SFD Lite Report

Cape Cod, MA
United States of America

Final Report

This SFD Lite was prepared by the Bill & Melinda Gates Foundation as part of the SFD Promotion Initiative.

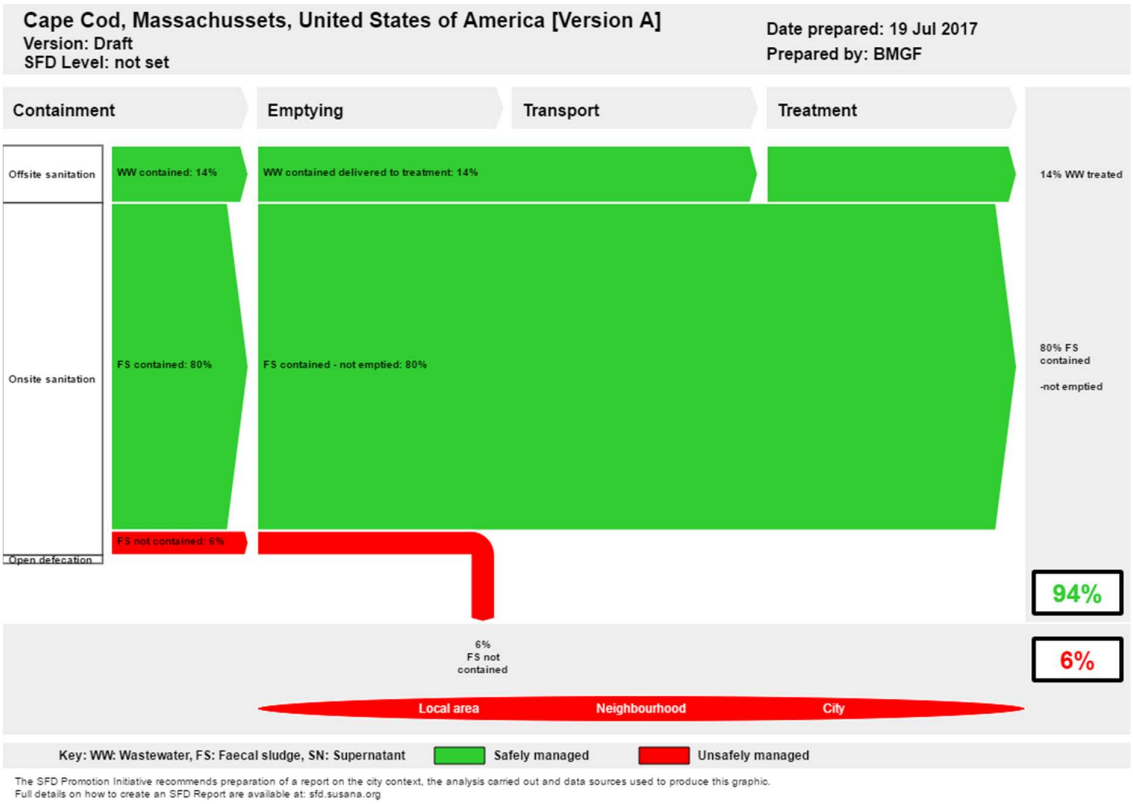
Date of production: 12/07/2017

Last update: 05/2018

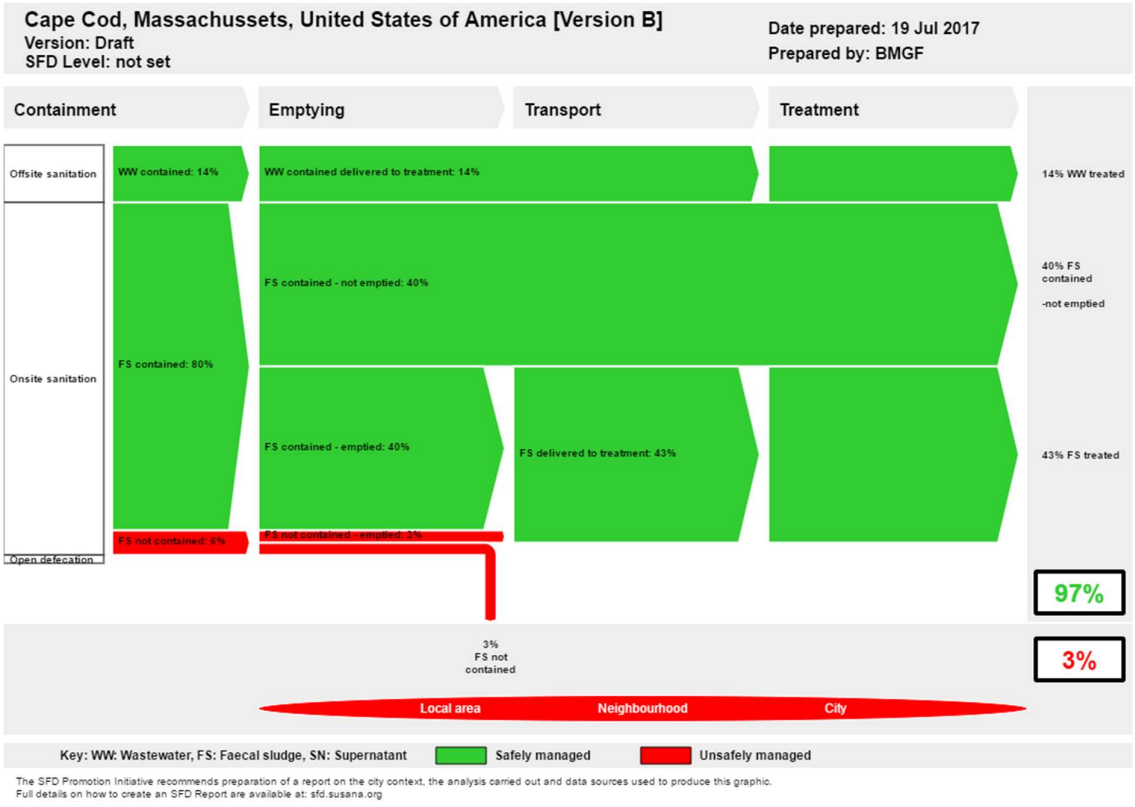
1 The SFD Graphic

Note: Three SFDs were generated for Cape Cod based on different assumptions on the frequency of septic tank emptying / pumping, as there was no documented data on this proportion available. All other assumptions made are consistent for the three diagrams below and have been documented in section 5.

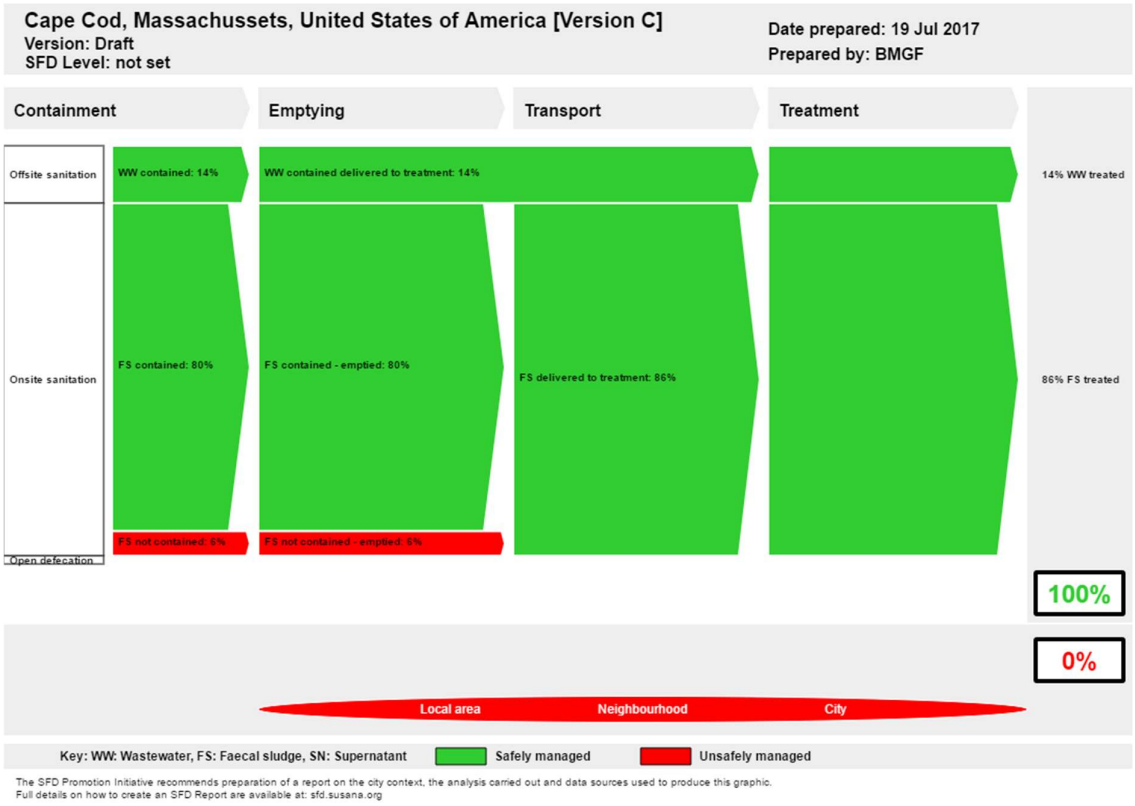
a) 0% or no septic systems were regularly emptied



b) 50% of septic systems were regularly emptied



c) 100% of septic systems were regularly emptied



2 SFD Lite information

Produced by:

The Faecal / Excreta / Shit Flow Diagram (SFD) for Cape Cod was created using the SFD Generator tool on the SuSanA website through desk-based research by the Bill & Melinda Gates Foundation in Seattle, Washington.

Date of production: 12/07/2017

3 General city information

Cape Cod is a geographic cape extending into the Atlantic Ocean from the southeastern corner of mainland Massachusetts, USA. It has a population of 215,888 people, which nearly doubles in the summer (U.S. Geological Survey, 2016). Cape Cod and associated islands together make up Barnstable County, whose seat is in the town of Barnstable.

Cape Cod covers an area of 339 square miles over 15 towns, and extends from Provincetown in the northeast to Woods Hole in the southwest and is bordered by Plymouth to the northwest. It has been separated from the mainland by the Cape Cod Canal since 1914, but is connected to it by the Sagamore and Bourne bridges. Cape Cod is surrounded by the Nantucket and Vineyard Sound to the south, Cape Cod Bay to the north, the Atlantic Ocean to the east and Buzzard Sound to the southwest.

The landscape in Barnstable County owes its characteristics to the last continental glacier and the rise in sea level that followed glaciation (US Department of Agriculture, 1993). The moving ice scraped ground and carried debris, known as drift, and deposited it on the ice front forming the glacial form of Cape Cod. Later as the sea drowned the glacial cape, the drift along the shoreline was eroded and redeposited as beaches and spits. Today, Cape Cod has a shallow water table and sandy, porous soil. The aquifer consists of six hydrologically independent lenses from which all the towns on the Cape obtain drinking water, and is particularly vulnerable to land use activity. Contamination of groundwater in the Cape is a concern (Silent Spring Institute, 2015).

Cape cod experiences a more moderate climate than inland locations, influenced by the Atlantic Ocean. Precipitation in Cape Cod is the lowest in the New England region, averaging slightly less than 40 inches a year although it experiences tropical storms or hurricanes once every five or six years.

The Cape Cod Commission has estimated that residences and businesses generate about 12 billion gallons of wastewater annually on Cape Cod; see the Comprehensive Cape Cod Regional Wastewater Management Strategy Development Project Report. On an annualized basis, this is approximately 32 mgd and 53 mgd on in the peak summer season.

4 Service outcomes

Cape Cod (Barnstable County), Massachussets, United States of America, 19 Jul 2017. SFD Level: not
Population: 215888
Proportion of tanks: septic tanks: 0%, fully lined tanks: 0%, lined, open bottom tanks: 0%

System label	Pop	W4a	W5a	F3	F4	F5
System description	Proportion of population using this type of system	Proportion of wastewater in sewer system, which is delivered to centralised treatment plants	Proportion of wastewater delivered to centralised treatment plants, which is treated	Proportion of this type of system from which faecal sludge is emptied	Proportion of faecal sludge emptied, which is delivered to treatment plants	Proportion of faecal sludge delivered to treatment plants, which is treated
T1A1C2 User interface discharges directly to a centralised foul/separate sewer	14.0	100.0	100.0			
T2A2C5 Septic tank connected to soak pit, where there is a 'significant risk' of groundwater pollution	6.0			0.0	100.0	100.0
T1A2C5 Septic tank connected to soak pit	80.0			0.0	100.0	100.0

Table 1: SFD Matrix for Cape Cod a) (BMGF 2017)

Cape Cod (Barnstable County), Massachussets, United States of America, 19 Jul 2017. SFD Level: not
Population: 215888
Proportion of tanks: septic tanks: 100%, fully lined tanks: 0%, lined, open bottom tanks: 0%

System label	Pop	W4a	W5a	F3	F4	F5
System description	Proportion of population using this type of system	Proportion of wastewater in sewer system, which is delivered to centralised treatment plants	Proportion of wastewater delivered to centralised treatment plants, which is treated	Proportion of this type of system from which faecal sludge is emptied	Proportion of faecal sludge emptied, which is delivered to treatment plants	Proportion of faecal sludge delivered to treatment plants, which is treated
T1A1C2 User interface discharges directly to a centralised foul/separate sewer	14.0	100.0	100.0			
T2A2C5 Septic tank connected to soak pit, where there is a 'significant risk' of groundwater pollution	6.0			50.0	100.0	100.0
T1A2C5 Septic tank connected to soak pit	80.0			50.0	100.0	100.0

Table 2: SFD Matrix for Cape Cod b) (BMGF 2017)

Cape Cod (Barnstable County), Massachussets, United States of America, 19 Jul 2017. SFD Level: not
Population: 215888
Proportion of tanks: septic tanks: 100%, fully lined tanks: 0%, lined, open bottom tanks: 0%

System label	Pop	W4a	W5a	F3	F4	F5
System description	Proportion of population using this type of system	Proportion of wastewater in sewer system, which is delivered to centralised treatment plants	Proportion of wastewater delivered to centralised treatment plants, which is treated	Proportion of this type of system from which faecal sludge is emptied	Proportion of faecal sludge emptied, which is delivered to treatment plants	Proportion of faecal sludge delivered to treatment plants, which is treated
T1A1C2 User interface discharges directly to a centralised foul/separate sewer	14.0	100.0	100.0			
T2A2C5 Septic tank connected to soak pit, where there is a 'significant risk' of groundwater pollution	6.0			100.0	100.0	100.0
T1A2C5 Septic tank connected to soak pit	80.0			100.0	100.0	100.0

Table 3: SFD Matrix for Cape Cod c) (BMGF 2017)

It is estimated that at least 94% of faecal sludge and wastewater is treated and safely managed in Cape Cod. The remaining 6% or less that is discharged into the environment or unsafely managed is due to the use of septic tanks that pose a significant risk of groundwater pollution in the region. The exact estimates of faecal sludge emptying from septic tanks could not be obtained and so two SFDs were generated that estimate the extreme scenarios where no faecal waste (0%) contained in septic tanks is regularly emptied and where all septic tanks (100%) are regularly emptied or pumped once in three years as per the Massachusetts state recommendations.

4.1 Groundwater contamination

All the drinking water on Cape Cod, except for one pond in Falmouth, comes from a single underground aquifer. In addition, 15% of the population uses private wells, that are often found near septic systems. This translates to approximately 96% of available water on Cape Cod coming from groundwater sources.

There are several regulations intended to protect public water supply wells from contamination. Massachusetts wellhead protection requirements do not allow any kind of development within 400 feet (also known as Zone I) of a public water supply well, although for some Cape wells pre-existing development is present in these areas. Land use activities that are known threats to water quality, such as large-scale hazardous and solid waste facilities, are prohibited within the Zone II, the area likely to contribute groundwater to a public supply well. In addition, new development of other potential sources of groundwater contamination, such as wastewater treatment plants and Title 5 septic systems, must meet certain standards. However, zoning restrictions established to protect the Zone IIs from new development are not always enforced and prior land uses are often already in place despite the zoning restrictions. These pre-existing uses include high density commercial and residential development, wastewater treatment plants and industrial areas.

Cape Cod's reliance on septic systems poses a risk to the contamination of groundwater and the surrounding marine environment and aquatic life. The Cod's reliance on septic systems stems from many towns opting out of purchasing sewer systems when the federal government subsidized them in the 1960s and 1970s for fear of attracting too many new homeowners to the communities. However, Cape Cod communities still grew despite the lack of public sewage systems, which resulted in the installation of many septic tanks in new homes. This widespread use of onsite sanitation couples with Cape Cod's shallow water table and sandy, porous soil makes it particularly vulnerable to land use activity and groundwater contamination.

For the purpose of generating this SFD, groundwater contamination risk was estimated using well nitrogennitrate levels, a major component of human wastewater, as a proxy. The Cape Cod Regional Policy Plan established a nitrogen loading concentration of 5 ppm to ensure that nitrate levels in drinking water will not approach the federal standard. This protection standard had been adopted both locally and at the state level. At the national level, the US EPA recommends a maximum contaminant limit of 10 ppm of nitrate for drinking water, a threshold established to protect infants from methemoglobinemia, or "bluebaby" syndrome, a potentially fatal blood disorder that can occur when too much nitrate limits the amount of oxygen in the blood. The quality of Cape Cod's community public drinking water supply is generally very good, but over the past 15 years there has been a trend toward some degradation.

As of 2008, about 93% of non-community public wells and 97% of community public wells had nitrate levels below 5 ppm. Using conservative estimates therefore, we can assume that 93% of septic tanks do not pose a significant risk of groundwater contamination.

4.2 Containment

Most of Cape Cod (87%) relies on individual on-site septic systems to treat wastewater and contain faecal sludge. About 10% of the population relies on centralized sewers, with most of this population being concentrated in Falmouth, Chatham and Barnstable. The remaining 3% relies on a mixture of satellite and cluster systems that mostly connect to decentralized sewers or treat wastewater on-site.

The widespread use of septic systems in Cape Cod can be attributed to towns opting out of purchasing sewer systems when the federal government subsidized them in the 1960s and 1970s for fear of attracting too many new homeowners to the communities.

Conventional Title 5 Septic Systems

Title 5 of the Massachusetts State Environmental Code, regulating septic systems and the transport and disposal of sanitary sewage, and as such, most conventional septic systems in Cape Cod are commonly referred to as Title 5 septic systems. Local Boards of Health are the primary regulatory authorities of septic systems however, the Massachusetts Department of Environmental Protection (MassDEP) is involved in the approval of some innovative/alternative technology approvals, shared systems, large systems and many variance requests. In addition, MassDEP is responsible for overseeing local implementation of Title 5 and provides local governments with training and technical assistance. Based on 87% of the total population of 215,888 using septic tanks and 2.5 users to one tank, it can be assumed that there are over 70,000 conventional Title 5 septic tanks in the county.

Innovative / Alternative (I/A) Title 5 Septic Systems

An I/A system is any septic system or part of one that is not designed or constructed in a way consistent with a conventional Title 5 system. A conventional system has a septic tank, a distribution box or dosing mechanism, a soil absorption system (SAS) and a reserve area. Some examples of alternative systems are recirculating sand filters, aerobic treatment units, Wisconsin mounds, peat filters, humus/composting toilets, and intermittent sand filters. There are currently 2220 I/A septic systems in use throughout the Cape Cod region.

4.3 Emptying

MassDEP recommends that conventional Title 5 septic systems be emptied once every three years. However, as there was no data available through secondary sources or email correspondences with individuals working in the region on the rate or frequency at which tanks are emptied, multiple SFDs were created based on hypothetical scenarios in which:

a) 0% or no septic tanks were emptied;

b) 50% of tanks were regularly emptied;

c) 100% of tanks were regularly emptied

The rate of emptying was assumed to be independent of the groundwater contamination risk posed by the septic system. Because there is documented evidence of septage being received regularly by treatment facilities (although volumes could not be estimated accurately), scenario a) is unlikely to accurately represent the reality of wastewater and faecal sludge management in Barnstable County / Cape Cod.

4.4 Transport

All wastewater flowing into sewers was assumed to be transported to the treatment plant for enhanced wastewater treatment as there were no documented combined sewer or separate sanitary sewer overflow problems in the county. For scenarios b) and c) where some or all septic systems are regularly emptied, it was assumed that all faecal sludge pumped was transported to one of the five centralized wastewater treatment facilities or the two smaller septage collection facilities in the county.

4.5 Treatment

Cape Cod defines enhanced wastewater treatment as that intended to provide a higher quality effluent than produced by a septic tank and leaching field. It is assumed that all wastewater transported to treatment plants, which includes all wastewater flowing through sewers, is safely managed and treated. There are several technologies approved by DEP for individual and cluster systems treating residential wastewater that remove nitrogen to less than 19 mg/l (compared with the 35 mg/l concentration commonly assumed for the discharge from a septic tank and leaching field system). There are several technologies approved by DEP for satellite and centralized plants where groundwater discharge permits typically require nitrogen concentrations below 10 mg/l. Some newer permits have nitrogen limits of 5 mg/l or below. All technologies deployed meet the definition of enhanced treatment. Enhanced treatment can also include phosphorus removal.

4.6 Reuse and disposal

All centralized and satellite treatment plants in Cape Cod are governed by groundwater discharge permits that require enhanced treatment. Given the relatively small percentage of individual systems with enhanced treatment, it can be concluded that less than 15% of the wastewater generated on Cape Cod is now subject to enhanced treatment. There is no information available on the recycling or reuse of wastewater for either potable or non-potable uses, neither is there available data on the recycling of faecal sludge or use as biosolids. Both wastewater and faecal sludge reuse are considered low on Cape Cod’s Comprehensive Wastewater Management Plan and instead, greater emphasis is laid on improving water quality when it is released into shellfish growing areas that are vulnerable to faecal coliform pollution and excessive algal growth that consumes oxygen from waterbodies and reduces light transmission through water, causing the death of eelgrass beds, the natural habitat for shellfish.

5 Data and assumptions

5.1 Total Population Served by Sanitation System (Containment)

	Sewers			Septic Systems		
	Centralized	Decentralized		Significant Risk of GW Pollution	Low Risk of GW Pollution	Total
		Satellite	Cluster			
Population served						215,888
Proportion / Percentage	10%	3%	1%	6%	80%	100%
		4%				

Calculations and assumptions:

1. Satellite and cluster systems might either treat wastewater on the spot and act as decentralized treatment plants or be connected to sewers. As such, they are considered decentralized sewers for the purpose of generating this SFD. This classification as decentralized sewers, even if they are eventually connected to centralized sewers and treatment plants, makes no difference to the final SFD that is generated or to the overall proportion of wastewater that is safely managed in the county.
2. Risk of groundwater contamination by septic systems was derived using a proxy of well-water contamination with nitrogen. As of 2008, about 93% of non-community public wells and 97% of community public wells had nitrate levels below 5 ppm. Using conservative estimates therefore, we can assume that 93% of septic tanks do not pose a significant risk of groundwater contamination. This translates to about 6% of the population using septic systems with a high risk of groundwater pollution and 80% of the population using septic systems with a low risk of groundwater contamination.

5.2 Transportation & Emptying

Assumptions:

1. It was assumed that 100% of sewers (centralized and decentralized), transported all wastewater to treatment plants as Cape Cod has no available information on sewer overflows or significant leakages.
2. As data on septic system emptying / pumping was not available through secondary sources of data or Key Informant Interviews, and so for the purpose of generating an SFD for Cape Cod, three scenarios were modelled assuming a) 0% or no regular septic tank emptying, b) 50% of septic tanks are regularly emptied and c) 100% of septic tanks are regularly emptied.

5.3 Treatment, Reuse & Disposal

Assumptions:

1. It was assumed that 100% of wastewater from sewers that is channeled to centralized treatment plants is subject to enhanced (at least secondary) treatment.
2. It was assumed that all septage (if regularly pumped) is transported and treated at one of the five centralized wastewater treatment facilities or at one of two septage treatment facilities.
3. Data on primary, secondary and tertiary treatment of wastewater in Cape Cod was not available through secondary sources of data.

4. Most effluent is discharged into groundwater, and not coastal water bodies due to the potential contamination with nutrients causing algal blooms and affecting the shellfish ecosystem and the economic implications to the shellfish and tourism industries.
5. No data was available on the reuse of wastewater for non-potable or potable reasons
6. No data was available on the reuse of faecal sludge as biosolids or other forms.

6 List of data sources

- *Cape Cod Commission, 2017. Wastewater. [Online] Available at: http://www.capecodcommission.org/index.php?id=170&maincatid=49 [Accessed 24 July 2017].*
- *ECFR, 2017a. Code of Federal Regulations. [Online] Available at: https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr503_main_02.tpl [Accessed 11 July 2017].*
- *ECFR, 2017b. Code of Federal Regulations. [Online] Available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=fb3251957978534805da15d6af7268ea&mc=true&node=pt40.32.503&rgn=div5 [Accessed 11 July 2017].*
- *Silent Spring Institute, 2015. Water Research. [Online] Available at: http://www.silentspring.org/research-area/water-research [Accessed 24 July 2017].*
- *U.S. Geological Survey, 2016. Land and People: Finding a Balance. [Online] Available at: https://online.wr.usgs.gov/outreach/landpeople/students/capeCod.html [Accessed 24 July 2017].*
- *US Department of Agriculture, 1993. Soil Survey of Barnstable County, Massachusetts. [Online] Available at: https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/massachusetts/MA001/0/barnstable.pdf [Accessed 24 July 2017].*
- *Wright-Pierce, Teal Ltd, CLF Ventures, 2004. Enhancing Wastewater Management on Cape Cod: Planning, Administrative & Legal Tools. [Online] Available at: http://www.capecodcommission.org/resources/waterresources/WWToolsRept.pdf [Accessed 24 July 2017].*

7 Supplementary information

7.1 Policy & institutional roles

At the federal level, wastewater treatment in the US is regulated under the Clean Water Act (1972), which is implemented by the Environmental Protection Agency (EPA). The EPA has developed evidence-based technical standards for biosolids (40 CFR Part 503, Standards for the Use or Disposal of Sewage Sludge) and implements them through the issuance of permits (40 CFR Part 122). (ECFR, 2017a; ECFR, 2017b)

Regional wastewater planning on Cape Cod involves the cooperation of all Cape Cod towns and Barnstable County. The various local bodies involved in wastewater treatment include the Barnstable County Department of Health and Environment, Barnstable County Commissioners (executive branch), the Assembly of Delegates (legislative branch), the Cape Cod Commission and the Cape Cod Water Protection Collaborative. Unlike Boston and 60 other area communities within the state of Massachusetts where the Massachusetts Water Resources Authority oversees the entire water supply, Cape Cod manages its groundwater through this group of entities that work with state and federal partners and the offices of the Cape's 15 municipalities to identify wastewater problems and recommend solutions to keep the ecology and economy healthy. (Cape Cod Commission, 2017)

The Department of Health & Environment's programs have addressed the public health aspects of wastewater for many years and operates a center to test alternative septic treatment methods, manages a septic loan program for homeowners and supports municipal boards of health. Similarly, the Cape Cod Commission and its predecessor agency (the Cape Cod Planning & Economic Development

Commission) has studied Cape Cod's hydrology and ecology and engaged in regional land use planning and policy making for decades. The Cape Cod Water Protection Collaborative, formed in 2005, was established by Barnstable County to coordinate and seek funding for the water and wastewater management efforts of Cape towns and the regional government.

The Cape Cod Regional Wastewater Management Plan (RWMP) was developed by the Cape Cod Commission to guide wastewater management. The plan promotes intergovernmental coordination and cooperation between towns that share watersheds, find solutions to problems, strengthen infrastructure and find sustainable 'green' alternatives to existing processes and outcomes. The plan recommends that wastewater planning ensures adequate infrastructure, especially in those areas anticipated to experience growth. Cape Cod Commission's work on wastewater management planning has intensified in the last few years as the Massachusetts Estuaries Project (MEP) documented the severity of the impacts of excess nitrogen from wastewater discharged from on-site septic systems, into Cape Cod's embayments and is currently undertaking comprehensive studies of 89 embayments that will determine their threshold nitrogen loads and serve as the basis for nutrient control programs.

7.2 Service provision

The sanitation infrastructure in Cape Cod consists of both centralized wastewater systems that provide public sewerage through a wastewater collection system leading to a publicly-owned wastewater treatment plant with effluent disposal; as well as decentralized wastewater systems. Figure 1 shows the use of each type of sanitation facility in Cape Cod and Figure 2 maps the geographical location of sewage and treatment facilities as well as the service providers in charge.

ESTIMATE OF WASTEWATER TREATMENT CAPACITY ON CAPE COD

Type of Facility	Permitted Capacity (mgd)	Percentage of Total Capacity
Centralized	6.75	~ 10 %
Satellite	1.83	~ 3 %
Cluster	≤ 0.1	~ 1 %
Individual	≥ 60	~ 87 %
Total	~ 70	

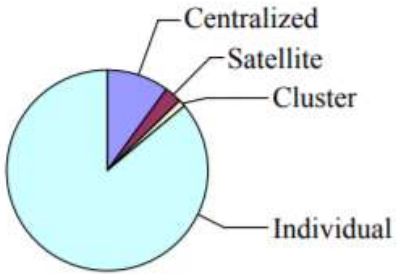


Figure 1: Estimate of wastewater treatment capacity on Cape Cod (Wright-Pierce, Teal Ltd, CLF Ventures, 2004)

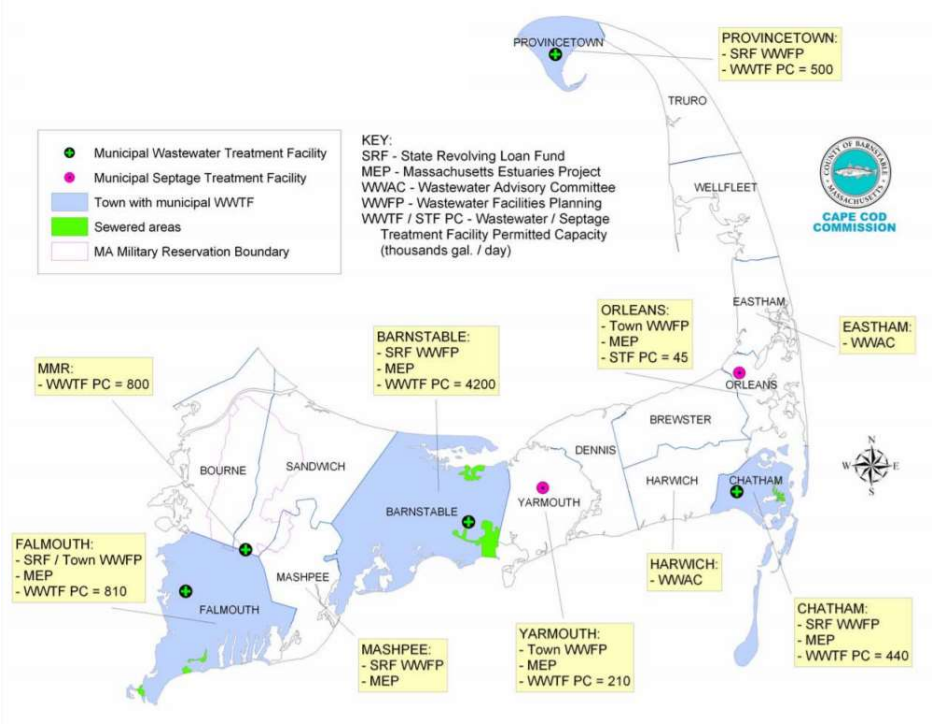


Figure 2: Wastewater management systems on Cape Cod (Wright-Pierce, Teal Ltd, CLF Ventures, 2004)

7.2.1 Centralized systems

Cape Cod has five centralized wastewater facilities (in Barnstable, Chatham, Falmouth, Provincetown and the MMR facility at Otis) which treat wastewater from sewers as well as septage. In addition, Cape Cod also has two stand-alone septage facilities (Yarmouth and Tri-Town). They are managed by local sewer commissioners or departments of public works at the municipality level in Falmouth, Barnstable, Chatham and Provincetown and Sandwich (MMR). All of the wastewater entering these five centralized treatment plants are assumed to undergo enhanced treatment.

7.2.2 Decentralized systems

Decentralized systems consist of onsite septic tanks, satellite systems and cluster systems. The Cod has 40 satellite systems, a handful of cluster systems and over 120,000 individual on-site systems. As about 90% of Cape Cod's population relies on decentralized systems for the containment of faecal sludge and treatment of wastewater, there is a heavy reliance on the over 170 private septic tank maintenance companies operating in the county, in addition to the local government or municipality.

(1) On-site septic systems

In the case of Cape Cod, septic tanks are mostly conventional systems (called Title 5 systems by the Massachusetts State Environmental Code) where wastewater is treated in a simple septic tank prior to discharge to a subsurface disposal system although there are some innovative / alternative systems as well that provide enhanced wastewater treatment. Septic tanks are maintained by homeowners who engage over 170 septic systems maintenance companies that operate in the area.

(2) Satellite systems

Satellite systems are onsite wastewater treatment plants that serve larger groups of the populations, such as condominiums, schools, nursing homes and shopping centers, as opposed to septic tanks that

serve individual households. They usually have flows exceeding 10,000 gpd (equivalent to that produced by 30 three-bedroom homes). Private satellite plants are typically managed by the commercial property owner or condominium association; publicly-owned satellite plants are managed by the local public works department, school department or other town entity.

(3) Cluster Systems

Cluster systems may be as simple as gravity pipes leading to a shared septic tank and shared disposal field, but may also include grinder pumps, low pressure sewer systems and modular plants providing enhanced treatment. A good example of a cluster system is the one serving the Red Lily Pond area of Barnstable, which has individual septic tanks that pump to a shared leaching area. Cluster systems typically have capacities between 1,000 and 10,000 gallons per day (gpd). These systems are typically permitted by local boards of health and by DEP, and are managed by associations of property owners.

ESTIMATED NUMBER OF WASTEWATER TREATMENT SYSTEMS ON CAPE COD

	Individual On-Site		Cluster Systems			
Town	All Systems	Enhanced Treatment	All Systems	Enhanced Treatment	Satellite Plants	Centralized Systems
Barnstable	19,600	29	Note 1	Note 1	2	4.2 mgd
Bourne	8,100	58	Note 1	Note 1	3	
Brewster	5,700	9	1	0	3	
Chatham	4,900	49	4	2	1	0.44 mgd
Dennis	12,600	43	0	0	2	
Eastham	5,400	55	0	0	1	
Falmouth	18,500	66	7	3	4	0.81 mgd
Harwich	8,100	21	0	0	4	
Mashpee	6,700	158	0	0	9	
Orleans	4,500	14	0	0	3	0.045 mgd (septage)
Provincetown	1,400	16	Note 1	Note 1	0	0.50 mgd
Sandwich	8,100	16	1	1	4	0.80 mgd (MMR)
Truro	1,900	4	0	0	0	
Wellfleet	3,300	60	0	0	1	
Yarmouth	13,900	51	0	0	7	0.11 mgd (septage)
Total	122,700	649	13	6	44	5 wastewater 2 septage

Note 1: Data on cluster systems is not available for all towns.

Table 4: Estimated Number of Centralized and Decentralized Wastewater Treatment Systems on Cape Cod (Wright-Pierce, Teal Ltd, CLF Ventures, 2004)