Article 123

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Dealing With Septic System Impacts

Much of the watershed development that has occurred in recent years has been in more rural areas that are not served by central water and sewer. This trend is amplified by the fact that these rural lots are often much cheaper than their counterparts in dense municipal areas. In Maryland, for example, over 80% of the land developed in the last decade was located outside the "envelope" of water and sewer lines (MOP, 1991). A consequence of this development pattern is the need for land treatment and disposal of wastewater on individual residential lots—usually by some kind of septic system. Over time, hundreds and even thousands of septic systems are constructed in the developing rural landscape. As a result, watershed managers are faced with an enormous challenge: how to limit the cumulative impact of thousands of septic systems on the quality of surface and groundwater over many decades.

This article reviews the potential water quality impacts of both functioning and failing septic systems. In addition, it summarizes recent research and local criteria for siting septic systems to reduce failure rates, as well as innovative septic system alternatives that have greater pollutant removal capability. The importance of routine inspection and maintenance of septic systems is emphasized. Lastly, innovative local programs to improve the level of septic system maintenance are highlighted.

What's a Septic System?

Septic systems are used to treat and discharge wastewater from toilets, wash basins, bathtubs, washing machines, and other water-consumptive items, which can be sources of high pollutant loads (Table 1). Septic systems are particularly common in rural or large lot settings, where centralized wastewater treatment systems are not economical. Nationally, one out of every four homes uses some form of septic system, which combined discharge over one trillion gallons of waste each year to subsurface and surface waters (NSFC, 1995). Because of their widespread use and high-volume discharges, septic systems have the potential to pollute groundwater, lakes and streams if located or operated improperly.

While septic systems are designed based on soil conditions, most are designed on the same principles (NVPDC, 1990). Conventional systems are comprised of a septic tank, a distribution system, and a soil absorption system (Figure 1). Variations of the basic design will be introduced later in this discussion. Wastewater is directed away from the building and into a below-ground septic tank. There, anaerobic bacteria digest organic matter, solids settle to the bottom, and low-density compounds such as oil and grease float to the water surface.

Partially-treated wastewater then leaves the septic tank and enters the distribution box, where it is discharged into the soil absorption system, also known as the drainage field. Effluent percolates through the soil

Table 1: Daily Water Use and Pollutant Loadings by Source (USEPA, 1980)

Water Use	Volume (liters/capita)	BOD (grams/capita)	Susp. Solids (grams/capita)	Total N (g/capita)	Total P (g/capita)
Garbage disposal	4.54	10.8	15.9	0.4	0.6
Toilet	61.3	17.2	27.6	8.6	1.2
Basins/Sinks	84.8	22.0	13.6	1.4	2.2
Misc	25.0	0	0	0	0
Total	175.6	50.0	57.0	10.4	3.5

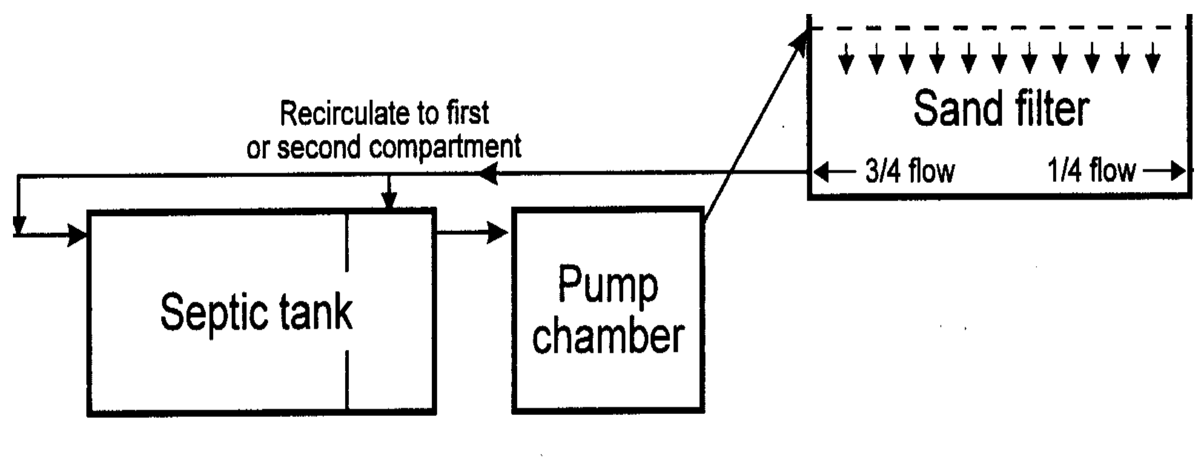


Figure 1: Conventional SepticSystem Arrangement

and remaining pollutants—nutrients, suspended solids, bacteria, viruses, and organic/inorganic compounds—are removed by filtration, adsorption, and microbial degradation (AGWT, 1990). The absorption system consists of a network of perforated pipes located in shallow trenches covered with backfill. Gravel usually surrounds the pipes to encourage even distribution of the effluent into the soil.

For the most part, properly sited and maintained septic systems can treat wastewater effectively and not threaten water quality. However, the effectiveness of septic systems strongly depends on site conditions and timely inspection and maintenance.

Pollutants From Functioning and Failing Systems

How does a septic system fail? Often, a flooded basement or lawn is the homeowner's only indicator that a septic system is not operating properly. As a rule of thumb, a failing system may be considered one that discharges effluent with pollutant concentrations exceeding established water quality standards. Proper siting is essential to sufficiently operating systems. Conventional systems require relatively large land areas to allow even effluent distribution in drainage fields. In addition, there must be adequate vertical distance between the drainage field and groundwater or bedrock to ensure that effluent can adsorb to soil. Soils of sufficient grain size and texture are also necessary to both purify effluent and allow the effluent to percolate. Septic systems, and in particular drainfields, operate best when placed laterally away from natural landscape and man-made features.

Table 2. Septic Tank Effluent Quality: Range of Values for Conventional Parameters - N=5 (Anderson *et al.* 1988)

Parameter	Value
Temperature	20.5–28.0 °C
pH	7.0–7.2
BOD_5	108–163 mg/l
Total dissolved solids	330–498 mg/l
TSS	74–122 mg/l
Organic nitrogen*	16–53 mg/l
Nitrate and nitrite nitrogen*	0.01–0.17 mg/l
Total phosphorous	12–17 mg/l
Chloride	20–29 mg/l
Fats, oils, and grease	15–36 mg/l
Methylene blue active substances (measures detergent surfactants)	3.0-8.2 mg/l
Fecal coliform bacteria	6.6–7.2 log/100 ml

* Organic nitrogen is often converted into nitrate within the drainfield

Even properly functioning septic systems can deliver significant pollutant loads to groundwater (Table 2). Phosphorous and nitrogen are of particular concern in areas threatened with eutrophication. The most common shortcoming of conventional septic systems is their inability to remove much nitrogen. Only 20% of nitrogen that passes through conventional septic systems is effectively removed, although this number may be influenced by several factors (Siegrist and Jenssen, 1989; Gold *et al.*, 1990). It is not uncommon for the effluent leaving a typical system to have a total nitrogen concentration of 40-60 mg/L, primarily in the form of ammonia and organic nitrogen (CBP, 1992). Once in the drainage field, organic nitrogen forms are easily converted into nitrates, which are quite soluble and easily mobilized, thus increasing the potential for ground and surface water contamination (WI DILHR, 1991).

The potential has been realized in several locations, including Buttermilk Bay, MA where it was found that 74% of the nitrogen entering the estuary was derived from septic systems (Horsley and Witten, 1994). The potential for septic systems to discharge excess pollutants is exacerbated when garbage disposal units are tied into the system (Table 3). Phosphorous loads are not great with septic systems due to its tendency to tightly adsorb to soil particles. Septic system phosphorous leaching, however, has been identified as a concern adjacent to some freshwater systems, where phosphorous limitation is prevalent (MI DNR, 1995).

A second group of pollutants associated with septic systems are pathogenic bacteria, parasites, and viruses. Improperly treated wastewater from septic systems can contain unhealthy concentrations of bacteria and viruses harmful to many organisms, including humans. In fact, the majority of groundwater-related health complaints in the U.S. are associated with septic system pathogens (NSFC, 1995). Contaminated surface waters are often closed to swimming and shellfishing due to this health risk.

Other problems with septic system performance are related to what goes into them. For example, household chemicals entering a septic tank can kill organic-consuming bacteria or cause sludge and scum to be flushed out into the drainfield. Such chemicals can include various readily available septic system additives, which ironically are advertised as having the ability to improve system performance. Not only are some household chemicals detrimental to the septic system itself, but they often reach ground or surface waters, where they exert toxic effects on organisms. Normal amounts of detergents, bleaches, drain cleaners, and toilet bowl deodorizers, however, can be used without causing harm to bacterial action in the septic tank (AGWT, 1990). Several other household wastes should be kept out of the septic system to prevent failure (Figure 2).

Pollutants that are not removed by septic systems can migrate into groundwater by leaching through the soil. Surface waters may eventually be affected as groundwater seeps into adjacent streams, lakes, rivers, and estuaries. Surface waters may also be directly impacted when systems fail and effluent ponds on or just below the soil surface. The effluent may enter ditches and open channels during storm or dry weather events. Regardless of the pathway, however, the end result can be contamination of ground and surface water resources. This problem may be magnified as the number of failing systems grows.

Table 3: Reduction in Pollutant Loading by Elimination of Garbage Disposals (USEPA, 1993)

Parameter	Reduction in Pollutant Loading (%)
Suspended Solids	25–40
Biochemical Oxygen Demand	20–28
Total Nitrogen	3.6
Total Phosphorous	1.7

Preventing Failure Through Improved Siting

Properly operating septic systems must be located in a way to ensure both lateral distance between surface waters and vertical separation to groundwater. Also drainfield areas must become larger when soils are not permeable or slopes are steep. Daily sewage flow also influences the size of drainfields; larger volumes require large drainfields. It is always necessary to maintain separation distance from groundwater, streams, water supply wells, building foundations, impervious surfaces, and other drainfields. There appears to be no standard separation distance between septic system components and natural and man-made features. This variability may reflect regional and local differences in the ability of soil to treat effluent. States often require percolation tests although acceptable regulatory values vary considerably. In Delaware, for example, percolation rates may be six to 60 min/in, while Georgia, Michigan, and Virginia require percolation rates of 50 to 90, three to 60, and five to 120 min/in, respectively (Woodward-Clyde, 1992).

It is interesting to note that Duda and Cromartie (1982) report that drainfield density in coastal North Carolina must be less than one system per seven acres in order to protect shellfish beds from bacterial contamination. Despite the need for better siting criteria, the reality is that developing criteria for individual sites can be impractical. A comparison of septic system siting requirements throughout the United States is shown in Table 4.

The Need for Alternatives

Unfortunately, many conventional septic systems have been constructed in areas poorly suited for their proper operation. Many were installed before the need for separation distances was understood or because no other wastewater treatment option was available. Others may have been initially installed and operated properly but have insufficient area for drainfields due to urban encroachment and high density development. Still other septic systems were installed improperly.

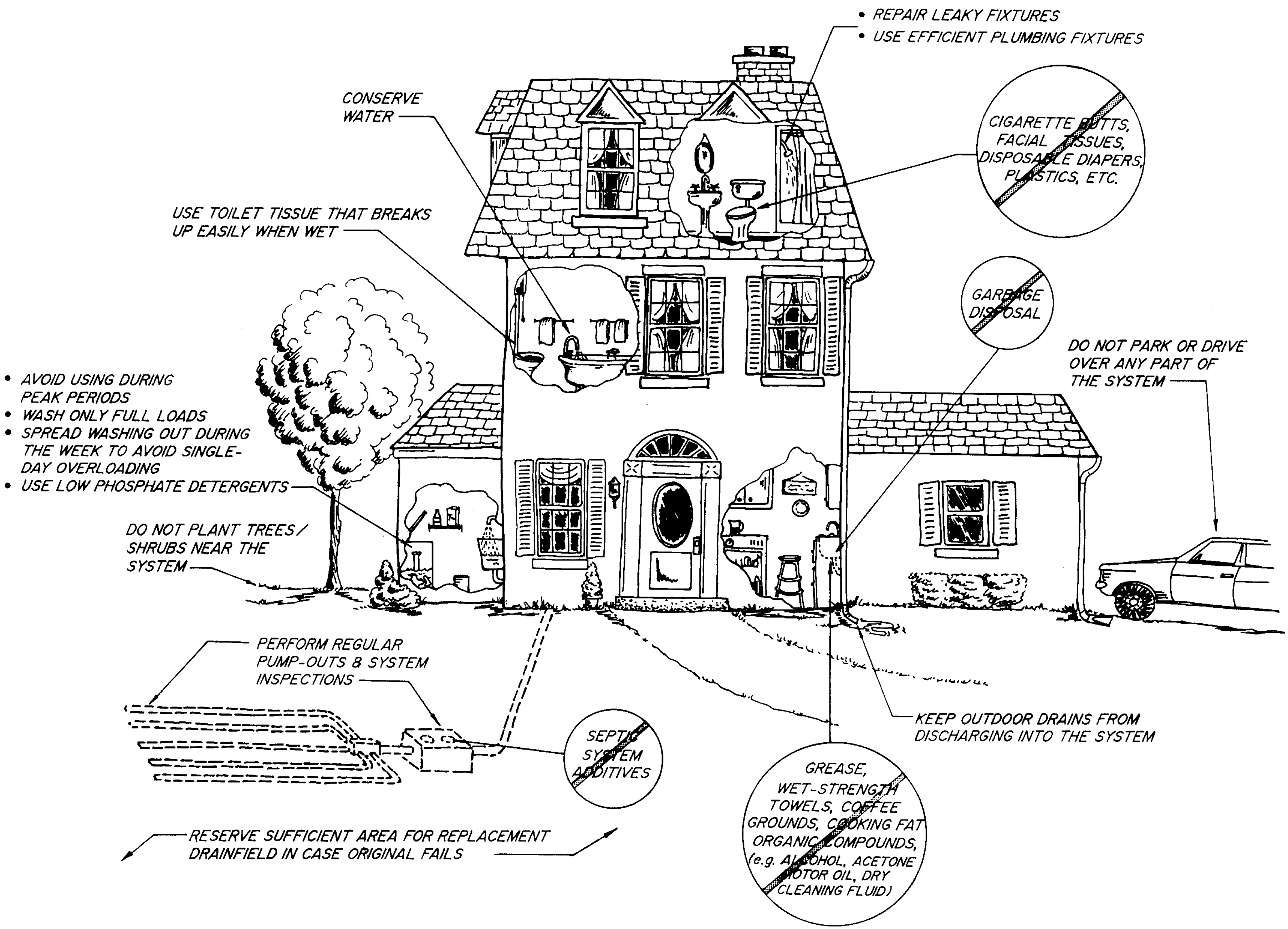


Figure 2: Household Practices That Prevent Septic Failure

Table 4: Example Soil Absorption System Siting Requirements and Recommendations (USEPA 1980, 1993)

Florida	no closer than: • 75 ft from private potable water wells and 100-200 from public wells • 5 ft from building foundations • 75 ft from mean high water line minimum lot size: 1/2 acre
Massachusetts	no closer than: • 10 and 20 ft from surface water supplies (septic tank and absorption field, respectively) • 25 and 50 ft from watercourses (septic tank and absorption field, respectively) systems must be at least 4 ft above groundwater
South Carolina	no state requirements; Charleston County requires minimum lot size of 12,500-30,000 ft^2, depending on whether lots are served by public or private water supplies
Virginia	no closer than: • 25 ft from Resource Preservation Watercourse • 100 ft from Resource Management Watercourse if above cannot be met, no closer than: • 70 ft from shellfish waters • 50 ft from impounded surface waters • 50 ft from streams
Washington	minimum lot size: • 1 to 2 acres (dependent upon soil type)
U.S. EPA *(recommended)*	no closer than: • 50-100 ft from water supply wells • 50-100 ft from surface waters and springs • 10-20 ft from escarpments • 5-10 ft from property boundaries • 10-20 ft from building foundations (30 feet when located upslope from building in slowly permeable soils) Increased setbacks may be necessary to protect waterbodies from viral and bacteria transport to account for tidal influences and account for sea level rise.

Since development continues to take place in rural areas where centralized sewer systems are impractical, it is reasonable to expect that septic systems will continue to be popular wastewater treatment options in many regions. Poor site conditions in many of these regions make conventional septic systems unsuitable. Much effort has been expended to develop alternatives to conventional septic systems. This reflects a need for other technologies that can perform well in areas where conventional systems cannot, and a desire to improve the removal of nitrogen from wastewater effluent.

Many alternatives follow the basic conventional septic system design, with certain modifications to conform with site conditions (some examples are found in Figure 3). Several designs are very attractive because of their decreased reliance on site conditions and their ability to remove pollutants that cannot be removed by conventional systems. A more detailed discussion of one of these alternatives, recirculating sand filters, is provided in article 124. Careful selection of septic system alternatives can provide significant water quality rewards (see Table 5).

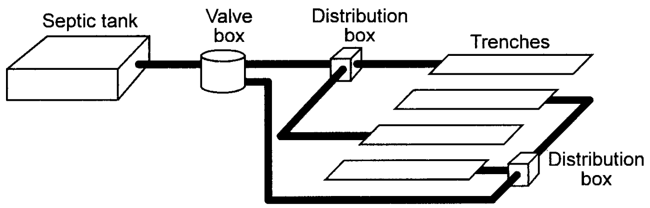
Septic System Maintenance

While alternative systems have some benefits over conventional septic systems, it is important to recognize that no system can simply be installed and forgotten. Regular inspection and maintenance is a necessity. For example, septic tanks should be periodically pumped out, since solids and sludge tend to accumulate over time (Table 6). Unfortunately, regular pumpouts of conventional septic systems is the exception rather than rule. State and local governments often refrain from aggressive enforcement of privately owned septic system maintenance requirements. As a result of the overall lack of enforcement many systems can fail for several years before a severely flooded basement or lawn prompts action on the part of the homeowner.

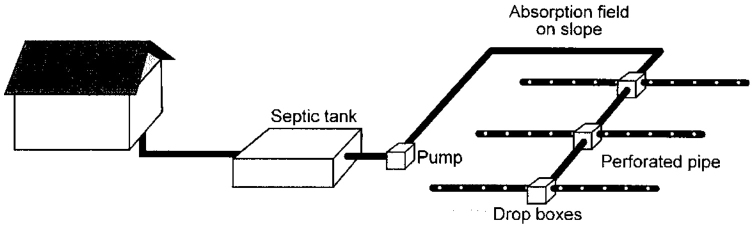
Several other effective and low-cost steps can be taken to better insure proper system operation, in combination with regular inspection, maintenance and pumpout (Figure 2). Interestingly, a major source of system failure can be mitigated simply by reducing the amount of wastewater discharged into the system. Overloading a system causes the system to back up or forces wastes through the tank before they can be adequately treated (AGWT, 1990). In addition, hydrau-

Figure 3: Selected Alternatives to Conventional Septic Systems

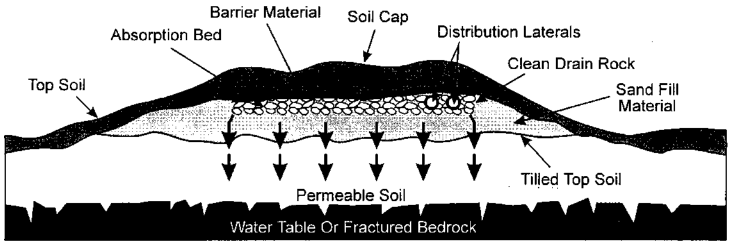
Conventional system with alternating absorption fields



Conventional system with serial distribution on sloping field



Mound system



Constructed wetland

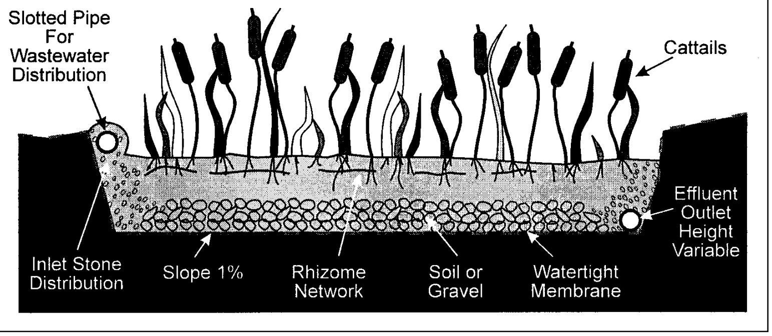


Table 5: Conventional and Selected Alternative Septic System Effectiveness and Cost Summary (USEPA, 1993)

	Average Effectiveness (total system reductions)					Cost*	
Onsite wastewater disposal practice	TSS (%)	BOD (%)	TN (%)	TP (%)	Pathogens (Logs)	Capital ($/House)	Maint. ($/Year)
Conventional Septic System	72	45	28	57	3.5	4,500	70
Mound System	NA	NA	44	NA	NA	8,300	180
Anaerobic Upflow Filter	44	62	59	NA	NA	5,550	NA
Intermittent Sand Filter	92	92	55	80	3.2	5,400	275
Recirculating Sand Filter	90	92	64	80	2.9	3,900	145
Water Separation System	60	42	83	30	3.0	8,000	300
Constructed Wetlands	80	81	90	NA	4.0	710	25

* shown in 1988 equivalent dollars; an average household with four occupants was assumed

Table 6. Suggested Septic Tank Pumping Frequency in Years (Mancl and Magette, 1991)

Tank Size	Household Size (number of people)									
(gal)	1	2	3	4	5	6	7	8	9	10
500	5.8	2.6	1.5	1.0	0.7	0.4	0.3	0.2	0.1	—
750	9.1	4.2	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3
1,000	12.4	5.9	3.7	2.6	2.0	1.5	1.2	1.0	0.8	0.7
1,250	15.6	7.5	4.8	3.4	2.6	2.0	1.7	1.4	1.2	1.0
1,500	18.9	9.1	5.9	4.2	3.3	2.6	2.1	1.8	1.5	1.3
1,750	22.1	10.7	6.9	5.0	3.9	3.1	2.6	2.2	1.9	1.6
2,000	25.4	12.4	8.0	5.9	4.5	3.7	3.1	2.6	2.2	2.0
2,250	28.6	14.0	9.1	6.7	5.2	4.2	3.5	3.0	2.6	2.3

lic overloading creates anaerobic conditions in the drainage field, reducing treatment efficiency.

The difficulty with septic system maintenance is the reluctance of many regulatory agencies to mandate, enforce or finance rehabilitation. As a result, septic system maintenance is the responsibility of the homeowner, suggesting the need for greater public education efforts to this group.

How can communities improve the maintenance of existing septic systems and rehabilitate failed ones? Rehabilitation of septic systems can be a very effective nonpoint source control strategy. Many communities have adopted this strategy to protect or restore shellfish beds and swimming beaches, or to limit nutrient loads to sensitive waters. As always, most communities have found that financing is the crucial element for success. Some innovative local septic management programs are highlighted in Table 7. Several jurisdictions charge homeowners a monthly fee that is used for inspection, maintenance and education. Others have developed a revolving loan program to provide low cost loans to repair failed systems. Yet others have devised more stringent siting and technology criteria for new systems, and certify each new system only after a post-construction inspection. Ultimately, local wastewater authorities need to allocate a greater portion of their budget to systematically improve local septic system management.

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Table 7: Examples of Septic System Management Programs (USEPA, 1993; CWP, 1995)

Georgetown Divide Public Utilities (CA)

- Approximately 10% of agency's resources are allocated to septic system management
- Provides comprehensive site evaluation program, designs septic system for each lot, lays out system for contractor, and makes numerous inspections during construction
- Conducts scheduled post-construction inspections
- Homeowners pay $12.50 per month for services

Stinson Beach County Water District (CA)

- Monitors septic system operation to identify failures
- Detects contamination of groundwater, streams, and sensitive aquatic systems from septic systems
- Homeowners pay $12.90 per month, plus cost of construction or repair

City of Bellevue (WA)

- Conducts biannual septic system inspections at no charge, unless remedial actions are necessary

Puget Sound Water Quality Authority (WA)

- Member jurisdictions have established revolving loan funds to provide low interest loans for repair of failing septic systems

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