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National Management Measures to Control Nonpoint Source Pollution from Urban Areas

Management Measure 6: New and Existing On-Site Wastewater Treatment Systems

November 2005

MANAGEMENT MEASURE 6 NEW AND EXISTING ON-SITE WASTEWATER TREATMENT SYSTEMS

6.1 Management Measure

Develop or maintain on-site wastewater treatment system (OWTS) permitting and installation programs that adequately protect surface water and ground water quality. Programs should include:

- A process to identify and protect sensitive areas (e.g., wellhead protection zones, nitrogen/phosphorus limited waters, shellfish habitat) and ensure that cumulative hydraulic discharges and mass pollutant loads from on-site systems do not impair surface or ground water;
- System selection, siting, design, and installation based on performance requirements, prescriptive technologies, protective setbacks, and separation distances that protect surface water and ground water resources;
- Education, training, licensing, and/or certification programs for system designers, site evaluators, permit writers, installers, inspectors, and other service providers; and
- Inspections of new on-site systems during and immediately following construction/installation to ensure that design and siting criteria are applied appropriately in the field.

Establish and implement management programs to ensure that newly permitted and existing on-site wastewater treatment systems are operated and maintained properly to prevent the impairment or degradation of surface and/or ground waters. On-site system operation and maintenance programs should include:

- System inventories and assessments of maintenance needs that provide management information regarding the types of systems in use and their location, capacity, installation date, owner, date of last inspection/service, and other data needed to support operation and maintenance oversight activities.
- Policies to ensure that on-site systems are managed, operated, and maintained to prevent degradation and impairment of surface and ground waters. These policies should include adequate authority to conduct inspections, revoke operating permits, and require pumping, repair, replacement, upgrade, or modification technologies when conditions indicate that surface and/or ground water resources might be adversely affected (e.g., eutrophication of surface waters, microbial or nitrate contamination of ground water).
- Periodic inspection and/or monitoring requirements to ensure that on-site systems are functioning properly. Inspection and monitoring programs should consider hydraulic, hydrologic, and mass pollutant loading impacts at both the site and watershed scales.
- Requirements to ensure that residuals pumped from the tank (i.e., septage) are reused or disposed of in a manner that does not present significant risks to surface waters or ground water resources.

6.2 Management Measure Description and Selection

6.2.1 Description

When properly planned, designed, installed, operated, and maintained, OWTSs (also referred to as septic systems) can effectively remove or treat contaminants such as pathogens, biochemical oxygen demand (BOD), and nutrients in human sewage. However, many on-site systems are failing because of age, inappropriate design, hydraulic/pollutant overloading, or poor maintenance (see Table 6.1). Detrimental impacts from on-site systems can occur when they are sited in sensitive ecological areas (such as wellhead protection zones, near nitrogen/phosphorus limited waters, or near beaches or shellfish habitat) or when they are installed at densities that exceed the hydraulic and hydrologic assimilative capacities of regional soils and aquifers. Pollutants of concern from on-site systems include pathogens, nitrogen compounds (e.g., nitrates), phosphorus, BOD, and other chemicals described in Table 6.2.

Table 6.1: Common causes of OWTS failure.

Type of failure	Contributing causes
Hydraulic	Excessive hydraulic loadings to undersized systems, low soil permeability, excessive ponding at the infiltrative surface, poor maintenance. Increases in water usage over a period of years can exceed the design capacity of the wastewater treatment system.
Organic	Excessive organic loading from unpumped or sludge-filled tanks results in biomat loss of permeability (biomats are discussed further in Section 6.3.1.5.2, which describes subsurface wastewater infiltration systems).
Soil depth to ground water table or bedrock	Insufficient soil depths (i.e., soil thickness between the subsurface wastewater infiltration system [SWIS] and ground water tables, impermeable strata, or bedrock is less than the recommended depth for soil texture and structure). High ground water is deleterious to pathogen removal and hydraulic performance.
System age	Systems more than 25 to 30 years old. Systems less than 25 to 30 years old experience considerably fewer hydraulic failures. Failure rates can more than triple for older systems. Regular tank pumping and use of alternating SWISs can prolong system life indefinitely.
Design failure	Inappropriate system design for the site; failure to adequately consider or characterize wastewater strength and flow (average daily and/or peak flows); failure to identify and consider restrictive soil/rock layers (e.g., fragipan) or regional geology (e.g., karst features, creviced bedrock); failure to assess landscape position.
System density	Cumulative effluent load from all systems in watershed or ground water recharge area exceeds the hydrologic capacity of the area to accept and/or properly treat effluent.

Table 6.2: Pollutants of concern for OWTSs (adapted from Tchobanoglous and Burton, 1991).

Pollutant	Reason for concern
Pathogens	Microorganisms such as parasites, bacteria, and viruses can cause communicable diseases through direct/indirect body contact or ingestion of contaminated water or shellfish. Pathogens pose a particular threat when partially treated sewage pools on ground surfaces or migrates to recreational waters. Transport distances for some pathogens in surface or ground waters can be significant.
Nitrogen	Nitrogen is a plant nutrient that can contribute to eutrophication and depletion of dissolved oxygen in surface waters, especially in estuaries and coastal embayments. Excessive nitrate-nitrogen in drinking water can cause methemoglobinemia in infants and complications for pregnant women. Livestock also can suffer health impacts from drinking water high in nitrate.
Phosphorus	Phosphorus is a plant nutrient that can contribute to eutrophication of inland fresh waters and some marine waters and eventually deplete dissolved oxygen.
Household chemicals	Chlorine, ammonia, and other cleaning compounds in high volumes may disrupt or disable biological activity in the septic tank. Wastes from hobby or craft activities (paints, solvents, etc.) and disposal of non-organic liquid wastes (old furniture polish, pesticides/herbicides, etc.) in onsite/cluster systems can have similar impacts.
Pharmaceuticals and endocrine disruptors	Disposal of large quantities of outdated antibiotics and other medicinal products in septic tank-based systems can impair or halt biological treatment processes. Disposal of products containing chemicals that disrupt endocrine system functions (e.g., regulation of metabolism, blood sugar, reproduction, embryonic development) in on-site systems might result in leaching of these chemicals into groundwater and surface waters and impair water quality and/or aquatic organisms, in some cases. Research on this issue, including toxicology, transport, and fate of potential endocrine disruptors, is ongoing (USEPA, 1998a; North Carolina Department Environment and Natural Resources, no date).

Estimates of on-site system failure rates range from 5 to 25 percent and higher in some states (USEPA, 2001b), resulting in contamination of drinking water, beaches, shellfish beds, and surface water resources. In 1996 septic systems were a contributing source of pollution for more than one-third (36 percent) of the impaired miles of ocean shoreline surveyed. The National Oceanic and Atmospheric Administration (NOAA) reported in 1995 that the discharge of partially treated sewage from malfunctioning septic systems was identified as a principal or contributing factor in 32 percent of all harvest-limited growing areas (NOAA, 1995).

In addition, ponds, lakes, and coastal embayments have been impaired by algal blooms caused in part by nutrient over-enrichment from failing OWTSs. For example, in Sarasota County, Florida, 45,000 septic systems contribute four times as much nitrogen to Sarasota Bay as the city of Sarasota's wastewater treatment plant. Septic systems are adding an estimated 1.5 million pounds of nitrogen per year to Florida's Indian River Lagoon, causing a decrease in freshwater wetlands and commercial shellfish harvests (USEPA, 2003).

States have identified OWTSs as the third most common contributor to ground water pollution and a significant threat to drinking water sources (Parsons Engineering Science, 2000). A 1999 outbreak of gastroenteritis at the Washington County (New York) Fair was linked to a failing septic system at a nearby dormitory. A failed septic system was blamed for 46 cases of hepatitis A in Racine, Missouri, in 1992, and other states have reported both health and water resource impacts from poorly functioning OWTSs (Fobbs and Skala, 1992).

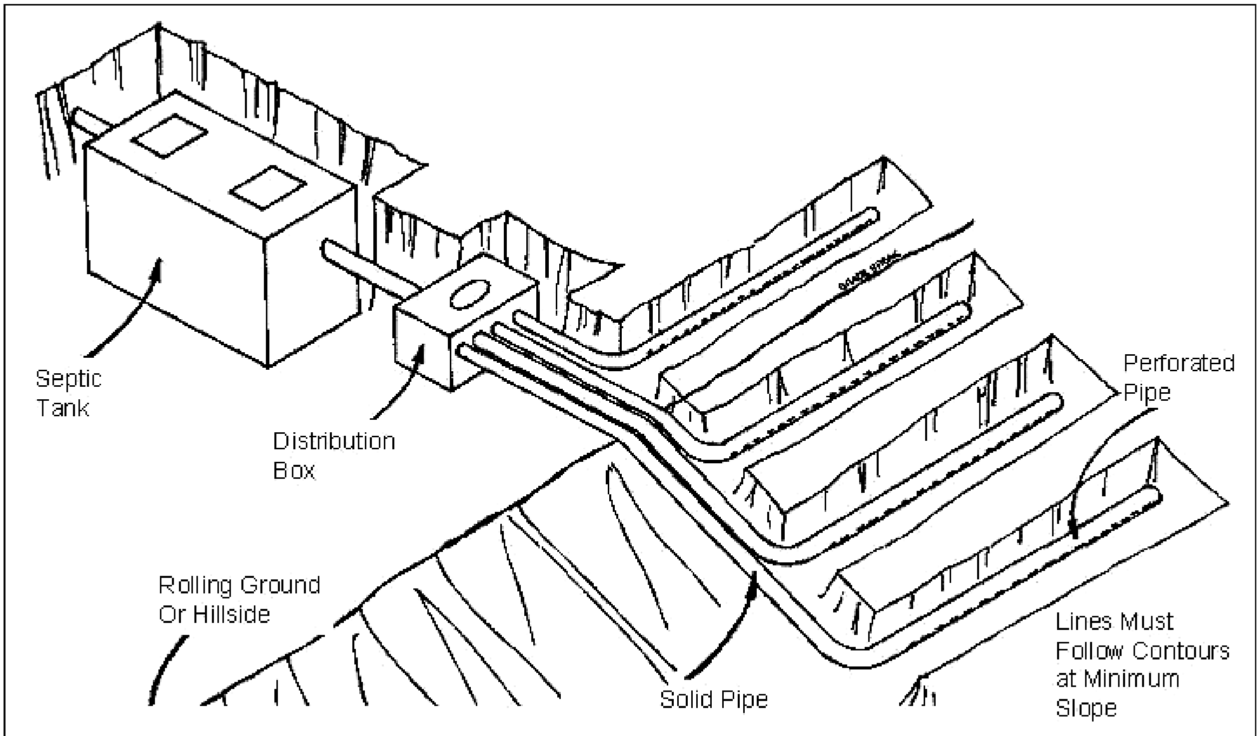

Figure 6.1: Conventional on-site wastewater treatment system.

OWTSs can generally be divided into two categories: conventional systems and alternative or innovative systems.

Conventional systems (see Figure 6.1) consist of a septic tank and a subsurface soil absorption field, commonly called a subsurface wastewater infiltration system (SWIS). Buried in the ground, septic tanks are essentially watertight, single- or multiple-chamber sedimentation and anaerobic digestion tanks. They are designed to receive and pretreat domestic wastewater, mediate peak flows, and keep settleable solids, oils, scum, and other floatable material out of the SWIS. Wastewater effluent is discharged from the tank and passes through pipes to a series of underground perforated pipes that can be wrapped in a permeable synthetic material. From there, the partially treated effluent flows onto and through the soil infiltrative surface, and finally into the SWIS infiltration medium (i.e., soil). Treatment occurs in the septic tank, on and within the biomat that forms at the soil infiltrative surface, and in the soil (or other medium); it then continues as the effluent moves through the underlying soil (biomats are discussed further in Section 6.3.1.5.2, which describes subsurface wastewater infiltration systems). Treated effluent that is not drawn into plant roots, incorporated into microbial biomass, or evaporated ultimately reaches ground waters and possibly nearby surface waters.

Alternative or innovative systems such as mound systems, fixed-film contact units, wetlands, aerobic treatment units ("package plants"), low-pressure drip applications, and cluster systems, are used in areas where conventional soil-based systems cannot provide adequate treatment of wastewater effluent. Areas that might not be suitable for conventional systems are those with nearby nutrient-sensitive waters, high densities of existing conventional systems, highly permeable or shallow soils, shallow water tables, large rocks or confining layers, and poorly drained soils. Alternative or innovative systems feature components and processes designed to promote degradation and/or treatment of wastes through biological processes, oxidation/reduction reactions, filtration, evapotranspiration, and other processes. Cluster systems can be used to collect and treat wastewater from multiple facilities at a common site (e.g., lagoon, wetland, infiltration field). Alternative, innovative, and cluster systems often require individual septic tanks for each facility served to provide primary treatment and minimize fat, oil, grease, and solids loadings to secondary treatment units. (Note: Cluster systems that serve 20 or more people may be regulated by a federal, state, and/or local Underground Injection Control Program for Class V facilities. For more information, visit EPA's Underground Injection Control Program Web site at http://www.epa.gov/safewater/uic.html.)

Many states, tribes, and municipalities use a prescriptive approach to on-site system management. Such an approach assumes that a prescribed system design will adequately protect public health and water resources when installed at sites meeting established minimum requirements. Site evaluations are usually based on empirical approaches such as percolation tests and setback/separation distance requirements.

These evaluations do not typically consider regional hydrology or the density and cumulative discharge of existing and planned treatment systems. They do not consider the overall assimilative capacity of regional soils and hydrology and do not assess complex relationships among soil characteristics, site conditions, wastewater composition, biological mechanisms, and regional climate (Otis and Anderson, 1994). A prescriptive approach is often restrictive and arbitrary and can be underprotective or overprotective of public health and water quality.

A performance-based on-site system management approach does not require specifications for treatment methods or processes, but rather establishes treatment performance requirements for protecting human health and water resources. For example, this approach requires additional nitrogen removal in designated nutrient-sensitive areas without specifying the type of technology to be used (Code of Massachusetts Regulations, 1995). A report issued by the Maryland Department of the Environment and Maryland Office of Planning (2000) recommends installation of systems with enhanced nitrogen removal capabilities in designated "areas of special concern" to reduce nutrient loadings to the Chesapeake Bay and other sensitive waters.

Under a performance-based approach, officials are free to consider the application of alternative and innovative on-site systems in addition to conventional systems. Systems are planned, designed, sited, and installed to achieve specified performance requirements within the context of regional and individual site conditions, rather than requiring site conditions to conform to the soils, slopes, and other needs of a restricted set of prescribed technologies. Performance-based on-site programs also include rigorous and ongoing system management, such as periodic inspections and required maintenance. Such a management approach can result in fewer system failures and greater protection of public health, surface waters, and ground water.

EPA issued *EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (USEPA, 2003), which recommends management measures for on-site systems based on the administrative and managerial capacity of management entities, the complexity of technologies used, and the value and proximity of resources to be protected. The guidance contains tools and directions to assist states and communities in developing management programs based on local needs and resources, as well as risks to human health and water resources. Activities include planning, design, site evaluation, inspections, monitoring, funding, and other functions. The guidelines note the shortcomings of on-site programs that: (1) do not have a planning element that considers regional hydrology and system densities and discharges; and (2) do not have operation and maintenance requirements that ensure monitoring, periodic septic tank pumping, system repair, and upgrades when necessary. Many existing OWTS regulatory programs fail to consider the ability of regional soils to assimilate pollutants from dozens or hundreds of treatment systems in an area and often leave operation and maintenance of these systems to uninformed and untrained homeowners.

In *EPA Voluntary National Guidelines for Management of Onsite and Clustered(Decentralized) Wastewater Treatment Systems*, EPA recognizes the benefits of both conventional and alternative systems and emphasizes the importance of proper planning, site evaluation, system design, installation, inspection, operation, monitoring, and maintenance. On-site systems, like sewage treatment plants that serve urban areas, require periodic attention and regular servicing to ensure that treatment levels meet established performance requirements. Management programs must comply with performance requirements by ensuring sludge is pumped from tanks periodically, failed or failing systems are detected promptly and repaired or replaced, and undersized or underperforming systems are upgraded.

6.2.2 Management Measure Selection

This management measure was selected to ensure that new and existing on-site wastewater treatment systems function properly. If these systems fail, wastewater can pool on ground surfaces or migrate to aquifers or surface waters and cause significant public health or environmental problems (e.g., disease outbreaks, eutrophication, loss of dissolved oxygen). This management measure supports a performance-based approach to system management and is consistent with the *EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (USEPA, 2003) and the *Onsite Wastewater Treatment System Manual* (USEPA, 2002a).

6.3 Management Practices

6.3.1 Permitting and Installation Programs

EPA believes that on-site system permitting and installation programs that protect surface and ground waters are necessary to decrease or eliminate risks to human health and sensitive ecological resources. Approaches that match the treatment capabilities of various on-site technologies to the conditions and sensitivity of the receiving environment (ground water or surface water) are preferred. EPA recognizes that, due to a lack of staff expertise, funding, assessment data, regulatory infrastructure, public support, and other resources, not all on-site regulatory agencies or management programs will have the ability to implement performance-based approaches.

Therefore, alternative approaches, which include prescriptive standards that provide appropriate levels of protection for human health and water resources, are included among the acceptable management practices summarized in this section. These standards include prescribed treatment technologies, minimum requirements (e.g., soils, slopes) for proposed installation sites, mandatory setback and separation distances, and specific system component requirements (e.g., septic tank screens, grease traps). They will be considered acceptable management practices if they provide reasonable assurances of protecting public health and water resources when applied under the specific site conditions.

Elements supporting this Management Practice are listed below and correspond with the management measures listed in Section 6.1.

6.3.1.1 Planning activities

Comprehensive planning can provide valuable information and support for on-site system placement and management. Integrating planning with regulatory programs can provide a basis for ensuring the performance of existing systems and permitting future installations. Planning involves the examination of many variables:

- A wide range of environmental characteristics (e.g., ground water, topography, soils, climate, sensitive ecological resources);
- The locations and types of facilities that could be part of an overall wastewater management plan;
- The organizational and institutional structures that exist or may need to be created; and
- Financial support for their development and implementation.

At a minimum, planning should identify areas where:

- Installation of conventional systems can be allowed at specified densities;
- Alternative systems could be required; and
- On-site systems could be permitted only under strict design and performance requirements and assurances for long-term monitoring and maintenance.

6.3.1.1.1 *Comprehensive planning*

Comprehensive planning provides one of the best vehicles for ensuring that on-site management issues are considered under future growth and development scenarios. Comprehensive planning and zoning are closely related and are usually integrated. Comprehensive planning sets overall guidance and policies; zoning provides the detailed regulatory framework for implementation. Comprehensive planning that addresses environmental protection while providing adequate public services such as wastewater treatment can be administered through zoning regulations that:

- Specify prescriptive or performance requirements for individual or clustered systems installed in unsewered areas, preferably by watershed, subwatershed, or ground water recharge area;

- Limit, manage, or prevent development on sensitive natural resource lands or in designated critical areas (e.g., in wellhead protection zones or shellfish habitat runoff catchments, or near nutrient-sensitive waters and wetlands);

- Encourage development within urban growth areas serviced by sewer systems, if adequate capacity exists; and

- Consider factors such as system densities, hydraulic and pollutant output, proximity to water bodies, soil and hydrogeological conditions, water quality, and cumulative loadings from all systems, including future systems, in planning and zoning decisions. Large numbers of soil-based on-site systems discharging to a confined area (e.g., high-density subdivisions) can overwhelm the capacity of soils to assimilate and treat wastewater pollutants of concern, such as nutrients and pathogens.

It should be noted, however, that it is not necessary for the on-site regulatory agency or management entity to oversee or administer the planning program. In many areas, local or regional planning offices collect and store the types of information needed for on-site system management. Some of these offices have the ability to generate geographic information system (GIS) maps that can incorporate water resource, soil, topographic, and other information that provides screening-level site criteria for proposed installation of on-site systems. Coordination with planning offices to designate ecologically sensitive areas and those approved for future on-site system installations can significantly improve the management capabilities of the on-site regulatory agency or management program and improve watershed protection.

6.3.1.1.2 *Wastewater treatment continuum concept*

Decision-makers responsible for approving wastewater collection and treatment services for existing or new facilities often require information and guidance on the various options available. Protection of public health and valued water resources and cost are the primary decision-making criteria in most cases. Both centralized sewer service and decentralized/on-site systems protect public health and water resources, though treatment levels and cost may vary depending on technology, operational factors, system maintenance, and site-specific conditions (e.g., combined sewer overflows, bypasses, and nutrient removal requirements for centralized systems; and geology, soils, climate, and other factors for decentralized/on-site systems).

A number of wastewater treatment and collection options exist along the continuum between individual on-site systems and centralized sewer service. The following options are suggested for decision-makers seeking to improve collection and treatment in existing areas or to provide these services to new development (Venhuizen, 2000):

- Current practice, employing conventional septic tank/soil absorption field systems within the confines of each residential or facility lot;

- Alternative on-site systems for each lot. Examples include sand filters, aerobic treatment units, vegetated submerged wetlands, and dispersal in shallow, pressure-dosed subsurface wastewater infiltration systems;

- Small-diameter collection/treatment facilities using septic tank effluent drains (STEDs) or other shallow, low-cost collection systems to pump or route the flow from each lot to a common site for final treatment and dispersal or discharge; or

- Centralized sewage collection and treatment with the option of either conventional or alternative treatment facilities at one centralized plant.

Each of these strategies should include oversight and management programs to ensure that collection and treatment equipment and processes continually meet performance requirements. The responsible management entity (RME) should be charged with keeping collection and treatment systems working. The RME should have sufficient authority to enforce programmatic and other requirements, pay for operational and other costs, and take necessary actions in the event of performance failure or emergencies.

Developing operation, maintenance, and management strategies for decentralized/on-site systems in a manner similar to those in existence for centralized systems—or incorporating on-site treatment options into the centralized system strategy—can help to ensure that public health and water resources are protected effectively and efficiently.

6.3.1.1.3 *Centralized sewage treatment*

As development activity increases the density of OWTS-served housing, commercial establishments, and other facilities in a region, it is sometimes cost-effective to extend service lines from centralized sewage treatment facilities (i.e., publicly owned treatment works or POTW) for wastewater collection and treatment at a central plant. Small towns in the past have typically only considered connections to a regional POTW or the construction of a treatment facility. Factors to consider other than costs when deciding whether it is beneficial to use decentralized/onsite systems, construct a new treatment plant, or extend service lines of a nearby system include the following:

- Age and operational history of existing OWTSs;

- The RME's capacity and authority to properly manage OWTSs;

- Future housing and other development trends based on land use planning information;

- Proximity and capacity of existing POTW service lines and treatment facilities;

- Potential for revision to an existing NPDES discharge permit;

- Suitable financing, land area, and site conditions for construction of POTWs or collection lines; and

- Hydrological impacts and catastrophic risk assessment due to failure of collection systems and POTWs.

6.3.1.2 System selection, site evaluation, design, and installation

On-site systems often fail because of improper design and inadequate site evaluation and/or installation. Some states require higher levels of treatment near wellhead recharge zones, nutrient-sensitive waters, shellfish habitat, or other areas of special concern. On-site wastewater treatment systems discharging pathogens that can reach wells or shellfish habitat areas, and those that discharge significant inputs of nitrogen or phosphorus to nutrient-sensitive waters, should be high-priority candidates for upgrade or replacement (Commonwealth Biomonitoring, 2001). A committee advising the Maryland Department of the Environment recommended in 2000 that legislation be adopted requiring county water and sewer agencies to designate areas of special concern to address elevated nitrogen inputs from existing and new on-site systems (Maryland Department of the Environment, 2000). State income tax credits of up to $1,100 per year for three years were suggested to assist homeowners with increased system costs. Existing systems would only require nitrate removal in these areas when system replacement was required.

6.3.1.2.1 *Performance-based programs*

Performance requirements for individual or clustered on-site treatment systems are most often based on assurances that system discharges will not cause violations of surface water quality standards or drinking water standards. A performance-based program includes the following components:

- Performance goals;
- Performance criteria;
- Performance requirements; and
- Performance monitoring.

(a) *Performance goals*. Performance goals define the larger issues that are important to consider in on-site system siting, selection, design, and management. A properly functioning on-site system should be able to meet two basic performance goals: protect public health and protect water resources.

An example of a performance goal might be to protect the surface water from nutrient enrichment in environmentally sensitive areas such as lakes or estuaries. Detailed planning, design, installation, and management programs can help prevent placement of inappropriate systems in areas with unsuitable soils, on sites adjacent to valued and sensitive surface water bodies, and at densities that exceed regional hydrologic and pollutant assimilative capacities. Such an approach can help control or minimize pollutant loadings and associated impacts on surface and ground waters.

Promoting System Upgrades Through Innovative Financing

The Code of Massachusetts Regulations allows a state tax credit of up to 40 percent of the cost of a new on-site system or system repairs. The credit is capped at $1,500 per year and $6,000 total and is limited to homeowners living in the residence served by the repaired or replaced on-site system (Code of Massachusetts Regulations, 2001).

(b) *Performance criteria*. Performance criteria are measurable indicators that identify the pollutants of concern for a particular area so that benchmarks or performance requirements can be established to reduce further inputs of those pollutants. Performance criteria are used to quantify progress in achieving performance requirements for specific pollutants. Some examples of site-scale performance criteria include effluent concentration limits for nitrate, biochemical oxygen demand (BOD), fecal coliform bacteria, and overall flow. Watershed-scale criteria might include total hydraulic input to a ground water recharge zone from on-site systems, and total nitrogen load or total phosphorus load to ground water or surface waters.

(c) *Performance requirements*. Performance requirements are criteria-based limits that define acceptable environmental impacts and public health risks associated with on-site systems. Performance requirements are based on the type of water body that ultimately receives treated wastewater effluent (ground water or surface water) and the present or projected uses of that water body (e.g., drinking water source, shellfish habitat, contact recreation). Examples of a performance requirement might be that on-site systems in nitrogen-sensitive areas must not discharge more than 5 pounds of nitrogen per year, or that nitrate concentrations in OWTS effluent cannot be greater than 15–20 milligrams per liter (mg/L).

Resource protection performance requirements are based on the assumption that any given resource has a threshold (carrying or assimilative capacity) beyond which it cannot function and may deteriorate. Nitrogen requirements are more likely to be appropriate near marine waters because this nutrient is usually the limiting factor for algal growth in coastal areas. In ground waters, nitrogen can degrade drinking water resources as well. The Commonwealth of Massachusetts has designated certain areas, such as wellhead protection areas, areas in public water supply watersheds, and nitrogen-sensitive coastal embayments or other nitrogen-sensitive water bodies, as "Nitrogen-Sensitive Areas" (Code of Massachusetts Regulations, 1995) and has issued requirements to ensure their protection. Environmentally sensitive areas might include nitrogen-limited coastal waters, phosphorus-limited inland waters, shellfish habitat, and ground water used as drinking water. Typical performance criteria and examples of corresponding performance requirements are listed below:

- Fecal coliform bacteria as an indicator of the possible presence of pathogens (e.g., less than 200 colony-forming units per 100 milliliters [cfu/100 ml]) for support of primary contact recreation or 14 cfu/100 ml in shellfish waters

- Nitrogen in the form of nitrate in potable ground water (e.g., less than 10 mg/L) and as total nitrogen in nitrogen-limited coastal waters to prevent or reduce enrichment

- Phosphorus concentration in surface waters where phosphorus is the limiting element for algal growth (e.g., less than 0.025 mg/L to support warm water aquatic habitat)

- BOD for surface waters requiring high levels of dissolved oxygen for propagation of fish and shellfish (e.g., 5–10 parts per million of 5-day BOD after tertiary treatment to support warm water aquatic habitat)

- Nuisance factors (e.g., no objectionable odors emanating from the septic tank or infiltration field area, no sewage surfacing to minimize risk of human contact)

(d) *Performance monitoring*. Performance monitoring tracks progress in achieving performance requirements. Typical approaches involve measuring or assessing performance criteria at some specified point of compliance (e.g., a designated performance boundary). For example, if waters of a commercial shellfish habitat in a coastal bay are experiencing elevated bacterial contamination, a fecal coliform bacteria performance requirement for on-site systems in the area might be established at the property line or shoreline of the lot. A variety of monitoring programs have been developed to assess the performance of on-site systems. Approaches include measurement of chemical parameters (e.g., nitrogen, phosphorus, BOD, nitrate) in effluent or receiving waters; analysis of fecal coliform/fecal streptococcus ratios; and a variety of new, experimental, analytical approaches using molecular, chemical, or biochemical methods (e.g., ribotyping, antibiotic resistance analysis, randomly amplified polymorphic DNA, pulse field gel electrophoresis, caffeine tracking) (Hagedorn, 2000). Validation and cost issues prevent widespread use of the newer methodologies at the present time, but research in the field shows significant promise.

The Critical Point Monitoring (CPM) approach being developed in Washington State provides a systematic approach to choosing critical locations to monitor specific water quality parameters (Eliasson et al., 2001). The program is most suitable for responsible management entities operating comprehensive management programs. CPM provides an appropriate framework for monitoring treatment train components (i.e., septic tank, infiltration field, sand/media filters, aerobic treatment units), though it should be recognized that evaluations of overall system effectiveness—and compliance with performance requirements—should be based on monitoring at designated performance boundaries.

Tracer dye tests, analysis of *E. coli* concentrations in receiving waters, and system inspections are the most widely used methods for monitoring on-site system performance at present. The first only provides indirect hydrologic information, while the latter two offer direct utility to assess whether performance goals are being achieved. For the purpose of watershed-scale monitoring and modeling, the use of output criteria derived from typical performance ranges of on-site system types used in the area is a common practice. Models can be useful tools to predict potential ground water impacts if they are based on site- or regional-specific characteristics and are calibrated to achieve the best estimates of actual field results. They are rarely accurate under all conditions, however, and must be supplemented with actual field monitoring results when available.

6.3.1.2.2 *Modeling system performance and impacts*

There have been relatively few attempts at developing modeling tools to predict and simulate nutrient fate and transport mechanisms from on-site system effluent (Tetra Tech, 2000; Bicki and Brown, 1991; Harmesen et al., 1991). Most of the work has focused on identifying nitrate loading to ground water for the purpose of planning for drinking water protection. Computer models require a considerable amount of site-specific information regarding wastewater characteristics, discharge volumes, soils, topography, underlying geology, ground water, and climate, but they can be useful tools for assessing the long-term impacts of OWTSs in an area and developing strategies to mitigate potential problems.

The State of Florida developed a computerized model to assess ground water contamination potential in selected hydrogeologic regions as a tool to guide development of subdivision regulations (Florida HRS, 1993). The model incorporated features of the state's varied surficial hydrology and soil regimes and provided estimations of the transport and fate of nitrogen compounds. The Florida model uses a steady-state, one-dimensional flow field with three-dimensional dispersion and assumes retardation and first-order decay rates to be zero. Nitrate contaminant plumes generated by the model show a variety of dispersion and transport scenarios and confirm that increasing lot size from four homes per acre to two homes per acre (and even fewer in areas of high porosity) reduce nitrate concentration and migration in ground water by approximately 50 percent (from 10 mg/L to 5 mg/L 700 feet downgradient of the subdivision under study). The results suggest that concerns over nitrate contamination of ground waters from large, densely developed subdivisions with OWTSs are not unfounded. They support recommendations to monitor ground water nitrate concentrations below and downgradient of large subdivisions with home densities greater than four units per acre.

Another model developed for the Indian River Lagoon National Estuary Program found that nitrogen inputs linked to on-site systems constituted 12 percent of the total nitrogen load into the lagoon, an amount nearly equal to the load from cattle. The loading model provides a mechanism for calculating total nitrogen inputs into the aquatic system, and it attempts to predict the nitrogen concentrations in ground water based on hydrological parameters (University of Massachusetts, 2000). Efforts to calibrate the ground water prediction capabilities of the model are ongoing.

6.3.1.2.3 *Applying system siting criteria*

Conventional and many alternative on-site systems include a SWIS, which requires a certain minimum area of soil, sand, or other treatment media to effectively remove pathogens and other pollutants. Under a prescriptive approach, setbacks from wells, surface waters, building foundations, and property boundaries are minimum requirements necessary to eliminate or reduce threats to public health and the environment. Setbacks are used only rarely but can be established based on soil type, slope, characteristics of the water table (as defined by the implementing agency), sensitivity of aquatic resources, and type of on-site system. Under a prescriptive program, setback guidelines also should be established for both conventional and alternative on-site systems. Recommendations for horizontal separation distances are based on the degree of pre-soil application treatment achieved, as well as site-specific factors such as climate, topography, soil permeability, ground water gradient, ground water flow, and geology. The management entity should adopt measures that restrict the placement of wastewater treatment systems in inappropriate soils, in proximity to valuable surface waters, and at densities too high for soils to treat pollutants sufficiently. One example is the lack of available concentrations of certain metals that retard phosphorus movement to nearby surface waters.

Separation and setbacks can also be used under the performance-based approach. Under this approach, setback or separation distances should be based upon research or field data that demonstrate pollutant removals needed to meet performance requirements given the specific site conditions and treatment technology applied. Pretreatment systems that discharge effluent containing concentrations of bacteria, nitrogen, and phosphorus below requirements established to protect water quality can be sited closer to water resources if impact analyses determine that contamination risk is unlikely.

6.3.1.2.4 *Site evaluations that assess suitability for specific technologies*

States vary greatly in their approach to evaluating site suitability; such approaches range from no specific requirements to very detailed evaluations that require qualified soil scientists and hydrogeologists (NSFC, 1995). A performance-based approach to site evaluation may involve one or more of three evaluation approaches:

1. *Soil-based.* Sites are characterized by conducting a soil profile analysis, usually through the use of soil maps, field data, and inspection of the soil profile in a backhoe pit. Many states now require a soil profile analysis to determine site suitability for conventional systems.

   The soil-based approach focuses on site-specific observation of soil properties that significantly affect the performance of soil-based on-site systems. The soil-based approach has two major advantages: (1) direct observation of soil properties provides a considerable amount of quantitative and qualitative information that can be used to select or modify on-site system design; and (2) site evaluations for individual systems can sometimes be completed in a single visit. The major disadvantage of this approach is that it provides little quantitative information on hydrologic properties and characteristics of the region and sub-watershed. The risk of inadequate hydrogeologic characterization increases when on-site system densities increase.

   Soil assessments are best conducted by observing the soil profile on the wall of a backhoe pit that is 48 to 72 inches deep. Soil layers should be characterized to a depth of at least 3 to 5 feet below the proposed excavation of the effluent absorption field, especially in highly porous soils. Characterizing the soil profile in a backhoe pit is best accomplished using natural lighting because soil texture, structure, color, mottling, and iron or manganese concretions can be observed, assessed, and described more accurately. Hand augers tend to disturb and compress the soil and disguise soil layers, making it difficult to observe structure and other features. Pits should be excavated at the perimeter of the soil absorption field rather than in the middle of it because settling might cause problems with distribution piping and absorption trench stability, and the disturbance could modify subsequent soil system performance.

2. *Hydrogeologic-based*. Surface water and ground water hydrology and the geology of the management area are characterized to determine treatment technology selection and maximum system densities. Zones can be created to establish minimum lot sizes, maximum discharge rates per acre, or minimum treatment efficiencies (e.g., effluent nitrogen concentrations). Percolation rate tests, which have been used extensively in the past to characterize wastewater dispersion in the soil, do not predict treatment effectiveness or ensure future hydraulic performance.

   Hydrogeologic-based evaluations originated with the development of the percolation test in the 1920s. Although the percolation test is simple to conduct and can provide some information on relative infiltration rates, it does not necessarily provide design information because of its inability to discern what controls the rate of water loss from the hole. Also, the test cannot accurately predict infiltration rates at equilibrium operation or in downgradient zones through which the effluent will migrate.

Hydrogeologic characterization can also include testing for hydraulic conductivity, porosity, and permeability, usually requiring multiple extended site visits. Cluster and small community on-site systems (> 2000 gpd) require more extensive hydrogeologic characterization. Multifactor approaches for site evaluation use information regarding soils, hydrogeology, mineralogy, cation exchange, and possibly other information such as regional effluent loading models.

3. *Multifactor-based*. A variety of factors (e.g., soils, climate, ground water conditions, slopes, OWTS densities, proximity to and status of water resources) in the management area are characterized to establish zones reflecting likely treatment effectiveness and the potential for public health and environmental impacts. Conventional systems are permitted in nonsensitive zones that meet minimum soil, separation/setback, and other prescriptive requirements. Alternative systems should be required for sensitive sites that cannot support conventional SWIS-based applications. Sites within sensitive zones can be required to meet performance standards and to be closely managed for continued compliance.

Regardless of approach, the objective of the site investigation is to evaluate the wastewater treatment and dispersal capabilities of the site and surrounding area. The site evaluation systematically gathers information that is used to narrow the range of OWTS design options to the one that best accomplishes the overall performance goals of protecting human health and the environment. The evaluation should begin with a consideration of both regional hydrology and the density and discharge of existing OWTSs in the area. Regional planning programs, where they exist, can provide a significant amount of information during this stage of the process. Other reconnaissance activities prior to the actual site visit should include researching the following: soil surveys; geology, topography, and surface water and ground water resources; OWTS installations in the vicinity and their operating record; well locations and hydrogeological records in the area; and maps showing utility lines and other features that might have an impact on design and placement of the system.

Landscape position, location of treatment unit components, slopes, trees, and other features (e.g., drainages, fences, pipelines, electric lines) should be noted on a site plan that is filed with permit documents. The soil analysis should include identification of the major horizons and their structure, texture, color, mottles and concretions, as well as other notable features (e.g., rocks, organic matter, wetness). If percolation tests are used, they should be conducted in strict accordance with established procedures and should always be accompanied by a detailed investigation of the soil profile and regional conditions. Permitting of OWTSs on the basis of percolation tests alone is not recommended.

Table 6.3 presents a list of site features that might require evaluation prior to selecting the system design and installation site. The site evaluation process typically differs for individual OWTSs and larger-scale cluster or small community systems; i.e., data on every feature on the checklist does not have to be collected for every individual home site. Site assessments should be performed to determine the soil infiltration rate, expected soil pollutant removal capacity, acceptable hydraulic loading rate, and required depth to the water table, at a minimum, prior to design and application for a construction permit for on-site systems. A simple individual home site evaluation can be accomplished in a single site visit when a soil-based approach is used.

Three American Society for Testing and Materials (ASTM) practices covering surface characterization (ASTM, 1995), subsurface soil characterization (ASTM, 1996b), and preliminary sizing and delineation of subsurface soil absorption or constructed filter field areas (ASTM, 1996a) give specific guidance on how this can be accomplished (http://www.astm.org/). Surface and some subsurface characterization practices are shown in Table 6.4. The ASTM standard practice for characterizing subsurface conditions through test pit inspection is summarized in Table 6.5. These practices can be specified when hiring contractors and consultants.

Table 6.3: Site features that should be evaluated before OWTS design and installation.

Type	Site Feature
Surface Features	Location of property boundaries, location of existing and/or proposed structures, location of surface water features (landscape position and land form, including intermittent and perennial drainage ways, irrigation ditches, streams, swales, depressions, water bodies, and wetlands), topography (use local regulatory suitability criteria or Natural Resources Conservation Service [NRCS] soil survey classes), location of water supply sources (well, public water supply reservoir), location of buried anthropogenic features (water lines, utility lines, etc.), location of disturbed soil (cut and fill), other significant features (large trees, bedrock at the surface, etc.)
Soil Features	Major soil horizons, texture and structure of each horizon, color, mottles, other relevant features of each horizon (rupture resistance, penetration resistance, wetness, pore characteristics, presence of roots), depth to bedrock, depth to low permeability (i.e., restrictive) soil horizons (fragipan, caliche, duripan, etc.), depth and thickness of strong textural contrasts. Phosphorus (P) Index when P retention is needed.
Hydrogeologic Features	Depth to seasonal high water table and shallow ground water tables, potentiometric surface, ground water flow direction and gradient, percolation test results, saturated hydraulic conductivity (estimated, field, and laboratory), ground water time of travel to points of interest, unsaturated hydraulic conductivity relationships, other water budget parameters (precipitation, potential evapotranspiration, etc.)

Table 6.4: Practices to characterize surface and subsurface features of proposed OWTS sites (ASTM, 1995, 1996b).

Description of activity	Information from research
Preliminary Documentation	– Site survey map – Soil survey, U.S. Geological Survey (USGS) topographic map – Aerial photos, wetland maps – Natural resource inventories – Applicable regulations and/or setbacks – Hydraulic loading rates – Criteria for alternative OWTSs – Size of house or facility – Loading rates, discharge types – Planned location of water well
Scheduling	– Planned construction schedule – Date and time for meeting
Description of Activity	– Information from field study
Identification of Unsuitable Areas	– Water supply separation distances – Regulatory buffer zones and setbacks – Limiting physiographic features

Table 6.4 (continued).

Description of activity	Information from research
Subsurface Investigations	– Ground water depth from pit or auger – Soil profile from backhoe pit – Percolation tests
Identification of Recommended OWTS Site	– Integration of all collected data – Identification of preferred areas – Assessment of gravity-based flow – Final selection of OWTS site

Table 6.5: Practices to characterize subsurface conditions through test pit inspection (ASTM, 1996a).

Description of activity	Process steps	Information to be collected
Select backhoe pit site(s) near but not in proposed drainfield	Orient pit so that sunlight illuminates vertical face of pit	Proposed location of soil absorption field
Excavate pit to depth required by regulations	Pit excavation	Required ground water separation distance, soil profile depth
Enter test pit	– Take safety precautions – Beware of cave-ins – Select area of pit wall to examine	Safe depths for unbraced pit walls
Expose natural soil structure	Use soil knife, blade, screwdriver, or other tool to pick at area 0.5 m wide along full height of pit wall	Soil structural type (e.g., prismatic, columnar, angular blocky, subangular blocky, platy, granular)
Describe soil horizons	– Note master soil horizon layers – Describe features of each horizon	List soil horizon features: – Depth of horizon and thickness – Moisture content – Color (i.e., hue, value, chroma) – Volumetric percentage of rock – Size, shape, type of rock found – Texture of <2mm fraction of horizon – Presence or absence of mottles and other redoximorphic features – Soil structure by grade – Level of cementation – Presence or absence of carbonates – Soil penetration resistance – Abundance, size, and distribution of roots
Determine lateral changes in soil profile	Use hand auger and/or compare to profile of second pit	Determine changes, if any, in soil profile across proposed site
Interpret results	Identify limiting depths	– Check vertical separation distances – Identify mottled layers and concretions – Determine depth to saturation – Measure depth to confining layer
Issue site report	Log all data onto survey form	Develop system type, site location, and installation recommendations

Several systems have been developed to perform source water vulnerability assessments and to map locations where site conditions might preclude the use of conventional on-site systems. A system such as the DRASTIC methodology (Aller et al., 1987) can be used to map areas where aquifers might be vulnerable to pollution from on-site systems. DRASTIC considers soil permeability, depth to ground water, and aquifer characteristics. Florida adapted the DRASTIC approach to produce digital maps showing potential areas where ground water threats might increase (http://www.dep.state.fl.us/gis/datadir.asp). The U.S. Department of Agriculture (USDA) developed soil maps that contain detailed information on regional soils, including suitability for conventional on-site systems, and is updating these maps in some areas. The USDA National Soils Survey Center (http://ssldata.nrcs.usda.gov/) provides county-level soil information nationwide.

States are implementing GIS-based programs for identifying and mapping critical water supplies and aquifer protection areas. Some states have established zones that define effluent quantity and quality and system options available to meet those requirements. Computer simulation models have also been developed that assess the impact from locating on-site systems at various densities within a watershed. For example, the Buzzards Bay Project of the National Estuary Program provides an online nitrogen input modeling spreadsheet that can be adapted for local use by entering appropriate information for land use, nitrogen loading rates, watershed size, projected build-out, and other parameters (http://www.buzzardsbay.org/nitrmang/bbploadcalc.xls).

6.3.1.3 Education, training, licensing, and/or certification programs

In the past, a few states established training programs for site evaluators and adopted more-stringent codes for system design, setback distances, and general site requirements (Kreissl, 1982). If a site were declared unsuitable by these evaluators under the code prescriptions, some of these states would allow professional engineers to propose system designs that could overcome site limitations. Many jurisdictions (regulatory agencies) have begun to favor employing trained, experienced, professional staff who can make judgments and decisions on system design and siting in an efficient, effective manner. This practice must be differentiated from programs that use compliance enforcement staff to design systems. Such approaches are not recommended due to potential conflicts of interest resulting from design and compliance determinations by the same entity.

Most states have minimum requirements (e.g., college coursework, state-sponsored training) for oversight agency staff (e.g., health department permitting personnel), but some states have more stringent competency requirements.

In many states, system installers must be certified (see Table 6.6). Florida requires installers to meet certain minimum requirements, demonstrate experience, provide references, pass an examination, and complete six hours of approved classroom instruction annually to retain their certification. Minnesota has had a certification program for installers, designers, pumpers, and inspectors since the early 1970s; the program became mandatory for all service providers in 1994. Maine instituted a licensing program for site evaluators in 1974 and saw system failure rates drop to insignificant levels (Kreissl, 1982). Site evaluators in Maine must now be licensed professional geologists, soil scientists, or engineers with at least one year of relevant field experience. They must also pass a written examination and a field practices test (Maine Department of Health Services, 1996).

Requirements for site evaluators, system designers, installers, inspectors, and maintenance service providers vary widely among the states. Some states have few, if any, requirements for service personnel, whereas other states require professional certification and ongoing training for most service providers (see Table 6.6). In addition, some states issue permits or grant exemptions that allow homeowners to design and install on-site treatment systems at their primary residence.

Table 6.6: Survey of state certification and licensing programs for onsite wastewater service providers (Noah, 2000).

State	Contractors	Installers	Inspectors	Pumpers	Designers	Engineers	Geologists	Operators
AL	Y	Y	Y	Y	N	Y	Y	Y
AK	Y	Y	NA	NA	NA	Y	NA	NA
AZ	Y	Y	NA	Y	NA	Y	Y	NA
AR	N	Y	N	Y	Y	N	N	N
CA	N	N	N	N	N	N	N	N
CO	N	N	N	N	N	Y	N	Y
CT	NA	Y	Y	Y	NA	Y	NA	NA
DE	Y	Y	N	Y	Y	Y	N	Y
FL	Y	Y	Y	Y	Y	Y	Y	Y
GA	Y	Y	Y	Y	N	N	N	N
HI	N	N	N	N	N	Y	N	Y
ID	N	Y	Y	Y	N	N	N	N
IL	Y	Y	NA	Y	NA	NA	NA	NA
IN	N	N	N	N	N	N	N	N
IA	N	N	N	Y	N	N	N	N
KS	NA	NA	NA	NA	NA	Y	Y	Y
KY	Y	Y	Y	Y	N	N	N	N
LA	NA	Y	NA	NA	NA	NA	NA	NA
ME	N	Y	Y	N	Y	Y	Y	N
MD	N	Y	Y	N	N	N	N	N
MA	Y	Y	Y	Y	Y	Y	N	Y
MI	N	N	N	N	N	N	N	N
MN	NA	Y	Y	Y	Y	NA	NA	Y
MS	NA	Y	Y	Y	NA	NA	NA	NA
MO	Y	N	N	Y	N	Y	N	N
MT	N	N	N	N	N	N	N	N
NE	N	N	N	N	N	N	N	N
NV	NA	NA	NA	NA	NA	NA	NA	NA
NH	N	Y	N	N	Y	Y	N	Y
NJ	N	N	N	N	N	N	N	N
NM	Y	Y	N	N	N	N	N	N
NY	N	N	N	Y	N	N	N	N
NC	N	N	Y	N	N	N	N	Y
ND	Y	Y	Y	N	N	N	N	N
OH	N	N	N	N	N	N	N	N
OK	Y	Y	N	Y	Y	N	N	Y
OR	Y	Y	Y	Y	Y	Y	Y	Y
PA	N	N	Y	N	N	Y	Y	N
RI	Y	Y	Y	N	Y	Y	N	Y

Table 6.6 (continued).

State	Contractors	Installers	Inspectors	Pumpers	Designers	Engineers	Geologists	Operators
SC	Y	Y	NA	Y	NA	NA	NA	NA
SD	N	Y	N	N	N	N	N	N
TN	N	Y	N	Y	N	Y	Y	Y
TY	N	Y	Y	Y	N	N	N	Y
UT	N	N	N	N	N	N	N	N
VT	N	N	N	N	Y	N	N	Y
VA	N	N	N	N	N	Y	Y	Y
WA	N	N	Y	N	Y	N	N	N
WV	N	N	N	Y	N	N	N	N
WI	N	Y	Y	Y	Y	Y	Y	N
WY	N	N	N	N	Y	Y	Y	N

Y = yes; N = no; NA = not available.

NSF Onsite Wastewater Inspector Accreditation Program

NSF International has developed an accreditation program to verify the proficiency of persons performing inspections on existing on-site wastewater treatment systems (NSF International, 2000). The accreditation program includes written and field tests and provides credit for continuing education. Inspectors who pass the tests and receive accreditation are listed on the NSF International Web site and in the NSF Listing Book, which is circulated among industry, government, and other groups.

The accreditation process includes four components. A written examination, conducted at designated locations around the country, covers a broad range of topics relating to system inspections, including equipment, evaluation procedures, trouble-shooting, and the NSF International Certification Policies. The field examination includes an evaluation of an existing on-site wastewater treatment system. An ethics statement, required as part of the accreditation, includes a pledge by the applicant to maintain a high level of honesty and integrity in the performance of evaluation activities. Finally, the continuing education component requires requalification every 5 years through retesting or earning requalification credits through training or other activities.

To pass the written examination, applicants must answer correctly at least 75 of the 100 multiple choice questions and score at least 70 percent on the field evaluation. A 30-day wait is required for retesting if the applicant fails either the written or field examination.

These code provisions, which are linked to outdated farmstead or homestead exemptions, should require some demonstration of competency on the part of the prospective homeowner designer or installer. For example, Alaska allows homeowners to design and install systems at their residence if they complete an approved training course and comply with state design, construction, and siting requirements. Approval is granted after the homeowner submits an infiltration field size estimate based on a professional analysis (i.e., by an engineer or a laboratory) of soils at the proposed site (Alaska Administrative Code, 1999). Another approach could include providing technical assistance for system design and close oversight of installation to ensure that homeowner-installed systems meet performance requirements.

On-site programs should establish minimum criteria for all service providers to ensure protection of public health and water resources. The Maine program requires that site evaluators be licensed and that designers of systems treating more than 2,000 gallons per day or systems with unusual wastewater characteristics be registered professional engineers. Prerequisites for applying for a license and taking the certification examination are either a degree in engineering, soils, geology, or a similar field plus one year of experience, or a high school diploma or equivalent and four years of experience (Maine Department of Human Services, 1996).

Some jurisdictions opt to secure planning, operation, maintenance, and inspection services by partnering with other agencies or contracting with private entities to perform these functions. For example, the Massachusetts communities of Yarmouth and Dennis contract with an engineering firm to conduct system inspections (Shephard, 1996). Many management agencies in highly developed areas depend on regional planning or environmental agencies for guidance on the hydraulic and pollutant assimilation capacity of water resources in areas proposed for development. When on-site management functions are performed by outside entities, it is important to establish clear, consistent, and reasonable program requirements, administrative processes, and communication procedures.

6.3.1.4 Inspection of new on-site wastewater treatment systems

Verifying that systems are constructed and installed as designed helps to ensure that they will perform as intended. A construction management program that includes multiple field inspections will ensure that system design and specifications are followed during the construction process. If a system is not constructed and installed properly, the chances of failure increase. For example, if the natural soil structure is not preserved during the installation process (i.e., if equipment compacts or smears infiltration field soils) the infiltration field can be significantly impaired. Most failures of conventional on-site system soil absorption fields have been attributed to hydraulic overloading (USEPA, 1993a). These failures can be exacerbated by poor design and installation practices. Effective on-site system management programs ensure proper system construction and installation through construction permitting, inspections during construction, and designer/installer certification programs.

Design and plan reviews before construction begins help to acquaint the installer with site conditions as characterized by the site evaluator and the proposed system design. During this review, details of the construction schedule, inspections, and final permit issuance can be discussed and agreed upon. In general, construction should conform to the approved plan and use appropriate methods, materials, and equipment. Typical regulatory mechanisms to ensure proper installation are reviews of site evaluation procedures and findings, and inspections of systems during and after installation. The review and inspection process should include:

- Preconstruction meeting of the owner, designer, regulator, and contractor;
- Inspection after delivery of components;
- Inspections during and after construction (e.g., during excavation and installation of components, and after backfilling); and
- Issuance of a permit to operate the system as designed and built.

During the construction process, inspections should verify compliance with approved construction documents and procedures. If there are not enough management program personnel to conduct these inspections, a trained/certified inspector should be assigned to oversee installation and certify that it has been conducted and recorded properly. The construction process for soil-based systems must be flexible, as construction during wet weather may compact, smear, or otherwise alter soil structure.

6.3.1.5 Installation of conventional or alternative systems

As noted previously, selection of an on-site system should consider climate, regional hydrology, site slopes, soil, ground water characteristics, and the quality requirements of the water(s) receiving on-site system effluent. Design, operation, and maintenance information for on-site systems can be found in the *Design Manual: Onsite Wastewater Treatment and Disposal Systems* (USEPA, 1980), the *Onsite Wastewater Treatment System Manual* (USEPA, 2002a) and the *Draft Onsite Wastewater System Management Handbook* (USEPA, 2002b). Table 6.7 summarizes the different treatment technologies used to remove various pollutants of concern.

A conventional on-site system consists of a septic tank, as shown in Figure 6.2, and a SWIS. Septic tanks perform the following four important functions:

1. Removal of settleable and floatable solids, oils, and grease from raw wastewater;
2. Storage of the removed solids;

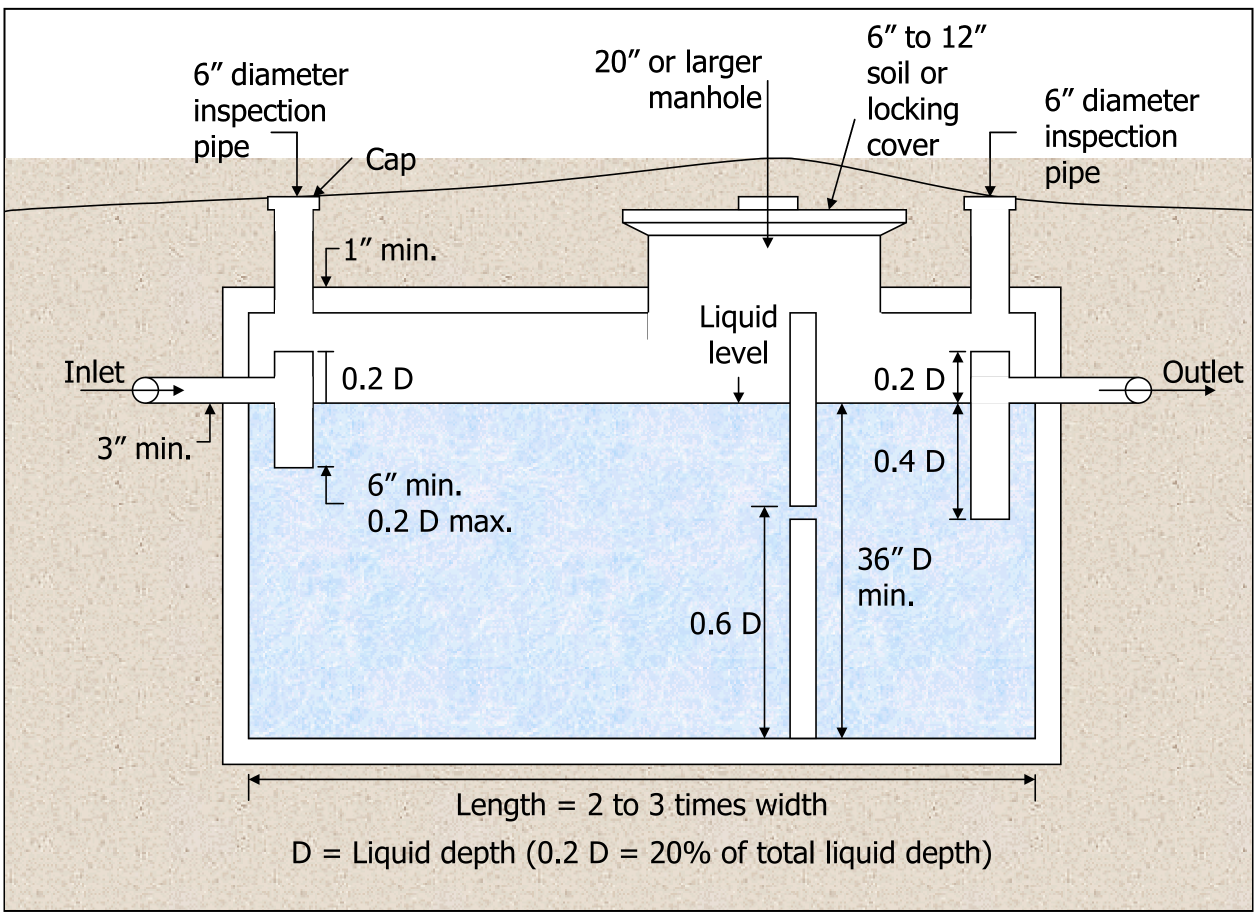

Figure 6.2: Septic tank detail (University of Missouri Extension Service, 1997).

3. Partial anaerobic digestion (liquefaction) of settled organic matter; and
4. Flow attenuation.

Table 6.7: Treatment technologies for OWTSs.

Treatment objective	Treatment process	Treatment methods
Suspended solids removal	Sedimentation	Septic tank Free water surface constructed wetland Vegetated submerged bed Lagoons Septic tank effluent screens
	Filtration	Packed bed media filters[a] Mechanical disc filters Soil infiltration
Soluble carbonaceous BOD and ammonia removal	Activated sludge	Extended aeration Fixed film activated sludge Sequencing batch reactors
	Fixed film aerobic bio-reactor	Soil infiltration Packed bed media filters[a] Trickling filter Fixed film activated sludge Rotating biological contactors
	Lagoons/wetlands	Free water surface constructed wetland
Nitrogen removal	Biological nitrification/ denitrification	Activated sludge (nitrification only) Sequencing batch reactor (only if designed with certain operating modes) Fixed film bio-reactor (nitrification only) Recirculating media filter Fixed film activated sludge (nitrification only) Anaerobic upflow filter (denitrification only) Anaerobic submerged media reactor (denitrification) Submerged vegetated bed (denitrification) Free water surface constructed wetland
	Ion exchange	Cation exchange (ammonium) Anion exchange (nitrate)
Phosphorus removal	Adsorption	Soil infiltration Iron-rich packed bed media filter Sequencing batch reactor (only if designed with certain operating modes)
Pathogen removal (bacteria, viruses, and parasites)	Filtration/predation/inactivation	Soil infiltration Packed bed media filters[a]
	Disinfection	Hypochlorite feed Ultraviolet light
Grease removal	Flotation/adsorption	Grease trap Septic tank Mechanical skimmer
	Aerobic biological treatment[b]	All types

[a] Including dosed systems; granular [sand, gravel, glass], peat, textile, foam.
[b] Incidental removal will occur, although overloading is possible.

Removal of total suspended solids (TSS) is usually 70 to 85 percent for well-designed septic tanks. Other pollutant removal rates are affected by the characteristics of the wastewater. Typically, reduction of BOD is 40 to 60 percent. Nitrogen and phosphorus removals are approximately 10 to 20 percent, while fecal coliforms are reduced by approximately 1 log (USEPA 2002a). The conventional system accepts both graywater (wastewater from showers, sinks, and laundry) and blackwater (wastewater from toilets). Depending on climate, diet, and other factors, the tank will need to be pumped every 3 to 5 years, since the pumping interval depends on the rate of accumulation of sludge, oils, and grease. Periodic visual inspection or remote sensing of the depth of those accumulations is possibly the most efficient way to determine pumping intervals.

A gravity-flow SWIS is the most commonly used treatment and discharge method for OWTS septic tank effluent. Soil absorption systems usually consist of covered excavations filled with porous media and perforated pipes or plastic leaching chambers with a distribution system for introducing and dispersing wastewater throughout. SWISs work well at sites with moderately permeable soils and sufficient vertical depth to ground water (i.e., the seasonally high water table), bedrock, or other limiting layer. The most common types of hydraulic failure of these systems are clogging of the infiltrative surface, insufficient separation distance to the water table, insufficient percolation capacity of the soil, and hydraulic overloading. Trenches and leaching chambers are the most widely used designs for both individual residences and commercial establishments. Uniform distribution and dosing via siphons or pressurized distribution are the best methods of pollutant removal because they distribute the wastewater load widely and uniformly across a large surface and sidewall area.

6.3.1.5.1 *Pollutant removal processes for conventional systems*

Nitrogen in domestic wastewater can be removed through effective linking of aerobic and anaerobic biochemical transformation processes, but in general, most conventional septic systems are not considered effective in removing nitrogen without additional treatment in the soil. Septic tanks remove approximately 30 percent of the nitrogen in raw domestic wastewater (University of Wisconsin, 1978). Percolation through 3 to 5 feet of soil can remove 0 to 20 percent of the total nitrogen in septic tank effluent (Siegrist, 2001). Additional nitrogen removal is possible under optimum soil and denitrification (e.g., anaerobic and carbon-rich) conditions. Factors that favor denitrification in soil absorption fields include fine-grained soils such as silts and clays, layered soils that feature alternating fine-grained and coarse-grained layers, and organic matter or sulfur compounds in the infiltrative medium. Placing the soil absorption field high in the soil profile where organic matter is more likely to exist, and dosing effluent to achieve alternating wet/dry (anaerobic/aerobic) cycles, can aid denitrification and reduce nitrate leaching. Maine’s Coastal Nonpoint Source Control Program and Division of Health Engineering favor shallow leach field installations to take advantage of the treatment potential in the upper soil horizon. Monitoring of shallow SWISs in Maine found total nitrogen reductions of 41 to 91 percent (Leyden, 1999).

In those areas where nitrogen is a problem pollutant, existing systems may be retrofitted to improve nitrogen removal, and new systems should include treatment components that are capable of removing nitrogen. Retrofitting upon failure of systems in these areas is recommended. Also, it is important to consider the density and overall discharge of on-site treatment systems. As the density of residences increases, lot sizes decrease and nitrogen impacts on surface and ground waters intensify. Lots of 1/2 acre to 5 acres are generally the minimal requirement of prescriptive codes for siting conventional on-site systems. The Code of Massachusetts Regulations identifies certain wellhead protection areas, public water supply recharge zones, and coastal embayments as nitrogen-sensitive areas and requires treatment systems in those areas to meet nitrogen loading limitations. For example, recirculating sand filters or equivalent technologies must be employed to limit total nitrogen (nitrogen as nitrate, nitrite, or ammonia) concentrations in effluent to no more than 25 mg/L and to remove a minimum of 40 percent of the influent nitrogen load. All systems in nitrogen-sensitive areas must discharge no more than 440 gallons of design flow per day per acre unless system effluent meets a nitrate standard of 10 mg/L or other nitrogen removal technologies or attenuation strategies are used (Code of Massachusetts Regulations, 1995). Any zone requiring such systems should have a management entity to assure sustained performance by these systems.

One of the most effective nitrogen removal methods is the recirculating sand filter (Table 6.8), which has been shown to remove approximately 50 percent of the total nitrogen from residual wastewater (USEPA, 1993b and 2002a). Other innovative and alternative systems have been developed to address site constraints and to provide improved on-site treatment and dispersal of wastewater. Many of these systems use advanced nutrient removal processes to enhance the ability of on-site systems to protect surface and ground water quality. Such systems include recirculating sand (nitrogen removal) and anaerobic upflow filters (denitrification), intermittent sand filters (nitrification), and subsurface-flow constructed wetlands (denitrification). The subsurface flow constructed wetland (i.e., vegetated submerged beds) and anaerobic upflow filters require nitrification of septic tank effluent before it enters the treatment process. Nitrification technologies include trickling filters with highly permeable plastic media, single-pass media filters, aerated sequencing batch reactors, activated sludge treatment systems, and filtration systems that use peat or other materials in place of sand. Table 6.8 presents an estimated performance summary for a variety of treatment technologies.

Another primary nutrient, phosphorus, is often the limiting factor for algal growth and eutrophication in freshwater systems. Because other nutrients necessary for the growth of algae and other aquatic plants are usually present in inland waters, low concentrations of phosphorus can lead to a direct increase in growth. Studies have shown that lakes with phosphorus concentrations as low as 20 to 30 parts per billion can become highly productive or eutrophic. Conventional OWTSs (septic tanks/SWISs) remove only 15 to 30 percent of the phosphorus in raw wastewater. Favorable phosphorus removal conditions exist for SWISs in most soils of the United States, but some phosphorus loading problems might be encountered in areas with older systems, highly permeable soils (e.g., sands), mineral-poor soils, nearby surface waters, and high system densities. Some technologies can enhance phosphorus removal (e.g., sand filters with high iron-content sand, sequencing batch reactors operated in certain modes).

Table 6.8: Wastewater constituents of concern and representative estimates of concentrations in the effluent of various treatment units (adapted from Siegrist et al., 2000).

Constituents of concern	Direct or indirect measures	Tank-based treatment unit effluent concentrations: Domestic STE[a]	Domestic STE with N-removal recycle[b]	Aerobic unit effluent	Recirculating sand filter effluent[c]	Recirculating foam or textile filter effluent[c]	SWIS percolate into ground water at 3- to 5-ft depth (% removal)
Oxygen demand	BOD_5 (mg/L)	140-200	80-120	5-50	2-15	5-15	>90
Particulate solids	TSS (mg/L)	50-100	50-80	5-100	5-20	5-10	>90
Nitrogen	Total N (mg N/L)	40-100	10-30	25-60	10-50	30-60	10-20
Phosphorus[d]	Total P (mg P/L)	5-15	5-15	4-10	3-9	4-10	0-100
Bacteria (e.g., *Clostridium perfringens, Salmonella, Shigella*)	Fecal coliform (organisms per 100 mL)	10^6-10^8	10^6-10^8	10^3-10^6	10^1-10^3	10^1-10^3	>99.99
Virus[e] (e.g., hepatitis, polio, echo, coxsackie, coliphage)	Specific virus (pfu/mL)	0-10^5	0-10^4	0-10^4	0-10^3	0-10^3	>99.9
Organic chemicals (e.g., solvents, petro-chemicals, pesticides)	Specific organics or totals (µg/L)	0 to trace	0 to trace	0 to trace	0 to trace	0 to trace	>99
Heavy metals (e.g., Pb, Cu, Ag, Hg)	Individual metals (µg/L)	0 to trace	0 to trace	0 to trace	0 to trace	0 to trace	>99

[a] Septic tank effluent (STE) concentrations given are for domestic wastewater. However, restaurant STE is markedly higher, particularly in BOD_5, COD, and suspended solids, while concentrations in graywater STE are noticeably lower in total nitrogen.
[b] N-removal accomplished by recycling STE through a packed bed for nitrification with discharge into the influent end of the septic tank for denitrification.
[c] Operated in recirculating mode.
[d] P-removal by adsorption or precipitation is highly dependent on media capacity, P loading, and system operation.
[e] Episodically present at high levels.

6.3.1.5.2 *Septic tanks*

Septic tanks are designed to retain a minimum 24- to 48-hour wastewater flow and are usually the first component in OWTSs. Additional treatment components (e.g., soil absorption field, sand/media filter) are necessary because the quality of septic tank effluent is not adequate for direct discharge. The septic tank should be watertight for two reasons: (1) infiltration into the tank can cause hydraulic overloading of treatment and/or dispersal components; and (2) leaks can cause discharge of scum and sludge to subsequent processes and increase potential for surface and ground water contamination. Many states and counties require tanks to be watertight. For example, Suffolk County, New York, regulations state that “all joints shall be sealed so that the tank is watertight and certified as to watertightness after installation. Tanks that are cast in place must be certified by a licensed professional engineer and, as a minimum, have the floor and walls monolithically poured.” Oregon septic tank standards stipulate that tanks are to be tested by filling them with water to a level 2 inches above the point of riser connection to the top of the tank. Leakage of no more than 1 gallon during a 24-hour period must be demonstrated. Because of leakage concerns, cast concrete and polyethylene tanks are preferred over those constructed of metal, redwood, concrete block, brick, or other materials, unless equipped with a watertight liner.

Septic tanks should be fitted with a regularly serviced effluent screen, commonly called a filter, at the outlet pipe. Several states and localities (e.g., Connecticut, Georgia, Florida, Alabama, North Carolina, Contra Costa County, California) now require septic tank screens to help protect the integrity of the SWIS for long-term performance (Schaub, 2000; Stuart, 2000). Screens not only prevent the discharge of neutrally buoyant solids and reduce TSS during tank upsets, but also provide an early warning sign that an inspection is needed, since they will clog and cause plumbing fixtures to drain poorly as they screen solids attempting to exit the tank through the outlet pipe.

Because septic tanks need to be serviced, the top of a septic tank riser should extend above the ground surface. Older installations can be difficult to locate when these features are not provided. Both septic tanks and SWISs are usually required to be at least 50 to 100 feet from any surface water body, but this setback might not be adequate in some cases (e.g., high-porosity soils, high water tables). Septic tanks should be inspected and pumped every 3-5 years.

6.3.1.5.3 *Subsurface wastewater infiltration systems*

Infiltration trenches containing perforated pipe and stone are the most widely used method for treating and dispersing septic tank effluent, though other septic tank effluent infiltration approaches (plastic open-bottomed leaching chambers, perforated pipes encased in net-wrapped foam pellets, and alternate media such as tire chips) have been used successfully. SWIS trenches are typically about 2 to 4 feet deep and about 2 to 3 feet wide. Soils, surface water drainage, and the slope of the land influence the location of the tank and field (Dickey et al., 1996). For example, septic systems are usually required to be located downslope from all wells, although ground water might not always follow this gradient. Trenches typically range in length from 45 to 100 feet.

Infiltration occurs through the bottom and sides of the trench. Gravelly soils promote rapid movement of wastewater contaminants, and poor-permeability soils (clays, etc.) require very large SWISs to accept the entire wastewater volume. Shallow trenches are generally preferred to deeper trenches because the upper soil horizons are usually more permeable and greater aeration and evapotranspiration can occur. A reserve area for future repairs or additions to the drainage field is often required by state code.

Septic tank effluent can be distributed to soil absorption system components by gravity, dosing, or uniform application. Dosing refers to periodically (e.g., 4 to 24 times per day) releasing effluent to the SWIS using a pump or siphon after a predetermined quantity has accumulated. Similarly, uniform application stores the effluent for a short time, after which it is pumped through smaller-diameter perforated pipes throughout the entire trench length to achieve uniform distribution. Distribution boxes have long been a source of poor performance in gravity-dosed systems, and they must be inspected frequently after initial installation because uneven settling causes uneven distribution of effluent. Ports with cam-type levelers can be adjusted to compensate for settling where regular inspection is required. Distribution boxes that do not have access ports or are not inspected or maintained are not recommended.

Uniform application can result in the least amount of infiltrative surface clogging and greatest treatment efficiency. Maintenance of trenches and beds is minimal, particularly if the tank is pumped regularly. Alternating SWIS systems are especially effective because they allow the use of one or more leaching systems while others rest for six months to a year to restore their effectiveness.

Most SWISs are designed to oxidize carbonaceous organics and convert the ammonium in septic tank effluent to nitrate by providing an aerobic environment. Nitrogen removal capabilities of SWISs are minimal and depend in part on temperature. Nitrate is water-soluble and travels freely to ground water. Elevated nitrate concentrations in ground water used as drinking water can cause the childhood illness methemoglobinemia (blue baby syndrome), can cause problems during pregnancy, and can present a risk to poultry livestock. In soils with no denitrifying capability, nitrate can travel with the ground water to nearby surface waters. Nitrogen loadings in coastal areas can cause eutrophication and related problems (e.g., low dissolved oxygen) that impair the life functions of desirable aquatic biota.

Some clogging of infiltrative surface pores from biomass and slimes produced by natural wastewater decomposition processes occurs under normal conditions. In coarser soils, this "biomat" improves treatment performance. Research conducted in Marion County, Florida, found that the predominant cause of hydraulic failure in systems less than five years old was hydraulic overload. After 15 years of service, root clogging was the cause of hydraulic failure in most cases. In general, SWISs located high in the soil profile provide access to both carbon (from organic matter) and oxygen (diffusion from ground surface), two elements needed for biochemical wastewater decomposition processes. Shallow placement also maximizes vertical separation between the infiltrative surface and ground water.

The vertical distance between the soil infiltration system and ground water is an important consideration. If seepage from the SWIS reaches the ground water in an area where unsaturated soil depth is inadequate, it could contaminate drinking water supplies. Furthermore, during wet seasons, ground water might rise into the SWIS, causing sewage to move upward toward the ground surface. This is especially important to consider in areas with a high water table (Lockwood, 1997) or in areas with poor permeability. Dickey et al. (1996) recommend that SWISs be placed at least 4 feet above the ground water table during the wettest season. The type of soil also influences the potential for ground water contamination. If sewage is applied to coarse soils, for example, the potential for contamination may be higher (Dickey et al., 1996). Clays that crack when dry or contain other types of macropores can also have a high contamination potential.

Installation of a conventional septic tank with a SWIS typically costs between $3,000 and $5,000 per home, but costs vary widely based on site-specific physical and regulatory limitations.

6.3.1.5.4 *Leaching chambers*

Molded plastic leaching chambers (see Figure 6.3) have been used in lieu of trench-based perforated pipe and aggregate infiltration systems to distribute septic tank effluent to the soil for final treatment. A typical leaching chamber infiltration system consists of interconnected arch-shaped bottomless chamber segments, installed below grade in level beds that comprise the drain field network. Aggregate is not needed, although porous media (e.g., gravel) is often used to fill in around the exterior of the vented chamber sidewalls to accommodate delivery of effluent through the sidewalls when ponding in the chambers occurs. Sizing of the network is based on wastewater characteristics, flows, and site conditions (soils, depth to groundwater/bedrock, etc.).

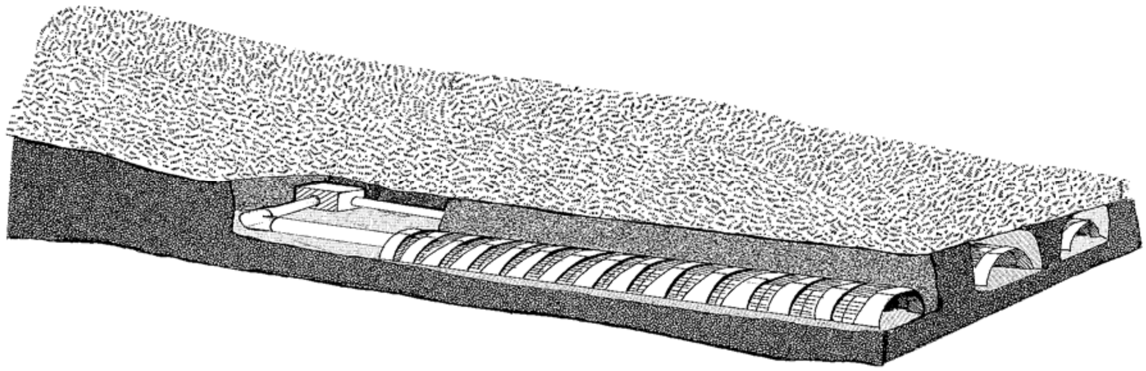

Figure 6.3: Leaching chamber subsurface wastewater infiltration system (Hoover et al., 1996).

Chamber systems have increased in use due to their performance, cost, light weight, and ease of installation.

6.3.1.5.5 *Alternative systems*

Several states have adopted provisions for the use of alternative and innovative technologies. Massachusetts has adopted a provision of its state environmental code that allows "approval of innovative (dispersal) systems if it can be demonstrated that their impact on the environment and hazard to public health is not greater than that of other approved systems" (Code of Massachusetts Regulations, 1995). Commonly referred to as Title 5, this legislation requires evaluation of pollutant loadings as well as management requirements prior to approval of alternative systems (Venhuizen, 1992).

The State of Maryland's regulations assert that the Maryland Department of the Environment (MDE) and the approving authority "shall consider all possible methods for correcting existing system failures and providing facilities for homes that lack indoor plumbing and, based on a case-by-case evaluation, provide the best technical guidance in attempting to resolve existing pollution or public health problems" (Code of Maryland Regulations, 2001). Alternative technology (with appropriate management) can be used for new construction on existing lots of record where site limitations prevent the use of conventional on-site systems. State regulations require that the local health unit and MDE monitor these systems for not less than two years.

More information on the alternative technologies described below is available from the National Small Flows Clearinghouse Environmental Technology Initiative (http://www.nesc.wvu.edu/nsfc/nsfc_ETI.htm) and EPA (http://www.epa.gov/owm/decent/treat.htm). An extensive list of links to public and private sector OWTS resources can be found at http://centreforwaterresourcesstudies.dal.ca/cwrs/onsite/info.htm. For information on loading rates, design, and performance capabilities for conventional and alternative treatment systems, refer to the *Onsite Wastewater Treatment System Manaual* (USEPA, 2002a). Table 6.9 provides a summary of capital and maintenance cost data for selected OWTS technologies.

Table 6.9: Summary of estimated capital and operation and maintenance costs for OWTSs (adapted from Hoover, 1997).

System Type	Costs (dollars)					
	Total materials & installation	Present value of total O&M[1]	Total over life of system	Amortized monthly materials & installation	Average monthly present value of O&M[1]	Average monthly over the life of the system
Septic Tank and Gravity Distribution						
Alone	2,504	6,845	9,349	20	19	39
With chambers	3,336	7,032	10,368	27	20	46
With styrene foam	2,846	6,920	9,767	23	19	42
With large diameter pipes	3,816	7,156	10,971	31	20	51
With pressure manifold	4,774	7,707	12,482	38	21	60
With pressure manifold and chambers	5,593	7,889	13,482	45	22	67
With pressure manifold and styrene foam	5,103	7,777	12,881	41	22	63
With pressure manifold large-diameter pipes	6,073	8,013	14,085	49	22	71
With sand filter pretreatment	7,296	12,069	19,364	59	34	92
With peat filter pretreatment	11,808	12,604	24,412	95	35	150
With recirculating sand filter pretreatment	6,226	12,059	18,285	50	33	84
With wetland cell	5,574	23,231	28,805	45	65	109
With 18" fill mound	4,507	6,850	11,357	36	19	55
With 18" fill mound and chambers	5,326	7,032	12,357	43	20	62
Septic Tank and LPP Distribution						
Alone	4,523	12,319	16,843	36	34	71
With sand filter pretreatment	10,223	13,338	23,561	82	37	119
With recirc. Sand filter pretreatment	8,232	13,007	21,239	66	36	102
In at-grade system	4,590	12,345	16,935	37	34	71
Septic Tank and Drip Distribution						
Alone	11,163	13,082	24,245	90	36	126
With sand filter pretreatment	15,994	14,101	30,095	129	39	168
With recirculating sand filter pretreatment	14,872	14,094	28,966	120	39	159
With sand filter pretreatment and chlorine disinfection	16,408	21,244	37,652	132	59	191
With recirculating sand filter pretreatment and chlorine disinfection	15,285	21,237	36,522	123	59	182
with sand filter pretreatment and UV disinfection	17,867	21,655	39,522	144	60	204
With recirculating sand filter pretreatment and UV disinfection	16,744	21,757	38,501	135	60	195
Septic Tank and Gravity Distribution						
Alone	2,504	6,845	9,349	20	19	39
With chambers	3,336	7,032	10,368	27	20	46
Septic Tank and Spray Irrigation						
With sand filter pretreatment and chlorine disinfection	11,890	20,670	32,580	96	57	153
With recirculating sand filter pretreatment and chlorination	10,768	20,663	31,431	87	57	144
With sand filter pretreatment and UV	13,349	21,190	34,539	107	59	166
With recirculating sand filter pretreatment and UV	12,227	21,183	33,410	98	59	157
Denitrification System Black Water and Gray Water Separation						
With gravity distribution	9,963	13,508	23,471	80	38	118
With LPP distribution	12,565	15,070	27,635	101	42	143

Table 6.9 (continued).

System Type	Costs (dollars)					
	Total materials & installation	**Present value of total O&M[1]**	**Total over life of system**	**Amortized monthly materials & installation**	**Average monthly present value of O&M[1]**	**Average monthly over the life of the system**
Other Types						
Aerobic treatment unit and gravity distribution	8,037	36,406	44,443	65	101	166
Septic tank and pressure-dosed sand mound system	4,863	12,407	17,269	39	34	74
Septic tank filter or screen (installation or retrofit into existing tank only)	200-400	938	1,250	1	<1	<1

Note: These numbers could be considered in the low to moderate range and may vary in other regions because of differences in material and labor costs.
[1] O&M = Operation and Maintenance

Regardless of the type of soil, sand, or other medium used for the absorption field, some sort of minimal maintenance is often required. It is important to restrict the operation of heavy equipment within the area proposed for soil absorption fields to prevent compaction of the soil structure and system clogging. Vehicles or other heavy equipment should not be operated over previously installed absorption fields or filters for the same reason. Concrete tanks are often capable of withstanding heavy loads, but operation of vehicles or other heavy equipment directly above them can cause settling or structural failure that can affect tank performance. Finally, because of the clogging effect of roots, vegetation above absorption fields and filter media should be restricted to types with short root structures. Trees or shrubbery should be immediately removed from absorption fields or filter medium installations.

6.3.1.5.6 *Elevated systems*

Mound systems are alternative soil absorption systems typically used at sites where insufficient ground water separation distances or slow-permeability soil conditions exist (see Figure 6.4). Mound systems are usually designed so that the effluent from the septic tank flows to a dosing tank and is then pumped to the top of the mound, which is constructed above the natural soil surface. The mound consists of a layer of suitable sand fill, an absorption bed filled with aggregate within the sand fill, and a covering layer of topsoil. The topsoil layer should be at least 6 inches deep and serves as a growth medium for vegetation. Converse and Tyler (2000) advise that mounds not be built on grades steeper than 25 percent.

At-grade systems are similar to mound systems, but the absorption bed is built directly on the ground surface, with aggregate placed on tilled soil instead of on top of raised sand. At-grade systems are typically designed for sites unsuitable for subsurface systems, but with less-restrictive conditions than sites where mounds would be needed (Converse and Tyler, 2000).

Pollutant removal effectiveness and operation and maintenance are similar to those of conventional systems with pressurized distribution. A mound system is more expensive to install than a typical soil absorption trench system. The cost of a complete mound system, including a septic tank, is typically $7,000 to $12,000 installed. Operation and maintenance include septic tank pumping every 3 to 5 years; annual or semiannual inspection of the pump, float switches, tank, and dosing chamber; and maintenance of vegetative cover (i.e., grass) to prevent erosion.

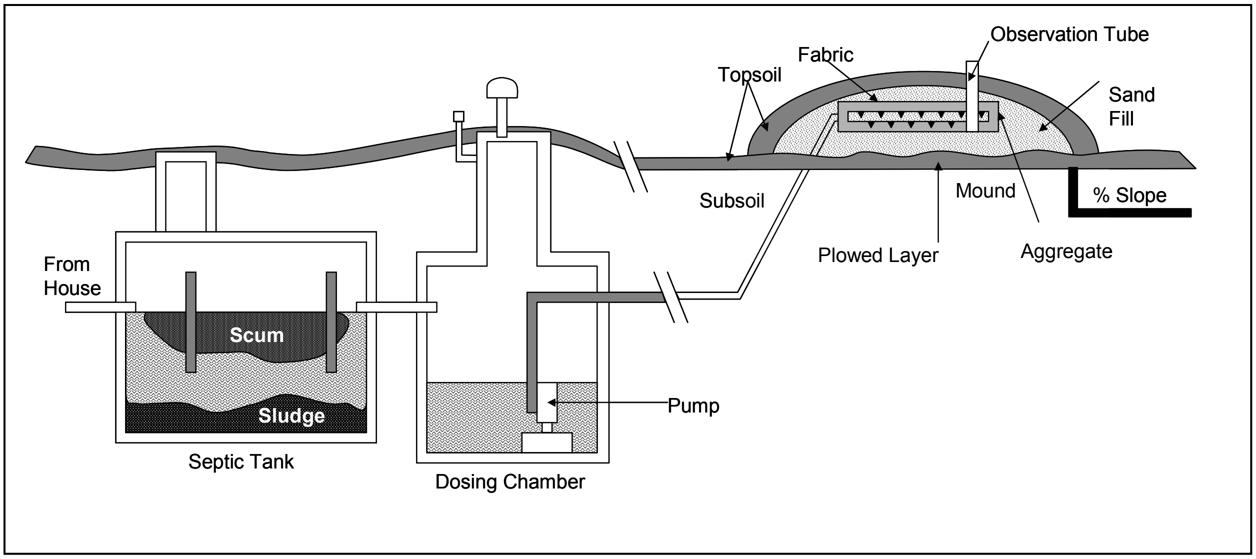

Figure 6.4: Schematic of a typical mound system (Ohio State University, no date).

6.3.1.5.7 *Intermittent sand/media filters*

An intermittent filter system receives and treats effluent from the septic tank via sand or other media (e.g., peat or composite materials) before it is discharged to the soil absorption field. Periodic, uniform dosing of septic tank effluent is distributed to the surface of the sand/media filter. The filter consists of a bed (either open or buried) of granular, synthetic, or organic material from 24 to 36 inches deep. Microorganisms living and growing on the filter medium consume nutrients and other wastes and facilitate aerobic decomposition of organic matter in the wastewater. The treatment medium is underlain by leveled rock or gravel and collector drains. Siphon or pressure distribution of septic tank effluent is used to dose wastewater to the surface of the media. Free access filters (media exposed to the atmosphere) should be covered with removable covers to prevent operation and maintenance problems (such as those caused by dust and rain), and should include insulation in cold and wet regions.

Intermittent media filters might become clogged as the pore space between the grains of the medium begins to fill with excessive amounts of inert biological materials. Resting the filter for several months in warm weather will restore hydraulic conductivity (Tyler et al., 1985). Free access filters should be checked every three to four months to prevent surface problems. Periodic raking is recommended to remove leaves and other debris where the system is not covered.

Intermittent sand filters typically produce high-quality effluents with BOD_5 and suspended solids concentrations below 10 mg/L (Tchobanoglous and Burton, 1991). Nitrogen compounds are almost completely nitrified if the filter remains aerobic, although nitrification rates might fall during cold weather. Total nitrogen removal rates average 15 to 35 percent (USEPA, 2002a). Installation cost ranges from $5,000 to $10,000. Systems that use peat or other organic media in place of the soil/sand filter media have been installed in several areas of the country to serve single- and multiple-family residences. This technology has shown excellent results in many applications but is still under study and considered a provisional application subject to monitoring in most jurisdictions.

Sand Filter System, Washington Island, Wisconsin

Washington Island, Wisconsin, covers a 36-square-mile area. Its geology consists of shallow soils and fissured, cavernous carbonate bedrock. Sinkholes are not uncommon and the threat of ground water contamination is real. Conventional systems serve older developments on the island, but the potential for ground water contamination from pathogens and nitrate spurred interest in alternative technologies. As part of a demonstration project, recirculating sand filters were installed and evaluated for 2 years. The demonstration project showed that total nitrogen could be reduced by 60 to 90 percent. Water quality was also improved by inserting an anaerobic upflow filter between the septic tank and the sand filter dosing tank.

Operation and maintenance include monitoring influent and effluent, inspecting the dosing equipment, maintaining the filtration medium surface (i.e., raking and replacing as needed), checking the discharge orifices for buildup or blockage, and flushing the distribution manifold annually. Costs for operation and maintenance of these systems include three or four visits per year ($100 to $150/year), in addition to septic tank maintenance.

6.3.1.5.8 *Recirculating sand/media filters*

A recirculating sand/media filter is a modified intermittent filter that recirculates the effluent from the filter through the septic tank and/or the recirculation tank before it is discharged to the wastewater infiltration system. The addition of the recirculation loop in the system enhances pollutant removal effectiveness by providing a denitrification step (i.e., in the septic or recirculating tank) in the treatment process. Nitrogen is both nitrified (in the media filter) and denitrified in these systems, resulting in 40 to50 percent or more (if enhanced) nitrogen removal. Recirculation rates of 3:1 or higher are generally recommended. Recirculating media filters can be used in new, on-site systems or applied to retrofits of failing conventional systems (Bruen and Piluk, 1994), particularly at sites with nitrogen concerns. Recirculating media filter effluent might also be appropriate for soil absorption systems with low-permeability soils.

BOD and suspended solid concentrations in the effluent are typically less than 10 mg/L (Roy and Dube, 1994; Bruen and Piluk, 1994; Loudon, 1996). Recirculating sand filters typically cost $8,000 to $11,000.

Operation and maintenance include monitoring effluent; inspecting the dosing equipment; maintaining the filtration surface (i.e., raking as needed); checking the discharge orifices for buildup and blockage; and flushing the distribution manifold annually in addition to septic tank maintenance.

6.3.1.5.9 *Anaerobic upflow filters*

An anaerobic upflow filter (AUF), which may resemble a septic tank filled with gravel, is designed so that the effluent flows up through the bottom of the AUF filter media (e.g., ⅜-inch gravel). Anaerobic bacteria that convert nitrate in the influent to nitrogen gas grow on the surfaces of the filter medium. Septic tank effluent is gravity-dosed or pumped (depending on site conditions) to the bottom of the AUF and up through the filter to the top, where a collection pipe transports it to a dosing chamber and/or SWIS for final discharge. A nitrogen-removal system may include a septic tank, a sand filter, an AUF, and a soil absorption field. AUFs are relatively small (e.g., 4 feet deep and 6 feet in diameter) (Boyle, 1995) and sized to allow retention times of 24 to 48 hours.

Nutrient Export from Conventional vs. Open Space Development in Maryland

Zielinski et al. (2000) undertook a study to compare nutrient export from several conventional development projects and the same projects designed using alternative open space strategies (see Management Measure 4 for a discussion of conventional and alternative development scenarios). One site was a low-density residential subdivision in Maryland. In the conventional design, each lot had an on-site private septic system and the neighborhood had a septic reserve field of approximately 10,000 square feet. When the site was redesigned to preserve open space, the individual septic systems were replaced with shared septic systems that used more advanced recirculating sand filter technology with better nutrient removal capacity and lower construction and installation costs. When the two development scenarios were modeled to determine relative rates of nutrient export, the redesigned septic system showed a substantial decrease in nutrient output. However, despite the use of more advanced technology, septic systems remained the predominant source of exported nutrients.

Total nitrogen concentrations from AUFs treating fully nitrified influent can range from less than 3 to 23 mg/L or higher, with removal efficiencies of approximately 60 to 70 percent. Boyle (1995) reported average total nitrogen concentrations below 15 mg/L in a recirculating sand filter-anaerobic upflow filter system. The cost of the filter varies by manufacturer and is approximately $1,000 to $1,500. Operation and maintenance tasks are minimal, especially if the filter medium consists of large gravel (i.e., > 1 inch). Sand-sized media will clog and should not be considered. Inspection of wastewater levels in the septic tank and AUF filter tank, as well as periodic inspection of pumps, float switches, discharge orifices, and other components, should be conducted to ensure continuous performance.

6.3.1.5.10 *Cluster systems*

For the purposes of this guidance, a cluster system is defined as a collection of individual on-site systems that provide primary treatment in septic tanks at each site. Septic tank effluent is collected and routed to another site for further treatment. Other designs in which primary treatment occurs at the treatment site instead of the septic tank are also possible. Collection and movement of effluent to the final treatment site can be accomplished by gravity flow or pumps.

Additional treatment for cluster systems may involve the use of conventional SWISs, sand filters, AUFs, constructed wetlands, aerobic lagoons, or aerobic treatment. The use of cluster systems can be advantageous in the case of inadequate soil, groundwater, or space at individual homes, or when better soil at is available at another location in the development.

6.3.1.5.11 *Constructed wetlands*

Constructed wetlands have traditionally been used for polishing effluent that has already had some degree of treatment. Vegetated submerged beds (VSBs), also known as submerged constructed wetlands, subsurface flow constructed wetlands, or plant rock filters (see Figure 6.5), are designed primarily to reduce concentrations of BOD and suspended solids in wastewater effluent from the septic tank. VSBs consist of horizontal flow gravel filters with wetland-type vegetation (e.g., cattails, canna lilies) and are usually underlain with an impermeable liner (e.g., plastic sheeting). The vegetation has a minimal role in treatment in this application. Residential vegetated submerged beds are normally followed by subsurface infiltration trenches or chambers.

The performance of constructed wetlands is not significantly degraded in colder climates during winter months because removal is by physical and chemical processes. Recent tests that

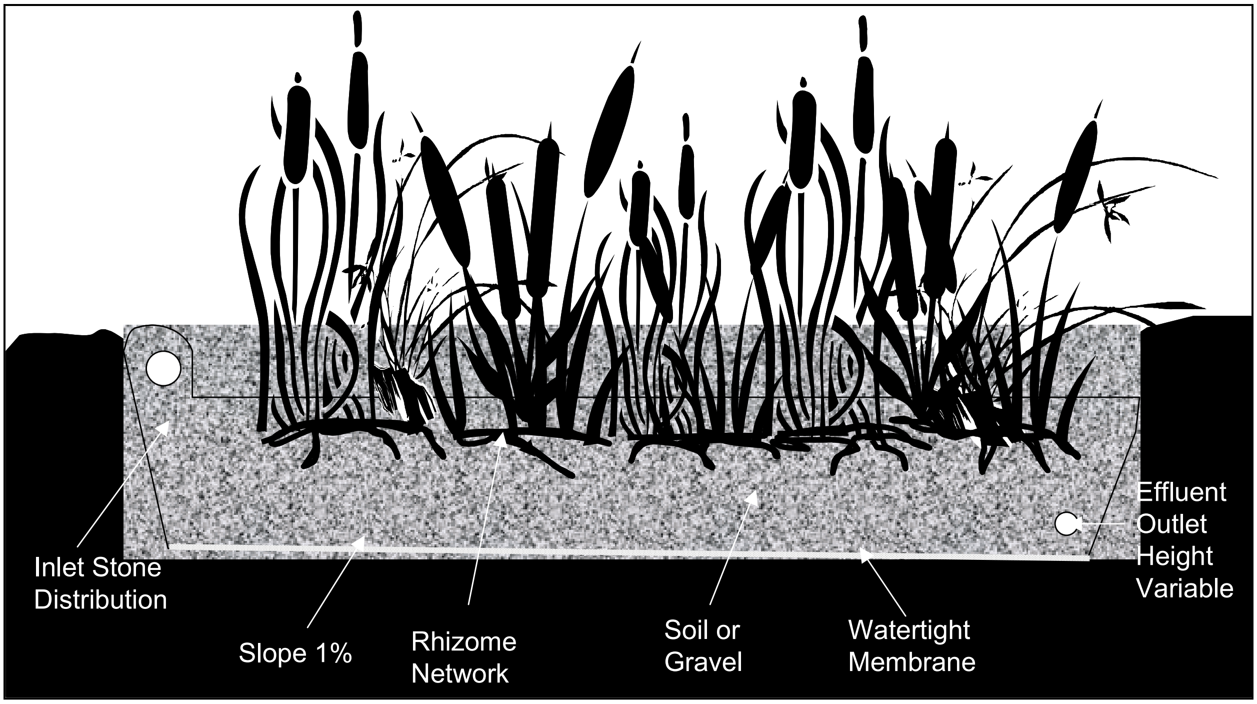

Figure 6.5: Components of a vegetated submerged bed.

incorporated a submerged aeration line in the wetland cell have shown promise in facilitating nitrification/denitrification (Wallace, 2000).

Constructed wetlands are configured as free-water surface wetlands, which can facilitate aerobic treatment processes, or subsurface flow wetlands, which are generally anaerobic. Removal rates for fecal coliform, BOD, and suspended solids can be as high as 90 percent for a gravel-based VSB (White and Shirk, 1998). However, removal of nitrogen and phosphorus compounds (e.g., ammonium, nitrate, SRP) is typically much less. Nitrogen removal can be enhanced through designs that accommodate nitrification-denitrification processes—i.e., aerobic treatment followed by anaerobic treatment zones—but significant phosphorus removal is much more difficult to achieve (USEPA, 2001a). Estimated costs for VSBs range from approximately $10,000 to $20,000 for a system serving a typical residence. Maintenance tasks include removing dead vegetation; inspecting and cleaning the inlet and outlets; inspecting wastewater levels in the tank and filter bed; and ensuring wastewater levels do not rise above the filter medium.

6.3.1.5.12 *Sequencing batch reactors*

A sequencing batch reactor (SBR) is a modified cyclically aerated and decanted activated sludge treatment system. The SBR carries out aeration, sedimentation, and clarification via timed cycles in the same tank. Continuously fed SBRs are compartmented to reduce short-circuiting. SBRs remove BOD and TSS from wastewater. Modification to the operational mode can enhance removal of phosphorus and nitrogen. Development of reliable and versatile control systems has been a major factor in the increased use of SBRs during recent years. However, repair and replacement costs and operator knowledge requirements should be considered in decisions regarding this technology.

SBRs can be used for new developments or connected to existing septic systems and can be designed to collect effluent from multiple septic tanks for treatment at a common site. SBRs can be sited in relatively small areas of only a few hundred square feet. SBR costs, operation, and maintenance requirements are greater than those of conventional on-site systems. SBRs can be suitable alternatives for sites where high-density development and/or unsuitable soils preclude adequate treatment of effluent by conventional systems.

With appropriate design and operation, SBR plants have been reported to produce high-quality effluents with very good removal rates for BOD and TSS. Typical ranges of $CBOD_5$ (carbonaceous 5-day BOD) are from 5 to 15 mg/L, while TSS levels can range from 10 to 30 mg/L in well-operated systems. Fecal coliform removal of 1 to 2 logs can be expected (USEPA, 2002b). By using an anaerobic-aerobic operating mode, significant nitrogen and phosphorus removals are also possible.

6.3.1.5.13 *Aerobic treatment units*

Packaged aerobic treatment units have been used for residential on-site use for nearly 40 years. Treatment unit storage volumes can provide a hydraulic retention time of several days based on typical household flows. These systems require regular supervision, operation, and maintenance to be effective. Since maintenance has been a particular problem with these units, requiring a perpetual maintenance contract at the time of permitting is strongly recommended. Packaged aerobic treatment units generally include pretreatment by settling (usually in a septic tank) to remove fats, oils, grease, and solids. Effluent is usually discharged to a SWIS. When additional treatment (e.g., filtration, disinfection, etc.) is provided, discharge to surface waters may be possible if a Clean Water Act Section 402 (National Pollutant Discharge Elimination System) permit is obtained. Power requirements can be significant for certain types of package plants. Mixed liquor solids must be disposed of regularly, so the system should be inspected at least every three months.

Extended aeration units can achieve BOD concentrations ranging from 30 to 50 mg/L and suspended solids concentrations ranging from 40 to 60 mg/L in well-operating systems, often reflecting 75 to 95 percent removal efficiency (Kellam et al., 1993; Ayres and Associates, 1991; Tchobanoglous and Burton, 1991). Installing a sand filter or other polishing unit to treat wastewater after an extended aeration unit can improve BOD and suspended solids removal performance, although nitrate levels might increase as a result (Kellam et al., 1993). Costs typically range from $3,000 to $6,000 for an installed unit, with maintenance costs of $200 to $300 per year.

6.3.1.5.14 *Fixed film systems*

Fixed film systems feature media (e.g. plastic disks, pellets, gravel, tire chips, fabric media, foam pellets) with large amounts of surface area where microorganisms that digest wastes become attached and grow. Colonies of bacteria and other organisms develop into a biologically active slime layer that is sustained by nutrients and other constituents in the effluent. As wastewater flows over the media, colonies of microorganisms extract soluble organic matter and nutrients as a source of carbon and energy. Oxygen, which is required by these microorganisms, can be supplied by natural ventilation or by mechanical or diffused aeration within the wastewater.

Fixed film systems include trickling filters (where the wastewater flows down through a bed of gravel, carbon-based, or composite media such as tire pellets, fabric strips, foam pellets, etc.) and rotating biological contactors (rotating plastic discs colonized by wastewater flora/fauna partially submerged in the wastewater). These systems require pretreatment of sewage in a septic tank. Final effluent can be discharged to a SWIS or reused. Disinfection is necessary if effluent may come into contact with humans or disease vectors. Both systems can achieve TSS concentrations of 60 to 80 mg/L and BOD levels of 80 to 90 mg/L. Maintenance includes periodic inspection of wastewater levels in the septic tank; inspection of pump switches and discharge orifices; and cleaning or replacement of the growth medium at regular intervals, or more frequently if clogging develops.

6.3.1.5.15 *Pressure distribution systems*

Low-pressure effluent distribution into the soil using technologies developed by the drip irrigation industry offers significant treatment performance improvements. Pumping effluent to the dispersal field typically creates a large flow surge that distributes effluent uniformly throughout the dispersal field. This minimizes localized overloading and the consequent potential for eventual failure (Venhuizen, 1995). Pressure systems are placed very high in the soil profile and use periodic dosing to distribute effluent to the soil matrix. Pressure distribution trenches are typically shallow and narrow, providing ease of installation and maximum carbon availability for treatment processes. Reaeration of the infiltrative surface and drying of the biomat between doses reduce potential clogging threats and help to ensure nitrification of ammonia in the septic tank effluent. Drip irrigation distribution lines are typically installed with a vibratory plow at shallower depths (i.e., 8-12 inches below surface grade) and should be preceded with pretreatment by a septic tank and fixed film filter to prevent clogging of emitters (USEPA, 2002a).

6.3.1.5.16 *Evapotranspiration*

Evapotranspiration (ET) systems are designed to remove wastewater through evaporation and transpiration; they are used mostly in dry climates (e.g., Arizona, New Mexico). They have been used in wetter climates where ET potential is sufficiently high in certain months. Seepage from an ET system can be reduced or eliminated by using a plastic, PVC, or clay liner, but leaving the system unlined allows both percolation and evapotranspiration to occur. Wastewater is applied below the surface to the sand medium of the ET system. Water moves to the soil surface by capillary action for use by plants or is evaporated to the atmosphere. Performance strongly depends on climate, available surface area, and physical properties of the sand. Properly operating ET systems must evaporate or transpire more water than is applied as waste or collected during precipitation. More than 5,000 ET systems are in use in the United States. The cost of installation ranges from $10,000 to $15,000, but operation and maintenance costs are generally quite low.

6.3.1.5.17 *Spray irrigation*

Spray irrigation is commonly used to discharge septic tank effluent as irrigation water to hayfields or other vegetated areas not used to produce food crops. Spray irrigation can effectively dispose of effluent from OWTSs. However, strict controls on human contact with discharges that might contain pathogens are required. Design of spray irrigation systems must consider soil permeability, slopes, climate, and the water and nutrient needs of vegetation growing on the spray field. Additional treatment and disinfection of spray irrigation water is necessary if human contact with the spray field or wet vegetation is likely. Successful applications have been installed in shallow soils in the Northeast. It is recommended that effluent be treated prior to spraying to remove most BOD for odor-prevention. Spray devices should not be activated during wet weather, freezing temperatures, or saturated soil conditions. Because large buffer areas around the spray sites are usually required, extensive land is required, limiting this option to very large lots.

6.3.1.5.18 *Disinfection devices*

In some areas (e.g., source water protection areas and sites near recreational lakes, and coastal beaches), pathogen contamination from on-site systems is a major concern. Disinfection devices can be used in conjunction with the technologies summarized above to treat effluent for pathogens before it is discharged. The three most common methods of disinfection in the United States are chlorination, ozonation, and ultraviolet (UV) disinfection (NSFC, 1998).

Installation of these devices in an on-site system increases its cost and adds to operation and maintenance requirements. Single-home chlorinators in non-dosed conventional OWTSs have a poor track record when applied without management oversight. These units can greatly overdose or not dose at all if proper operation and maintenance are not performed. Chlorine is a powerful biocide and can have significant impacts on aquatic biota at concentrations well below 1 mg/L. Some states (e.g., Maryland) have additional requirements for maximum chlorine concentrations in effluent or prohibit the use of halogen (i.e., chlorine and iodine) processes. UV units generally require controlled dosing of a high-quality influent (BOD of 30 mg/L and TSS of 30 mg/L or better) for consistent performance. Maintenance includes periodically cleaning UV tube surfaces to maintain integrity and inspecting the contact chamber to ensure that solids have not accumulated. Annual replacement of UV bulbs is suggested. UV units cost $1,000 to $2,000 (installed) or about the same as tablet chlorinator units. Operation and maintenance costs for UV are about $150 to $200, similar to the chlorinator.

6.3.1.5.19 *Water separation systems*

A water separation system separates graywater from sinks, tubs, and appliances from toilet blackwater. The graywater is treated by using a somewhat smaller conventional OWTS or a SWIS. The blackwater can be treated in another OWTS or stored in a holding tank and periodically hauled off site for treatment or disposal. For extreme situations or for seasonal residents, some form of separation of toilet wastes from bath and kitchen wastes can be helpful. Most nitrogen discharges in residential wastewater come from human wastes, and they also provide almost half of phosphorus, TSS, and BOD. Use of holding tanks can be very expensive owing to the cost of $0.10 to $0.20 per gallon for pumping and hauling.

6.3.1.5.20 *Vaults or holding tanks*

Vaults or holding tanks are used to contain wastewater in emergencies or other temporary situations and to hold wastewater from a blackwater system. These systems require frequent pumping, which can be expensive if the total wastewater flow is contained.

6.3.2 Operation and Maintenance Programs

This chapter discusses two broad functions that have an impact upon on-site wastewater treatment systems: regulatory oversight and management. In the following discussion, oversight refers to the regulatory and enforcement functions (e.g., issuing permits, compelling compliance with local or state codes) typically performed by the regulatory authority (i.e., state health departments and their agents, which are usually local health departments). The term management includes other functions and services that may or may not fall under the direction of the regulatory authority, such as long-term planning, ensuring that septic tanks are pumped regularly, conducting periodic system inspections, arranging for financial assistance for installations/repairs, and other activities.

Management services may be provided by a management entity separate from the regulatory authority, such as a sanitation district, contracted firm, or homeowners' association. It is important to recognize that while the enforcement of codes and regulations (i.e., by the regulatory authority) provides a very basic level of protection for public health and environmental resources, the execution of management tasks (e.g., planning, monitoring, operation, maintenance, inspection) by a designated management entity helps to ensure that long-term system use meets established performance requirements.

Implementation of the various management program elements will undoubtedly be subject to the authority of the regulatory agency or agencies, but may be accomplished by another management entity, such as a public or private utility, regional planning agency, or water monitoring council. Some management program elements may require special arrangements or agreements if they are to be performed by a separate management entity. For example, where state codes require the regulatory authority to oversee system design and permitting, a formal agreement would likely be required if an outside management entity assumed those duties. The exact nature of the relationship between the regulatory authority and any management entities servicing a particular jurisdiction will vary considerably and depend upon the capacity of the regulatory authority, state and local codes, and the ability of management entities to provide designated services in an acceptable manner.

According to the U.S. Census Bureau (1997b), approximately 25 percent of the estimated 112 million occupied homes in the United States are served by on-site systems, a proportion that has changed little since 1970. Distribution and density of homes with OWTSs varies widely by state, with a high of about 55 percent in Vermont and a low of around 9.8 percent in California. New England states have the highest proportion of OWTS-served homes: New Hampshire and Maine both report that about half of all homes are served by on-site systems. More than a third of homes in the southeastern states depend on OWTSs, including approximately 48.5 percent in North Carolina and about 40 percent in both Kentucky and South Carolina.

More than half of the nearly 26 million homes with on-site treatment systems are more than 30 years old (U.S. Census Bureau, 1997a, 1999) and a significant number report problems. A survey conducted by the U.S. Census Bureau (1997a) estimated that 403,000 homes experienced septic system breakdowns within a three-month period during 1997, with 31,000 reports of four or more breakdowns at the same home. Typical reported malfunction rates average between 1 and 5 percent annually, with reported failure rates in a study conducted in the State of Washington ranging between 2.6 percent and 6.1 percent (USEPA, 1993b). It has been estimated that in some areas of Connecticut, 4 percent of on-site systems fail each year. The failure rate might be high because many on-site systems are approved in areas with unsuitable soil conditions.

Reported failure rates may underestimate true failure rates because they typically consider only plumbing backup and sewage surfacing, and not ground water or surface water contamination. Parsons Engineering Science (2000) reported that dye testing conducted for the Rouge River National Wet Weather Demonstration Project found failure rates (defined as short-duration appearance of dye in receiving waters) of 39 to 72 percent. Nelson et al. (1999) reported that estimates of partial and total system failure rates in some states range as high as 50 percent and more in some cases, but definitions of failure were highly variable and included all systems that were not designed according to the states revised codes.

Besides design, installation, and maintenance problems, regional hydraulic overloading (i.e., hundreds or thousands of densely sited systems discharging into a single ground water aquifer or subwatershed) can cause OWTSs to fail to meet requirements for protection of public health and water quality. Other factors include lack of maintenance and system age. In some areas, on-site systems are installed at a density that exceeds the capacity of the local soil to assimilate hydraulic and pollutant discharge loads. In addition, the design life of many OWTSs built between 1960 and 1980 has been exceeded. System owners are not likely to repair or replace aging OWTSs unless sewage backup, septage pooling on lawns, or targeted monitoring and failure documentation occurs. Approaches for reducing operation and maintenance failures through development of management activities and systems are outlined below.

The following sections describe recommended management measures that promote the protection of public health and water resources from risks linked to on-site systems. More information on OWTS management measures and system technologies, as well as case studies from across the nation, are available from EPA at http://cfpub.epa.gov/owm/septic/home.cfm and from the National Small Flows Clearinghouse at http://www.nesc.wvu.edu/nsfc/nsfc_index.htm. A model framework for management programs and other information on OWTS issues is posted by the National On-Site Wastewater Recycling Association at http://www.nowra.org/.

6.3.2.1 Development of system inventories and assessment of maintenance needs

System inventories are critical elements of an effective on-site/decentralized system management program. An inventory is essential to both long- and short-term planning. Knowledge of factors such as system location, type, age, maintenance schedule, and potentially affected water resources is necessary to predict watershed and site-specific pollutant loadings. This knowledge is also needed to achieve a community's public health, environmental, and fiscal goals.

Inventories can also give owners information regarding the proper operation and maintenance of their systems. A typical inventory will contain information such as: owner name, contact information, system type, location, installation date, design capacity, and last date of service.

Clermont County, Ohio, developed an OWTS owner database by cross-referencing water line and sewer service customers (Caudill, 1998). Because most people in the county were public water line customers, subtracting those who were also connected to the public sewer system yielded a database of nearly all the OWTS users. Contact information from the database was used to mass-mail information on system operation and maintenance and the county's new inspection program to 70 percent of the target audience. Other approaches used in the Clermont County outreach program were advisory groups, homeowner education meetings, news releases and interview programs, meetings with real estate agents, presentations at Farm Bureau meetings, displays at public events, and targeted publications.

System inventories are essential elements for management programs, and most jurisdictions maintain databases of new systems through their permitting programs. However, older systems (e.g., those installed prior to 1970) are often not included in those data files. Some on-site management programs or other entities conduct inventories of older systems when they are included in a special study area. For example, Cass County and Crow Wing County, Minnesota, have developed projects to inventory and inspect systems at more than 2,000 properties near lakes in the north-central part of the state (J. Sumption, Deputy Director of Cass County, Minnesota, Environmental Services, 2000). The project inventoried but did not inspect systems that were less than five years old unless a complaint or other report indicated possible problems. Costs for inventorying and inspecting 234 systems in one lake watershed totaled $9,000, or nearly $40 per site (J. Sumption, Deputy Director of Cass County, Minnesota, Environmental Services, 2000).

In some cases, data necessary for on-site system management may be held and administered by other agencies. For example, land and water resource characterization data are often collected, stored, and analyzed by environmental or planning agencies. Developing data-sharing policies with other entities through cooperative agreements can help all organizations involved with health and environmental issues improve their efficiency and overall program performance. The RME should ensure that data on existing systems are available to health and water resource organizations (usually regulatory authorities) so that their activities and analyses reflect this important aspect of public health and environmental protection.

Education for system owners is an important component of the outreach for management programs that rely on homeowners for system operation and maintenance. Educational initiatives are most effective when they result in understanding of the relationship between ground water and surface water, and how septic system siting, design, installation, operation, and maintenance can affect those resources and public health. Surveys show that many people have their septic tank pumped only after the system fails. Property owners who are educated in proper system operation and maintenance practices, and who understand the consequences of system failure, are more likely to take actions to ensure that their systems function properly. Typical public outreach and education program topics for homeowners in the present system of prescriptive and conventional on-site systems include:

- How an on-site wastewater treatment system works;
- System siting and design considerations;
- How on-site systems can affect health, ground water, and surface water;
- The importance of water conservation in minimizing hydraulic failures;
- Practices to reduce mass pollutant loadings and toxic inputs to the system;
- Typical operation and maintenance practices, procedures, and timetables;
- How delaying septic tank pumpout can cause solids to clog infiltration systems; and
- Costs of repairs, upgrades, or replacement of system components.

Inventories of existing systems can be developed by consulting wastewater treatment plant service area maps, identifying areas not served by POTWs, and working with public and private utilities (drinking water, electricity, and septage pumpers and haulers) to develop a database of system owners and contact information.

A variety of commercially available software exists for managing system inventory and other information. Electronic databases can make collecting, retrieving, using, and integrating data fairly easy after the initial implementation (data entry) and learning curve have been overcome. For example, if system locations are described in terms of specific latitude and longitude coordinates, a data layer for existing on-site systems can be created and overlaid on geographic information system (GIS) topographical maps. Adding information on on-site wastewater hydraulic output, estimated mass pollutant loads, and transport times expected for specified hydrogeomorphological conditions can help managers understand how water resources become contaminated. This can also help target remediation and prioritization actions to sources primarily responsible. Models can also be constructed to predict impacts from proposed development and suggest guidance on performance requirements for on-site systems in proposed development areas.

6.3.2.2 Management, operation, and maintenance policies

There are three basic approaches for developing and implementing a management program (see below). In addition, EPA has issued the *EPA Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems* (USEPA 2003). See http://cfpub.epa.gov/owm/septic/home.cfm for management guidelines, technology fact sheets, links, and other information). The guidelines describe five progressive tiers of management in the form of model programs that can be tailored by local communities to meet their public health and water resource protection needs (Table 6.10). Appropriate adoption of these guidelines based on level of risk and value of resources affected by on-site systems is strongly recommended. Table 6.11 shows an example matrix of different on-site system management program elements and functional responsibilities.

Table 6.10: Guidelines for OWTS management programs under a tiered approach (adapted from USEPA, 2002a).

Program type	Program objectives	Basic management program elements
System inventory and awareness of operation and maintenance needs	– Owner awareness of permitting program, installation, and operation and maintenance needs – Compliance with codes and regulations	– Only conventional systems allowed – Prescriptive design and site requirements – Owner education to promote operation and maintenance – Complaint inspections and investigations – Point-of-sale inspections
Management through maintenance contracts	– Maintain prescriptive program for sites that meet siting criteria – Permit proven alternative systems on sites not meeting criteria	– Prescriptive design/site requirements – Measurable operation and maintenance requirements – Allowances for approved alternatives – Operation and maintenance contracts for alternative systems – Inspections, owner education
Operating permits	– System design based on site conditions and performance requirements – System performance verified through permit renewal inspections	– Wide variety of designs allowed – Performance governs acceptability – Compliance monitoring essential – Property sale or change of use triggers compliance assurance inspection
Management entity operation and maintenance	Public or private entity assumes operation and maintenance responsibilities for all systems in management area	– Performance governs acceptability – Operating permits ensure compliance – All systems are inspected regularly – Monthly/yearly fees support program – Owner relieved of operation and maintenance responsibility
Management entity ownership	– Public or private entity owns and operates all systems in management area – Similar to centralized sewage treatment service approach	– Performance governs acceptability – Operating permits ensure compliance – All systems are inspected regularly – Monthly/yearly fees support program – Management entity responsible for operation and maintenance – Management entity finances installation, repairs

Table 6.11: Program elements and functional responsibilities example matrix.

Program Element	Responsible Party							Comments
Planning								
Stakeholder involvement process								
Watershed assessments								
Sensitive area and critical area designations								
Performance Requirements								
Health and environmental goals								
General requirements								
Requirements for sensitive and critical areas								
Site Evaluation								
Wastewater characterization procedures								
Site suitability analysis								
Design								
Prescriptive or performance criteria								
Design review and approval process								
Construction								
Permitting requirements and process								
Construction and/or installation oversight								
Operation and Maintenance								
Owner/operator requirements								
Performance certification approaches								
Residuals Management								
Residuals removal/disposal requirements								
Tracking and reporting system								
Certification and Licensing								
Staff and service providers covered								
Certification/licensing requirements								
Education and Training								
System owner/operator education								
Requirements for staff and service providers								
Provision of training programs								
Inspections and Monitoring								
Routine (point-of-sale) and emergency inspections								
Targeted surface water and ground water monitoring								
Corrective Actions								
Compliance schedules and enforcement program								
Repair, upgrade, or replacement oversight								
Record Keeping and Reporting								
Existing and new systems inventory								
Tracking system for permits/inspection/maintenance								
Financial/administrative/program management								
Financial Assistance								
Funding source development								
Administration/management funding								
Installation and operation and maintenance assistance								

● State Health Department
■ State Water Agency
▲ District/County/Local Health Department
✪ County or Local Government Office
▼ Local/Regional Planning Office
◆ Utility District
✷ System Owner
✦ Private Contractor

6.3.2.2.1 *Voluntary Management*

An effective voluntary program develops recommended guidelines and educational materials and distributes this information to the homeowner or system operator. Voluntary management programs are highly dependent on comprehensive, easy-to-understand educational materials and an aggressive outreach program that includes distribution of the materials, training workshops, and site visits to provide individual assistance.

In 1997 the University of Minnesota Cooperative Extension Service published a guide for homeowners that incorporates important elements of an on-site training program. The guide is available online at http://www.extension.umn.edu/distribution/naturalresources/DD6583.html. Another equally useful guide can be found on the North Carolina Cooperative Extension Web site at http://ces.soil.ncsu.edu/soilscience/publications/Soilfacts/AG-439-22.

6.3.2.2.2 *Regulatory Management*

Under this approach, the regulatory authority—typically a district or local health department—oversees and enforces an on-site program of system design, permitting, installation, operation, and maintenance authorized under state and local codes. The codes may require routine inspections by the health officer either on an annual basis or at the time of property transfer, as is

On-site System Operating Permits in St. Louis County, Minnesota

St. Louis County, located in the northeastern region of Minnesota, extends from the southwestern tip of Lake Superior north to the Canadian border. The physical characteristics of the region are poorly suited for application of traditional on-site treatment systems. Many of the soils are very slowly permeable lacustrine clays, shallow to bedrock, and often near saturation. The existing state code restricts on-site systems to sites with permeable soils of sufficient unsaturated depths to maintain a 3-foot separation distance to the saturated zone. The county has adopted performance requirements that can be followed in lieu of the prescriptive requirements where less than 3 feet of unsaturated, permeable soils exist. In such cases the county requires the owner to continuously demonstrate and certify that the system is meeting performance requirements. This is achieved through the issuance of renewable operating permits for all alternative treatment systems. The operating permit is based on evaluation of system performance rather than design prescription and includes the following:

- System (technology) description.
- Description of environmental conditions.
- Site evaluation documentation.
- Performance requirements.
- System design, construction plan, specifications, and construction drawings.
- Maintenance requirements.
- Monitoring requirements (frequency, protocol, and reporting).
- Contingency plan to be implemented if the system fails to perform to requirements.
- Enforcement and penalty provisions.

The permit is issued for a limited term, typically 5 years. Renewal requires that the owner document that the permit requirements have been met. If documentation is not provided, a temporary permit is issued with a compliance schedule. If the compliance schedule is not met, the county has the option of reissuing the temporary permit and/or assessing penalties. The permit program is self-supporting through permit fees.

the case in Washtenaw County, Michigan (Washtenaw County, 1999), the Code of Massachusetts Regulations, and other state and local statutes. Financial incentives and disincentives usually aid compliance; these can vary from small fines for poor system maintenance to mandatory repairs if the wastewater treatment system is not functioning properly. Inspection fees can cover program costs. Some jurisdictions (e.g., Florida) issue renewable operating permits and/or ground water discharge permits to manage system operation and maintenance. These permits may require homeowners either to have a contract with an authorized inspection and maintenance contractor or to demonstrate that periodic inspection and maintenance procedures have been performed (Florida Statutes, 2001). Permits or inspection requirements for alternative systems, especially those with mechanical components, are recommended.

6.3.2.2.3 *Direct management*

Another option for managing and maintaining on-site systems is a management entity, typically a wastewater utility or district. From a regulatory standpoint, an OWTS management program can save both time and money by allowing a management entity to execute various management program tasks. Incorporating on-site systems into a local or regional wastewater management district, with the district responsible for system operation and maintenance, is a means to ensure that small wastewater systems in a designated area function properly and do not threaten ground water or surface water. State legislation to create wastewater management districts is sometimes required. Enabling legislation for special districts allows district personnel to enter private properties within the district for the purpose of inspecting, repairing, upgrading, or replacing on-site systems. Taxpayers in the proposed district often must vote to create the special district.

The regulatory authority also may decide to perform these tasks and assume overall responsibility for managing the on-site systems in its jurisdiction. Health departments can serve as the management entity under some of the approaches outlined above because they often have considerable permitting, installation, and inspection authority. Regardless of the approach, system users usually pay an annual fee that is applied to operation, maintenance, and management costs. Texas law authorizes local governments to petition the Texas Natural Resource Conservation Commission to assume management authority for on-site systems (Texas

On-Site Sewage Management Ordinance, Chippewa County, Michigan

Chippewa County is located on Michigan's Upper Peninsula, along the shores of Lake Superior. Over the past 10 years, the number of requests for OWTS permits has tripled. The high demand for property in the county, as well as its increased value as a tourist destination, has dramatically increased the county's population. Many of the properties to be developed are located in environmentally sensitive areas, including fractured bedrock and limestone, which puts the county's ground water at high risk of contamination from faulty septic systems.

The county's Environmental Health Department amended the existing sanitary codes to allow the installation of alternative on-site systems for lakeshore areas. County officials worked with a Michigan State University professor to educate the citizens and local officials of Chippewa County about the values of these alternative systems. Some of these alternative systems include recirculating systems, single-pass filter systems, sewage waste lagoons, and mound systems. In the end, both the public and the local government supported the new codes, and no new bacterial contamination has been found since the codes were passed.

Administrative Code, 1997). Procedures that can be used to apply the wastewater management district concept to a specific problem area include:

- Researching relevant legal and regulatory issues;
- Conducting a thorough site investigation;
- Identifying the specific geographic area to be included within the wastewater management district;
- Selecting the performance standards to be met and the means of attaining them;
- Preparing accurate cost estimates;
- Receiving approval from ratepayers within the proposed district for the creation of the management district;
- Preparing and adopting regulations, as needed, to establish the wastewater management district; and
- Adopting a management strategy (including operational, administrative, and financial processes).

Resources are available to help management entities explore the concept of an onsite wastewater management district. For example, the City of Austin, Texas, provides online resources related to its study of management district establishment (see http://www.ci.austin.tx.us/wri/altern.htm)

6.3.2.3 Inspection and monitoring programs

Inspection and monitoring programs are recommended to assess current and likely (future) on-site wastewater impacts. A means of inventorying existing and new systems, conducting inspections, providing monitoring data, or responding to treatment failures should be developed. As noted above, information on new systems (system owner, contact information, system type, location, design life and capacity, recommended service schedule) should be collected by the OWTS regulatory agency at the time of permitting and installation. Telephone, door-to-door, or mail surveys can be helpful to gather information on system type, tank capacity, installation date, last date of service (e.g., pumping, repair), problem incidents, and other relevant information. A number of private firms marketing new treatment technology packages (e.g., fixed film reactors, sand/media filters, aeration units) include remote monitoring services as part of the system package. For example, some companies install controls that continuously upload key system data (e.g., flow rates, pump cycles) to dedicated Web sites. Management staff can monitor the performance of multiple systems by accessing these Web sites, allowing detection of problems before massive failures occur. The per-unit cost of remote monitoring, which is required under the system installation contract, can range from $25 to $50 or more, depending on the type of unit and maintenance needs. The extra expense for necessary equipment is typically less than 10 percent of the cost of the packaged system.

6.3.2.3.1 *System inspections*

On-site system operation and performance inspections should check for the following (USEPA, 2002a):

- Evidence of vehicles being driven over the septic tank or reserve field;
- Installation of pavement, driveways, or structures over the septic tank or reserve field;
- Wet areas or poor drainage in or around the infiltration field;
- Slow flushing or gurgling of water in plumbing fixtures;
- Leaking toilets or addition of significant wastewater-generating fixtures such as water softeners;
- Additions to the house or building after system installation;
- Surface drainage patterns in the area of the tank and infiltration field;
- Broken or open tank access covers or doors; and
- Sludge or scum buildup in the septic tank; clogging of tank filters (if present).

More-detailed inspections of the system are recommended if there is evidence of a problem and should include the following:

- Pump and inspect the tank for structural deficiencies.
- Inspect the pumping components of the system.
- Test the system by filling the tank and observing the water level rise and fall.
- Inspect the baffles, valves, or other key appurtenances.
- Check all piping from the fixtures to the tank.
- Inspect runoff pathways of water from roofs, driveways, and other sources.
- Uncover distribution boxes (if used), and check flow distribution.
- Check for plumbing fixture leaks.

Inspections can be conducted in several ways (USEPA, 1993b). Homeowners can serve as monitors if they are educated and trained on how to inspect their own systems; however, this approach has not been effective in most cases. Brochures are often made available to instruct individuals on how to monitor their systems and the steps to take if they determine that their on-site system is not functioning properly. It should be noted, however, that homeowners rarely inspect their own systems, even with training. Trained inspectors are the best means for identifying failing systems.

Inspections can be conducted at the time of property transfer (point-of-sale inspections). Massachusetts has a rule that has required regular inspections since 1995. Colorado mandates inspections at the time of transfer, although its inspection requirements are less stringent than those of other states. Inspections are discussed further in *EPA Voluntary National Guidelines for*

Comprehensive Monitoring and Inspection Program in Nags Head

The town of Nags Head has implemented a program to identify and address on-site system impacts in that North Carolina Outer Banks community. The town's Septic Health Initiative Program secured competitive bids for tank pumping and inspection and will reimburse full inspection costs (about $65) and provide a $30 rebate on the next water bill if the system owner has the tank pumped. Monitoring consists of a series of ground water well and surface sites that are tested for fecal coliform, ammonia, dissolved oxygen, nitrate, pH, salinity, phosphorus, specific conductance, and turbidity. An education program complements the effort by circulating information on treatment processes, operation, and maintenance (Krafft, 2001).

Management of Onsite/Decentralized Wastewater Treatment Systems (http://cfpub.epa.gov/owm/septic/home.cfm).

Inspection programs operated by OWTS management agencies, special districts, and utilities can be the most effective in terms of cost and results. The State of Arizona requires routine operation and maintenance inspections for alternative on-site systems and pre-sale inspections (NSFC, 1995). Massachusetts requires inspections by a certified individual at the time of property transfer. Minnesota requires property transfers to be accompanied by certification that the on-site system is performing in a satisfactory manner. More than half of all Minnesota counties and most lending entities require inspections because of market-driven desires to ensure that on-site systems are operating properly at the time of property sale (Prager, 2000). Massachusetts also requires that systems with a design flow of 10,000 gal/day or more be inspected every three years, and shared facilities must be inspected annually (Massachusetts Department of Environmental Protection, 1996). Some counties (e.g., Washtenaw County, Michigan) with mandatory property transfer inspection programs require inspectors to be certified. New Hampshire requires an assessment and an on-site system inspection by a permitted designer prior to the sale of any developed waterfront property (New Hampshire Code of Administrative Rules, 2001).

States and localities can also indirectly assess whether on-site systems are failing through surface water and ground water monitoring. If indicator pollutants (e.g., fecal coliform as an indicator of potential pathogen contamination) are found, nearby on-site systems should be inspected to determine if they are a contributing or primary source of the contaminants. For example, residents living along the shore of Ten Mile Lake in Minnesota support a lake association that conducts regular fecal coliform monitoring below lakefront homes. High coliform concentrations prompt system inspections and involvement of property owners in remediation discussions. Owners who repair their system or install a new one are added to the OWTS "honor roll," which is published in the association's monthly newsletter.

Health department personnel and/or system inspectors often use tracer dye to observe effluent movement (USEPA, 1991). Many local agencies use non-toxic tracer dye to determine wastewater migration into nearby wells or surface waters. Tracer dye, which is typically flushed down the toilet, is often used to demonstrate to system owners that effluent is migrating rapidly into nearby surface waters or ground water. Rapid movement of effluent, that is, 20 to 30 feet in less than 30 minutes, may indicate that subsurface infiltration and treatment of wastewater have been short-circuited. Other confirmatory tests should be employed to verify this fact.

Galveston Bay Project Targets "Hot Spots"

In support of the Galveston Bay Estuary Program, the Galveston county health department conducted an intensive survey of on-site systems in the Dickinson Bayou watershed to identify failed systems and improve homeowner operation of existing systems. During the first part of the project, 36 of 90 (40 percent) systems inspected exhibited some degree of failure and were likely contributing to significant fecal coliform water quality violations in the bayou (Galveston County Health District, 1998).

A variety of online resources are available for agencies seeking information on the operation, maintenance, or inspection of on-site systems. The Rhode Island Department of Environmental Management published the *Septic System Checkup* inspection guide in 2000 and posted an online version at http://www.dem.ri.gov/pubs/regs/regs/water/isdsbook.pdf. A general operation and maintenance manual entitled *The Septic System Owner's Guide* is available online from the University of Minnesota Extension Service at http://www.extension.umn.edu/distribution/naturalresources/DD6583.html. For links to other online resources, visit the links page maintained by the Consortium of Institutes for Decentralized Wastewater Treatment at http://www.onsiteconsortium.org/links.cfm. The Wayne County, Ohio, Health District also has an extensive list of links on its Web site (http://wchd.neobright.net/wc_wastewater_tx2.html).

6.3.2.3.2 *Improving system effectiveness through water conservation and pollutant reduction*

In addition to structural methods to remove nitrogen and other pollutants from wastewater, management practices that reduce wastewater flow and/or pollutants are effective. Reducing the overall hydraulic load by installing water-saving devices and adopting water conservation practices can increase the residence times for wastewater pretreatment and, most importantly, reduce the amount of wastewater that must be infiltrated into the soil. Jarrett et al. (1985) stated that 75 percent of soil absorption field failures could be attributed to hydraulic overloading. Several practices are available to retrofit these failing systems so that they operate properly. Eliminating the use of garbage disposals (pollutant reduction), installing low-volume plumbing fixtures (flow reduction), and adopting water conservation practices (flow reduction) are usually the most cost-effective approaches for reducing pollutant and hydraulic loads to the field.

Reduced loading of organics and chemicals can extend the useful life of the on-site system and improve treatment effectiveness. Mass pollutant loads in the OWTS can be significantly decreased by avoiding detergents that contain phosphates, cleaning food debris and grease from dishes before washing, removing or not using in-sink garbage disposal units, and eliminating the disposal of sanitary napkins and disposable diapers in toilets. Inputs of discarded antibiotics, dialysis unit discharges, and toxic cleaners and other chemicals can cause treatment process upsets and may impact public health if they reach the ground water. These problems can be addressed through homeowner education and better disposal practices. See Management Measure 9 (Pollution Prevention) for more information about proper disposal practices.

Reducing hydraulic loads can achieve significant reductions in OWTS failure rates. In 1992 Congress adopted the Energy Policy Act, which established national standards governing water use and energy conservation for showers, kitchen sinks, basins, and toilets (see Table 6.12). Several states have implemented specific water conservation practices (USEPA, 1998b). If low-flow plumbing fixtures are used, it is important that on-site system design not be modified to decrease the required septic tank size. The use of smaller septic tanks could negate the advantages of using low-flow plumbing fixtures by increasing organic loading rates to the soil infiltrative surface.

Table 6.12: Comparison of current and federally mandated flow rates and flush volumes (USEPA, 1998b).

Fixture	Current Practice	Energy Policy Act of October 1992	Potential reduction in water used (%)
Kitchen Sink	3.0 gpm	2.5 gpm	17
Lavatory	3.0 gpm	2.5 gpm	17
Shower	3.5 gpm	2.5 gpm	29
Tub	6.0 gpm	4.0 gpm	33
Water closet (tank)	3.5 gal	1.6 gal	54
Water closet (valve)	3.5 gal	1.6 gal	54
Urinal	3.0 gal	1.5 gal	50

Eliminating the use of garbage disposals can significantly reduce the loading of suspended solids and BOD to OWTSs (Table 6.13) unless OWTSs are designed for their use. Eliminating garbage disposals can decrease the buildup of solids in the septic tank and reduce the frequency of pumping required. A number of states have regulations prohibiting the installation of garbage disposals where on-site systems are used. New OWTSs can be designed to accommodate garbage disposals and the associated increase in organic and solids loadings to wastewater by increasing tank volume or pumping frequency (USEPA, 2001c).

Table 6.13: Residential wastewater pollutant contributions by source (adapted from USEPA, 1992b).

Parameter		Garbage disposal (gpcd)	Toilet (gpcd)	Bathing, sinks, appliances (gpcd)	Approximate total (gpcd)
BOD_5	Mean	18.0	16.7	28.5	63.2
	Range	10.9–30.9	6.9–23.6	24.5–38.8	–
	% of total	(28%)	(26%)	(45%)	(100%)
TSS	Mean	26.5	27.0	17.2	70.7
	Range	15.8–43.6	12.5–36.5	10.8–22.6	–
	% of total	(37%)	(38%)	(24%)	(100%)
Nitrogen	Mean	0.6	8.7	1.9	11.2
	Range	0.2–0.9	4.1–16.8	1.1–2.0	–
	% of total	(5%)	(78%)	(17%)	(100%)
Phosphorus	Mean	0.1	1.6	1.0	2.7
	Range	–	–	–	–
	% of total	(4%)	(59%)	(37%)	(100%)

6.3.2.4 Management of residuals to ensure that they do not present significant risks to human health or water resources

On-site systems are not maintenance-free systems. Huang (1983) stated that half of on-site system failures are due to poor operation and maintenance. Most residential septic tanks are designed for approximately 72- to 96-hour retention of wastewater to allow for the removal of solids, greases, and fats. Some of the solids retained in the tank decompose naturally by bacterial and chemical action. As sludge accumulates on the bottom of the tank, however, the decrease in tank volume available for storing settleable solids and raw wastewater results in less contact time. When sludge or scum levels get too near the outlet entrance level, solids can move directly to the soil absorption system and cause clogging (Mancl and Magette, 1991). Septic tank effluent screens can provide some protection from neutrally buoyant solids and during tank upsets, but periodic removal of solids from the tank is necessary to protect the soil absorption system. Most tanks should be pumped out every three to five years in lieu of a regular inspection program. If a septic system is not pumped out regularly, failure will not occur immediately; however, continued neglect will cause the SWIS to fail because it is no longer protected from greases, oils, and solids. Failure may require replacement, often at considerable expense.

Responsibility for ensuring proper operation and maintenance is most often left to homeowners. Homeowners generally are not properly trained or informed on how to take care of their systems, and many do not care to do so. On-site system regulatory authorities and management entities have recognized the need for more comprehensive management programs and have developed educational and other programs to help owners understand their responsibility for system management. Some regulatory authorities have opted for a more proactive approach and have developed inspection programs, renewable permits, and financial incentives (e.g., low-interest loans, grants) for installing, upgrading, or repairing underperforming systems. More than 100 OWTS management programs that provide operational oversight beyond initial permitting are now operating across the country (Knowles, G., Coordinator, National Onsite Demonstration Program (NODP) Phase IV, personal communication, 2000; see also http://www.nodp.wvu.edu/).

The primary objective of a residuals management program is to establish procedures and rules for handling and disposing of accumulated sludge and wastewater removed from tanks (i.e., septage, also called biosolids) in an affordable manner that protects public health and ecological resources. When planning a program, it is important to have a thorough knowledge of legal and regulatory requirements regarding handling and disposal. In general, state and local septage management programs that incorporate land application or disposal to landfills must comply with Subpart C of 40 CFR (U.S. Code of Federal Regulations) Part 503. Detailed guidance for identifying, selecting, developing, and operating reuse or disposal sites for septage can be found in the two process design manuals*: Land Application of Sewage Sludge and Domestic Septage* and *Surface Disposal of Sewage Sludge and Domestic Septage* (USEPA, 1995 a and b), which are posted on the Internet at http://www.epa.gov/ORD/WebPubs/sludge.pdf. Additional information can be found in *Domestic Septage Regulatory Guidance* (USEPA, 1993a).

States and municipalities typically establish additional public health and environmental protection regulations for residuals handling, transport, treatment, and reuse or disposal. In addition to regulations, practical limitations such as land availability, site conditions, buffer zone requirements, hauling distances, fuel costs, and labor costs play a major role in evaluating septage reuse or disposal options. These options generally fall into three basic categories: land application; treatment at a wastewater treatment plant; or treatment at a special septage treatment facility. Initial steps in the residuals reuse or disposal decision-making process include characterizing the quality and quantity of the septage to be produced annually and determining potential adverse impacts associated with various reuse or disposal scenarios. In general, program officials strive to minimize the exposure of humans, animals, ground water, and surface water to potentially toxic or hazardous chemicals and pathogenic organisms found in septage.

Other key aspects of residuals management programs are tracking or manifest systems that identify septage sources, pumpers, transport equipment, final destination, and treatment, along with procedures such as vector control, wet weather runoff, and access to disposal sites for controlling human exposure to residuals.

6.4 Information Resources

The *Onsite Wastewater Treatment System Manual* (EPA, 2002a) is an update to EPA's 1980 manual entitled *Design Manual: Onsite Wastewater Treatment and Disposal Systems*. This comprehensive reference manual is designed to provide state and local governments with guidance on the planning, design, and oversight of onsite systems. This manual will also be useful for onsite wastewater professionals, developers, land planners, and academics. It is available in PDF format from http://www.epa.gov/ORD/NRMRL/Pubs/625R00008/625R00008.htm.

EPA Voluntary National Guidelines for Management of Onsite/Decentralized Wastewater Treatment Systems is a set of recommended practices needed to raise the level of performance of on-site/decentralized wastewater systems through improved management programs. Five model programs are presented as a progressive series: (1) system inventory and awareness of maintenance needs; (2) management through maintenance contracts; (3) management through operating permits; (4) operation and maintenance by a public or private management entity; and (5) ownership and management by a public or private management entity. Each of these model programs includes a set of recommended approaches for planning, siting, design, performance, installation, operation, maintenance, and monitoring of wastewater systems. The guidelines can be obtained at EPA's Office of Wastewater Management Web site at http://cfpub.epa.gov/owm/septic/home.cfm.

Funded by the U.S. Environmental Protection Agency, the National Small Flows Clearinghouse (NSFC) helps small communities and individuals find affordable wastewater treatment options to protect public health and the environment. The NSFC Web site, which can be accessed at http://www.nesc.wvu.edu/nsfc/nsfc_index.htm, offers news, publications, databases, discussion groups, information about innovative and alternative wastewater technology projects (through EPA's Environmental Technology Initiative project), and links related to small wastewater systems.

The ASTM International Web site (http://www.astm.com/) offers guides to standard practices and technical publications on environmental assessment and waste management practices that can be useful for siting, designing, and installing OWTSs.

The American Society of Agricultural Engineers (ASAE) offers several proceedings from conferences focusing on on-site wastewater treatment at its publications page (http://www.asabe.org/pubs/PubCat02/waste.html). ASAE also has a searchable library of technical articles (http://asae.frymulti.com/), many of which pertain to OWTSs.

The National Onsite Wastewater Recycling Association (NOWRA) Web site, which can be accessed at http://www.nowra.org/, offers a calendar of events related to OWTSs, contact information for state and local OWTS organizations, links to OWTS-related businesses and organizations, the *Onsite Insight* newsletter, technical guidance for owners and operators of OWTSs, a bookstore with conference proceedings available for purchase, and the *Model Framework for Unsewered Wastewater Infrastructure*, which is a guide for establishing future national policy for onsite systems.

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