Background Use of Onsite Wastewater Treatment Systems

Course No: C02-008
Credit: 2 PDH

Gilbert Gedeon, P.E.

engineering.com
PDH FOR THE PROFESSIONAL

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.com

This course was adapted from the Environmental Protection Agency (EPA), EPA Onsite Wastewater Treatment Systems Manual, Chapter 1, EPA/625/R-00/008, which is in the public domain.

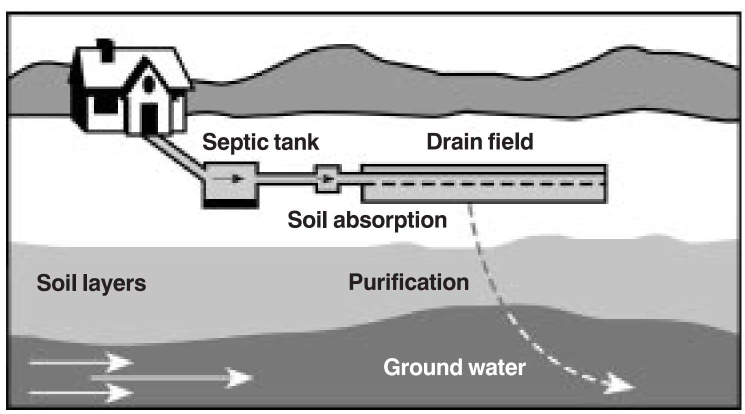
Chapter 1: Background and use of onsite wastewater treatment systems

1.1 Introduction

Onsite wastewater treatment systems (OWTSs) have evolved from the pit privies used widely throughout history to installations capable of producing a disinfected effluent that is fit for human consumption. Although achieving such a level of effluent quality is seldom necessary, the ability of onsite systems to remove settleable solids, floatable grease and scum, nutrients, and pathogens from wastewater discharges defines their importance in protecting human health and environmental resources. In the modern era, the typical onsite system has consisted primarily of a septic tank and a soil absorption field, also known as a subsurface wastewater infiltration system, or SWIS (figure 1-1). In this manual, such systems are referred to as *conventional systems*. Septic tanks remove most settleable and floatable material and function as an anaerobic bioreactor that promotes partial digestion of retained organic matter. Septic tank effluent, which contains significant concentrations of pathogens and nutrients, has traditionally been discharged to soil, sand, or other media absorption fields (SWISs) for further treatment through biological processes, adsorption, filtration, and infiltration into underlying soils. Conventional systems work well if they are installed in areas with appropriate soils and hydraulic capacities; designed to treat the incoming waste load to meet public health, ground water, and surface water performance standards; installed properly; and maintained to ensure long-term performance.

These criteria, however, are often not met. Only about one-third of the land area in the United States has soils suited for conventional subsurface soil absorption fields. System densities in some areas exceed the capacity of even suitable soils to assimilate wastewater flows and retain and transform their contaminants. In addition, many systems are located too close to ground water or surface waters and others, particularly in rural areas with newly installed public water lines, are not designed to handle increasing wastewater flows. Conventional onsite system installations might not be adequate for minimizing nitrate contamination of ground water, removing phosphorus compounds, and attenuating pathogenic organisms (e.g., bacteria, viruses). Nitrates that leach into ground

Figure 1-1. Conventional onsite wastewater treatment system



Source: NSFC, 2000.

water used as a drinking water source can cause methemoglobinemia, or blue baby syndrome, and other health problems for pregnant women. Nitrates and phosphorus discharged into surface waters directly or through subsurface flows can spur algal growth and lead to eutrophication and low dissolved oxygen in lakes, rivers, and coastal areas. In addition, pathogens reaching ground water or surface waters can cause human disease through direct consumption, recreational contact, or ingestion of contaminated shellfish. Sewage might also affect public health as it backs up into residences or commercial establishments because of OWTS failure.

Nationally, states and tribes have reported in their 1998 Clean Water Act section 303(d) reports that designated uses (e.g., drinking water, aquatic habitat) are not being met for 5,281 waterbodies because of pathogens and that 4,773 waterbodies are impaired by nutrients. Onsite systems are one of many known contributors of pathogens and nutrients to surface and ground waters. Onsite wastewater systems have also contributed to an overabundance of nutrients in ponds, lakes, and coastal estuaries, leading to overgrowth of algae and other nuisance aquatic plants.

Threats to public health and water resources (table 1-1) underscore the importance of instituting management programs with the authority and resources to oversee the full range of onsite system activities—planning, siting, design, installation, operation, monitoring, and maintenance. EPA has issued draft *Guidelines for Management of Onsite/ Decentralized Wastewater Systems* (USEPA, 2000) to improve overall management of OWTSs. These guidelines are discussed in more detail in chapter 2.

1.2 History of onsite wastewater treatment systems

King Minos installed the first known water closet with a flushing device in the Knossos Palace in Crete in 1700 BC. In the intervening 3,700 years, societies and the governments that serve them have sought to improve both the removal of human wastes from indoor areas and the treatment of that waste to reduce threats to public health and ecological resources. The Greeks, Romans, British, and French achieved considerable progress in waste removal during the period from 800 BC to AD 1850, but removal often meant discharge to surface waters; severe contamination of lakes, rivers, streams, and coastal areas; and frequent outbreaks of diseases like cholera and typhoid fever.

By the late 1800s, the Massachusetts State Board of Health and other state health agencies had documented links between disease and poorly treated sewage and recommended treatment of wastewater through intermittent sand filtration and land application of the resulting sludge. The past century has witnessed an explosion in sewage treatment technology and widespread adoption of centralized wastewater collection and treatment services in the United States and throughout the world. Although broad uses of these systems have vastly improved public health and water quality in urban areas, homes and businesses without centralized collection and treatment systems often con-

Table 1-1. Typical pollutants of concern in effluent from onsite wastewater treatment systems

Pollutant	Public health or water resource impacts
Pathogens	Parasites, bacteria, and viruses can cause communicable diseases through direct or indirect body contact or ingestion of contaminated water or shellfish. Pathogens can be transported for significant distances in ground water or surface waters.
Nitrogen	Nitrogen is an aquatic plant nutrient that can contribute to eutrophication and dissolved oxygen loss in surface waters, especially in nitrogen-limited lakes, estuaries, and coastal embayments. Algae and aquatic weeds can contribute trihalomethane (THM) precursors to the water column that might generate carcinogenic THMs in chlorinated drinking water. Excessive nitrate-nitrogen in drinking water can cause methemoglobinemia in infants and pregnancy complications.
Phosphorus	Phosphorus is an aquatic plant nutrient that can contribute to eutrophication of phosphorus-limited inland surface waters. High algal and aquatic plant production during eutrophication is often accompanied by increases in populations of decomposer bacteria and reduced dissolved oxygen levels for fish and other organisms.

tinue to depend on technologies developed more than 100 years ago. Septic tanks for primary treatment of wastewater appeared in the late 1800s, and discharge of tank effluent into gravel-lined subsurface drains became common practice during the middle of the 20th century (Kreissl, 2000).

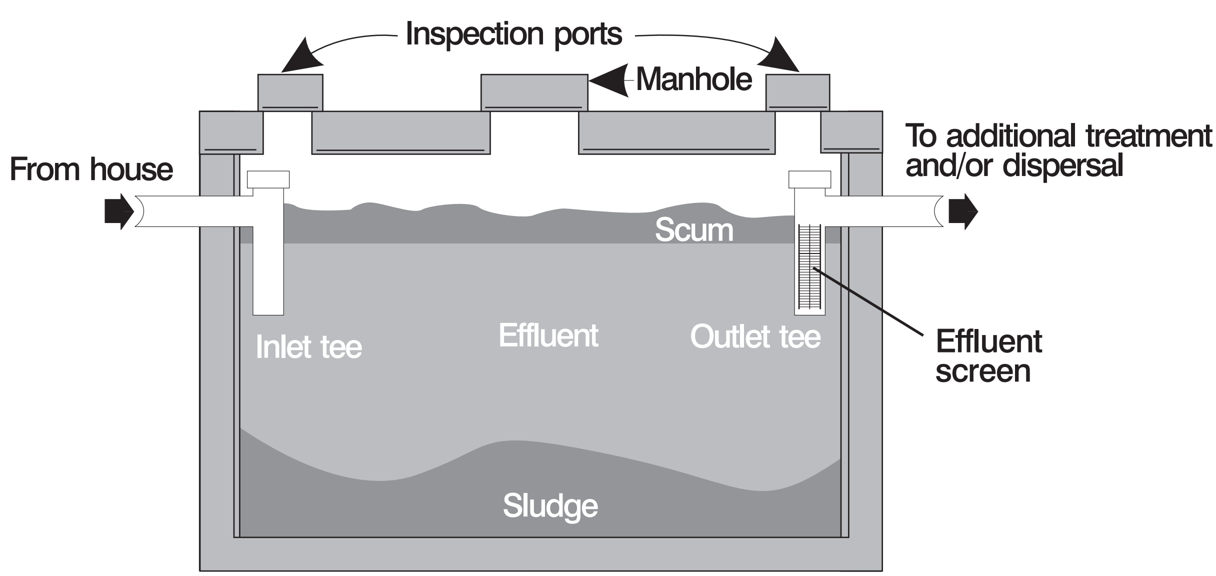
Scientists, engineers, and manufacturers in the wastewater treatment industry have developed a wide range of alternative technologies designed to address increasing hydraulic loads and water contamination by nutrients and pathogens. These technologies can achieve significant pollutant removal rates. With proper management oversight, alternative systems (e.g., recirculating sand filters, peat-based systems, package aeration units) can be installed in areas where soils, bedrock, fluctuating ground water levels, or lot sizes limit the use of conventional systems. Alternative technologies typically are applied to the treatment train beyond the septic tank (figure 1-2). The tank is designed to equalize hydraulic flows; retain oils, grease, and settled solids; and provide some minimal anaerobic digestion of settleable organic matter. Alternative treatment technologies often provide environments (e.g., sand, peat, artificial media) that promote additional biological treatment and remove pollutants through filtration, absorption, and adsorption. All of the alternative treatment technologies in current use require more intensive management and monitoring than conventional OWTSs because of mechanical components, additional residuals generated, and process sensitivities (e.g., to wastewater strength or hydraulic loading).

Replacing gravity-flow subsurface soil infiltration beds with better-performing alternative distribution technologies can require float-switched pumps and/or valves. As noted in chapter 4, specialized excavation or structures might be required to house some treatment system components, including the disinfection devices (e.g., chlorinators, ultraviolet lamps) used by some systems. In addition, it is often both efficient and effective to collect and treat septic tank effluent from clusters of individual sources through a community or cluster system driven by gravity, pressure, or vacuum. These devices also require specialized design, operation, and maintenance and enhanced management oversight.

1.3 Regulation of onsite wastewater treatment systems

Public health departments were charged with enforcing the first onsite wastewater "disposal" laws, which were mostly based on soil percolation tests, local practices, and past experience. Early codes did not consider the complex interrelationships among soil conditions, wastewater characteristics, biological mechanisms, and climate and

Figure 1-2. Typical single-compartment septic tank with at-grade inspection ports and effluent screen



Source: NSFC, 2000.

prescribed standard designs sometimes copied from jurisdictions in vastly different geoclimatic regions. In addition, these laws often depended on minimally trained personnel to oversee design, permitting, and installation and mostly untrained, uninformed homeowners to operate and maintain the systems. During the 1950s states began to adopt laws upgrading onsite system design and installation practices to ensure proper functioning and eliminate the threats posed by waterborne pathogens (Kreissl, 1982). Despite these improvements, many regulations have not considered cumulative ground water and surface water impacts, especially in areas with high system densities and significant wastewater discharges.

Kreissl (1982) and Plews (1977) examined changes in state onsite wastewater treatment regulations prompted by the publication of the first U.S. Public Health Service *Manual of Septic-Tank Practice* in 1959. Plews found significant code revisions under way by the late 1970s, mostly because of local experience, new research information, and the need to accommodate housing in areas not suited for conventional soil infiltration systems. Kreissl found that states were gradually increasing required septic tank and drainfield sizes but also noted that 32 states were still specifying use of the percolation test in system sizing in 1980, despite its proven shortcomings. Other differences noted among state codes included separation distances between the infiltration trench bottom and seasonal ground water tables, minimum trench widths, horizontal setbacks to potable water supplies, and maximum allowable land slopes (Kreissl, 1982).

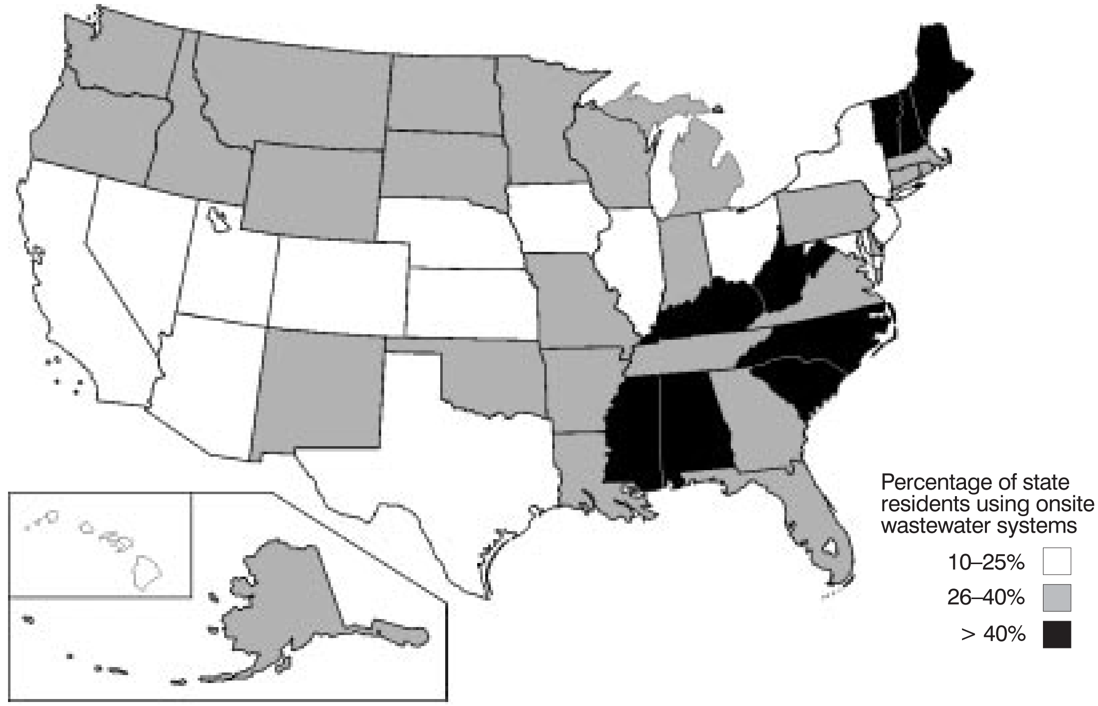
Although state lawmakers have continued to revise onsite system codes, most revisions have failed to address the fundamental issue of system performance in the context of risk management for both a site and the region in which it is located. Prescribed system designs require that site conditions fit system capabilities rather than the reverse and are sometimes incorrectly based on the assumption that centralized wastewater collection and treatment services will be available in the future. Codes that emphasize prescriptive standards based on empirical relationships and hydraulic performance do not necessarily protect ground water and surface water resources from public health threats. Devising a new regime for protecting public health and the environment in a cost-effective manner will require increased focus on system performance, pollutant transport and fate and resulting environmental impacts, and integration of the planning, design, siting, installation, maintenance, and management functions to achieve public health and environmental objectives.

1.4 Onsite wastewater treatment system use, distribution, and failure rate

According to the U.S. Census Bureau (1999), approximately 23 percent of the estimated 115 million occupied homes in the United States are served by onsite systems, a proportion that has changed little since 1970. As shown in figure 1-3 and table 1-2, the distribution and density of homes with OWTSs vary widely by state, with a high of about 55 percent in Vermont and a low of around 10 percent in California (U.S. Census Bureau, 1990). New England states have the highest proportion of homes served by onsite systems: New Hampshire and Maine both report that about half of all homes are served by individual wastewater treatment systems. More than a third of the homes in the southeastern states depend on these systems, including approximately 48 percent in North Carolina and about 40 percent in both Kentucky and South Carolina. More than 60 million people depend on decentralized systems, including the residents of about one-third of new homes and more than half of all mobile homes nationwide (U.S. Census Bureau, 1999). Some communities rely completely on OWTSs.

A number of systems relying on outdated and underperforming technologies (e.g., cesspools, drywells) still exist, and many of them are listed among failed systems. Moreover, about half of the occupied homes with onsite treatment systems are more than 30 years old (U.S. Census Bureau, 1997), and a significant number report system problems. A survey conducted by the U.S. Census Bureau (1997) estimated that 403,000 homes experienced septic system breakdowns within a 3-month period during 1997; 31,000 reported four or more breakdowns at the same home. Studies reviewed by USEPA cite failure rates ranging from 10 to 20 percent (USEPA, 2000). System failure surveys typically do not include systems that might be contaminating surface or ground water, a situation that often is detectable only through site-

Figure 1-3. Onsite treatment system distribution in the United States



Source: U.S. Census Bureau, 1990.

level monitoring. Figure 1-4 demonstrates ways that effluent water from a septic system can reach ground water or surface waters.

Comprehensive data to measure the true extent of septic system failure are not currently collected by any single organization. Although estimates of system failure rates have been collected from 28 states (table 1-3), no state had directly measured its own failure rate and definitions of failure vary (Nelson et al., 1999). Most available data are the result of incidents that directly affect public health or are obtained from homeowners' applications for permits to replace or repair failing systems. The 20 percent failure rate from the Massachusetts time-of-transfer inspection program is based on an inspection of each septic system prior to home sale, which is a comprehensive data collection effort. However, the Massachusetts program only identifies failures according to code and does not track ground water contamination that may result from onsite system failures.

In addition to failures due to age and hydraulic overloading, OWTSs can fail because of design, installation, and maintenance problems. Hydraulically functioning systems can create health and ecological risks when multiple treatment units are installed at densities that exceed the capacity of local soils to assimilate pollutant loads. System owners are not likely to repair or replace aging or otherwise failing systems unless sewage backup, septage pooling on lawns, or targeted monitoring that identifies health risks occurs. Because ground and surface water contamination by onsite systems has rarely been confirmed through targeted monitoring, total failure rates and onsite system impacts over time are likely to be significantly higher than historical statistics indicate. For example, the Chesapeake Bay Program found that 55 to 85 percent of the nitrogen entering an onsite system can be discharged into ground water (USEPA, 1993). A 1991 study concluded that conventional systems accounted for 74 percent of the nitrogen entering Buttermilk Bay in Massachusetts (USEPA, 1993).

1.5 Problems with existing onsite wastewater management programs

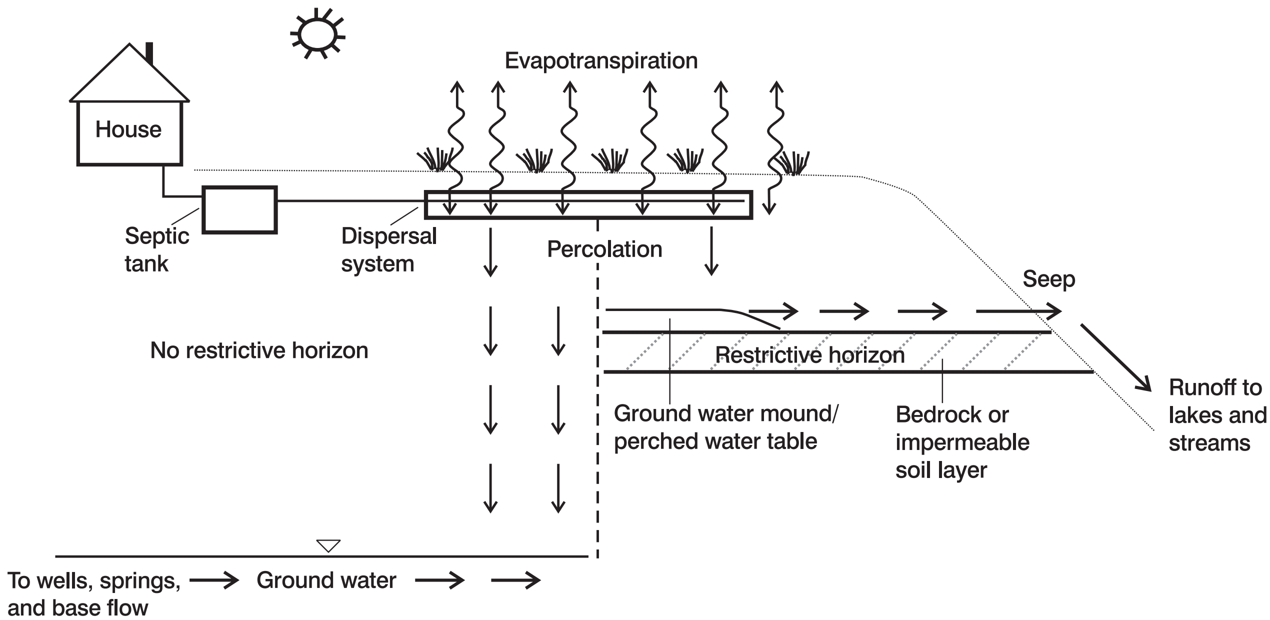
Under a typical conventional system management approach, untrained and often uninformed system owners assume responsibility for operating and

Table 1-2. Census of housing tables: sewage disposal, 1990

	Public sewer		Septic tank or cesspool		Other means	
	Number	Percent	Number	Percent	Number	Percent
United States	76,455,211	74.8	24,670,877	24.1	1,137,590	1.1
Alabama	910,782	54.5	728,690	43.6	30,907	1.9
Alaska	144,905	62.3	59,886	25.7	27,817	12.0
Arizona	1,348,836	81.3	282,897	17.0	27,697	1.7
Arkansas	601,188	60.1	382,467	38.2	17,012	1.7
California	10,022,843	89.6	1,092,174	9.8	67,865	0.6
Colorado	1,283,186	86.9	183,817	12.4	10,346	0.7
Connecticut	935,541	70.8	378,382	28.6	6,927	0.5
Delaware	212,793	73.4	74,541	25.7	2,585	0.9
District of Columbia	276,481	99.3	575	0.2	1,433	0.5
Florida	4,499,793	73.8	1,559,113	25.6	41,356	0.7
Georgia	1,638,979	62.1	970,686	36.8	28,753	1.1
Hawaii	312,812	80.2	72,940	18.7	4,058	1.0
Idaho	264,618	64.0	142,879	34.6	5,830	1.4
Illinois	3,885,689	86.2	598,125	13.3	22,461	0.5
Indiana	1,525,810	67.9	703,032	31.3	17,204	0.8
Iowa	869,056	76.0	264,889	23.2	9,724	0.9
Kansas	847,767	81.2	187,398	17.9	8,947	0.9
Kentucky	849,491	56.4	600,182	39.8	57,172	3.8
Louisiana	1,246,678	72.6	442,758	25.8	26,805	1.6
Maine	266,344	45.4	301,373	51.3	19,328	3.3
Maryland	1,533,799	81.1	342,523	18.1	15,595	0.8
Massachusetts	1,803,176	72.9	659,120	26.7	10,415	0.4
Michigan	2,724,408	70.8	1,090,481	28.3	33,037	0.9
Minnesota	1,356,520	73.4	467,936	25.3	23,989	1.3
Mississippi	585,185	57.9	387,406	38.3	37,832	3.7
Missouri	1,617,996	73.6	532,844	24.2	48,289	2.2
Montana	218,372	60.5	135,371	37.5	7,412	2.1
Nebraska	534,692	80.9	117,460	17.8	8,469	1.3
Nevada	456,107	87.9	60,508	11.7	2,243	0.4
New Hampshire	250,060	49.6	246,692	49.0	7,152	1.4
New Jersey	2,703,489	87.9	357,890	11.6	13,931	0.5
New Mexico	452,934	71.7	161,068	25.5	18,056	2.9
New York	5,716,917	79.1	1,460,873	20.2	49,101	0.7
North Carolina	1,403,033	49.8	1,365,632	48.5	49,528	1.8
North Dakota	204,328	73.9	66,479	24.1	5,533	2.0
Ohio	3,392,785	77.6	940,943	21.5	38,217	0.9
Oklahoma	1,028,594	73.1	367,197	26.1	10,708	0.8
Oregon	835,545	70.0	349,122	29.3	8,900	0.7
Pennsylvania	3,670,338	74.3	1,210,054	24.5	57,748	1.2
Rhode Island	293,901	70.9	118,410	28.6	2,261	0.5
South Carolina	825,754	58.0	578,129	40.6	20,272	1.4
South Dakota	207,996	71.1	78,435	26.8	6,005	2.1
Tennessee	1,213,934	59.9	781,616	38.6	30,517	1.5
Texas	5,690,550	81.2	1,266,713	18.1	51,736	0.7
Utah	528,864	88.4	65,403	10.9	4,121	0.7
Vermont	115,201	42.5	149,125	55.0	6,888	2.5
Virginia	1,740,787	69.7	707,409	28.3	48,138	1.9
Washington	1,387,396	68.3	630,646	31.0	14,336	0.7
West Virginia	427,930	54.8	318,697	40.8	34,668	4.4
Wisconsin	1,440,024	70.0	580,836	28.3	34,914	1.7
Wyoming	151,004	74.2	49,055	24.1	3,352	1.6

Source: U.S. Census Bureau, 1990.

Figure 1-4. Fate of water discharged to onsite wastewater treatment systems.



Source: Adapted from Venhuizen, 1995.

Table 1-3. Estimated onsite treatment system failure rates in surveyed states

State	Estimated system failure rate (percentage)	Failure definition
Alabama	20	Not given
Arizona	0.5	Surfacing, backup, surface or ground water contamination
California	1–4	Surfacing, backup, surface or ground water contamination
Florida	1–2	Surfacing, backup, surface or ground water contamination
Georgia	1.7	Public hazard
Hawaii	15–35	Improper construction, overflow
Idaho	20	Backup, surface or ground water contamination
Kansas	10–15	Surfacing, nuisance conditions (for installations after 1980)
Louisiana	50	Not given
Maryland	1	Surfacing, surface or ground water contamination
Massachusetts	25	Public health
Minnesota	50–70	Cesspool, surfacing, inadequate soil layer, leaking
Missouri	30–50	Backup, surface or ground water contamination
Nebraska	40	Nonconforming system, water quality
New Hampshire	<5	Surfacing, backup
New Mexico	20	Surfacing
New York	4	Backup, surface or ground water contamination
North Carolina	15–20	Not given
North Dakota	28	Backup, surfacing
Ohio	25–30	Backup, surfacing
Oklahoma	5–10	Backup, surfacing, discharge off property
Rhode Island	25	Not given
South Carolina	6–7	Backup, surface or ground water contamination
Texas	10–15	Surfacing, surface or ground water contamination
Utah	0.5	Surfacing, backup, exceed discharge standards
Washington	33	Public health hazard
West Virginia	60	Backup, surface or ground water contamination
Wyoming	0.4	Backup, surfacing, ground water contamination

[a] Failure rates are estimated and vary with the definition of failure.

Source: Nelson et al., 1999.

maintaining their relatively simple, gravity-based systems. Performance results under this approach can vary significantly, with operation and maintenance functions driven mostly by complaints or failures. In fact, many conventional system failures have been linked to operation and maintenance failures. Typical causes of failure include unpumped and sludge-filled tanks, which result in clogged absorption fields, and hydraulic overloading caused by increased occupancy and greater water use following the installation of new water lines to replace wells and cisterns. Full-time or high use of vacation homes served by systems installed under outdated practices or designed for part-time occupancy can cause water quality problems in lakes, coastal bays, and estuaries. Landscape modification, alteration of the infiltration field surface, or the use of outdated technologies like drywells and cesspools can also cause contamination problems.

Newer or "alternative" onsite treatment technologies are more complex than conventional systems and incorporate pumps, recirculation piping, aeration, and other features (e.g., greater generation of residuals) that require ongoing or periodic monitoring and maintenance. However, the current management programs of most jurisdictions do not typically oversee routine operation and maintenance activities or detect and respond to changes in wastewater loads that can overwhelm a system. In addition, in many cases onsite system planning and siting functions are not linked to larger ground water and watershed protection programs. The challenge for onsite treatment regulators in the new millennium will be to improve traditional health-based programs for ground water and surface water protection while embracing a vigorous role in protecting and restoring the nation's watersheds.

The challenge is significant. Shortcomings in many management programs have resulted in poor system performance, public health threats, degradation of surface and ground waters, property value declines, and negative public perceptions of onsite treatment as an effective wastewater management option. (See examples in section 1.1.) USEPA (1987) has identified a number of critical problems associated with programs that lack a comprehensive management program:

- Failure to adequately consider site-specific environmental conditions.
- Codes that thwart adaptation to difficult local site conditions and are unable to accommodate effective innovative and alternative technologies.
- Ineffective or nonexistent public education and training programs.
- Failure to include conservation and potential reuse of water.
- Ineffective controls on operation and maintenance of systems, including residuals (septage, sludge).
- Failure to consider the special characteristics and requirements of commercial, industrial, and large residential systems.
- Weak compliance and enforcement programs.
- These problems can be grouped into three primary areas: (1) insufficient funding and public involvement; (2) inappropriate system design and selection processes; and (3) poor inspection, monitoring, and program evaluation components. Management programs that do not address these problems can directly and indirectly contribute to significant human health risks and environmental degradation.

1.5.1 Public involvement and education

Public involvement and education are critical to successful onsite wastewater management. Engaging the public in wastewater treatment issues helps build support for funding, regulatory initiatives, and other elements of a comprehensive program. Educational activities directed at increasing general awareness and knowledge of onsite management efforts can improve the probability that simple, routine operation and maintenance tasks (e.g., inspecting for pooled effluent, pumping the tank) are carried out by system owners. Specialized training is required for system managers responsible for operating and maintaining systems with more complex components. Even conventional, gravity-based systems require routine pumping, monitoring, and periodic inspection of sludge and scum buildup in septic tanks. Failing systems can cause public health risks and environmental damage and are expensive to repair. System owners should be made aware of the need for periodically removing tank sludge, maintaining system components, and operating systems within their design limitations to help maximize treatment effectiveness and extend the life of the systems.

Information regarding regular inspections, pumping, ground water threats from chemicals, hydraulic overloading from roof runoff or other clear water sources, pollutant loads from garbage disposal units, drain field protection, and warning signs of failing systems can be easily communicated. Flyers, brochures, posters, news media articles, and other materials have proven effective in raising awareness and increasing public knowledge of onsite wastewater management issues (see Resources section). Meetings with stakeholders and elected officials and face-to-face training programs for homeowners can produce better results when actions to strengthen programs are required (USEPA, 1994). Public involvement and education programs are often overlooked because they require resources, careful planning, and management and can be labor-intensive. However, these efforts can pay rich dividends in building support for the management agency and improving system performance. Public education and periodic public input are also needed to obtain support for developing and funding a wastewater utility or other comprehensive management program (see chapter 2).

1.5.2 Financial support

Funding is essential for successful management of onsite systems. Adequate staff is required to implement the components of the program and objectively enforce the regulations. Without money to pay for planning, inspection, and enforcement staff, these activities will not normally be properly implemented. Financial programs might be needed to provide loans or cost-share grants to retrofit or replace failing systems. Statewide public financing programs for onsite systems like the PENNVEST initiative in Pennsylvania provide a powerful incentive for upgrading inadequate or failed systems (Pennsylvania Infrastructure Investment Authority, 1997). Regional cost-share programs like the Triplett Creek Project in Kentucky, which provided funding for new septic tanks and drain field repairs, are also effective approaches for addressing failed systems (USEPA, 1997). Chapter 2 and the Resources section provide more information on funding options for onsite systems and management programs.

Managing onsite systems is particularly challenging in small, unincorporated communities without paid staff. Programs staffed by trained volunteers and regional "circuit riders" can help deliver technical expertise at a low cost in these situations. Developing a program uniquely tailored to each community requires partnerships, ingenuity, commitment, and perseverance.

1.5.3 Support from elected officials

In most cases the absence of a viable oversight program that addresses the full range of planning, design, siting, permitting, installation, operation, maintenance, and monitoring activities is the main reason for inadequate onsite wastewater system management. This absence can be attributed to a number of factors, particularly a political climate in which the value of effective onsite wastewater management is dismissed as hindering economic development or being too restrictive on rural housing development. In addition, low population densities, low incomes, underdeveloped management entities, a history of neglect, or other unique factors can impede the development of comprehensive management programs. Focusing on the public health and water resource impacts associated with onsite systems provides an important perspective for public policy discussions on these issues.

Sometimes state and local laws prevent siting or design options that could provide treatment and recycling of wastewater from onsite systems. For example, some state land use laws prohibit using lands designated as resource lands to aid in the development of urban uses. Small communities or rural developments located near state resource lands are unable to use those lands to address onsite problems related to space restrictions, soil limitations, or other factors (Fogarty, 2000).

The most arbitrary siting requirement, however, is the minimum lot size restriction incorporated into

> *Note:* This manual is not intended to be used to determine appropriate or inappropriate uses of land. The information the manual presents is intended to be used to select appropriate technologies and management strategies that minimize risks to human health and water resources in areas that are not connected to centralized wastewater collection and treatment systems.

many state and local codes. Lot size limits prohibit onsite treatment system installations on nonconforming lots without regard to the performance capabilities of the proposed system. Lot size restrictions also serve as an inappropriate but de facto approach to land use planning in many localities because they are often seen as establishing the allowable number of housing units in a development without regard to other factors that might increase or decrease that number.

When developing a program or regulation, the common tendency is to draw on experience from other areas and modify existing management plans or codes to meet local needs. However, programs that are successful in one area of the country might be inappropriate in other areas because of differences in economic conditions, environmental factors, and public agency structures and objectives. Transplanting programs or program components without considering local conditions can result in incompatibilities and a general lack of effectiveness. Although drawing on the experience of others can save time and money, local planners and health officials need to make sure that the programs and regulations are appropriately tailored to local conditions.

Successful programs have site evaluation, inspection, and monitoring processes to ensure that regulations are followed. Programs that have poor inspection and monitoring components usually experience low compliance rates, frequent complaints, and unacceptable performance results. For example, some states do not have minimum standards applicable to the various types of onsite systems being installed or do not require licensing of installers (Suhrer, 2000). Standards and enforcement practices vary widely among the states, and until recently there has been little training for local officials, designers, or installers.

USEPA has identified more effective management of onsite systems as a key challenge for efforts to improve system performance (USEPA, 1997). In its *Response to Congress on Use of Decentralized Wastewater Treatment Systems,* USEPA noted that "adequately managed decentralized wastewater treatment systems can be a cost-effective and long-term option for meeting public health and water quality goals, particularly for small towns and rural areas."

In addition, the Agency found that properly managed onsite systems protect public health and water quality, lower capital and maintenance costs for low-density communities, are appropriate for varying site conditions, and are suitable for ecologically sensitive areas (USEPA, 1997). However, USEPA identified several barriers to the increased use of onsite systems, including the lack of adequate management programs. Although most communities have some form of management program in place, there is a critical lack of consistency. Many management programs are inadequate, underdeveloped, or too narrow in focus, and they might hinder widespread public acceptance of onsite systems as viable treatment options or fail to protect health and water resources.

1.6 Performance-based management of onsite wastewater treatment systems

Performance-based management approaches have been proposed as a substitute for prescriptive requirements for system design, siting, and operation. In theory, such approaches appear to be both irresistibly simple and inherently logical. In practice, however, it is often difficult to certify the performance of various treatment technologies under the wide range of climates, site conditions, hydraulic loads, and pollutant outputs they are subjected to and to predict the transport and fate of those pollutants in the environment. Despite these difficulties, research and demonstration projects conducted by USEPA, the National Small Flows Clearinghouse, the National Capacity Development Project, private consultants and engineering firms, academic institutions, professional associations, and public agencies have collectively assembled a body of knowledge that can provide a framework for developing performance-based programs. Performance ranges for many alternative systems operating under a given set of climatic, hydrological, site, and wastewater load conditions have been established. The site evaluation process is becoming more refined and comprehensive (see chapter 5) and has moved from simple percolation tests to a more comprehensive analysis of soils, restrictive horizons, seasonal water tables, and other factors. New technologies that incorporate lightweight media, recirculation of effluent, or disinfection processes have been developed based on performance.

A performance-based management program makes use of recent developments to select and size system technologies appropriate for the estimated flow and strength of the wastewater at the site where treatment is to occur. For sites with appropriate soils, ground water characteristics, slopes, and other features, systems with subsurface wastewater infiltration systems (SWISs) might be the best option. Sites with inadequate soils, high seasonal water tables, or other restrictions require alternative approaches that can achieve performance objectives despite restrictive site features. Selecting proven system designs that are sized to treat the expected wastewater load is the key to this approach. Installing unproven technologies on provisional sites is risky even if performance monitoring is to be conducted because monitoring is often expensive and sometimes inconclusive.

1.6.1 Prescriptive management programs

Onsite system management has traditionally been based on prescriptive requirements for system design, siting, and installation. Installation of a system that "complies" with codes is a primary goal. Most jurisdictions specify the type of system that must be installed and the types and depth of soils that must be present. They also require mandatory setbacks from seasonally high water tables, property lines, wells, surface waters, and other landscape features. Some of these requirements (e.g., minimum setback distances from streams and reservoirs) are arbitrary and vary widely among the states (Curry, 1998). The prescriptive approach has worked well in some localities but has severely restricted development options in many areas. For example, many regions do not have appropriate soils, ground water tables, slopes, or other attributes necessary for installation of conventional onsite systems. In Florida, 74 percent of the soils have severe or very severe limitations for conventional system designs, based on USDA Natural Resources Conservation Service criteria (Florida HRS, 1993).

1.6.2 Hybrid management programs

Some jurisdictions are experimenting with performance-based approaches while retaining prescriptive requirements for technologies that have proven effective under a known range of site conditions. These prescriptive/performance-based or "hybrid" programs represent a practical approach to onsite system management by prescribing specific sets of technologies or proprietary systems for sites where they have proven to be effective and appropriate. Regulatory entities review and evaluate alternative systems to see if they are appropriate for the site and the wastewater to be treated. Performance-based approaches depend heavily on data from research, wastewater characterization processes, site evaluations, installation practices, and expected operation and maintenance activities, and careful monitoring of system performance is strongly recommended. Programs that allow or encourage a performance-based approach must have a strong management program to ensure that preinstallation research and design and postinstallation operation, maintenance, and monitoring activities are conducted appropriately.

Representatives from government and industry are supporting further development of management programs that can adequately oversee the full range of OWTS activities, especially operation and maintenance. The National Onsite Wastewater Recycling Association (NOWRA) was founded in 1992 to promote policies that improve the market for onsite wastewater treatment and reuse products. NOWRA has developed a model framework for onsite system management that is based on performance rather than prescriptive regulations. The framework endorses the adoption and use of alternative technologies that achieve public health and environmental protection objectives through innovative technologies and comprehensive program management. (NOWRA, 1999)

1.7 Coordinating onsite system management with watershed protection efforts

During the past decade, public and private entities involved in protecting and restoring water resources have increasingly embraced a watershed approach to assessment, planning, and management. Under this approach, all the land uses and other activities and attributes of each drainage basin or ground water recharge zone are considered when conducting monitoring, assessment, problem targeting, and remediation activities (see figure 1-5). A watershed approach incorporates a geographic focus, scientific principles, and stakeholder partnerships.

Because onsite systems can have significant impacts on water resources, onsite/decentralized wastewater management agencies are becoming more involved in the watershed protection programs that have developed in their regions. Coordinating onsite wastewater management activities with programs and projects conducted under a watershed approach greatly enhances overall land use planning and development processes. A cooperative, coordinated approach to protecting health and water resources can achieve results that are greater than the sum of the individual efforts of each partnering entity. Onsite wastewater management agencies are important components of watershed partnerships, and their involvement in these efforts provides mutual benefits, operating efficiencies, and public education opportunities that can be difficult for agencies to achieve individually.

1.8 USEPA initiatives to improve onsite system treatment and management

In 1996 Congress requested USEPA to report on the potential benefits of onsite/decentralized wastewater treatment and management systems, the potential costs or savings associated with such systems, and the ability and plans of the Agency to implement additional alternative wastewater system measures within the current regulatory and statutory regime. A year later USEPA reported that properly managed onsite/decentralized systems offer several advantages over centralized wastewater treatment facilities (USEPA, 1997; see **http://www.epa.gov/owm/decent/response/index.htm**). The construction and maintenance costs of onsite/decentralized systems can be significantly lower, especially in low-density residential areas, making them an attractive alternative for small towns, suburban developments, remote school and institutional facilities, and rural regions. Onsite/decentralized wastewater treatment systems also avoid potentially large transfers of water from one watershed to another via centralized collection and treatment (USEPA, 1997).

USEPA reported that both centralized and onsite/decentralized systems need to be considered when upgrading failing systems. The report concluded that onsite/decentralized systems can protect public health and the environment and can lower capital and maintenance costs in low-density communities. They are also appropriate for a variety of site conditions and can be suitable for ecologically sensitive areas (USEPA, 1997). However, the Agency also cited several barriers to implementing more effective onsite wastewater management programs, including the following:

- Lack of knowledge and public misperceptions that centralized sewage treatment plants perform better, protect property values, and are more acceptable than decentralized treatment systems.
- Legislative and regulatory constraints and prescriptive requirements that discourage local jurisdictions from developing or implementing effective management and oversight functions.

Model framework for onsite wastewater management

- Performance requirements that protect human health and the environment.
- System management to maintain performance within the established performance requirements.
- Compliance monitoring and enforcement to ensure system performance is achieved and maintained.
- Technical guidelines for site evaluation, design, construction, and operation and acceptable prescriptive designs for specific site conditions and use.
- Education/training for all practitioners, planners, and owners.
- Certification/licensing for all practitioners to maintain standards of competence and conduct.
- Program reviews to identify knowledge gaps, implementation shortcomings, and necessary corrective actions.

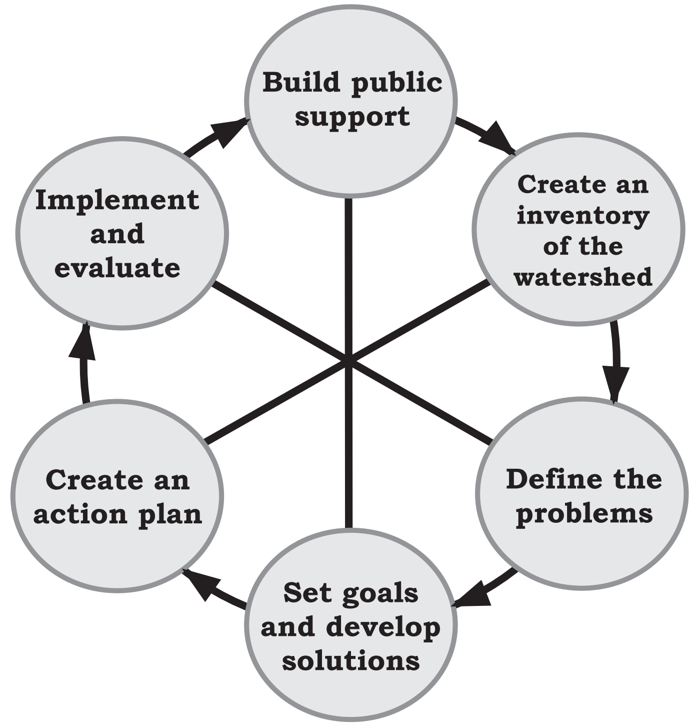
Source: NOWRA, 1999.

- Splitting of regulatory authority, which limits the evaluation of alternatives, and a lack of management programs that consolidate planning, siting, design, installation, and maintenance activities under a single entity with the resources and authority to ensure that performance requirements are met and performance is maintained.
- Liability laws that discourage innovation, as well as cost-based engineering fees that discourage investment in designing innovative, effective, low-cost systems.
- Grant guidelines, loan priorities, and other financial or institutional barriers that prevent rural communities from accessing funds, considering alternative wastewater treatment approaches, or creating management entities that span the jurisdictions of multiple agencies.

USEPA is committed to elevating the standards of onsite wastewater management practice and removing barriers that preclude widespread acceptance of onsite treatment technologies. In addition, the Agency is responding to calls to reduce other barriers to onsite treatment by improving access to federal funding programs, providing performance information on alternative onsite wastewater treatment technologies through the Environmental Technology Verification program (see **http://www.epa.gov/etv/**) and other programs, partnering with other agencies to reduce funding barriers, and providing guidance through cooperation with other public agencies and private organizations. USEPA supports a number of efforts to improve onsite treatment technology design, application, and funding nationwide. For example, the National Onsite Demonstration Project (NODP), funded by USEPA and managed by the National Small Flows Clearinghouse at West Virginia University, was established in 1993 to encourage the use of alternative, decentralized wastewater treatment technologies to protect public health and the environment in small and rural communities (see **http://www.nesc.wvu.edu**).

In addition, USEPA is studying ground water impacts caused by large-capacity septic systems, which might be regulated under the Class V Underground Injection Control (UIC) program. Large-capacity septic systems serve multiple dwellings, business establishments, and other facilities and are used to dispose of sanitary and other wastes through subsurface application (figure 1-6). Domestic and most commercial systems serving fewer than 20 persons are not included in the UIC program (see **http://www.epa.gov/safewater/uic/classv.html** for exceptions and limitations), but some commercial facilities serving fewer than 20 people may be regulated. States and tribes with delegated authority are studying possible guidance and other programs that reduce water resource impacts from these systems. USEPA estimates that there are more than 350,000 large-capacity septic systems nationwide.

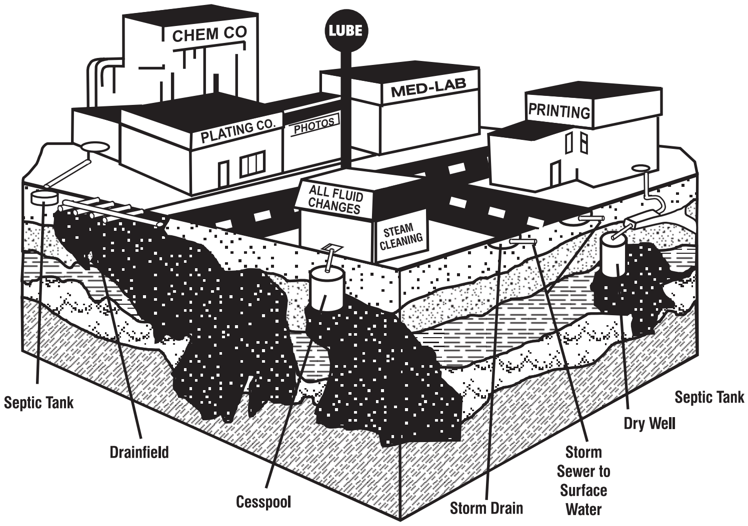
Figure 1-5. The watershed approach planning and management cycle



Source: Ohio EPA, 1997.

USEPA also oversees the management and reuse or disposal of septic tank residuals and septage through the Part 503 Rule of the federal Clean Water Act. The Part 503 Rule (see **http:// www.epa.gov/ owm/bio/503pe/**) established requirements for the final use or disposal of sewage sludge when it is applied to land to condition the soil or fertilize crops or other vegetation, deposited at a surface disposal site for final disposal, or fired in a biosolids incinerator. The rule also specifies other requirements for sludge that is placed in a municipal solid waste landfill under Title 40 of the Code of Federal Regulations (CFR), Part 258. The Part 503 Rule is designed to protect public health

Figure 1-6. Large-capacity septic tanks and other subsurface discharges subject to regulation under the Underground Injection Control Program and other programs



and the environment from any reasonably anticipated adverse effects of certain pollutants and contaminants that might be present in sewage sludge, and it is consistent with USEPA's policy of promoting the beneficial uses of biosolids.

USEPA has also issued guidance for protecting wellhead recharge areas and assessing threats to drinking water sources under the 1996 amendments to the Safe Drinking Water Act (see **http://www.epa.gov/safewater/protect.html** and **http://www.epa.gov/safewater/whpnp.html**). State source water assessment programs differ because they are tailored to each state's water resources and drinking water priorities. However, each assessment must include four major elements:

- Delineating (or mapping) the source water assessment area
- Conducting an inventory of potential sources of contamination in the delineated area
- Determining the susceptibility of the water supply to those contamination sources
- Releasing the results of the determinations to the public

Local communities can use the information collected in the assessments to develop plans to protect wellhead recharge areas and surface waters used as drinking water sources. These plans can include local or regional actions to reduce risks associated with potential contaminant sources, prohibit certain high-risk contaminants or activities in the source water protection area, or specify other management measures to reduce the likelihood of source water contamination. Improving the performance and management of onsite treatment systems can be an important component of wellhead and source water protection plans in areas where nitrate contamination, nutrient inputs, or microbial

Integrating public and private entities with watershed management

In 1991 the Keuka Lake Association established a watershed project to address nutrient, pathogen, and other pollutant loadings to the upstate New York lake, which provides drinking water for more than 20,000 people and borders eight municipalities and two counties. The project sought to assess watershed conditions, educate the public on the need for action, and foster interjurisdictional cooperation to address identified problems. The project team established the Keuka Watershed Improvement Cooperative as an oversight committee composed of elected officials from the municipalities and counties. The group developed an 8-page intermunicipal agreement under the state home rule provisions (which allow municipalities to do anything collectively that they may do individually) to formalize the cooperative and recommend new laws and policies for onsite systems and other pollutant sources.

Voters in each municipality approved the agreement by landslide margins after an extensive public outreach program. The cooperative developed regulations governing onsite system permitting, design standards, inspection, and enforcement. The regulations carry the force of law in each town or village court and stipulate that failures must be cited and upgrades required. Inspections are required every 5 years for systems within 200 feet of the lake, and alternative systems must be inspected annually. The cooperative coordinates its activities with state and county health agencies and maintains a geographic information system (GIS) database to track environmental variables and the performance of new technologies. The program is financed by onsite system permit fees, some grant funds, and appropriations from each municipality's annual budget.

Source: Shephard, 1996.

contaminants are identified as potential risks to drinking water sources.

1.9 Other initiatives to assist and improve onsite management efforts

Financing the installation and management of onsite systems can present a significant barrier for homeowners and small communities. USEPA and other agencies have developed loan, cost-share, and other programs to help homeowners pay for new systems, repairs, or upgrades (see chapter 2). Some of the major initiatives are the Clean Water State Revolving Fund (CWSRF), the Hardship Grant Program, the Nonpoint Source Pollution Program, USDA Rural Development programs, and the Community Development Block Grant (CDBG) program.

The ***CWSRF*** is a low-interest or no-interest loan program that has traditionally financed centralized, publicly owned treatment works across the nation (see **http://www.epa.gov/owm/finan.htm**). The program guidance, issued in 1997, emphasizes that the fund can be used as a source of support for the installation, repair, or upgrading of OWTSs in small-town, rural, and suburban areas. The CWSRF programs are administered by states and the territory of Puerto Rico and operate like banks. Federal and state contributions are used to capitalize the fund, which makes low- or no-interest loans for important water quality projects. Funds are then repaid to the CWSRFs over terms as long as 20 years. Repaid funds are recycled to support other water quality projects. Projects that might be eligible for CWSRF funding include new system installations and replacement or modification of existing systems. Also covered are costs associated with establishing a management entity to oversee onsite systems in a region, including capital outlays (e.g., for pumper trucks or storage buildings). Approved management entities include city and county governments, special districts, public or private utilities, and private for-profit or nonprofit corporations.

The ***Hardship Grant Program*** of the CWSRF was developed in 1997 to provide additional resources for improving onsite treatment in low-income regions experiencing persistent problems with onsite treatment because of financial barriers. The new guidance and the grant program responded to priorities outlined in the Safe Drinking Water Act Amendments of 1996 and the Clean Water Action Plan, which was issued in 1998.

The ***Nonpoint Source Pollution Program*** provides funding and technical support to address a wide range of polluted runoff problems, including contamination from onsite systems. Authorized under section 319 of the federal Clean Water Act and financed by federal, state, and local contributions, the program provides cost-share funding for individual and community systems and supports broader watershed assessment, planning, and management activities. Demonstration projects funded in the past have included direct cost-share for onsite system repairs and upgrades, assessment of watershed-scale onsite wastewater contributions to polluted runoff, regional remediation strategy development, and a wide range of other projects dealing with onsite wastewater issues. (See **http://www.epa.gov/OWOW/NPS** for more information.)

The USEPA ***Office of Wastewater Management*** supports several programs and initiatives related to onsite treatment systems, including development of guidelines for managing onsite and cluster systems (see **http://www.epa.gov/own/bio.htm**). The disposition of biosolids and septage pumped from septic tanks is also subject to regulation by state and local governments (see chapter 4).

The ***U.S. Department of Agriculture*** provides grant and loan funding for onsite system installations through USDA ***Rural Development*** programs. The Rural Housing Service program (see **http://www.rurdev.usda.gov/rhs/Individual/ind_splash.htm**) provides direct loans, loan guarantees, and grants to low or moderate-income individuals to finance improvements needed to make their homes safe and sanitary. The Rural Utilities Service (**http:www.usda.gov/rus/water/programs.htm**) provides loans or grants to public agencies, tribes, and nonprofit corporations seeking to develop water and waste disposal services or decrease their cost.

The ***U.S. Department of Housing and Urban Development*** (HUD) operates the ***Community Development Block Grant Program***, which provides annual grants to 48 states and Puerto Rico. The states and Puerto Rico use the funds to award grants for community development to small cities and counties. CDBG grants can be used for numerous activities, including rehabilitation of residential and nonresidential structures, construction of public facilities, and improvements to water and sewer facilities, including onsite systems. USEPA is working with HUD to improve system owners' access to CDBG funds by raising program awareness, reducing paperwork burdens, and increasing promotional activities in eligible areas. (More information is available at **http://www.hud.gov/cpd/cdbg.html**.)

The ***Centers for Disease Control and Prevention*** (CDC) of the U.S. Public Health Service (see **http://www.cdc.gov**) conduct research and publish studies on waterborne infectious disease outbreaks and illness linked to nitrate contamination of ground water, both of which have been linked to OWTSs, among other causes. Disease outbreaks associated with contaminated, untreated ground water and recreational contact with water contaminated by pathogenic organisms are routinely reported to the CDC through state and tribal infectious disease surveillance programs.

Individual ***Tribal Governments*** and the ***Indian Health Service*** *(*IHS) handle Indian wastewater management programs. The IHS ***Sanitation Facilities Construction Program***, within the Division of Facilities and Environmental Engineering of the Office of Public Health, is supported by engineers, sanitarians, technicians, clerical staff, and skilled construction workers. Projects are coordinated through the headquarters office in Rockville, Maryland, and implemented through 12 area offices across the nation. The program works cooperatively with tribes and tribal organizations, USEPA, HUD, the USDA's Rural Utilities Service, and other agencies to fund sanitation and other services throughout Indian Country (see **http://www.ihs.gov/nonmedicalprograms/dfee/reports/rpt1998.pdf**).

References

Curry, D. 1998. *National Inventory of Key Activities Supporting the Implementation of Decentralized Wastewater Treatment*. Fact Sheet No. 3-2. Research conducted by the U.S. Environmental Protection Agency, Office of Wastewater Management. Available from Tetra Tech, Inc., Fairfax, VA.

Florida Department of Health and Rehabilitative Services (Florida DHRS).1993. *Onsite Sewage Disposal System Research in Florida: An Evaluation of Current OSDS Practices in Florida*. Report prepared for the Florida Department of Health and Rehabilitative Services, Environmental Health Program, by Ayres Associates, Tallahassee, FL.

Fogarty, S. 2000. Land Use and Zoning Laws. *Small Flows Quarterly* 1(1):13.

Hoover, M.T., A.R. Rubin, and F. Humenik. 1998. *Choices for Communities: Wastewater Management Options for Rural Areas*. AG-585. North Carolina State University, College of Agriculture and Life Sciences, Raleigh, NC.

Kreissl, J.F. 1982. Evaluation of State Codes and Their Implications. In *Proceedings of the Fourth Northwest On-Site Wastewater Disposal Short Course*, September, University of Washington, Seattle, WA.

Kreissl, J.F. 2000. Onsite Wastewater Management at the Start of the New Millenium. *Small Flows Quarterly* 1(1):10-11.

National Onsite Wastewater Recycling Associations (NOWRA). 1999. *Model Framework for Unsewered Wastewater Infrastructure*. National Onsite Wastewater Recycling Association. July 1999. <http://www.nowra.org/Sept99/article-frame.html>. Accessed March 29, 2000.

Nelson, V.I., S.P. Dix, and F. Shepard. 1999. Advanced On-Site Wastewater Treatment and Management Scoping Study: Assessment of Short-Term Opportunities and Long-Run Potential. Prepared for the Electric Power Research Institute, the National Rural Electric Cooperative Association, and the Water Environment Research Federation.

Ohio Environmental Protection Agency (Ohio EPA). 1997. *A Guide to Developing Local Watershed Action Plans in Ohio*. Ohio Environmental Protection Agency, Division of Surface Water, Columbus, OH.

Otis, J. 2000. Performance management. *Small Flows Quarterly* 1(1):12.

Parsons Engineering Science. 2000. Septic System Failure Summary. Prepared for U.S. Environmental Protection Agency, Office of Water, under Contract 68-C6-0001. June 13, 2000.

Pennsylvania Infrastructure Investment Authority (PENNVEST). 1997. *A Water, Sewer, and Stormwater Utility's Guide to Financial and Technical Assistance Programs*. Pennsylvania Infrastructure Investment Authority, Harrisburg, PA.

Plews, G.D. 1977. The Adequacy and Uniformity of Regulations for Onsite Wastewater Disposal—A State Viewpoint. In *Proceedings of the National Conference on Less Costly Treatment Systems for Small Communities*. U.S. Environmental Protection Agency, Cincinnati, OH.

Shephard, F.C. 1996, April. *Managing Wastewater: Prospects in Massachusetts for a Decentralized Approach.* Prepared for the ad hoc Task Force for Decentralized Wastewater Management. Marine Studies Consortium and Waquoit Bay National Estuarine Research Reserve.

Suhrer, T. 2000. NODP II at Work in the Green Mountain State. *Small Flows Quarterly* 1(1):12. Published by the National Small Flows Clearinghouse, Morgantown, WV.

Tchobanoglous, G. 2000. Decentralized Wastewater Management: Challenges and Opportunities for the Twenty-First Century. In *Proceedings of the Southwest On-Site Wastewater Management Conference and Exhibit*, sponsored by the Arizona County Directors of Environmental Health Services Association and the Arizona Environmental Health Association, Laughlin, Nevada, February 2000.

U.S. Census Bureau. 1990. *Historical Census of Housing Tables: Sewage Disposal*. <http://www.census.gov/hhes/www/housing/census/historic/sewage.html>.

U.S. Census Bureau. 1999. 1997 *National Data Chart for Total Occupied Housing Units.* <http://www.census.gov/hhes/www/housing/ahs/97dtchrt/tab2-6.html>.

U.S. Environmental Protection Agency (USEPA). 1980b. *Planning Wastewater Management Facilities for Small Communities*. EPA-600/8-80-030. U.S. Environmental Protection Agency, Office of Research and Development, Wastewater Research Division, Municipal Environmental Research Laboratory, Cincinnati, OH.

U.S. Environmental Protection Agency (USEPA).1980a. *Design Manual: Onsite Wastewater Treatment and Disposal Systems*. EPA 625/1-80/012. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1987. *It's Your Choice: A Guidebook for Local Officials on Small Community Wastewater Management Options.* USEPA Office of Municipal Pollution Control (WH-595).

U.S. Environmental Protection Agency (USEPA). 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1994. *Environmental Planning for Small Communities: A Guide for Local Decision-Makers*. EPA/625/R-94/009, U.S. Environmental Protection Agency, Office of Research and Development, Office of Regional Operations and State/Local Relations, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1996a. *National Water Quality Inventory Report to Congress.* [305b Report.] EPA 841-R-97-008. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1996b. *Clean Water Needs Survey Report to Congress*. <http://www.epa.gov/owm/toc.htm>.

U.S. Environmental Protection Agency (USEPA). 1997. *Response to Congress on Use of Decentralized Wastewater Treatment Systems*. EPA 832-R-97-001b. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1998. *Guidelines for Ecological Risk Assessment*. EPA 630-R-95-002F. U.S. Environmental Protection Agency, Office of

Research and Development, Risk Assessment Forum, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 2000. *Draft EPA Guidelines for Management of Onsite/Decentralized Wastewater Systems*. U.S. Environmental Protection Agency, Office of Wastewater Management, Washington, DC. *Federal Register*, October 6, 2000, 65(195): 59840-59841.

U.S. Public Health Service (USPHS). 1967. (Updated from 1959 version.) *Manual of Septic Tank Practice*. U.S. Public Health Service Publication No. 526. U.S. Department of Health, Education and Welfare.

Venhuizen, D. 1995. *An Analysis of the Potential Impacts on Ground Water Quality of On-Site Watershed Management Using Alternative Management Practices.* <http://www.venhuizen-ww.com>.

Water Environment Research Foundation (WEF). 1998. *Watershed-Scale Ecological Risk Assessment—Watersheds*. Final report, Project 93-IRM-4(A). Water Environment Research Foundation, Alexandria, VA.