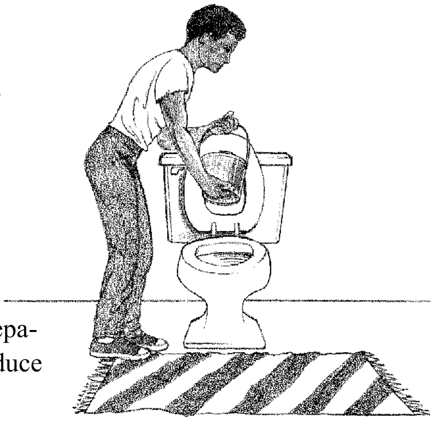
# The Influence of Septic Systems at the Watershed Level

*by Chris Swann*



## Introduction

Septic systems remain an enigmatic but potentially significant pollutant source in small watersheds. An estimated 23% of all households in the United States rely on septic systems to meet their wastewater disposal needs (US Census, 1999), and watershed managers routinely express concern about their potential impact on the quality of lakes, coastal waters and drinking water supplies. However, while we know a great deal about the performance of individual septic systems at the site level, we know very little about their aggregate impacts at the watershed level, and what influence they may collectively have on water quality.

A quick perusal of the literature will reveal hundred of citations on the performance of different septic system technologies under a variety of soil conditions. But at almost any level, we lack the hard data on the collective influence of septic systems on the watershed. We are often in the dark about questions like the following:

- How many septic systems are actually located in any given watershed?
- How many of these systems are failing, and what exactly constitutes failure?
- What nutrient loads are generated from a functioning septic system?
- What happens to nutrients after they leave the drainfield?
- How much does septic system performance decline with age?
- How much vertical and lateral separation distance is needed to reduce loadings?
- Is there a threshold value for septic loadings to the soil on a watershed basis?

This article summarizes current research on the potential risk of surface and subsurface pollution from septic systems. First, we provide a quick overview of basic septic system concepts and define some of the terminology every watershed manager should know when examining septic systems as a pollutant source. Next, we review research on nutrient loading from septic systems and estimate their potential nitrogen and phosphorus loads. From there, we examine the causes of septic system failure and explore recent changes in technology that could address possible failures. Next, we look at the pros and cons of using septic system regulation as a growth management technique for sensitive watersheds. Finally, we suggest some priorities for future watershed research.

## Basic Concepts for Septic Systems

The diverse terminology used to describe septic system technologies can often be quite confusing. For example, septic systems are sometimes referred to as onsite wastewater treatment systems (OWTS), onsite sewage disposal systems (OSDS), or wastewater infiltration systems. To facilitate understanding, we have simplified the terminology and placed septic systems into three basic categories: conventional, alternative, and innovative (Table 1).

**Table 1. Summary of Septic System Types**

| System Type | Construction Cost | Maintenance Needs | Nitrogen Removal Capability | Acceptance by Public Health Officials |
|---|---|---|---|---|
| Conventional | + | + | + | # |
| Alternative | * | * | * | * - # |
| Innovative | # | # | # | + - * |

+ Low * Moderate # High

The *conventional septic system* is composed of two main parts: a septic tank, designed to collect and hold wastewater, and a septic absorption system, which disperses wastewater into the soil (Figure 1). The principal purpose of the septic tank is to act as a settling chamber and an anaerobic digester to break down and retain solid matter while passing the partially treated liquid phase of the wastewater on for disposal through a soil absorption system. The soil absorption system (also known as a drainfield) is designed to dispose of and treat the liquid portion of wastewater by filtering it through a layer of material (often sand or gravel) placed around distribution pipes and then through the soil below the drainfield. Conventional systems constitute the vast majority of septic systems approved for use, as long as soil conditions permit. A 1993 survey conducted by the National Small Flows Clearinghouse found that 97% of the health departments in the U.S. permitted the conventional septic tank-soil absorption system (NSFC, 1996). A conventional system usually costs less than $5,000 to install, and has a relatively low maintenance burden. However, the conventional system has very low nitrogen removal capabilities, since it is primarily designed to remove solids from wastewater and protect human health by disposing of wastewater below the soil surface.

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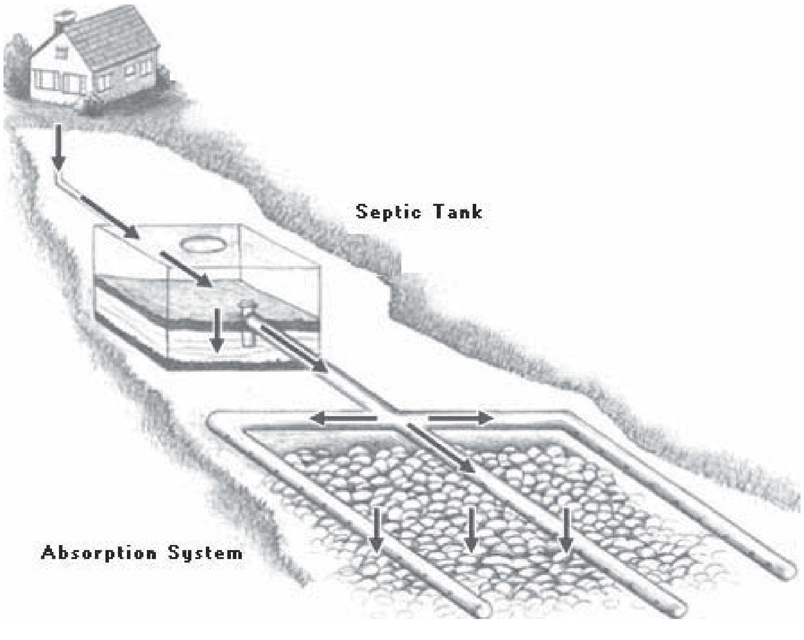

**Figure 1. Conventional Septic System Design (Soap and Detergent Association, 2001)**

*Alternative septic systems* refer to a group of septic system technologies primarily intended to relieve site constraints, such as unsuitable soils or water tables, that would otherwise prevent the use of conventional systems. Alternative septic systems use the same basic design as conventional systems, but make alterations to achieve separation distance (mound systems) or disperse wastewater (low pressure dosing) in order to comply with septic regulations. Alternative systems often provide no material gain in nitrogen removal, and are only installed when conventional systems are not feasible at the site. Alternative systems typically cost $5,000 to $10,000 to install, and require more annual maintenance effort.

The last category contains the *innovative septic systems*. These systems utilize new technologies that are primarily intended to increase the removal of nutrients or other pollutants, especially compared to conventional septic systems. Innovative systems are primarily installed when local water quality concerns require greater nitrogen removal. And indeed, several innovative septic system designs have been demonstrated to achieve nitrogen removal on the order of 40-60% (Table 2). Aerobic treatment units, sand filters, and constructed wetlands have all been designed to improve the removal of nitrogen from septic tank effluent before its discharge to the drainfield. The drawback to innovative septic systems is that the installation cost and annual maintenance effort are high, primarily because of pumps and mechanical equipment that require more routine care. In addition, some innovative systems are still considered experimental, and may not be permitted in some jurisdictions. Furthermore, some researchers are dubious about the long-term performance of these systems, given that regular maintenance is critical to their performance.

### Septic System Regulation and Cleanout

Currently, most septic systems are regulated by local public health authorities. Typically, the authorities review permits and siting for systems prior to installation, with a possible inspection after construction to assure that the system complies with permit conditions. After construction, long-term maintenance of the septic system is typically the responsibility of the individual homeowner. This is less than ideal, since studies have suggested that only about half of all septic owners maintain their systems according to recommended guidelines (*i.e.*, annual inspection and pumpout of the septic tank every three to five years (Swann, 1999; Gomez *et al*., 1992).

**Table 2: Nitrogen Removal for Innovative Septic Systems**

| System Type | Nitrogen Removal Range (mg/L) | Average Nitrogen Removal (%) | Estimated Lbs. of N Removed * | Capital Cost ($ Per System) | Annual Maintenance Cost ($/yr) |
|---|---|---|---|---|---|
| Conventional Septic System | 10-40 | 20 | 5.5 | 2,700-6,700 | 95 |
| Intermittent Sand Filter System | 10-65 | 45 | 12.5 | 5,360-10,720 | 140 |
| Recirculating Sand Filter System | 40-85 | 60 | 16.75 | 6,000-10,700 | 195 |
| Aerobic Treatment Units | 25-65 | 55 | 15 | 3,000-6,300 | 225 |
| Constructed Wetland | 25-90 | 55 | 15 | 4,000-10,000 | 55 |

*Sources: U.S. EPA, 1993; Reed et al., 1995; Tetra Tech, Inc., 1999; Mooers and Waller, 1997; MSSAC, 2000.*
**assumed 2.5 persons per system*

Inspection and maintenance can have a direct impact on the life span of septic systems. The design life of a septic system is estimated to be 12 to 20 years (MOSDTF, 1999). However, many existing septic systems are much older, having been installed several decades ago. For example, one national survey (US EPA, 2000) indicated that more than half of existing systems are more than 30 years old. The same survey found that at least 10% of all systems are not working at any given time. Another survey discovered that about one fourth of all septic systems in the Chesapeake Bay watershed are more than 30 years old (Swann, 1999). Nationally, more than 80 million homes were built before 1979, and many of these are served by septic systems that are presumably well beyond their design life.

## Septic System Failure From a Watershed Perspective

For the watershed manager, it could be argued that every septic system experiences failure to some degree, since they can never produce zero wastewater discharge. Nationwide, failure rates for septic systems vary, but the regional rate of septic failure is reported to range between five and 40%, with an average of about 10%. Maryland and Virginia have reported failure rates of 5% for their septic systems (Fehr and Pae, 1997).

To further complicate the picture, septic system authorities often give conflicting definitions of failure. At the watershed level, a failing system may be considered one that discharges effluent with pollutant concentrations that can impair downstream water quality. An understanding of septic system failure is important, since it has implications for watershed-appropriate management.

Failures can usually be placed into one of three categories: hydraulic failures, subsurface failures, and treatment failures. *Hydraulic failure* is the type that people traditionally think of when talking about failing systems: the drainfield or distribution system has become completely clogged, and sewage backs up in the house or breaks out on the surface of the field. With hydraulic failure, the septic system discharges partially treated wastewater that can have nitrogen, phosphorus, bacteria, and BOD levels similar to untreated wastewa-

**Figure 2. An Example of Hydraulic Failure (Houston/Galveston Area Council, 2000)**

ter. This type of failure is often short-term in nature, since it is readily noticeable to the homeowner (see Figure 2). Because of the risks for public health, hydraulic failures are usually quickly corrected by local agencies once they are identified.

Hydraulic failures obviously deliver a significant amount of pollutants to local water bodies, especially in coastal and lake shoreline areas. For example, a study of phosphorus contribution from older septic systems to a lake in Washington state found a failing system that daily contributed 3.5 mg/L total phosphorus directly to the lake through surface flow (Gilliom and Patmont, 1983). The author suggested that poor siting in a wet area may have contributed to the problem.

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With hydraulic failure, the threat of bacterial contamination becomes very important. Many reports of disease outbreaks are linked to ground water contamination by septic system effluent. In fact, effluent from septic systems is the most frequently cited source of ground water contamination leading to diseases such as acute gastrointestinal illness, hepatitis A, and typhoid (US EPA, 1986). Surface and groundwater impacts from hydraulic failures have been documented in a number of studies. For example, Cogger (1988) reported incomplete microbe removal when groundwater is near or at the same depth as the absorption trench. Another study of seasonally used septic systems in coastal Rhode Island found that fecal coliform concentrations at two sites were often in excess of marine recreational standards, even at 20 meters away from the soil absorption system. This was attributed to the absence of a biological clogging mat and poor distribution of effluent throughout the drainfield (Postma *et al.*, 1992).

The second category of septic system failure involves *subsurface plumes*. In this case sewage is distributed into the drainfield, but a plume of partially treated sewage moves through soil macropores, cracks or ditches. The extent of subsurface failure depends on site conditions and system age, but plume formation appears to be a fairly common occurrence in sandy soils. The main water quality problems associated with subsurface plumes are high nitrogen and phosphorus loads to downstream receiving waters.

Many studies have shown that subsurface nitrogen plumes have a major impact on local water quality. Several studies have reported nitrate ($NO_3$) concentrations varying from 10 mg/l to 70 mg/l within 10 to 100 feet from the drainfield (Caradona, 1998). For phosphorus, subsurface movement depends on soil texture and structure, pH, mineral content, and depth to the water table or confining soil layer. Most research has shown that phosphorus plumes are unusual in unsaturated soils with finer textures because most phosphorus is absorbed by the soil (Stolt and Reneau, 1991), and numerous studies have documented a high degree of phosphorus removal within the first few meters downgradient from the drainfield (Weiskel and Howes, 1992; Robertson *et al.*, 1991; Wilhelm *et al.*, 1994). It appears that for a properly functioning system not

**Table 3. Subsurface Plumes and Septic Systems**

| Study | Location | Results |
|---|---|---|
| Grant, 1998 | Indiana | A study of near-shore development on 18 lakes found septic plumes entering the lakes even though all failing septic systems had been replaced. Orthophosphate concentrations were found to be 2-10 times higher near-shore than for mid lake samples. |
| Harman *et al.*, 1996 | Ontario | Found nitrate plumes in the groundwater beneath a 44-year-old septic system with nitrate concentrations above drinking water limits as far as 100 meters from the drainfield. |
| Robertson *et al.*, 1991 | Ontario | A study documented rapid nitrification in a septic plume, with. nitrate concentrations in the plume core varying within a range from 21 to 48 mg/l. Nitrate concentrations did not change as the septic plume moved downgradient through a distance of 330 feet. |
| Robertson and Harman, 1999 | Ontario | A study of two decommissioned septic systems found that if a phosphate plume is present before decommissioning, downgradient P loading is not likely to diminish for several years and may constitute a threat to downgradient surface waters. |

**Table 4. Treatment Failure and Nitrate Contamination**

| Study | Location | Results |
|---|---|---|
| Arnade, 1999 | Florida | A study of 60 residential wells found a correlation between increasing nitrate and phosphate concentrations and decreasing well and septic tank distance during the wet season from July to September. |
| Horsley and Witten, 1994 | Massachusetts | Found that 74% of nitrogen entering the Buttermilk Bay estuary was due to septic system effluent. |
| MPCA, 1999 | Minnesota | A study in the town of Baxter found higher concentrations of nitrate in unsewered areas compared to sewered areas. These concentrations decreased with increasing well depth. |
| Pinnette *et al.*,1999 | Maine | Analysis of 18 subdivisions found that wells paired with septic systems older than 15 years had higher nitrate levels. |
| Tinker, 1991 | Wisconsin | Samples from five unsewered subdivisions found a correlation between decreasing lot size and increasing nitrate values in groundwater. |
| Tuthill *et al.*, 1998 | Maryland | Study found negative correlation between lot size and well contamination. The study also found that increasing well casing length was correlated with lower nitrate levels. |

located in soils conducive to plume formation, as much as 95% of the phosphorus may be retained in the soil (Mandel and Haith, 1992). The exception appears to be sandy soils and/or saturated soils, where movement of phosphorus into surface waters due to lower phosphorus adsorption capacity has been cited as a source of phosphorus to lakes (Sagona, 1988; Grant, 1998). Table 3 examines the results of number of studies of plume formation and nitrate and phosphate movement.

The final septic system failure category, *treatment failure*, may be the most ominous for the watershed manager trying to protect water quality, particularly in coastal waters that are nitrogen sensitive. Treatment failure means that sewage is adequately treated within the soils of the drainfield, but nitrogen is not reduced before it reaches groundwater. Nitrogen is delivered to groundwater in the form of nitrate, which can contribute to eutrophication in nitrogen-sensitive waters such as estuaries, coastlines and some springs. (It should be noted that nitrogen loads are also produced by the discharge of wastewater treatment plants, given how difficult it is to reduce nitrate from wastewater).

Research has shown that conventional septic systems can only remove about 10 to 20% of the nitrogen that enter them. As a result, an average of about 23 pounds of nitrogen (primarily nitrate) each year can move from the drainfield and into groundwater, if no treatment in the soil occurs. The ultimate fate of this nitrogen load is not known, although several research studies indicate that as much as 75% can be delivered to surface waters, depending on the terrain, soils and the physiographic region. Horsley and Witten (1994) reported that nitrogen concentrations attributable to septic effluent accounted for more than 74% of the anthropogenic nitrogen entering Buttermilk Bay, MA. Table 4 summarizes six studies that have examined well contamination and nitrate movement from septic systems.

## Causes of Failure

Failure has many different causes, most commonly poor installation/location, hydraulic overloading and lack of maintenance (Table 5). Reported failure rates are quite variable, but even the most conservative estimates suggest that at least 5% of all septic systems are failing in any given year. Many failures are associated with inappropriate location of systems in areas with inadequate separation distances to ground water, insufficient absorption area, fractured bedrock, sandy soils (especially in coastal areas), or inadequate soil permeability. Improper design or installation, including smearing of trench bottoms during construction, compaction of the soil bed by heavy equipment, or improperly performed percolation tests can also contribute to system problems (US EPA, 1993).

**Table 5. Watershed Factors That Suggest Potential Subsurface Plume or Nitrogen Failure**

Density
Lot Size
Well Casing Length
Proximity to Lakefront
Gradient
Soil Type
Water Table

## Watershed Tank Density

What indicators can be used to determine the potential impact of septic systems in a watershed? One useful indicator of potential impact is septic tank density (tanks per square mile). For example, based on our best estimates, about two million septic systems are currently in the ground in the Chesapeake Bay watershed, with another 15,000 to 20,000 new systems installed each year. The majority of the septic systems utilize the conventional septic tank and drainfield design. This equates to one tank per 20 acres. However, in a small watershed tank density can become significant: Figure 3 illustrates the relationship between septic density, watershed development and residential zoning for a 10 square mile watershed.

And certainly, an understanding of density is critical to the watershed manager concerned with collective septic system impacts. A number of studies have indicated that septic density is correlated to nitrogen loading to groundwater. Cogger (1988) reported on a study of nitrate levels in a shallow aquifer beneath a densely populated, 30 square mile unsewered area east of Portland, Oregon. Nitrate averaged nearly 8 mg/L, with some wells exceeding the 10 mg/L EPA standard. Population density was about five people/acre. Gold *et al.* (1990) also found that unsewered residential development using half-acre zoning could produce nitrogen loadings comparable to production agriculture. He recommended that denitrification systems be required on small lot zoning to ensure potable groundwater in coastal areas.

A knowledge of watershed tank density helps managers calculate potential subsurface waste flows from existing systems, identify areas of concern and plan for more intensive monitoring. In addition, septic density can be combined with information on system age to locate areas with high potential failure rates. Finally, septic density permits the watershed manager to estimate the sum of the potential pollutant load from both existing and future systems and determine the best way to control septic system discharges to meet water quality standards. Suggestions for changes in land use planning to limit new development in areas with high septic densities can be made to avoid additional nutrient loading to local waters.

## Potential Pollutant Loadings From Septic Systems

Conventional septic tank effluent can contribute nitrogen, phosphorus, and bacteria to the drainfield, a fraction of which will eventually enter ground or surface waters. Of paramount concern to the watershed manager is the amount of these pollutants that will enter local lakes, streams, or estuaries. The many studies on septic system performance are often conflicting or confusing in this regard. However, a review of some basic numbers can help watershed managers understand the potential pollutant loads from septic systems.

The first numbers needed to make an estimate of potential septic system loads are per-capita or per household sewage flows. The average person generates about 40 - 80 gallons per day of wastewater, with households on septic systems tending to fall on the lower end of the range. The household sewage flow is easily estimated by multiplying the per capita flow rate by the average number of people per household (nationally, about 2.7 people per household). Under these calculations, approximately 108 - 218 gallons of waste-

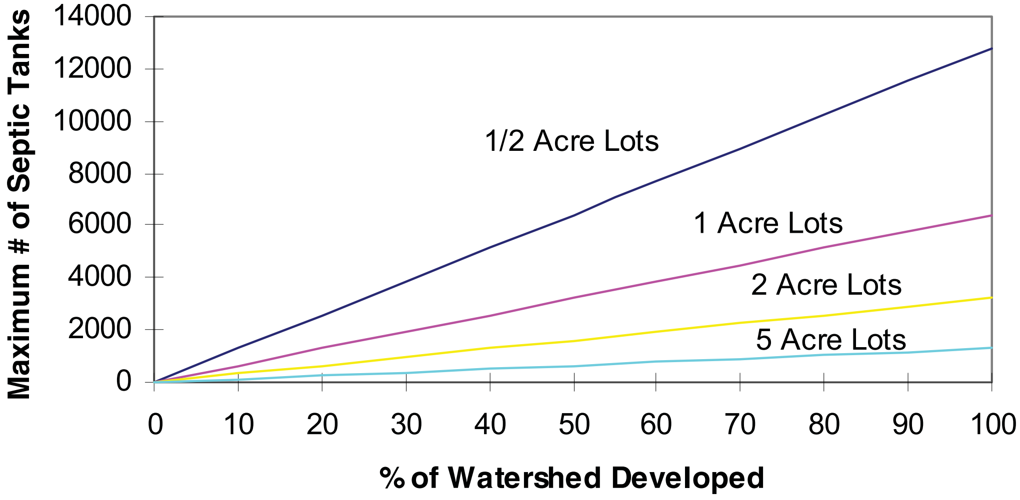


Figure 3. The Relationship Between Septic Density and Watershed Development

**Table 6: Characteristics of Untreated Residential Wastewater**

| | | Source | | | | | |
|---|---|---|---|---|---|---|---|
| Constituent | Unit | Canter and Knox, 1985 | | Tchobanoglous and Burton, 1991 | | Burks and Minnis, 1994 | |
| | | Range | Typical | Range | Typical | Range | Typical |
| TSS | mg/L | 221-300 | **250** | 240-600 | **436** | 100-400 | **220** |
| $BOD_5$ | mg/L | 217-310 | **300** | 216-540 | **392** | 100-400 | **250** |
| Total N | mg/L | 37-76 | **38** | 31-80 | **57** | 15-90 | **40** |
| Total P | mg/L | 24-25 | **25** | 10-27 | **19** | 5-20 | **12** |
| Total Coliform | # /100 ml | ND | **ND** | $10^7$-$10^{10}$ | **$10^8$** | $10^6$-$10^8$ | **$10^8$** |

*ND = no data*
*Numbers have been rounded*

water flows are produced daily by each household. To put these statistics into perspective, a one million gallon per day sewer system that collects and treats wastewater typically serves from two to 10 thousand households (with a mean of 7,500).

The next key number to calculate is the basic "strength" of untreated residential wastewater. Table 6 compares the relative concentrations of several pollutants frequently considered when determining septic system impacts.

Next, it is useful to calculate the potential household nutrient loading rate for septic tank effluent that could move into groundwater or surface waters. Table 7 provides typical concentrations of nitrogen, phosphorus, and fecal coliform bacteria found in septic tank effluent.

The actual nutrient load that ultimately reaches receiving waters is the most difficult number to calculate. The final delivery of pollutants to receiving waters is determined by both site conditions and the type of failure that a system might be experiencing. Some estimates of "edge of drainfield" concentrations have been reported (see Table 8), but final estimates for discharge of nitrogen to ground and surface waters are usually reported with the assumption that no attenuation in the soil occurs since the anaerobic conditions required for denitrification are usually absent.

## Septic Systems: An Agent of Sprawl or a Tool of Watershed Protection?

One of the most difficult decisions facing a watershed manager involves deciding how to treat and dispose of wastewater in lightly developed watersheds (i.e., less than 15% impervious cover). Should a sewer be extended to collect wastewater, or should individual septic systems be relied upon to serve new development instead? The choice of how wastewater will be handled in a small watershed often has an enormous influence on its ultimate development density and percent impervious cover.

We recently engaged in an intensive search of the planning literature to find quantitative data on this topic. While there was no shortage of opinions on it, we could find little or no hard data to guide watershed planning. This gap is surprising, given the hundreds of local battles over sewer extensions or septic system regulations that have occurred in recent decades. This section seeks to outline the complex choices that accompany handling wastewater dischargers in a small watershed. On one hand, choosing to sewer a watershed can induce growth, since most communities cannot easily restrict which future developments will tap into the sewer. In addition, since extending sewers is costly, planners often concentrate development in fairly dense zoning categories that often collectively exceed 10% impervious cover in a small watershed. While the cumulative amount of potential development in a watershed can be controlled to some extent by the diameter or capacity of the sewer line, it is important to keep in mind

One of the most difficult decisions involves deciding how to treat and dispose of wastewater in lightly developed watersheds.

**Table 7: Characteristics of Septic Tank Effluent**

| | | Source | | | |
|---|---|---|---|---|---|
| Constituent | Unit | Tchobanoglous and Burton, 1991 | SSWMP, 1978 | U.S. EPA, 1980 | Canter and Knox, 1985 |
| | | Range | Typical | Typical | Typical |
| TSS | mg/L | 50-90 | 49 | 77 | 75 |
| $BOD_5$ | mg/L | 140-200 | 138 | 142 | 140 |
| Total N | mg/L | 25-60 | 45 | 42 | 40 |
| Total P | mg/L | 10-30 | 13 | NR | 15 |
| Fecal Coliform | # /100 ml | $10^3$-$10^6$ | $5 \times 10^6$ | NR | NR |

*NR = not reported*
*All numbers have been rounded*

that sewer capacity often increases over time. Sewer lines are much like roads, in that they can be easily expanded once capacity is exceeded. Consequently, a decision to sewer a watershed can often make it very difficult to meet a low watershed impervious cover limit over the long run. Other watershed implications associated with choosing to extend sewers are summarized in Table 9.

On the other hand, septic systems are often argued to be an agent of sprawl. Residential development that relies on septic systems for wastewater disposal is inherently of a low density nature, as most public health authorities require minimum lot sizes, reserve fields and soil suitability that effectively make it impossible to use individual septic systems on lots smaller than a half acre in area (and often one to two acres in size). Choosing to rely on septic systems typically means that large-lot zoning will become the primary watershed planning tool to stay below a watershed impervious cover threshold or limit.

**Table 8: Nitrogen Loading Rates From the Edge of the Drainfield (lbs N/yr)**

| Source | Pounds of Nitrogen |
|---|---|
| Bauman and Schafer, 1985 | 20.98 ± 7.3 |
| EPA, 1980 | 22.8 |
| Mandel and Haith, 1992 | 25.6 |
| EPA, 1993 | 21.0 |
| Urish and Gomez, 1998 | 23.7 |

*Table adapted from Maizel et.al., 1997, and assumed 2.5 persons per system.*

In addition, planners should realistically assess how conventional septic systems make land development in a watershed easier and cheaper. For example, Swann (2000) recently compared the actual costs of constructing and maintaining septic systems on a typical residential lot in the Chesapeake Bay watershed, as compared with serving it with a public sewer. The cost analysis utilized recent survey data on septic and public sewer costs as reported by more than 20 localities in the Chesapeake Bay area. Swann found that the cost for a conventional septic system at a residential lot was about $3,400 less than the cost of providing public sewer, over a 20-year span.

This difference, termed a "septic subsidy," suggests that the life cycle costs for a conventional septic system are about 25% lower than for public sewer, assuming that they are regularly maintained. If a homeowner fails to regularly perform cleanouts, the cost differential grows to nearly 40%. This large septic subsidy makes land development with septic systems extremely attractive, particularly if rural land prices are low. Consequently, planners should be careful when using septic systems, given their potentially powerful influence on the conversion of open space in the watershed.

### Table 9. Key Watershed Issues to Consider When Choosing Wastewater Options

| EXTEND SEWERS | | EMPLOY SEPTIC SYSTEMS | |
|---|---|---|---|
| **PRO** | **CON** | **PRO** | **CON** |
| Single NPDES permit | possible infiltration/inflow | potential growth control in watershed | harder to treat multiple units or dense development |
| greater probability of regular maintenance | probability of sanitary sewer overflows | lower life cycle cost per dwelling unit | subsurface nitrogen loads |
| potentially higher nitrogen removal, if BNR used | risk of induced growth | potentially higher nitrogen removal, if innovative systems | high potential for future failure, in some areas |
| immediate repair for failing septic systems | higher life cycle cost per dwelling unit | | hundreds of owners to monitor |
| utility structure exists for wastewater mgmt | physical alteration of stream corridor by sewer line construction | | no enforcement mechanism to maintain, upgrade or rehab older units |
| | | | potential well contamination |

It should be noted that the septic subsidy completely disappears when innovative septic systems are installed to reduce nitrogen loads. Over a 20-year period, the cost to construct and maintain innovative septic systems was roughly equivalent to the average cost for public sewer.

Still, septic systems can be a useful tool for achieving watershed impervious cover limits of 10 or 15%, if their aggregate impact on pollutant loading and land conversion are considered in a watershed plan. For example, watershed managers might want to consider setting a minimum residential lot size greater than one acre. As noted by Cappiella and Brown (this issue), even one-acre lot zoning produces more than 10% impervious cover across a small watershed, unless a considerable fraction of watershed area cannot be developed because of the presence of parks, farms, steep slopes, flood plains, wetlands, buffers, conservation areas or unsuitable soils.

Watershed managers should also carefully evaluate the available range of alternative septic systems that can be installed in the watershed. Often, these alternative systems enable septic treatment on sites where conventional septic systems are unsuitable, and consequently, increase the inventory of buildable residential lots in a watershed. In some cases, this may exceed maximum impervious cover thresholds or targets for a small watershed. In addition, while alternative septic systems alleviate many site constraints, most provide no material improvement in pollutant reduction, particularly for nutrients. Lastly, alternative systems usually have higher maintenance needs, and thus may present a higher risk of one of the three kinds of potential failure.

### Septic System Criteria for Sensitive Watersheds

If septic systems are chosen to treat wastewater in a sensitive watershed, managers should carefully regulate where and how they are installed, and whether or not they should use innovative technologies to reduce nitrogen. With this in mind, 10 criteria should be considered when regulating septic systems to protect a sensitive watershed:

> Planners should realistically assess how conventional septic systems make land development in a watershed easier and cheaper.

*1. Designate Areas of Concern in the Watershed.* More stringent septic system setbacks and/or innovative technologies should be required for new systems located within areas of concern (MOSDTF, 1999). Examples of potential areas of concern that might be delineated within a watershed include areas with the following characteristics:

- Have experienced prior widespread failures
- Drain to water supply reservoirs
- Are within a wellhead protection area

- Currently experience high nitrate concentration in wells
- Are in close proximity to tidal waters
- Are in close proximity to lake shorelines
- Have karst terrain
- Drain to shellfish beds or swimming beaches

*2. Setbacks*: Communities should examine their mandatory distances from streams, ditches, tidal water waters, lake shorelines, and down gradient wells to ensure adequate water quality protection.

*3. Separation Distances*: The vertical separation from bedrock, confining soil layers, or seasonally high water table should be based on soils and terrain, but should be a minimum of two to four feet.

4. *Reserve Fields*: For communities that have a reserve field requirement, the reserve area should also be afforded protection. This might include marking the location on septic systems plans, placing restrictions on how the land is used, and avoiding activities that could compact the soil. In addition, communities might examine the concept of alternating drainfields on a regular basis to extend the life of the system.

*5. Alternative Technology*: Communities should establish a certification/verification process for alternative technologies (MOSDTF, 1999).

*6. Innovative Technology*: When an onsite wastewater treatment system is to be located in an area of concern, regulations should require either mandatory or preferred use of recirculating sand filters, aerobic treatment units or constructed wetlands.

*7. Creation of septic management districts or enforceable maintenance agreements*. Lack of maintenance is a leading cause of septic failure, and communities should create a mechanism to guarantee continued maintenance (see Table 10).

*8. Minimum Lot Size*: Given the minimum lot sizes established by zoning, watershed managers should calculate what the impervious cover will be to ensure that impervious cover limits or targets are not exceeded.

9. *Inspections and certification*: Many communities have made inspections of existing systems mandatory at time of real estate transfer, expansion or change in use (*e.g*., Massachusetts, Wayne County, MI, Cuyahoga County, OH, Thurston County, WA, Stinson Beach, CA). An example of a septic inspection ordinance is available at the Center for Watershed Protection website at www.cwp.org.

10. *Allow shared systems*: Shared wastewater systems should be permitted for appropriate open space or cluster subdivisions that promote greater watershed protection.

EPA plans to publish a new *Onsite Wastewater Treatment Systems Manual* in 2001 that will encourage the use of performance-based systems and will contain current information on the performance and design of alternative systems, especially those installed in areas with sensitive or threatened water resources. Check the EPA Office of Wastewater Management website at http://www.epa.gov/owm/decent for more information.

### Septic System Maintenance Programs

Proper maintenance of existing and new septic systems should be an integral part of local watershed plans. A recent survey found that 46% of septic system owners in the Chesapeake Bay had not performed a pumpout in the recommended timeframe (Swann, 1999). An extrapolation of this number across the Chesapeake Bay suggests that almost a million septic systems are not properly inspected or maintained.

A number of variables should affect how the management of septic systems occurs. These include protection of public health, the sensitivity of the receiving environment, the cost of the treatment processes and/or equipment employed, and the resources and administrative authority of the local government. A comprehensive septic system management program should ultimately contain the following elements:

1. System performance requirements to protect human health and the environment
2. System management agreements or guidelines to maintain performance
3. Compliance inspection and enforcement to ensure system performance is maintained
4. Technical guidelines for site evaluation, design, construction, operation and acceptable designs for specific site conditions and use
5. Training and certification/licensing for system installers and septage haulers

6. Program audits to maintain the foundation of the management program on sound practices and procedures

A number of program options exist to improve the maintenance of septic systems. These programs may use a variety of tools to keep existing septic systems properly maintained, such as regular inspection programs, discharge permits, certification at time of sale and resale, operational permits, and mandatory inspection contract requirements. Several innovative septic system management programs are profiled in Table 10. Communities should consider adopting these innovative programs, especially for sensitive watersheds such as drinking water reservoirs, natural lakes, and coastal shellfish areas. In addition, the responsibilities of septic system ownership should be a stronger and more consistent theme of watershed education programs.

The US EPA recognized the importance of improved management with its recently issued draft guidelines for management of septic systems. The guidelines include a description of five model management programs designed to improve the level of septic system performance. The goal of these model programs is to manage septic systems on a watershed basis through performance standards and progressively more rigorous management requirements. The draft guidelines and outline of the guidance manual are available at http://www.epa.gov/owm/decent.

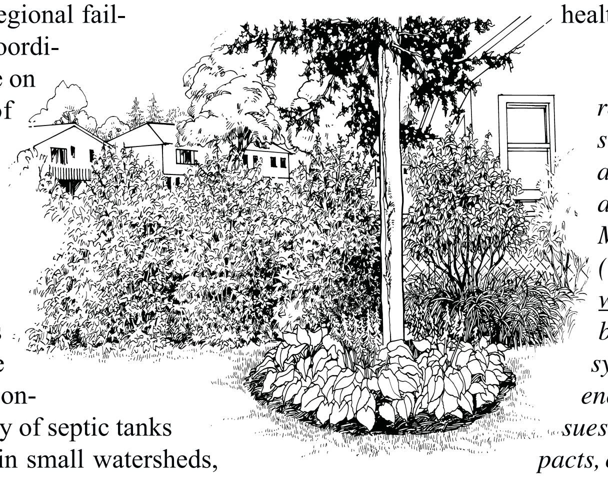
## Watershed Research Needs

A recurring theme of this article is our uncertain understanding of real world performance of septic systems. Consequently, there are four critical research priorities that would be of great value to watershed managers.

**Table 10. Existing Septic System Management Programs**

| Entity | Management Activity |
|---|---|
| Catskill Watershed Corporation, New York | Not-for-profit corporation that provides subsidies for septic system upgrades or replacements. The CWC reimburses 60-100% of the eligible costs for residents in areas designated as highly sensitive to water quality for repair of failing systems. |
| Cuyahoga County Board of Health, Ohio | Annual operational permits required. Operation and Maintenance Program provides for countywide stream monitoring and sampling. Point-of-sale inspections and nuisance complaint investigations, operational maintenance inspections of household sewage systems. Offers low interest loans to homeowners to repair or replace failing systems. Registers septic system installers. |
| Hamilton County, Ohio Health Department | Inspect mechanical septic system on a yearly basis. Non-mechanical systems inspected at least once every 5 years. Final inspection performed after system installation. Department reviews plans for all new subdivisions less than five acres and individual plots for soil suitability for system use. |
| Kitsap County-Bremerton Health Department, Washington | Certifies maintenance specialists. Keeps records of as-built drawings of most installed drainfield after 1970. Provides inspections and places notices on titles for properties with alternative systems. |
| Stinson Beach County Water District, California | Operational permits issued for 1-2 years following inspection by staff. Every system inspected at least once every three years and at change of ownership. District approval of system design required before issuing of a building permit for new construction. Monitoring of surface and groundwater to detect possible occurences of failure. |
| Thurston County Department of Environmental Health, Washington | Professional training and certification of designers, installers, pumpers, and monitoring specialists. Review of permit applications for new systems, repaired systems, or expanded systems. Issuance and renewal of Operational Certificates for 1-4 years. Evaluation of systems when property is sold and initial inspection when a permit is issued. Administration of a low-interest loan program to help those who need financial assistance to repair failing systems. |

First, most watershed managers lack basic research and tracking of the performance of septic systems in their watershed. More systematic reporting of working and failing septic systems is recommended in order to accurately assess the potential impacts of system discharges on water quality. Better coordination among local public health authorities is also needed to get better estimates of regional failure rates. In addition, coordination is needed to agree on common definitions of failure, standard inspection protocols, and isolate critical site factors that lead to higher nitrogen loading.



Second, research is required to determine whether consistent relationships between the density of septic tanks and water quality exist in small watersheds, especially with regards to bacteria, nitrogen and phosphorus. Research is also needed to determine whether these relationships can be detected during storm events or dry weather flow.

Third, we need to improve our ability to predict the delivery of nutrients from the edge of the drainfield to surface waters, and in particular, isolate the critical factors at a site that influence this subsurface delivery. Further research is needed to identify whether denitrification can be promoted or enhanced within stream or shoreline buffers.

Lastly, more data is needed on the performance of aging septic systems in order to determine whether these older systems contribute higher nitrogen and phosphorus loads. This research effort could involve systematic groundwater sampling around both older and younger drain fields under controlled soil, terrain and geologic conditions. This monitoring would help watershed managers determine whether the estimated 12 million septic systems nationwide that are more than 30 years old should be targeted as a controllable source of nutrients.

## Conclusion

Septic systems are a frequently cited but poorly understood water quality problem. In 1996, septic systems were identified as a leading source of pollution for ocean shorelines, and were reported to be the third most common source of groundwater contamination (US EPA, 1996). Unfortunately, septic systems have seldom been managed or regulated from a watershed perspective. The need to revamp siting and maintenance requirements for septic systems has recently received much-needed attention by government agencies and wastewater professionals. The push for new performance standards as part of a comprehensive watershed approach is welcomed, but many questions still remain about the true role of septic systems in watershed management. More watershed research is needed to get a clearer picture of the impact of these enigmatic pollutant sources on the health of out nation's watersheds.

***Editors Note:*** *The Center recently completed a review of septic system related literature, and has made the bibliography available at our Stormwater Manager's Resource Center (SMRC) website at* *<u>www.stormwatercenter.net</u>*. *The bibliography contains short synopses of more than 80 references dealing with numerous issues regarding septic system impacts, costs, performance and design, and policy and management. The bibliography provides an excellent starting point for watershed managers interested in learning more about the role of septic systems in watershed management.*

## Septic System Websites

National On-Site Wastewater Recycling Association (NOWRA): **www.nowra.org**

National Small Flows Clearinghouse (NSFC) **www.estd.wvu.edu/nsfc**

Septic System Owner's Guide and Other Sewage Treatment Pubs **www.extension.umn.edu**

U.S. EPA Office of Wastewater Management **www.epa.gov/owm/decent**

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