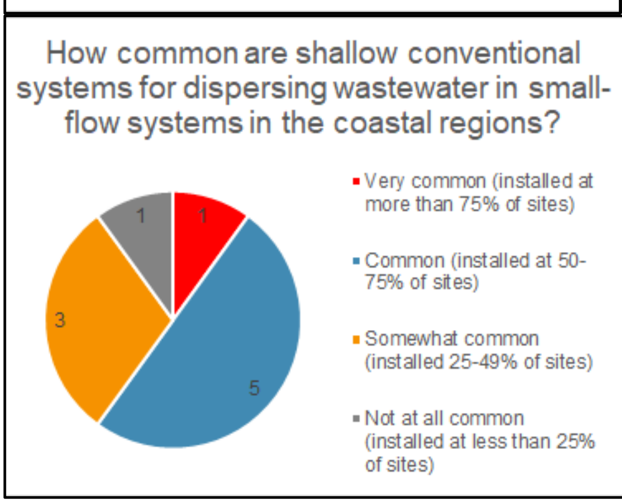

How effectively does each type of dispersal system reduce fecal coliform bacteria in a small-flow system?
Conventional System
Shallow Conventional System
Gravelless Trench/Chamber System
Low-Pressure Pipe System (LPP)
Drip Distribution System
Mound System
0 1 2 3 4 5 6 7
Number of participants
Very effective (removes >75%)
Effective (removes 50-75%)
Somewhat effective (removes 25-49%)
Not effective (removes <25%)

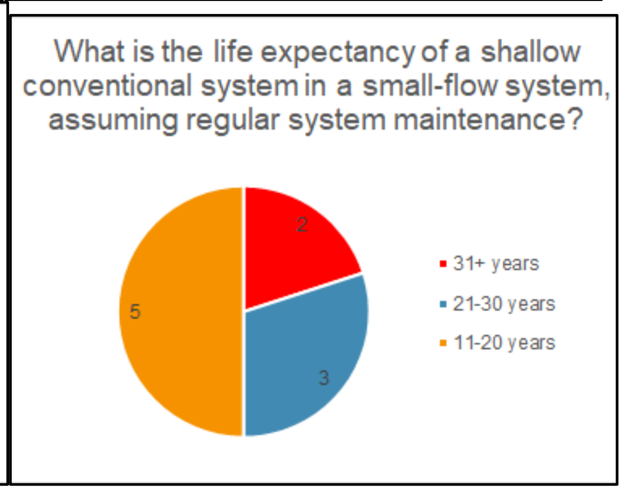

How much maintenance does each type of small-flow dispersal system require to keep the system working properly?
Conventional System
Shallow Conventional System
Gravelless Trench/Chamber System
Low-Pressure Pipe System (LPP)
Drip Distribution System
Mound System
0 5 10 15 20
Number of participants
High maintenance
Moderate maintenance
Low maintenance
No maintenance

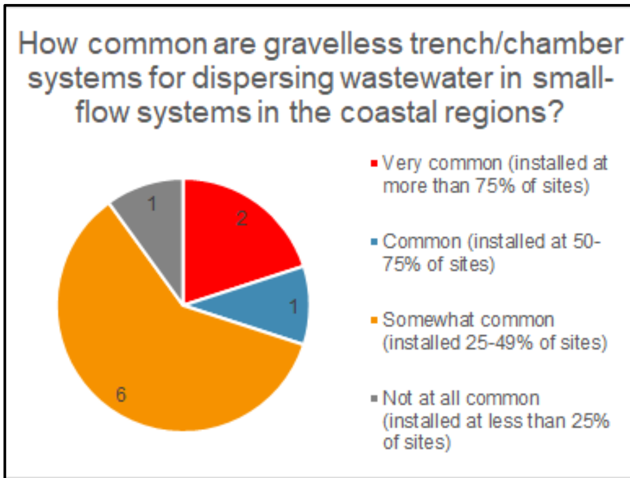

How resilient is each type of small-flow dispersal system to flooding and extreme weather events, like hurricanes?
Conventional System
Shallow Conventional System
Gravelless Trench/Chamber System
Low-Pressure Pipe System (LPP)
Drip Distribution System
Mound System
0 2 4 6 8 10 12 14 16
Number of respondents
Very resilient
Somewhat resilient
Not resilient

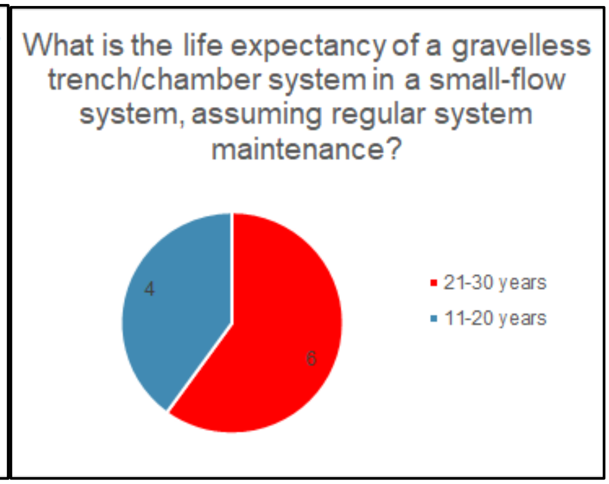

How common are conventional systems for dispersing wastewater in small-flow systems in the coastal regions?
1
1
11
Very common (installed at more than 75% of sites)
Common (installed at 50-75% of sites)
Not at all common (installed at less than 25% of sites)

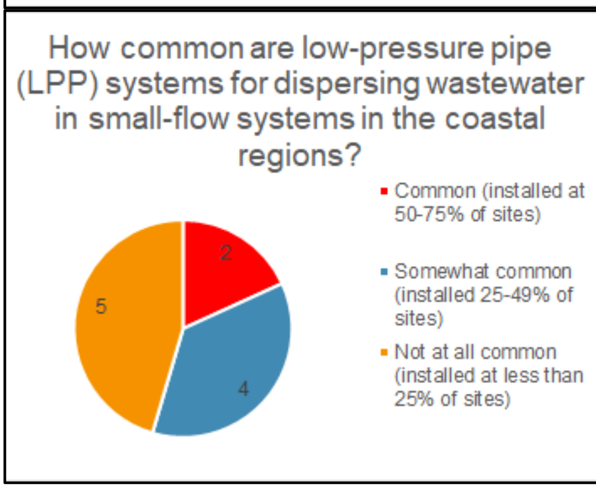

What is the life expectancy of conventional system in a small-flow system, assuming regular system maintenance?
2
4
7
31+ years
21-30 years
11-20 years

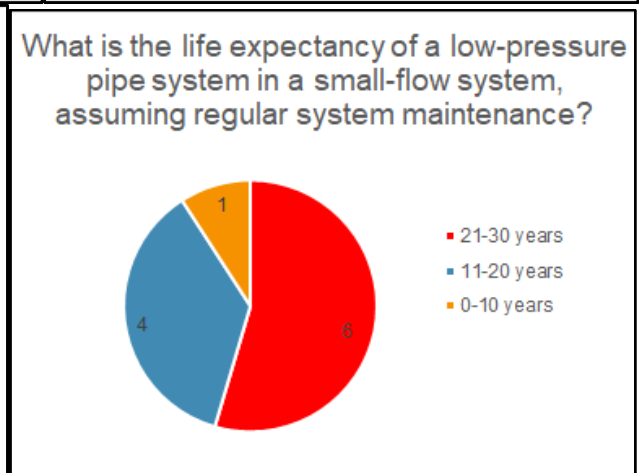

How common are shallow conventional systems for dispersing wastewater in small-flow systems in the coastal regions?
1
1
3
5
Very common (installed at more than 75% of sites)
Common (installed at 50-75% of sites)
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)

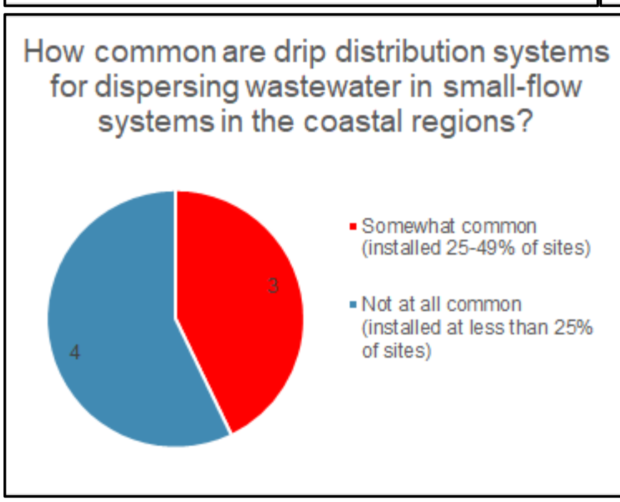

What is the life expectancy of a shallow conventional system in a small-flow system, assuming regular system maintenance?
2
5
3
31+ years
21-30 years
11-20 years

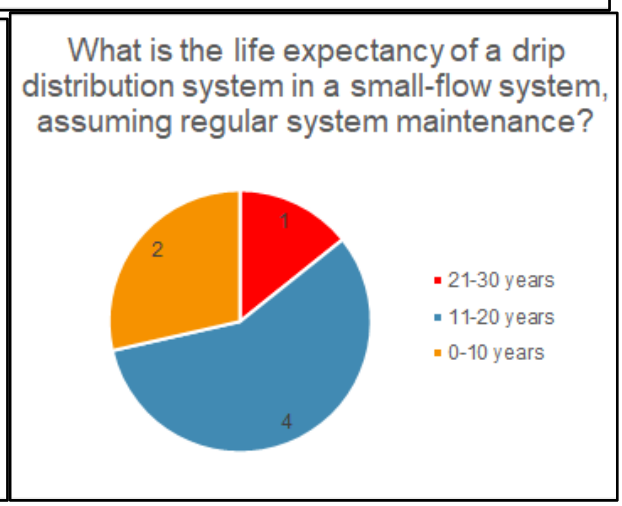

How common are gravelless trench/chamber systems for dispersing wastewater in small-flow systems in the coastal regions?
Very common (installed at more than 75% of sites)
Common (installed at 50-75% of sites)
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)
2
1
6
1

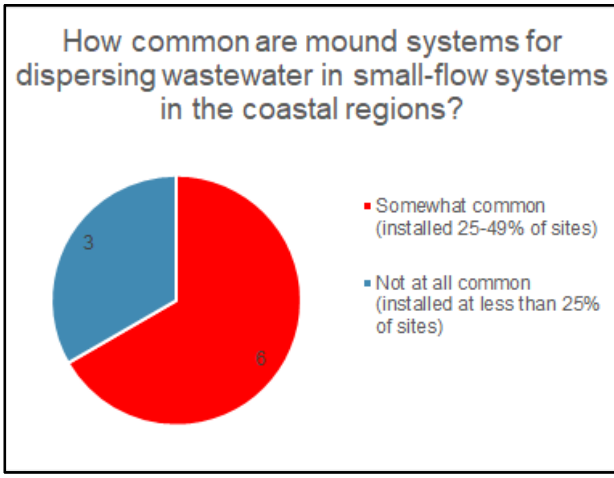

What is the life expectancy of a gravelless trench/chamber system in a small-flow system, assuming regular system maintenance?
21-30 years
11-20 years
6
4

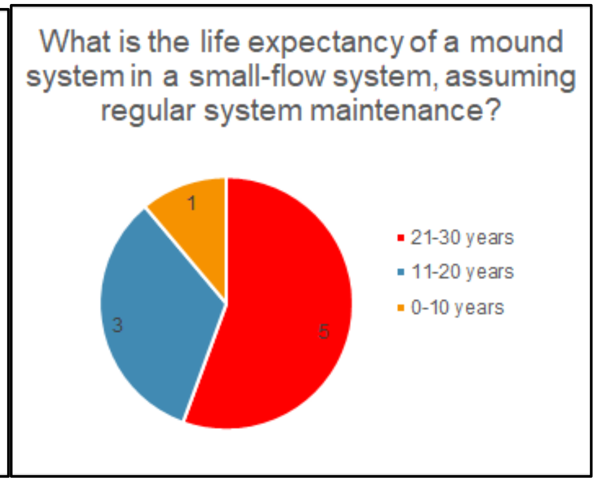

How common are low-pressure pipe (LPP) systems for dispersing wastewater in small-flow systems in the coastal regions?
Common (installed at 50-75% of sites)
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)
2
4
5


What is the life expectancy of a low-pressure pipe system in a small-flow system, assuming regular system maintenance?
21-30 years
11-20 years
0-10 years
6
4
1

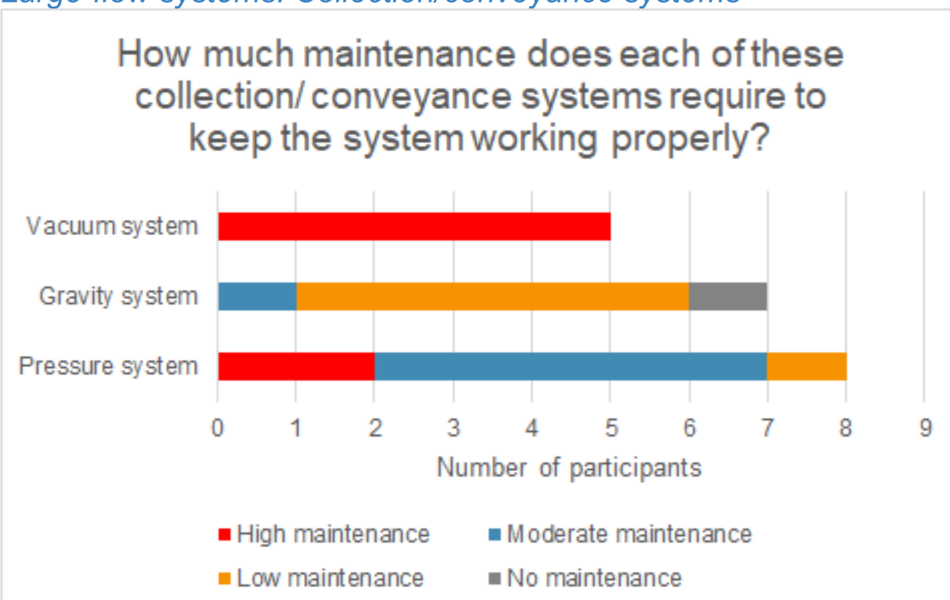

How common are drip distribution systems for dispersing wastewater in small-flow systems in the coastal regions?
Somewhat common (installed 25-49% of sites)
Not at all common (installed at less than 25% of sites)
3
4

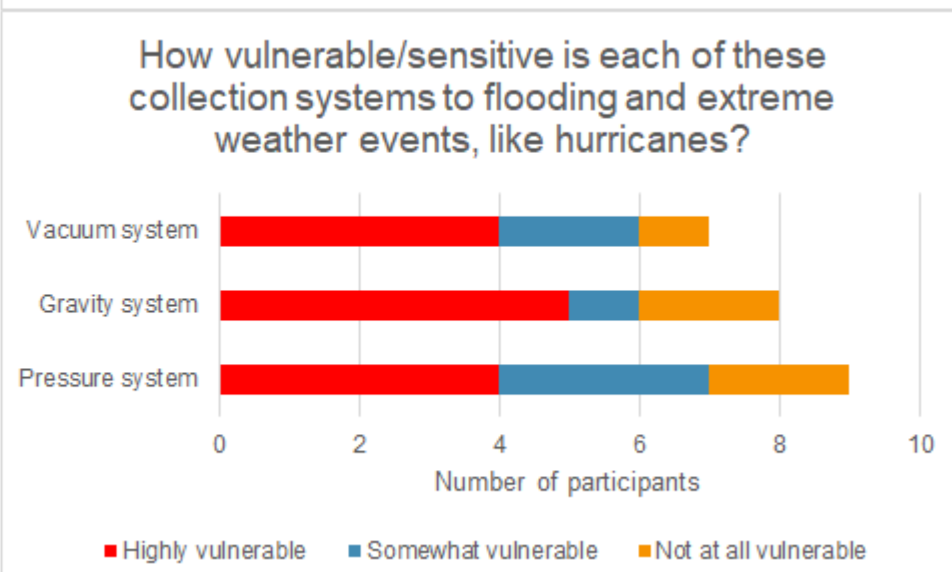

What is the life expectancy of a drip distribution system in a small-flow system, assuming regular system maintenance?
21-30 years
11-20 years
0-10 years
1
4
2

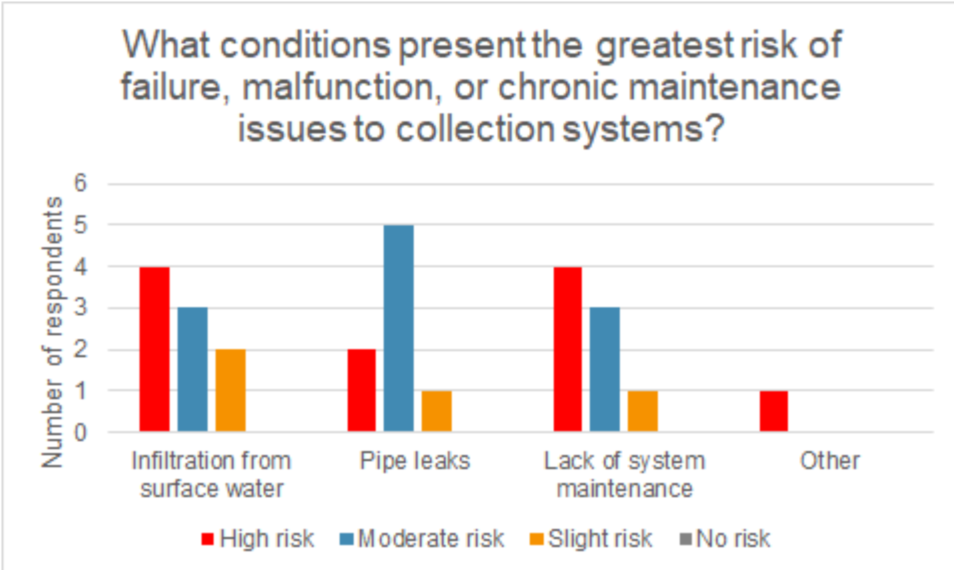




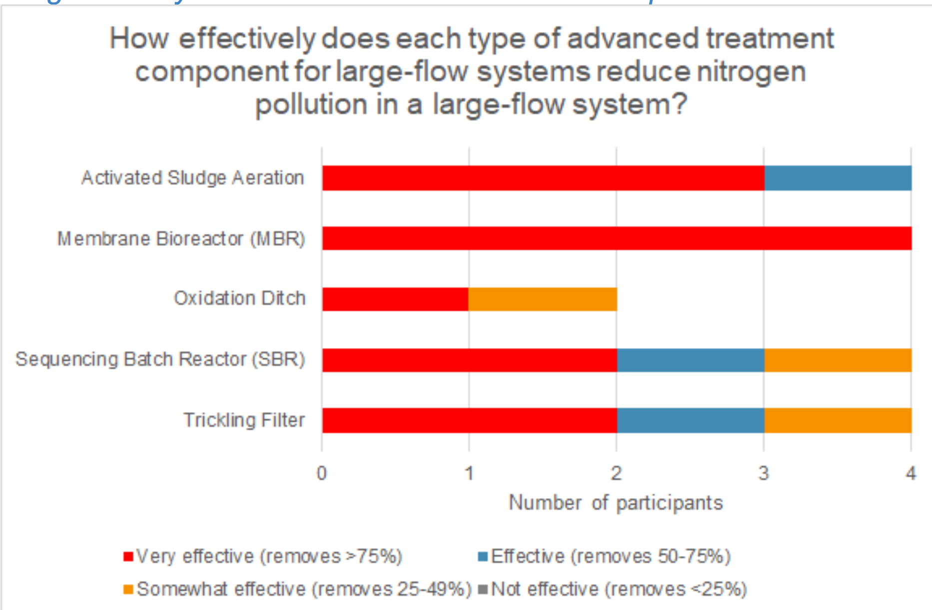
Large-flow systems: Collection/conveyance systems

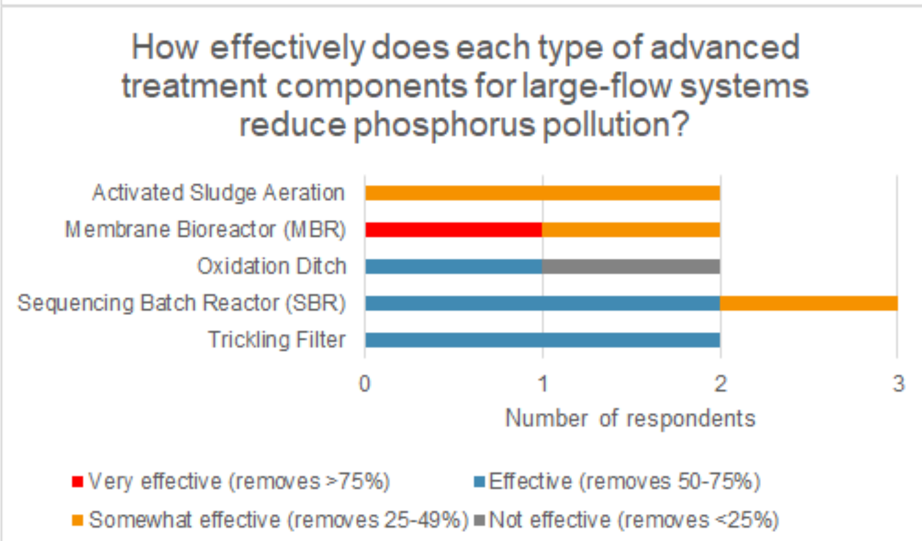


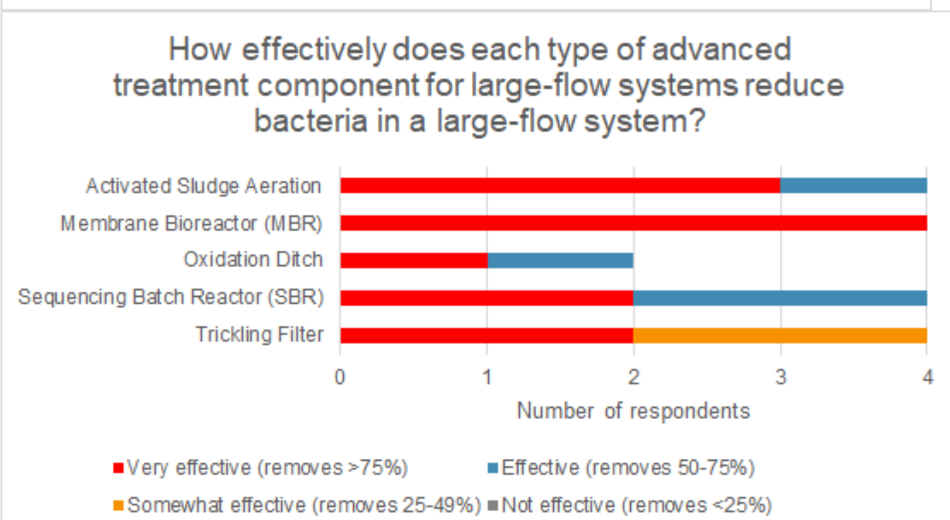


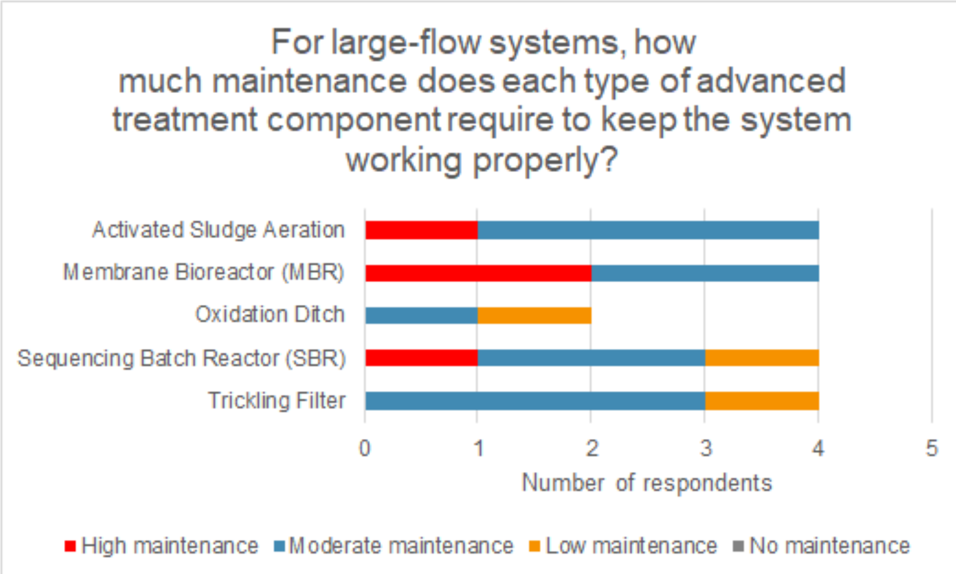

What conditions present the greatest risk of failure, malfunction, or chronic maintenance issues to collection systems?
Number of respondents
0
1
2
3
4
5
6
Infiltration from surface water
Pipe leaks
Lack of system maintenance
Other
High risk
Moderate risk
Slight risk
No risk

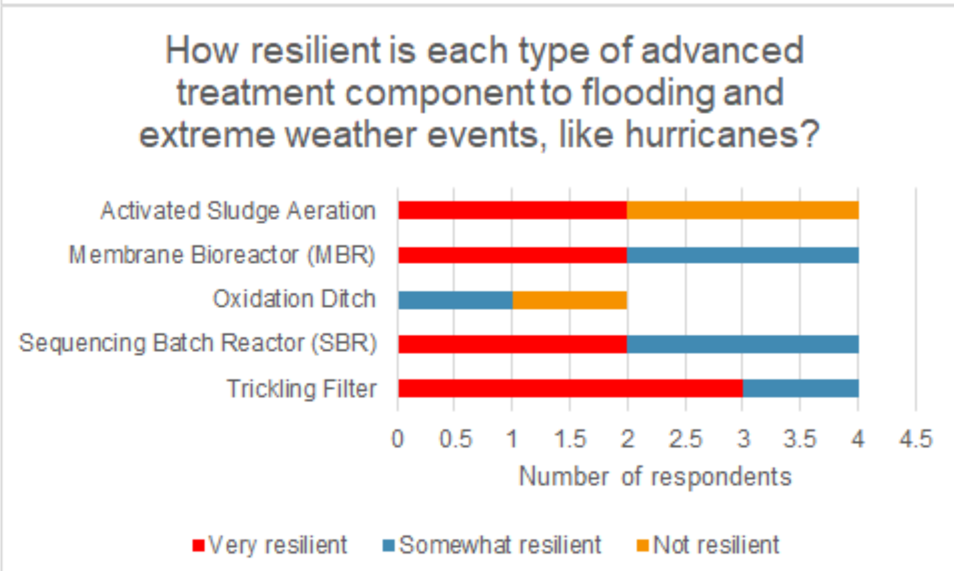
Large-flow systems: Advanced treatment components

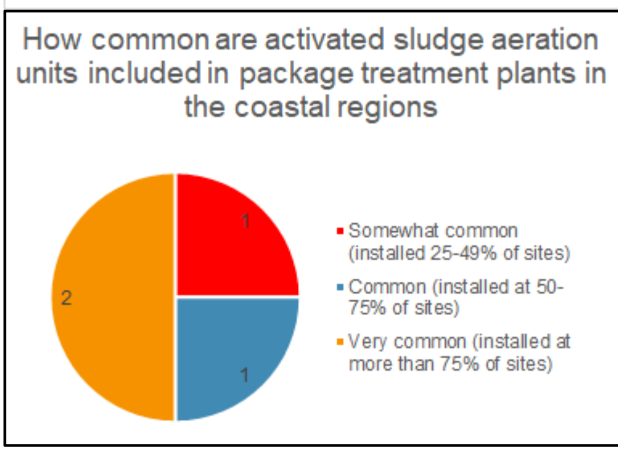


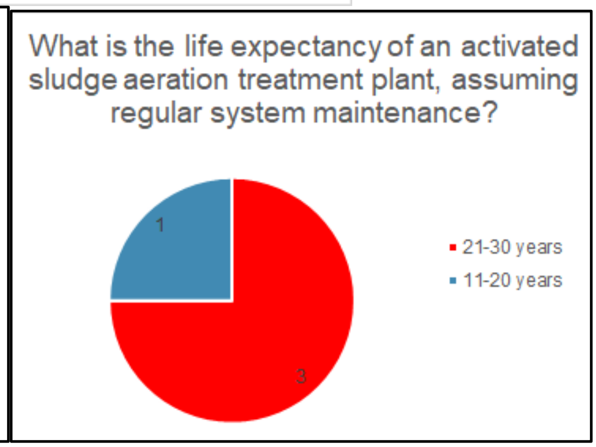


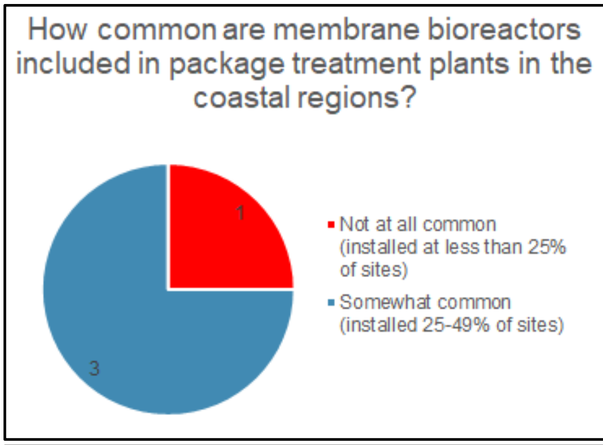


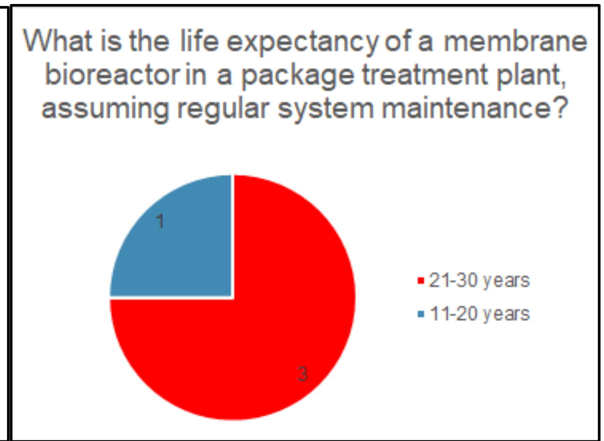

For large-flow systems, how much maintenance does each type of advanced treatment component require to keep the system working properly?
Activated Sludge Aeration
Membrane Bioreactor (MBR)
Oxidation Ditch
Sequencing Batch Reactor (SBR)
Trickling Filter
0
1
2
3
4
5
Number of respondents
High maintenance
Moderate maintenance
Low maintenance
No maintenance

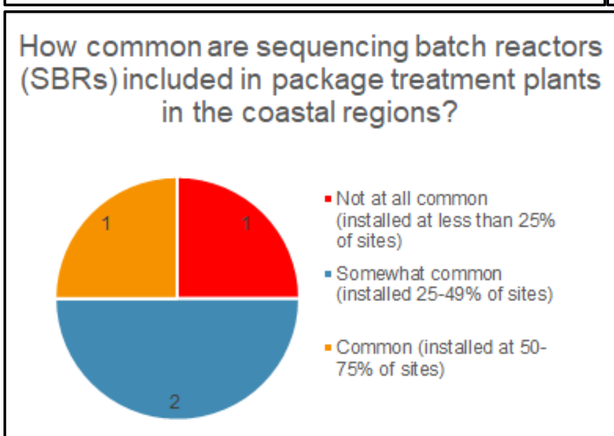

How resilient is each type of advanced treatment component to flooding and extreme weather events, like hurricanes?
Activated Sludge Aeration
Membrane Bioreactor (MBR)
Oxidation Ditch
Sequencing Batch Reactor (SBR)
Trickling Filter
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Number of respondents
Very resilient
Somewhat resilient
Not resilient

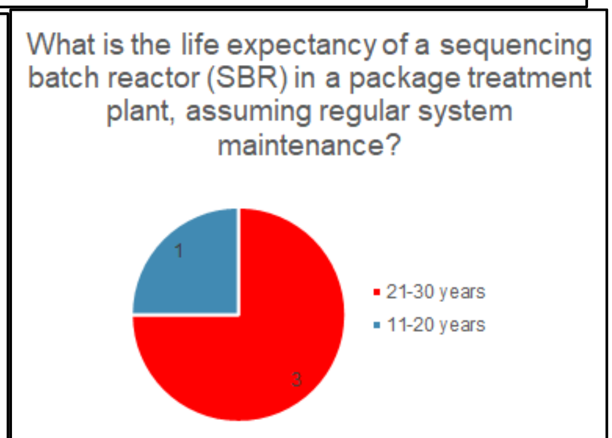

How common are activated sludge aeration units included in package treatment plants in the coastal regions
1
2
1
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)
Very common (installed at more than 75% of sites)

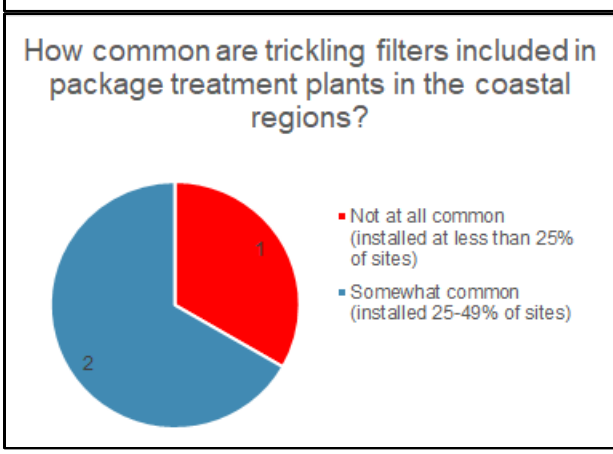

What is the life expectancy of an activated sludge aeration treatment plant, assuming regular system maintenance?
1
3
21-30 years
11-20 years

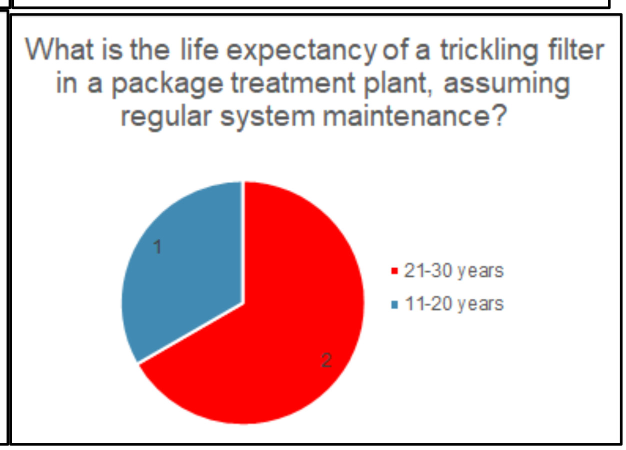

How common are membrane bioreactors included in package treatment plants in the coastal regions?
1
3
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)

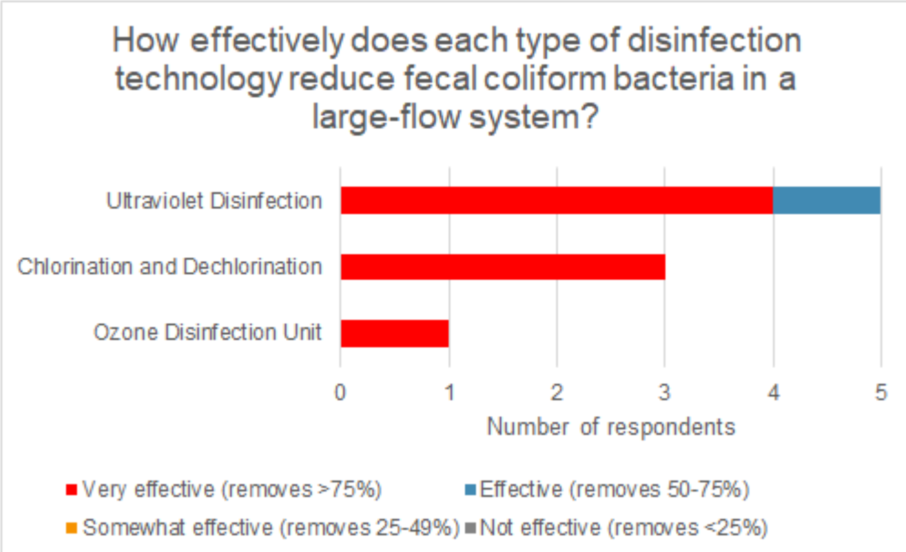

What is the life expectancy of a membrane bioreactor in a package treatment plant, assuming regular system maintenance?
1
3
21-30 years
11-20 years

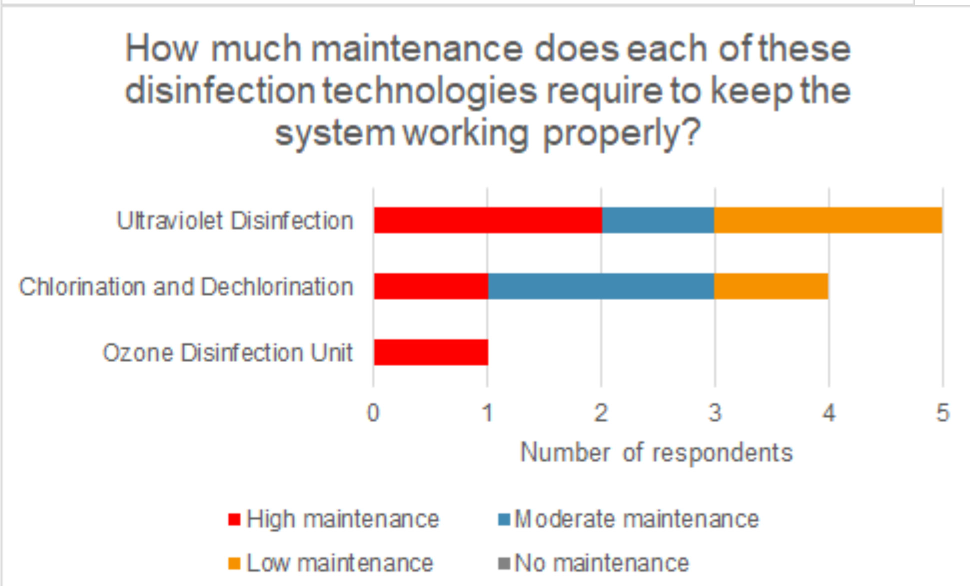

How common are sequencing batch reactors (SBRs) included in package treatment plants in the coastal regions?
1
1
2
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)

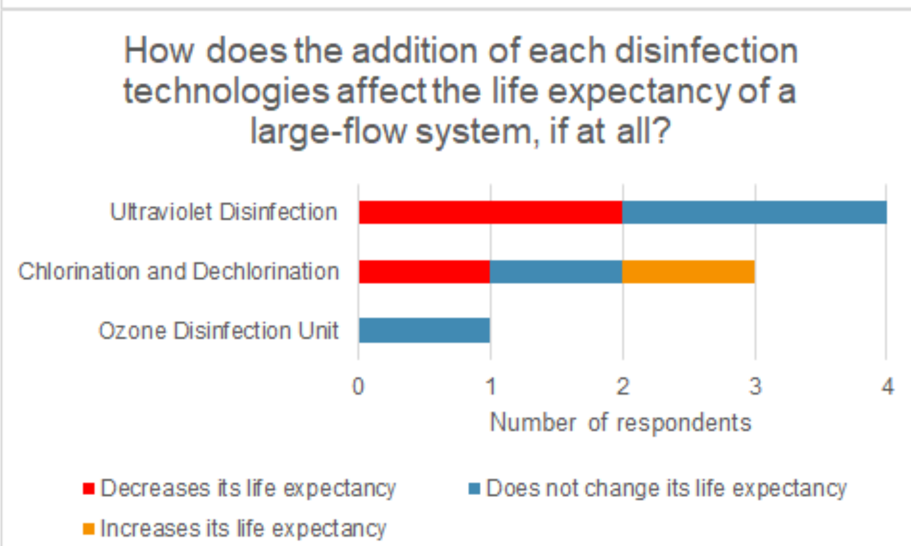

What is the life expectancy of a sequencing batch reactor (SBR) in a package treatment plant, assuming regular system maintenance?
1
3
21-30 years
11-20 years

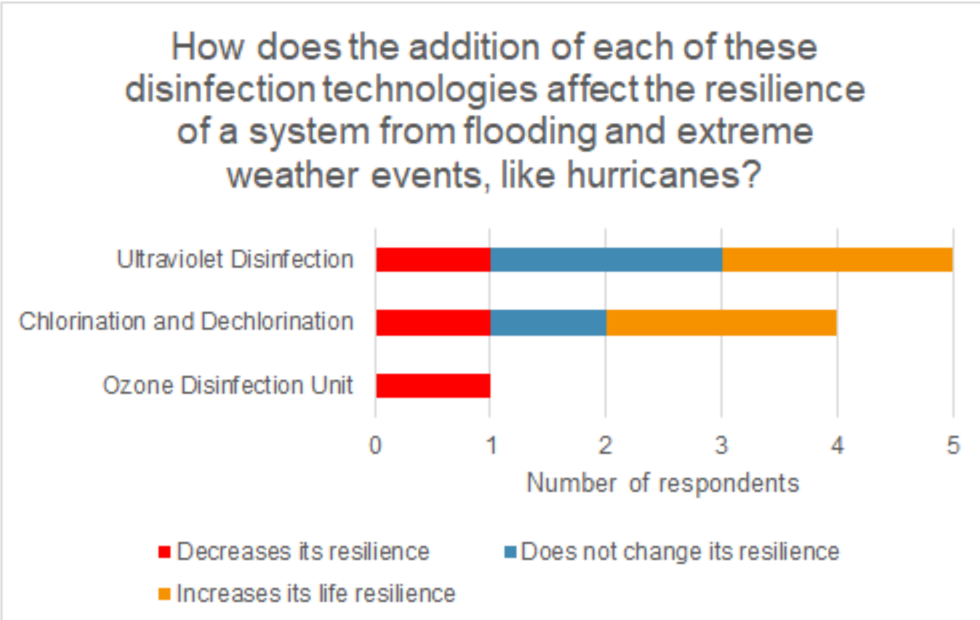

How common are trickling filters included in package treatment plants in the coastal regions?
1
2
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)

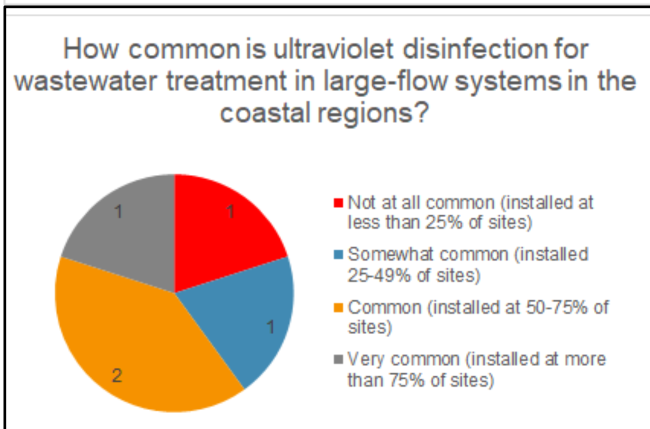

What is the life expectancy of a trickling filter in a package treatment plant, assuming regular system maintenance?
1
2
21-30 years
11-20 years

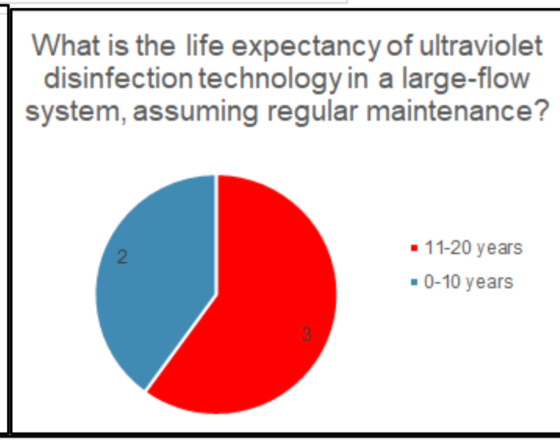

How effectively does each type of disinfection technology reduce fecal coliform bacteria in a large-flow system?
Ultraviolet Disinfection
Chlorination and Dechlorination
Ozone Disinfection Unit
0
1
2
3
4
5
Number of respondents
Very effective (removes >75%)
Effective (removes 50-75%)
Somewhat effective (removes 25-49%)
Not effective (removes <25%)

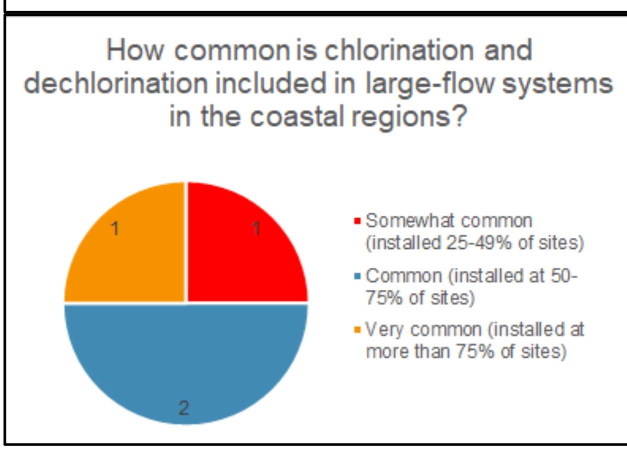

How much maintenance does each of these disinfection technologies require to keep the system working properly?
Ultraviolet Disinfection
Chlorination and Dechlorination
Ozone Disinfection Unit
0
1
2
3
4
5
Number of respondents
High maintenance
Moderate maintenance
Low maintenance
No maintenance

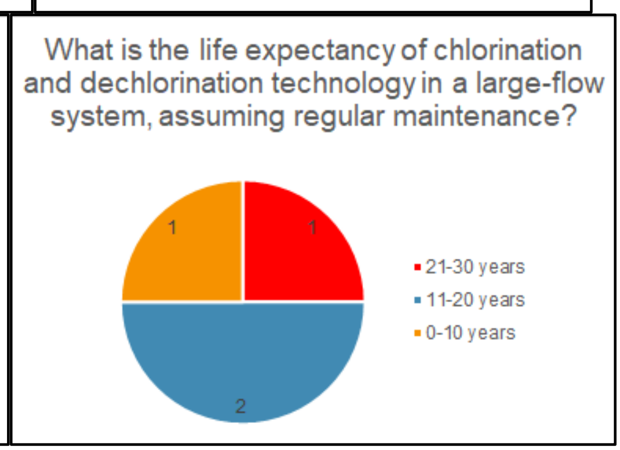

How does the addition of each disinfection technologies affect the life expectancy of a large-flow system, if at all?
Ultraviolet Disinfection
Chlorination and Dechlorination
Ozone Disinfection Unit
0
1
2
3
4
Number of respondents
Decreases its life expectancy
Does not change its life expectancy
Increases its life expectancy


How does the addition of each of these disinfection technologies affect the resilience of a system from flooding and extreme weather events, like hurricanes?
Ultraviolet Disinfection
Chlorination and Dechlorination
Ozone Disinfection Unit
0
1
2
3
4
5
Number of respondents
Decreases its resilience
Does not change its resilience
Increases its life resilience

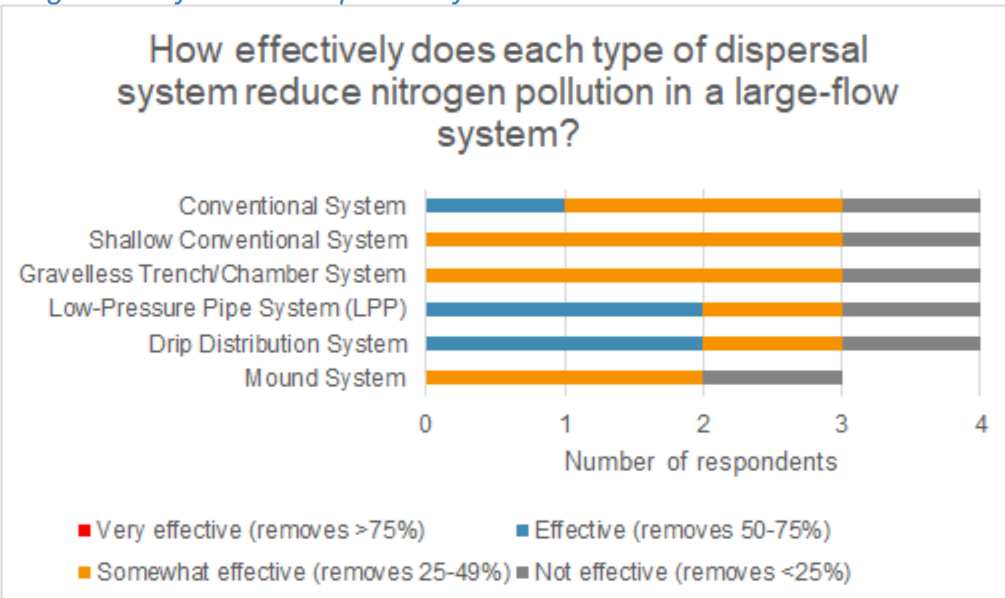

How common is ultraviolet disinfection for wastewater treatment in large-flow systems in the coastal regions?
1
1
1
2
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)
Very common (installed at more than 75% of sites)

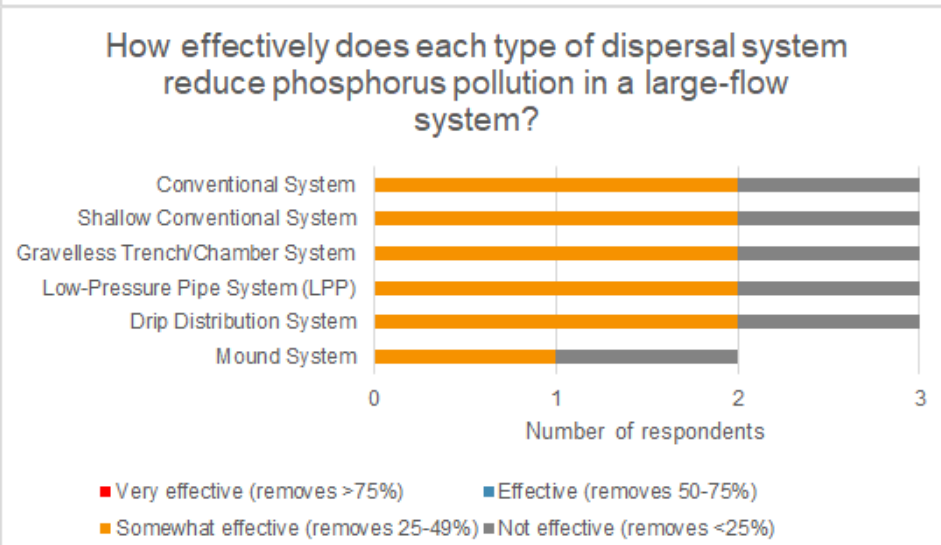

What is the life expectancy of ultraviolet disinfection technology in a large-flow system, assuming regular maintenance?
2
3
11-20 years
0-10 years

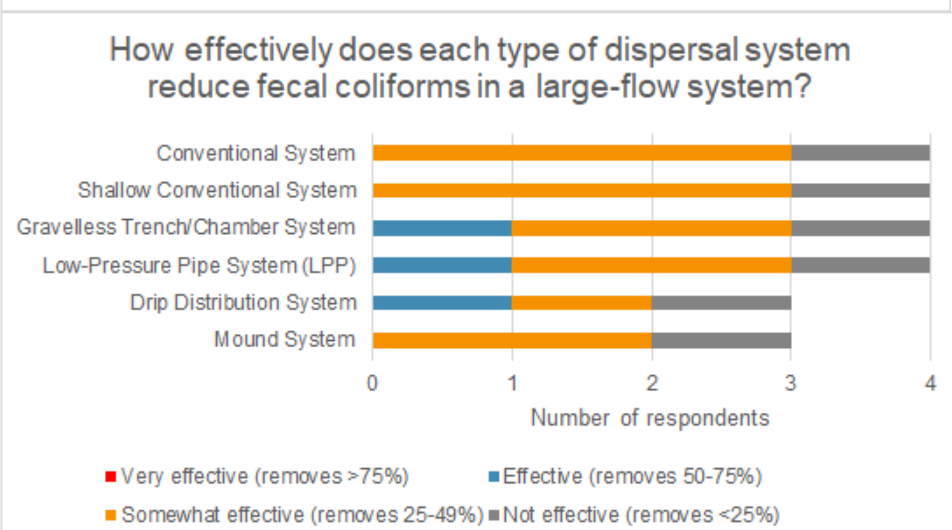

How common is chlorination and dechlorination included in large-flow systems in the coastal regions?
1
1
2
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)
Very common (installed at more than 75% of sites)

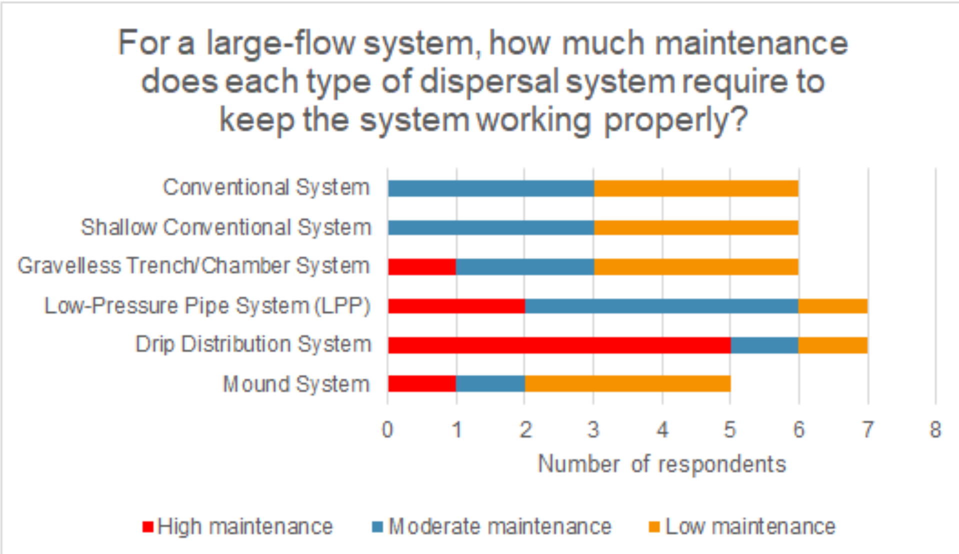

What is the life expectancy of chlorination and dechlorination technology in a large-flow system, assuming regular maintenance?
1
1
2
21-30 years
11-20 years
0-10 years

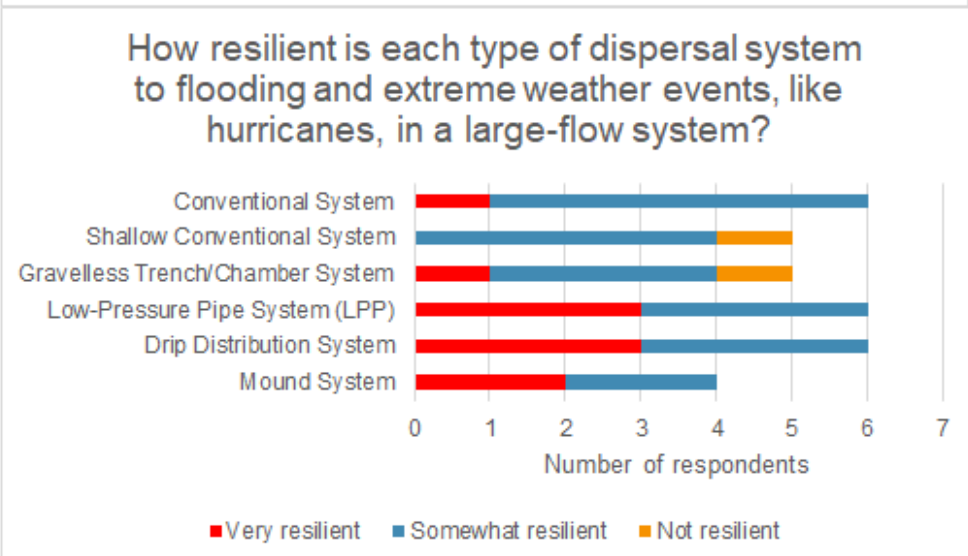
Large-flow systems: Dispersal systems

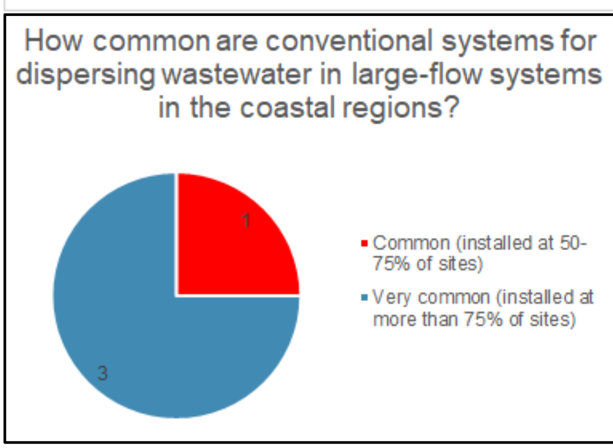


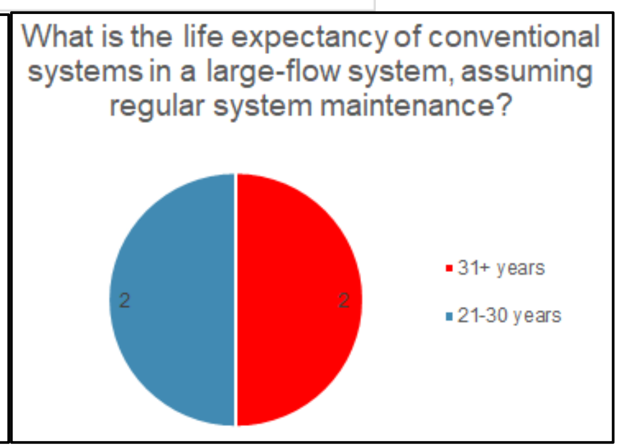


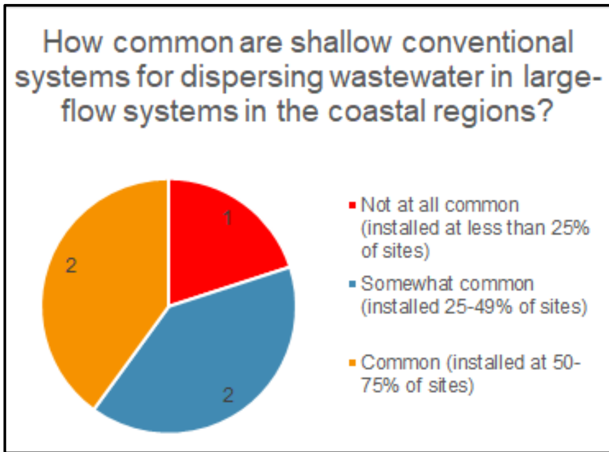


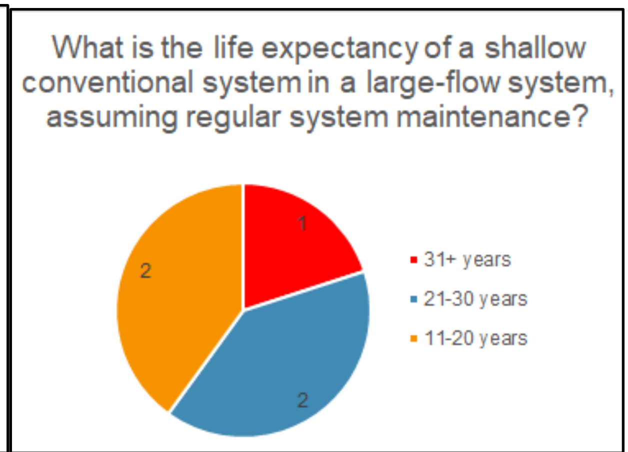

For a large-flow system, how much maintenance does each type of dispersal system require to keep the system working properly?
Conventional System
Shallow Conventional System
Gravelless Trench/Chamber System
Low-Pressure Pipe System (LPP)
Drip Distribution System
Mound System
0
1
2
3
4
5
6
7
8
Number of respondents
High maintenance
Moderate maintenance
Low maintenance

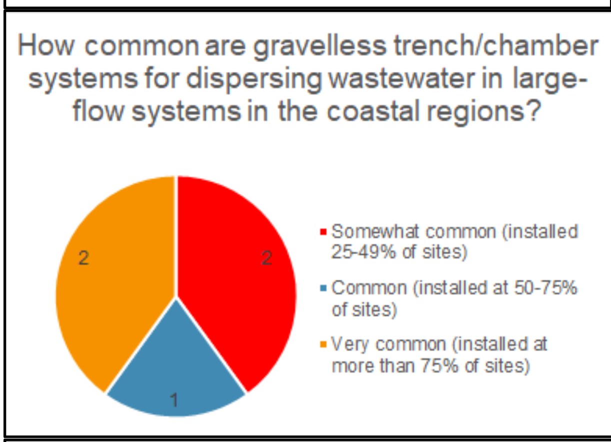

How resilient is each type of dispersal system to flooding and extreme weather events, like hurricanes, in a large-flow system?
Conventional System
Shallow Conventional System
Gravelless Trench/Chamber System
Low-Pressure Pipe System (LPP)
Drip Distribution System
Mound System
0
1
2
3
4
5
6
7
Number of respondents
Very resilient
Somewhat resilient
Not resilient

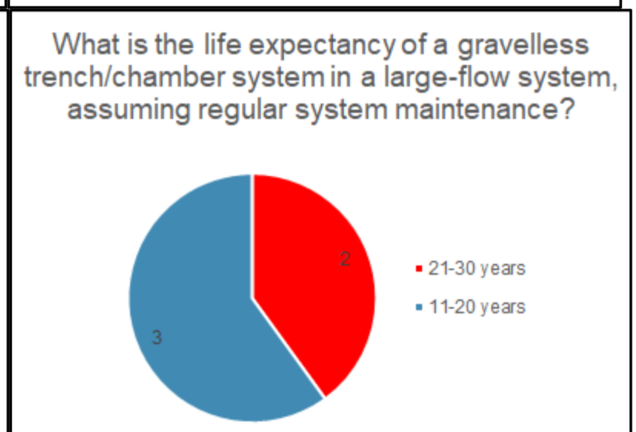

How common are conventional systems for dispersing wastewater in large-flow systems in the coastal regions?
1
3
Common (installed at 50-75% of sites)
Very common (installed at more than 75% of sites)

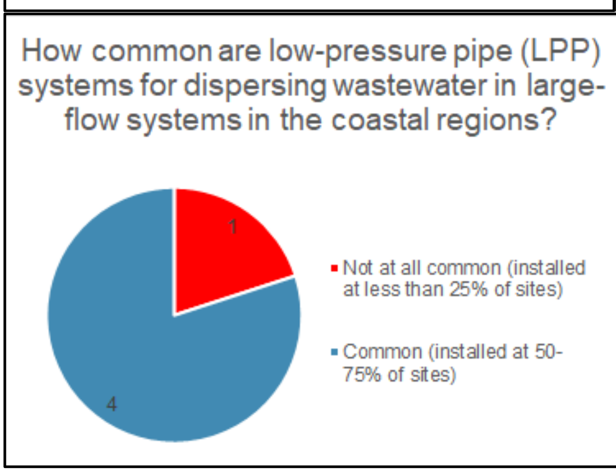

What is the life expectancy of conventional systems in a large-flow system, assuming regular system maintenance?
2
2
31+ years
21-30 years

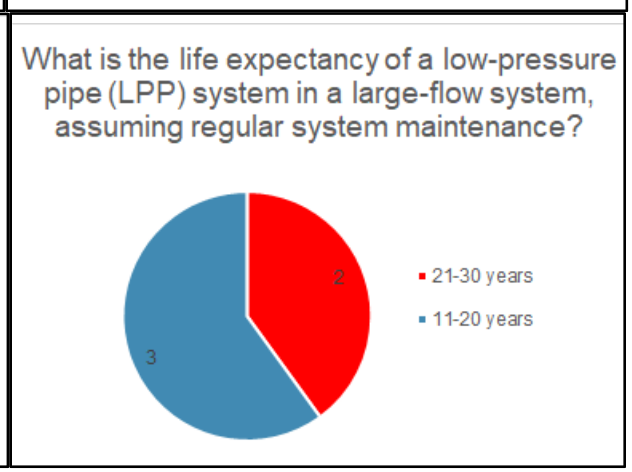

How common are shallow conventional systems for dispersing wastewater in large-flow systems in the coastal regions?
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)
1
2
2

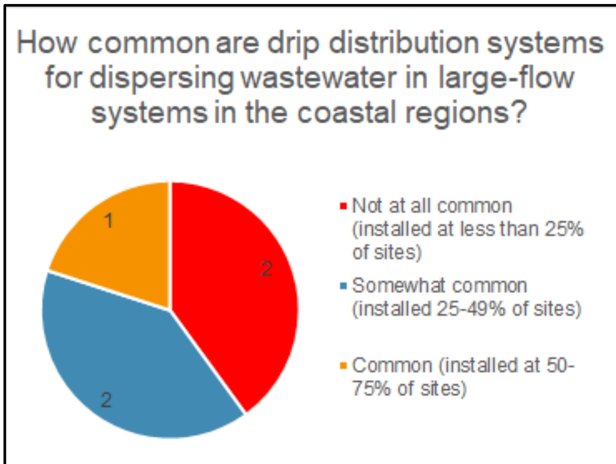

What is the life expectancy of a shallow conventional system in a large-flow system, assuming regular system maintenance?
31+ years
21-30 years
11-20 years
1
2
2

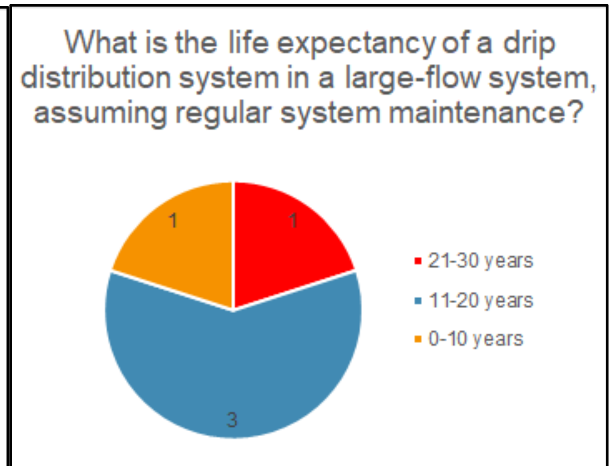

How common are gravelless trench/chamber systems for dispersing wastewater in large-flow systems in the coastal regions?
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)
Very common (installed at more than 75% of sites)
2
2
1

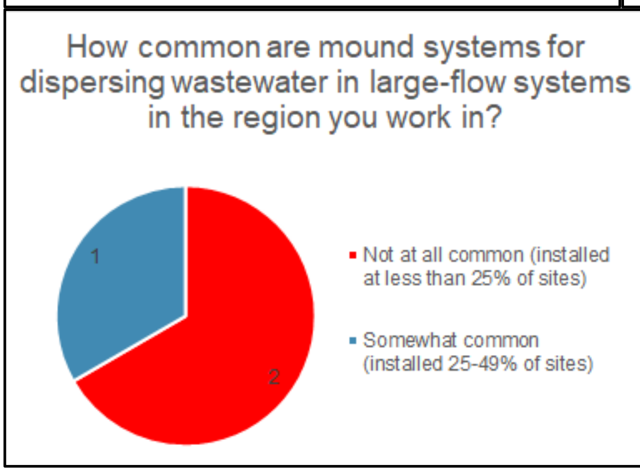

What is the life expectancy of a gravelless trench/chamber system in a large-flow system, assuming regular system maintenance?
21-30 years
11-20 years
2
3

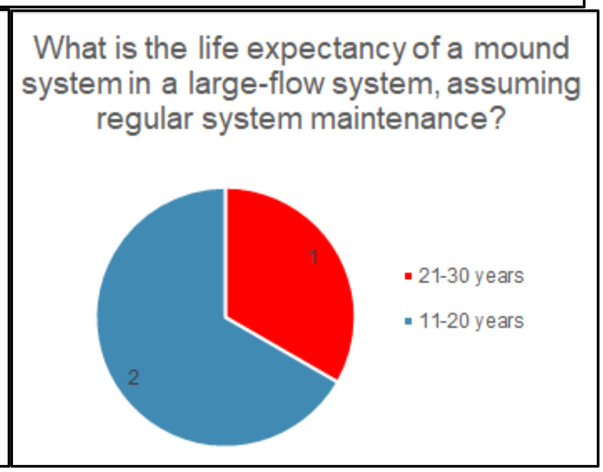

How common are low-pressure pipe (LPP) systems for dispersing wastewater in large-flow systems in the coastal regions?
Not at all common (installed at less than 25% of sites)
Common (installed at 50-75% of sites)
1
4


What is the life expectancy of a low-pressure pipe (LPP) system in a large-flow system, assuming regular system maintenance?
21-30 years
11-20 years
2
3


How common are drip distribution systems for dispersing wastewater in large-flow systems in the coastal regions?
1
2
2
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)
Common (installed at 50-75% of sites)


What is the life expectancy of a drip distribution system in a large-flow system, assuming regular system maintenance?
1
1
3
21-30 years
11-20 years
0-10 years


How common are mound systems for dispersing wastewater in large-flow systems in the region you work in?
1
2
Not at all common (installed at less than 25% of sites)
Somewhat common (installed 25-49% of sites)


What is the life expectancy of a mound system in a large-flow system, assuming regular system maintenance?
1
2
21-30 years
11-20 years