This paper was first presented by Terry R. Bounds, P.E., at the 1994 conference of the American Society of Agricultural Engineers, in Atlanta, Georgia. This article may describe design criteria that was in effect at the time the article was written. FOR CURRENT DESIGN CRITERIA, call Orenco Systems, Inc. at 1-800-348-9843.

Septic Tank Septage Pumping Intervals

T.R. Bounds, P. E.*

Abstract

When a designer initiates an economic analysis of an effluent sewer—e.g. a septic tank effluent pump (STEP) collection system or a variable-grade collection system—or an on-site management district, the ability to predict tank pumping intervals is necessary for assigning a cost to that function. An arbitrarily short pumping interval may distort this operational cost by a factor of ten or twenty, causing it to appear prohibitive, or, at the very least, resulting in the expensive practice of transporting septage composed primarily of water. Pumping tanks more often than necessary not only wastes money and resources, but increases pressure on already overburdened septage receiving facilities.

In the 1970s effluent sewer systems were relatively rare, and operation and maintenance scheduling, including septic tank pumping intervals, were projected using information from U.S. Public Health Service studies published in 1955. During the 1980s, an eight-year audit of 450 watertight septic tanks in an effluent sewer system at Glide, Oregon, demonstrated respectable correlation with those Public Health Service studies, determining that 12 year pumping intervals predicted 30 years before, for an average size family with an adequately sized tank, were not unreasonably long. In 1991 Montesano, Washington, an effluent sewer community of 1,125 watertight septic tanks, found after monitoring 19% of their system that they too experience similar septage accumulation rates.

Based on the assumption that watertight tanks are an essential ingredient in any effluent sewer or managed on-site district, methods are presented to enable designers, regulators, and operations personnel to size tanks relative to occupancy loading, to achieve adequate hydraulic retention times for settlement of solids, to determine a tank's optimum effluent withdrawal level, and to predict septage pumping intervals.

Keywords

Septic tanks, Septage, Pumping, Interval, Frequency

Septic Tanks

There is a good reason why, in this age of advanced technology, the septic tank is still in use. It works. More than 45% of ultimate treatment can be accomplished in the septic tank. Its anoxic digestion can reduce solids as much as 80%. In short, the energy free septic tank is the most cost efficient primary treatment available for nonindustrial sewage. Eventually, however, a septic tank's undigested solids must be removed and disposed of. When is "eventually?" Opinions vary widely. Estimations based on guesswork or on traditional practices are frequently unreliable. Making accurate predictions of septage pumping intervals, however, is not only possible, it's often essential. When a designer undertakes an economic analysis of an effluent sewer—e.g. septic tank effluent pump (STEP) or variable-grade collection system—and when the manager of an on-site district establishes a maintenance budget, the ability to predict tank pumping intervals is imperative for assigning a cost to that function. An arbitrarily shortened pumping interval may inflate this operational cost causing it to appear prohibitive,

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or, at the very least, resulting in the expensive practice of transporting septage that is mostly water. Pumping tanks more often than necessary not only wastes money and resources, but it increases pressure on already overburdened septage receiving facilities. Those in charge of collection systems and on-site systems with septic tanks must have a logical basis for scheduling septage removal.

Old-fashioned septic tanks, constructed without benefit of concrete design and with little or no reinforcing, are now outmoded. Design demands and progressive manufacturers are now able to supply sophisticated constructions that are engineered to be structurally sound and watertight. Leaky tanks, which turn many traditional on-site systems into nothing more than cesspools, are unacceptable in managed systems. Where ground water levels are high, leaky tanks allow infiltration that causes solids and greases to wash through the tank, eventually damaging pumps and, further, the disposal system. Where high ground water is not a problem, a leaky tank will exfiltrate, lowering the scum layer to the outlet level and discharging solids and grease. It follows, then, that for wastewater systems with septic tanks to be efficient and reliable, and for predictions of solids accumulations and pumping intervals to have validity, septic tanks must be watertight.

Calculations presented here enable designers, regulators, and operations personnel dealing with structurally-sound, watertight septic tanks to achieve adequate hydraulic retention times for settlement of solids, to determine a tank's optimum effluent withdrawal level, to predict septage pumping intervals, and to size tanks relative to occupancy loading.

Defining the Tank

Figure 1 depicts a 1000 gallon concrete septic tank typical of the type used in on-site disposal systems, maintenance districts, and effluent sewers. The 1000 gallon designation is nominal and refers to the volume normally occupied by the tank's contents, not including reserve space. Total volume is actually 1200 gallons.

Wastewater flows for single-family dwellings typically range from 40 to 60 gallons per capita per day (gpcd); 50 gcpd is a commonly used design parameter and is the value used in calculations herein. The number of individuals (capita) is assumed to average three per dwelling.

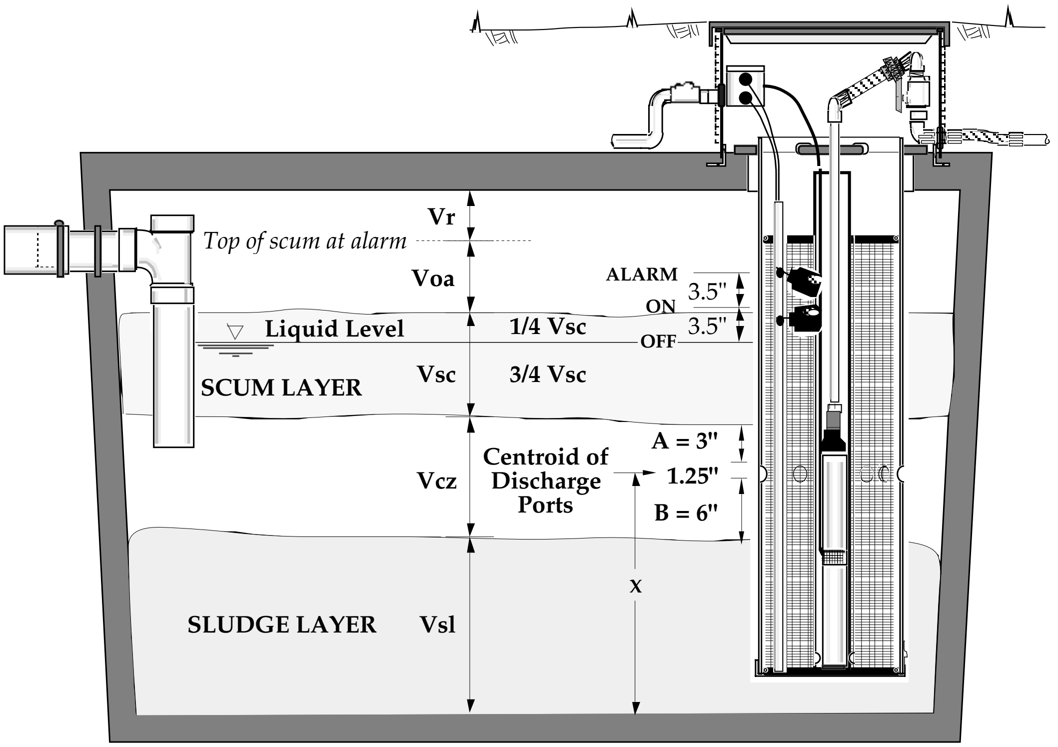

Figure 1: Typical 1000 gallon septic tank

inside top length = 93 in
inside bottom length = 87 in
inside height = 57 in

top width = 57 in
bottom width = 51 in
floor to invert of inlet = 51 in

The ***reserve space*** *(V_r)* is that portion of the tank from the soffit to the top of the scum layer when the liquid level is at the alarm stage. The 200 gallon reserve volume allowed is usually sufficient to permit 24 to 48 hours of normal use, in case of malfunction, before repairs must be made. The reserve space also allows for adequate tank ventilation back through the inlet plumbing.

The ***operating zone*** *(V_{oa})* is that portion of the tank between the "off" level and the "high-water alarm" level. Keeping this zone small has the advantage of maximizing sludge and scum storage volume and minimizing disturbance of the scum layer during pumping cycles.

The ***scum layer*** *(V_{sc})* is that portion of the septic tank's contents which floats. One-quarter of this layer is expected to float above the liquid level; three-quarters is submerged. *Scum clear space **"A"*** is the distance between the bottom of the scum layer at the pump's "off" level and the outlet (top of the discharge ports) of the septic tank. This distance should be a minimum of three inches.

The ***sludge layer*** *(V_{sl})* is the accumulation of solids that settle on the bottom of the tank. *Sludge clear space **"B"*** is the distance between the top surface of the sludge and the outlet (bottom of the discharge ports) of the septic tank. For tanks having surface area of 27 square feet or more, this distance **"B"** should be a minimum of six inches. The following equation may be used to express the sludge clear space for tanks with less than 27 square feet of surface area (Wiebel et al., 1955).

$$SCS = 2.66 - 0.08A_{sl} \qquad (1)$$

where: SCS is the sludge clear space, in feet.
A_{sl} is the sludge surface area, in square feet.

Retention Time

The ***clear zone*** *(V_{cz})* lies between the scum and sludge layers. Dunbar (1908), Laak (1980) and Winneberger (1977) suggest minimum retention times from 6 to 24 hours for adequate suspended solids removal. When a tank's hydraulic retention time is sufficient for settlement, the clear zone contains liquid waste fairly free of solids. Reasonable estimates of the volumes of individual zones can be calculated by using the average surface area of the tank. In Figure 1, the clear zone depth is 10.25 inches. Assuming average tank width of 54 inches and average length of 90 inches, the volume of the clear zone will be approximately 216 gallons.

If average flow is 50 gpcd and average population density is 3.0 per dwelling unit, the average daily flow per dwelling unit is 150 gallons. Retention time is 216 gal ÷ 150 gal/day x 24 hours per day or nearly 35 hours; hence, the most conservative criterion suggested—24 hours—is satisfied.

Solids Accumulation Rates

Predicting scum and sludge accumulations in order to determine septage pumping intervals is possible using data collected in various studies of septic tanks. The study most commonly cited is by Weibel, Bendixen and Coulter for the U.S. Public Health Service (1955), and its rate of accumulation has been corroborated by Winneberger (1977), Schmidt (1976), and Bounds (1988). See Figure 2.

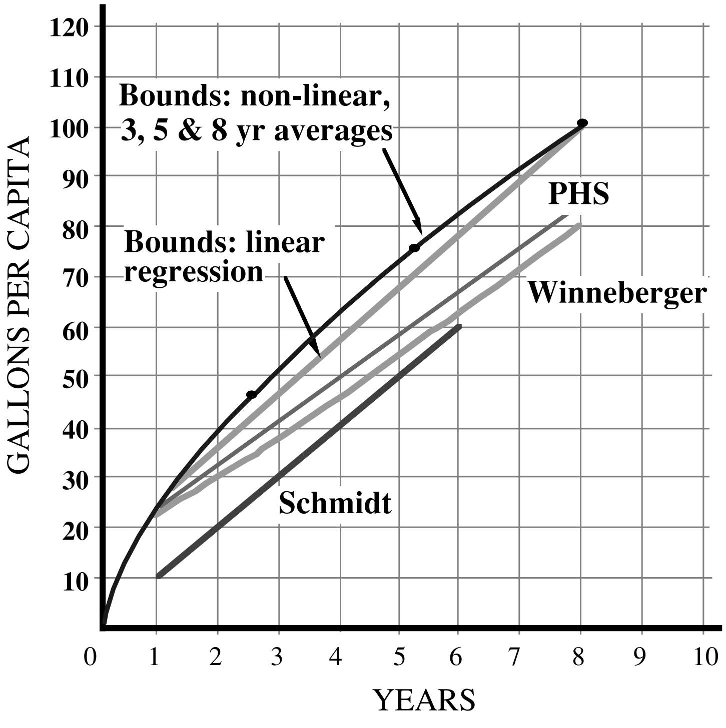

Figure 2: Average Rates of Sludge and Scum Accumulation

The set of equations derived from the Public Health Service studies, which is most commonly used for estimating septage pumping intervals, has a confidence level of 95%, i.e. no more than 5% of the time will accumulation rates be greater.

Rate of Scum accumulation *(95% confidence, PHS)*, gpc $R_{sc} = 5.24t + 12.04$ (2)
Rate of Sludge accumulation *(95% confidence, PHS)*, gpc $\underline{R}_{sl}\ \underline{= 8.15t + 38.82}$ (3)
$R_{sl+sc} = 13.39t + 50.86$ (4)

where: R_{sc} is the volume rate of scum accumulation, gallons/capita
R_{sl} is the volume rate of sludge accumulation, gallons/capita
t is the time, in years

Pumping Intervals

The total volume of the tank in Figure 1 is expressed as the sum of the volumes of the individual zones:

$$V_t = V_r + V_{oa} + V_{cz} + V_{sc} + V_{sl} \tag{5}$$

where: V_t = Total Volume = 1200 gallons ±
V_r = Reserve Volume = 200 gallons ±
V_{oa} = Volume between off and alarm levels = 150 gallons ±
V_{cz} = Volume of clear zone between scum and sludge layers, in gallons
V_{sc} = Scum Volume = Rate of Accumulation (R_{sc}) x capita, in gallons
V_{sl} = Sludge Volume = Rate of Accumulation (R_{sl}) x capita, in gallons

The length of time between tank cleanings—the septage pumping interval—may be estimated by substituting all the known values into Eq. (5) for total volume (V_t):

1200 gal = 200 gal + 150 gal + 216 gal + (13.39t + 50.86)(3 cap)

which yields a pumping interval (t) of 12 years for this typical 1000 gallon concrete tank serving a 3-person household.

The volumes of sludge (V_{sl}) and scum (V_{sc}) expected to accumulate in 12 years are

$$V_{sl} = [8.15(12 \text{ yrs}) + 38.82]\ (3 \text{ cap}) = 410 \text{ gal} \tag{6}$$

$$V_{sc} = [5.24(12 \text{ yrs}) + 12.04]\ (3 \text{ cap}) = 225 \text{ gal} \tag{7}$$

Figure 3 shows that, in the 1000-gallon tanks in use in the Glide, Oregon, effluent sewer system, the limiting volume for the accumulation of sludge and scum is about 635 gallons.

Optimum Effluent Withdrawal Level

Because concrete tanks are usually poured with walls that are slightly sloped, so that the forms can be removed easily, volumes based on average length and width are only approximate. The true volume at any depth of the tank in Figure 1, as measured from the floor upward, may be determined with the following equation.

$$V_x = 19.207\ x + 0.0315\ x^2 + 2.49(10^{-5})\ x^3 \qquad (8)$$

where: V_x is the volume at depth x, in gallons
x is the depth (distance measured upward from the floor of the tank), in inches

Inserting the sludge and scum volumes above and solving for “x” results in maximum allowable depths of 20.7 inches for sludge and 10.5 inches for scum for the tank in Figure 1. Depths estimated using a tank’s average area vary from actual depths by about 6%. In this case, *estimated* maximum sludge depth is 19.5 inches and *estimated* maximum scum depth is 10.7 inches.

Addition of the depth measurements in Figure 1 reveals that the optimum effluent withdrawal elevation (**x**) from the floor of the tank to the center of each 1.25 inch inlet port is 27.3 inches. The minimum operating liquid depth (“off” level) is 38.8 inches from the floor of the tank. Thus the discharge ports are centered at 70.4% of the lowest operating liquid level, which is consistent with the requirement adopted by many governing jurisdictions that the withdrawal elevation (**x**) be at 65 to 75% of the lowest operating liquid depth. This method may be used to establish, for any given tank, the appropriate elevation from which the clear effluent should be withdrawn.

Fiberglass tanks usually are more or less cylindrical in shape, which makes their solids retention capacity less than concrete tanks of the same volume. Tanks of the same depth, however, whether fiberglass or concrete, usually have the same centroid location for the effluent withdrawal ports. In tanks having shapes other than rectangular, the actual volumes of sludge and scum accumulations must be determined by empirical depth-to-volume measurements for each style of tank.

Liquid-level float settings are based on a minimum separation between the “alarm” and the “on” level and the drawdown between “on” and “off.” With three quarters of the scum layer submerged, the lowest “off” level for the tank in Figure 1 should be no less than 11.5 inches above the centroid of the vault discharge ports. The shorter the drawdown, the smaller the operating zone and the greater the solids storage capacity of the tank. A single float effecting a drawdown of only 2 inches instead of 3.5 inches, for example, would increase scum storage volume to 240 gallons and sludge storage volume to 430 gallons, extending the septage pumping interval to 13 years.

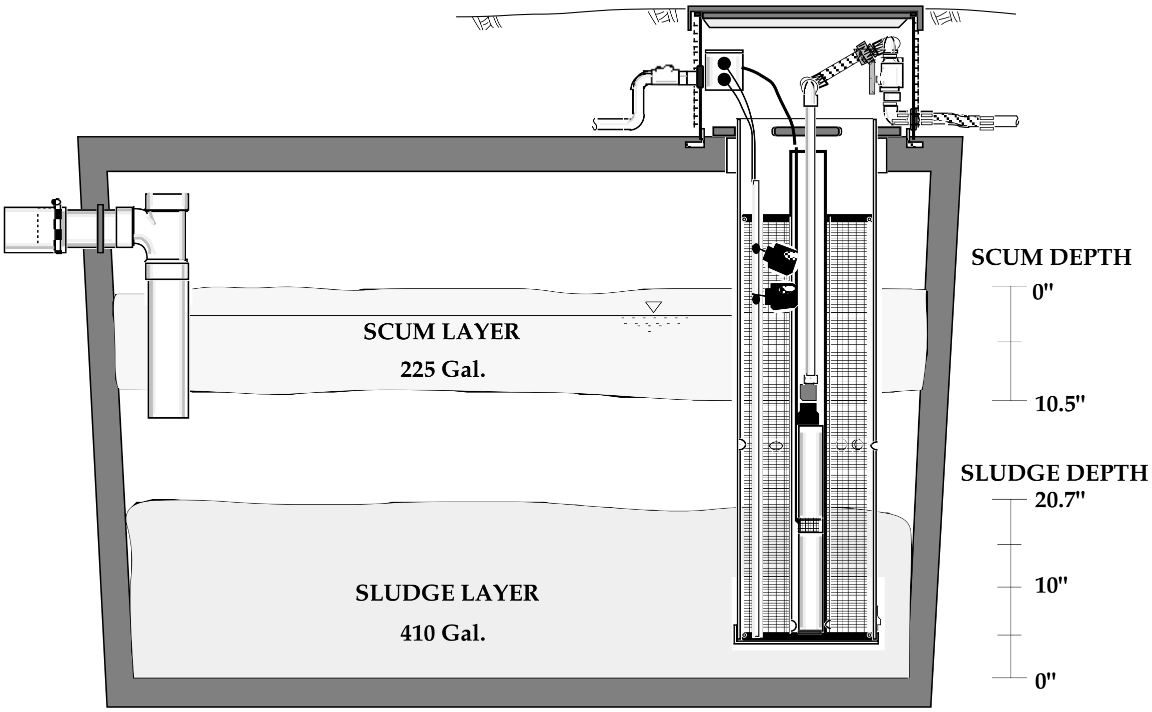

Figure 3: Sludge and Scum Depths in 1000 gallon Concrete Septic Tank, Glide, Oregon

Glide's Experience

During the 1980s, an eight year audit of 450 watertight septic tanks in an effluent sewer in Glide, Oregon, demonstrated respectable correlation with the U.S. Public Health Service studies and confirmed that, for the average household serviced by an adequately sized tank, the 12 year pumping intervals predicted 30 years before are not unreasonably long.

Monitoring

Although predictions of average septage pumping intervals are useful, accumulation rates in a few individual tanks may vary significantly from the average. Therefore, it's essential to monitor conditions in the tanks. At Glide, the first inspections were made following 2.8 years of service. Unless frequent service calls or excessive solids accumulation indicated otherwise, the next inspections took place after the fifth year of operation. Septage removal for typical 1000 gallon residential tanks is scheduled when the sludge thickness approaches 20.7 inches or the scum layer approaches 10.5 inches as illustrated in Fig 3. For a family of three, we can predict, with a 95% level of confidence, this will happen no more frequently than every 12 years. For a family of four, the interval would be every 7 or 8 years. Regardless of the projected pumping interval, in actual practice, each tank's pump-out date is based on measured sludge and scum thicknesses.

Figures 4 and 5 graphically illustrate the comparability of both the U.S. Public Health Service (USPHS) and the Glide (Bounds_1, 1988) studies. Both graphs typically show that in the Glide study a slightly greater rate of sludge and scum accumulation is expected; therefore, pump-out intervals will be shorter.

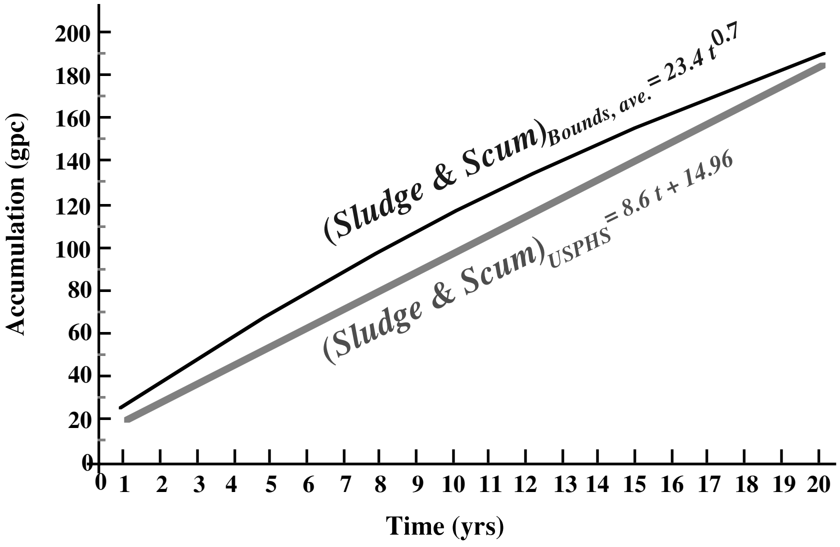

Figure 4: Average Rates of Septage (sludge + scum) accumulation

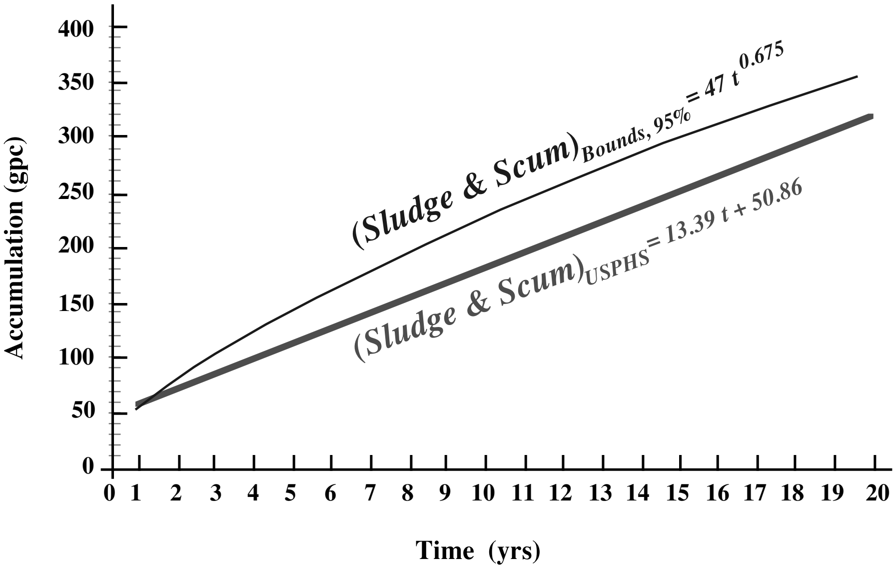

Figure 5: Rates of Septage (sludge + scum) accumulation at a 95 % level of confidence

These curves represent the ***gallons per person*** that have accumulated at any given time in ***years***, so they can be used to project pumping intervals for any occupancy and size or shape tank, including compartmented tanks.

Recognizing that the best forecasts of pumping intervals are useless if septic tanks are substandard or if users abuse them by disposing in them inappropriate substances (Bounds_2, 1993) the Glide district enforces strict standards—every new tank installed is tested to ensure watertightness—and strives to keep its patrons informed. To explain the district's policies and property owners' responsibilities, for example, a list of "dos and don'ts" is provided to patrons and is updated regularly. If a district fails to educate its users adequately or if the level of cooperation is suspect, an inspection after the first year of service is advisable to head off problems that may be developing.

Of special concern is backwash brine discharged from water softeners, which may increase the hydraulic load 20% to 40% and may elevate chloride concentrations to levels that are as toxic to essential septic tank microbes as chlorine is to bacteria in a swimming pool. The rate of solids accumulation is accelerated whenever the microbial activity is suppressed. Ionic polarization, due to the heavy metallic salts, may cause solids in the septic tank to remain in suspension and prevent the natural scum layer from forming. As a result, effluent leaving the tank may contain high levels of suspended solids.

Effects of Occupancy, Loading and Tank Size

The following tables are design aids formulated by the system's design engineers. Note that the operating conditions of the concrete tanks at Glide referred to in Table 1 and Table 2 are the same as those shown in Figure 1. That is, scum clear space = 3", sludge clear space = 6", operating space (liquid level off to alarm) = 5.5", reserve storage time = 24 hours, and occupant loading rate = 50 gpcd.

Table 1 compares pumping intervals, at the 95 % confidence level, from the Glide study to those from the Public Health Service study. *The statistical confidence level indicates that 95 out of 100 tanks do not require pumping before the intervals shown*. This table is used for establishing pumping programs and monitoring schedules, for operation and maintenance budgeting, and for comparing the cost effectiveness of sewering alternatives.

Table 1: Septage Pumping Interval (95% level of confidence)

Glide Effluent Sewer 1987

1000 Gallon Tank				
Number of Occupants	**2**	**3**	**4**	**5**
Pump-out Interval, yrs	**22**	**11**	**7**	**4**

1500 Gallon Tank				
Number of Occupants	**5**	**6**	**7**	**8**
Pump-out Interval, yrs	**9**	**7**	**5**	**4**

US Public Health Service 1955

1000 Gallon Tank				
Number of Occupants	**2**	**3**	**4**	**5**
Pump-out Interval, yrs	**25**	**14**	**9**	**5**

1500 Gallon Tank				
Number of Occupants	**5**	**6**	**7**	**8**
Pump-out Interval, yrs	**12**	**9**	**6**	**4**

When the occupancy load reaches five, when there are four bedrooms, or when garbage grinders are in use, using a 1500 gallon tank helps keep the pumping interval uniform without sacrificing effluent quality. When the occupancy load exceeds nine, or when the residence is exceptionally large, the tank sizing requires special consideration.

When a tank's discharge is by gravity rather than by pump, the liquid level operating range is considerably smaller. To modulate the flow through the tank, the operating range in a gravity discharge tank is normally set at about two inches, which allows more space for sludge and scum accumulation. Therefore, the expected intervals between septage removals are slightly longer than they are in tanks with pumps.

Table 2 compares the <u>*average*</u> pumping intervals established by the Glide study to those from the Public Health Service study. That is, about half the tanks require pumping sooner than the indicated interval and half will have pumping intervals greater than the average. This table is used not for predicting, but for tracking performance and maintenance costs (it's interesting to note that the average pump-out interval is about twice the length of the 95% confidence intervals).

Table 2: Average Septage Pumping Interval

Glide Effluent Sewer 1987

1000 Gallon Tank				
Number of Occupants	2	3	4	5
Pump-out Interval, yrs	55	28	17	10

1500 Gallon Tank				
Number of Occupants	5	6	7	8
Pump-out Interval, yrs	23	17	12	8

US Public Health Service 1955

1000 Gallon Tank				
Number of Occupants	2	3	4	5
Pump-out Interval, yrs	43	26	18	12

1500 Gallon Tank				
Number of Occupants	5	6	7	8
Pump-out Interval, yrs	23	18	14	10

Tables like these are useful tools for establishing a basis for a pumping schedule. In creating meaningful tables, the first step is to develop design criteria that fit local parameters and philosophies. For example, as water usage per capita increases, the reserve storage and the hydraulic retention time require more volume, thus reducing volume available for sludge and scum storage. Reserve storage also may be increased or decreased depending on customary response time and usual length of power outages, the hydraulic retention time may be increased or decreased, and the volume of the operating zone depends on the float switches being used.

Special consideration must be given to tanks with less than 1000 gallons of primary capacity. Because small tanks have limited capacity for reserve storage and hydraulic retention, they require more maintenance. For example, if a 500 gallon tank with an additional 100 gallons of reserve space (600 gallons total) serves a household of three people each of whom uses 60 gallons per day, the space allowable for the accumulation of solids plus the operating volume is only about 240 gallons. That tank's pumping interval, then, is about 1.5 years.

Garbage Disposals

In-sink kitchen garbage disposals add significantly to the floating scum layer in the septic tank. There was approximately a 36% increase in total solids accumulation in tanks receiving wastewater from homes with garbage disposals. The garbage disposals accelerated the scum accumulation rates by about 34%, yet made little difference in the rate of sludge accumulation, only increasing it about 2%. The increases in accumulation rates were similar in both concrete and fiberglass tanks, although the fiberglass tanks exhibited the greatest difference. 6 illustrates the linear differences in sludge and scum accumulation rates.

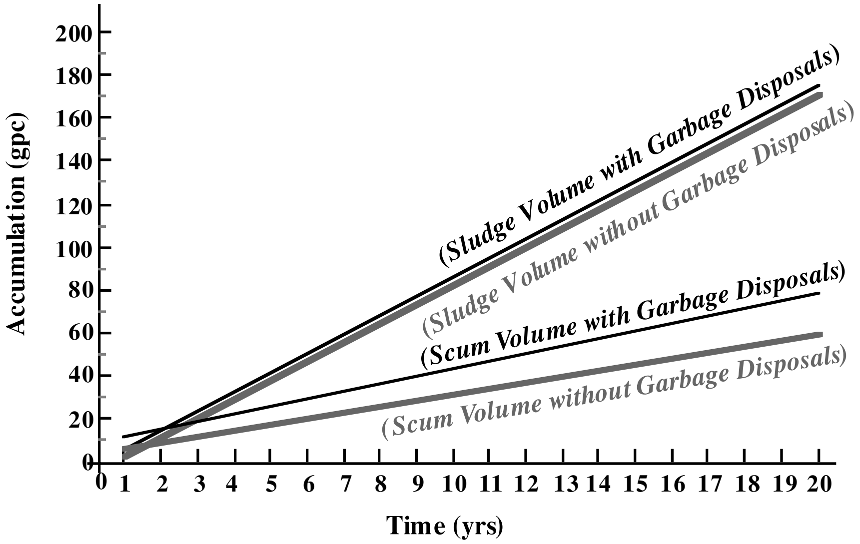

Figure 6: Accumulation rates for systems with garbage disposals and those without.

Montesano's Audit

In the fall of 1988, the community of Montesano, Washington began construction of a 1,125 unit septic tank effluent pumping system to replace a faulty gravity sewer. The Montesano system employed all fiberglass septic tanks and they developed a database system, similar to the one used at Glide, for establishing their monitoring and pumping schedules. In 1993, after monitoring 19% of their system, Montesano's engineers (Ollivant, 1993) found that they too experience similar septage accumulation rates and that their planned 10 year pump-out frequency was conservative by a factor of 2.5.

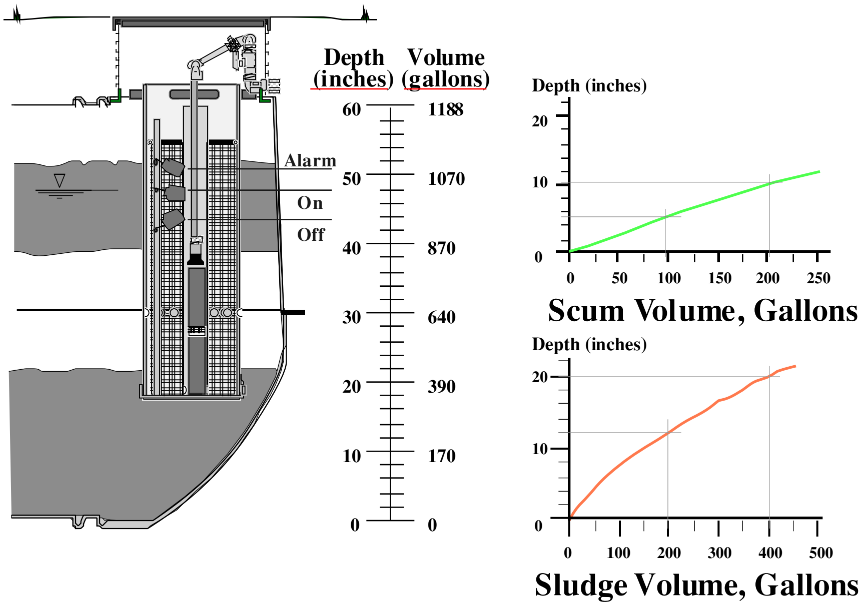

Figure 7: Sludge and Scum Depths in 1000 gallon Fiberglass Tanks, Montesano, Washington

Regardless of their expected pump-out intervals, the city monitors sludge and scum accumulation in each tank every 3 years; their schedule is staggered, so they monitor only about one-third of the tanks every year. Tanks are pumped according to the depth of accumulation of either sludge or scum as shown in 7.

By December of 1993 some 727 tanks had been monitored (Montesano, 1993). Over a period of 3 years the rate of septage accumulation, at a 95% level of confidence, is about 12.6 gpcyr (the average is about 5.7 gpcyr). Their pumping interval, base on the 95% confidence level, is about 13.6 years and is controlled by the rate of scum rather than the rate of sludge accumulation.

While the data from the Montesano system is still not long-term enough to be considered conclusive, preliminary measurements over the last few years indicate accumulation rates consistent with the US Public Health Service and Glide data.

Drainfield Protection

In managed systems, regular monitoring prevents the problems that can result from tanks that go too long without pumping. However, in unmanaged on-site systems, i.e. those systems not part of a district or under a maintenance contract, homeowners may fail to have septage removed in time to prevent solids carryover that can destroy the drainfield. The conservative response is often to recommend frequent septage removal, as often as every two or three years. But that may not allow sufficient time for a tank's microbes to optimize digestion. Philip et al. (1993) suggest that the reduction of sludge volume begins to be optimal only after 2.5 to 3 years, when accumulation of soluble metabolites increases microbial diversity which results in more thorough digestion. Septic tank effluent filters are probably a more efficacious means of protecting drainfields. Not only can filters cut in half the suspended solids discharged daily from the tank, models are available that provide an absolute barrier to solids leaving the tank, even when excessive scum and sludge have accumulated.

Septic Tank Capacities

The pump-out interval must be within a range that is affordable and provides adequate long-term solids retention for ensuring thorough digestion. Intervals that are too short not only retard digestion, but force users to pay significantly more for continuous service and pumping. The initial cost difference for a larger prefabricated tank is usually insignificant; especially when compared to the present–worth value of long-term maintenance.

A typical interval range is illustrated in 8; therefore, given an average wastewater flow of 50 gpcd, a single-family residential tank, for 4 or fewer occupants, should be 1000 gallons, and 1500 gallons for 5 to 7 occupants. These curves in 8 result from the following curve-a-linear relationship developed for total sludge and scum accumulation *(also refer to 5, <u>95 % confidence</u>, (Sludge & Scum)$_{Bounds,\ 95\%}$)*:

$$N_{sl+sc} = 47\ t^{0.675} \qquad (9)$$

where: N_{sl+sc} is the average volume of sludge and scum, in gallons/capita
t is the time in years

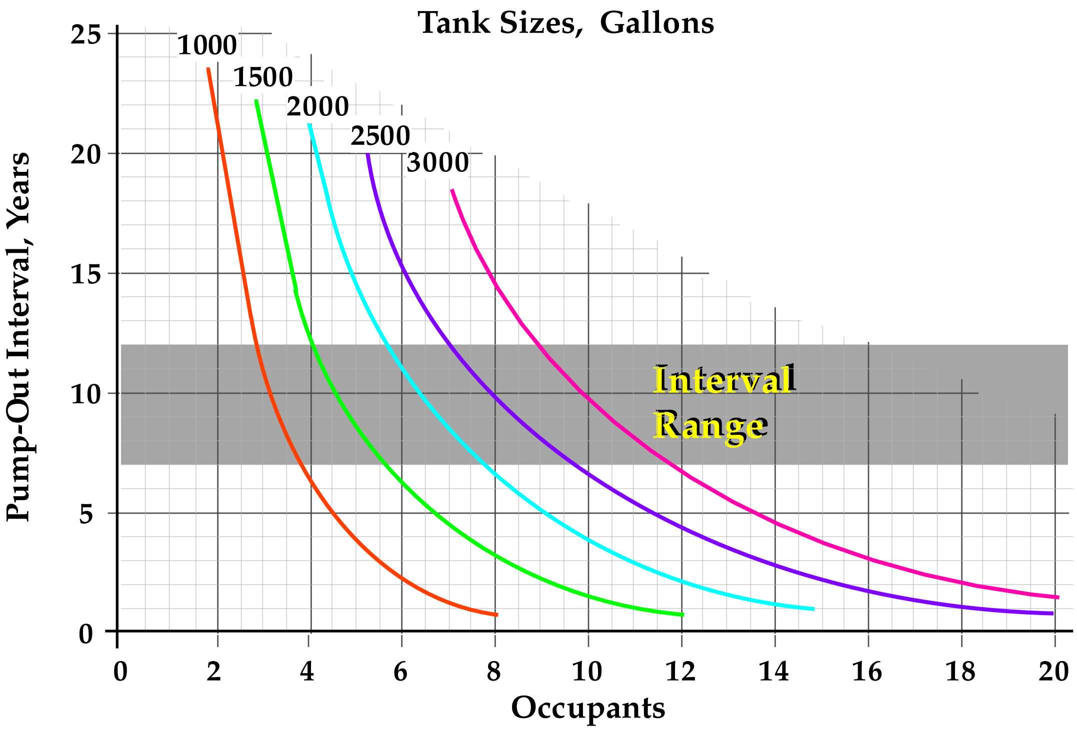

Figure 8: Pump-Out Intervals at 95% level of Confidence

Conclusion

In summary, predicting reasonable septic tank pumping intervals with a respectable degree of reliability is an achievable goal. Suggestions or requirements that all septic tanks must be pumped every two, three or even five years are simply unsupported by scientific evidence. The microbial activity that affects optimal decomposition takes up to three years to develop fully. In five years, considerably less than half of most tanks' scum and sludge capacity has been reached (Bounds$_1$, 1988). When a management program is in place, pump-outs are scheduled based on inspections and monitoring records so that costs are controlled. Onsite design manuals may encourage frequent pump-outs as a precautionary measure when an inspection program is not in effect; however, longer intervals are usually justified, particularly if an effluent screening device is in place. Adequately sized tanks ensure less frequent pump-outs. Septic tank systems may once have been considered a stopgap until such time as a “real” sewer could be built. As technology has improved the image of the septic tank, it has come to be appreciated as a effective, permanent solution. As such, it deserves to be accorded the same scientific consideration as other treatment systems.

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