SMALL-DIAMETER EFFLUENT SEWERAGE SYSTEMS

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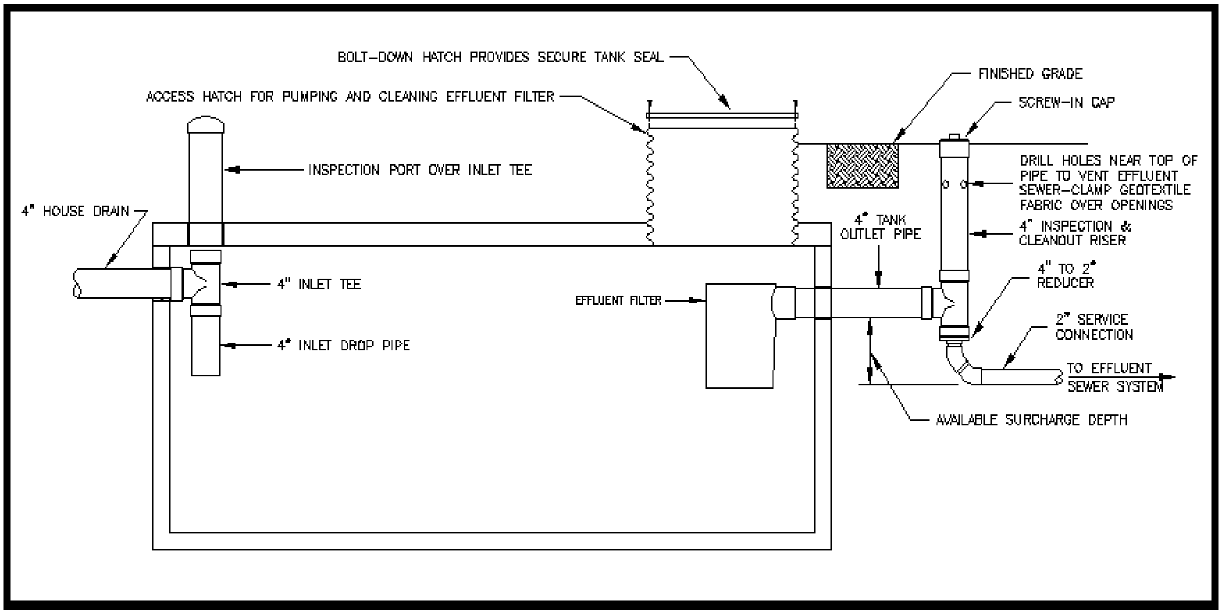
This document reviews the small-diameter effluent sewerage concept and offers recommendations for how to “best” implement and manage this form of collection system. A primary issue is the need to provide primary clarification at the site of wastewater generation, so this is the place to begin the discussion.

Effluent sewerage strategies employ interceptor tanks (primary septic tanks) at each source of wastewater generation to intercept solids, allowing the use of small-diameter effluent sewers in the collection systems. While many call to question whether, in a system of any significant overall size, this would create an untenable O&M liability, it can be argued that it offers a sludge management strategy that is actually less onerous than how it is typically handled at conventional centralized treatment plants. Installing interceptor tanks at the sources of flow offers the following advantages:

- These interceptor tanks are the major sludge handling system. Sludge separation and storage in septic tanks is a passive process, requiring no operator intervention until the tank is pumped.
- Sludge digestion in septic tanks is an anaerobic process, which—relative to aerobic sludge digestion typically employed at conventional treatment plants—greatly reduces the volume of solids to be eventually handled.
- Sludge from each tank only needs to be handled at very long intervals, as detailed below. Therefore, even though there would be many dispersed sources, sludge management logistics would not be untenable.
- Sludge handling is executed without taking any part of the system out of service. Each tank can be pumped in a very short amount of time, and the users can even load the system <u>while</u> it is being pumped.
- Sludge handling is executed in small increments—one or a few tanks at a time, depending on the capacity of the pumper truck. This allows maximum flexibility, and thus perhaps maximum cost efficiency, in planning for sludge handling.
- Timing of sludge removal is not critical because sludge builds up very slowly. Several months could pass between the time that sludge depth monitoring indicates pumping of a given tank should be executed and the time that pumping actually occurs without degrading the overall system in any meaningful way.
- Because timing of sludge removal is not critical, tank pumping could be scheduled when the biosolids could be readily used. This may eliminate the need for intermediate storage and handling facilities.
- Sludge from each generator is segregated, so it can be classified by source. Sludge from domestic sources rarely contains contaminants rendering the sludge unusable as a soil amendment, and the input to each tank is fairly "secure" against dumping of hazardous materials, unlike a conventional collection system with its very many unsecured access points (manholes). Being readily reusable, this sludge stream is a potential revenue source.
- Institutional arrangements for sludge handling are already in place. Existing septic tank pumpers could be contracted to pump the interceptor tanks.
- If found to be necessary or cost efficient, a local sludge handling process could be readily set up, requiring only a pumper truck and an area on which to landspread the sludge, or a composting area to “treat” the septage. However, these costs can probably be deferred for several years, until it is time for the first tank pumping.

Interceptor Tank Design for an Effluent Sewer System

A design of the interceptor tank for an effluent sewer system is shown in Figure 1. The tank shown is a reinforced concrete model, but other materials may also be considered. The major factor in considering tank materials and construction is that interceptor tanks <u>must</u> be watertight to preclude excessive flow through the system due to groundwater or stormwater intrusion. It is typically presumed that an interceptor tank would be installed to receive flow from each house. However, it may be practical in some cases to route two houses into each tank, thereby perhaps significantly decreasing total cost of the collection system. For non-residential flows, tanks of appropriate size for the generation rate at that source are employed, but should adhere to this general design.



INTERCEPTOR TANK DESIGN
FIGURE 1

Two features of this tank should be noted. One is the effluent filter. Experience has shown that effluent filters can considerably reduce the level of solids passing out of the septic tank. Thus, an effluent filter is inexpensive protection against needing to ever flush or "pig" an effluent sewer system, and it assures that a consistently lower strength, more highly clarified wastewater would be routed to the treatment/dispersal system.

While the effluent filter must be cleaned periodically, that is a very simple process, consisting of pulling the filter body out of the housing, hosing it off and reinserting it. To accommodate this cleaning, a readily accessible riser/hatch of the type shown in Figure 1 must be installed. Experience indicates that cleaning once a year would be a very conservative maintenance protocol. This can be readily executed at the same time that sludge depth is checked.

The other feature is the cleanout/"breather" assembly on the tank outlet. Interceptor tank outlets must all be above the hydraulic grade line of the effluent sewer. Installing this assembly at each tank outlet allows the sewer system to "breath" directly, without depending on the building plumbing to be properly vented. It also provides a cleanout for each house connection, and assures that the tank outlet is elevated several inches above the end of the house connection. This allows that depth of surcharge on the sewer line at the point where this house connection joins it without causing backflow into the septic tank. Effluent sewer systems can be designed to essentially eliminate the likelihood of surcharging the sewer line at all, so this feature provides a "safety factor" for the system.

Interceptor Tank Pumping Frequency

As it does for all septic tanks, required pumping intervals for these interceptor septic tanks will depend upon the habits of the users. However, a general idea can be provided by applying an equation based on studies by the U.S. Public Health Service and others. The equation defines the rate of sludge buildup as follows:

$$R_{sl} = 8.15\,t + 38.82$$

where t is time between pumpings in years and R_{sl} is sludge accumulation in gallons per capita. The recommended criterion for pumping is when sludge level rises to within 6 inches of the effluent filter inlet. Based upon one model of 1,000-gallon septic tank, which has a plan area of 47.1 sq. ft. and an allowable sludge depth of 17 inches, the resulting maximum storage is 66.7 cu. ft., or about 500 gallons. Assuming an occupancy of 4 persons, allowable sludge accumulation is 125 gallons/capita. Substituting this for R_{sl} and solving for t yields a pumping interval of 10.6 years. This example indicates that pumping intervals of several years should be routinely expected. The actual interval depends on the sizing criteria for interceptor tanks and, as noted, on habits of the users of each tank. In any case, sludge depth would be monitored periodically and each tank would be pumped only when actually needed.

Effluent Sewer Concepts

Effluent sewers convey interceptor tank effluent from the tank to further treatment or to a remote dispersal field. General advantages of effluent sewers relative to conventional "big pipe" sewers include:

- Because they carry only liquid effluent, effluent sewers can employ small-diameter pipes and can be very flexibly routed. Varying, non-uniform grades can be used—even locally negative gradients are allowed—so construction is somewhat less exacting.
- Small-diameter pipes can be flexed, so that curvilinear routing can be used, further enhancing routing flexibility.
- No minimum flow velocity needs to be maintained to prevent solids deposition, so gravity effluent sewer lines can be laid on significantly smaller grades than conventional mains.
- Because routing is so flexible and very small grades can typically be used, burial depth is generally shallow.
- The small pipes and shallow burial allow installation in a very narrow construction corridor. This allows effluent sewers to be more easily fit into the built environment.
- Shallow, narrow trenches obviate expensive trench safety requirements—as workers do not enter the trench—and minimize the need to dewater trenches.
- The small pipes are joined with "tight" joints, and cleanouts instead of manholes are used to access the system if cleaning is needed. Therefore, infiltration/inflow is typically not a problem in an effluent sewer system.
- The smaller pipes, shallower burial, narrower construction corridor, more flexible routing, and lack of manholes allow effluent sewers to be installed at lower cost than conventional mains.
- Because effluent sewers can run at very small grades, gravity flow can be maintained for a longer distance relative to conventional mains without requiring deep trenches. This can allow some or all lift stations to be eliminated in some circumstances.

- Where grades are unfavorable, septic tank effluent pump (STEP) systems can be used, with a pump station at each interceptor tank, or a collective pump station for a group of tanks. Pumps need be used only where grades require it, utilizing gravity flow in the rest of the system.

There are three basic types of effluent sewer system:

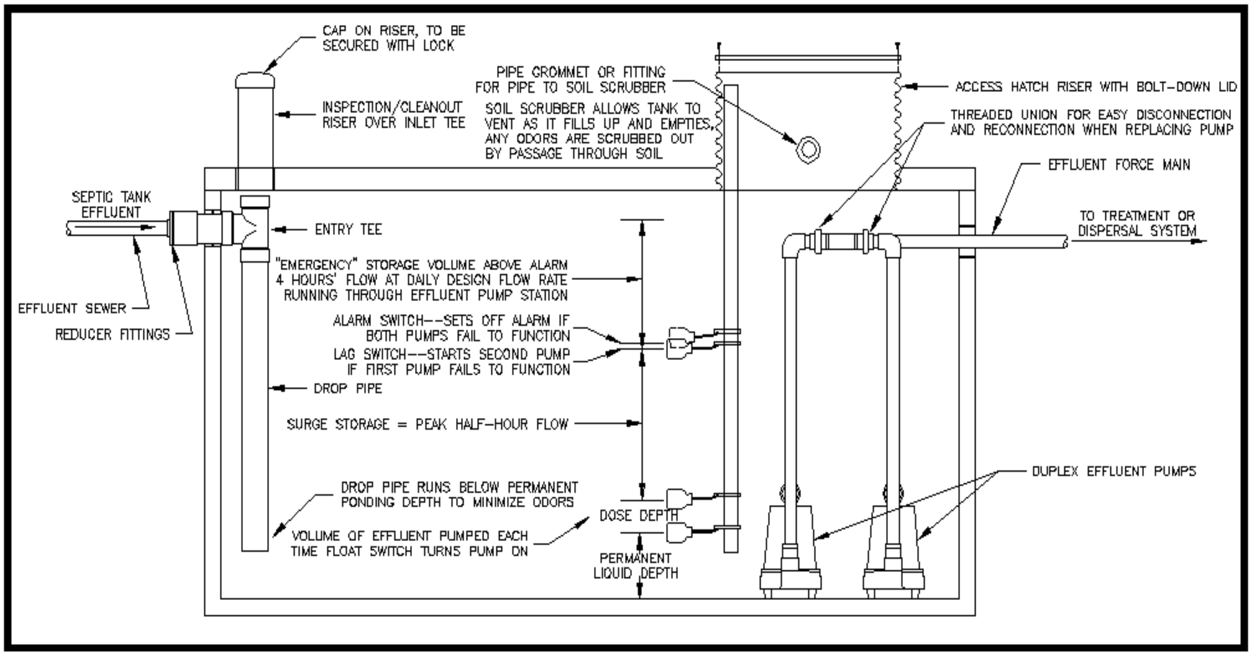
- Variable-grade effluent sewers (VGES). In this concept, sewer lines run with the lay of the land, so there may be locally adverse grades, creating isolated low points and high points. The pipe system works like a sink trap through the low sections. The system is designed to assure that the hydraulic grade line is below all interceptor tank outlets, taking care that any connections which enter the sewer along these low-point sections are not surcharged to such an elevation that wastewater would flow back into the interceptor tank. This is done by increasing pipe sizes as required to lower the hydraulic grade line. Air release systems must be provided for isolated high points to prevent "air lock". To prevent odor problems, these should feed into a soil scrubber.
- Minimum grade effluent sewers (MGES). In this concept, sewer lines generally run constantly downhill, but, with no solids to transport, no set minimum velocity must be maintained. Maintaining a continuously uniform grade is not critical—even some flat sections could be allowed as long as allowance is made for some surcharging (as would be provided "automatically" by the proposed septic tank outlet piping shown in Figure 1), so the line is much easier to lay than conventional gravity sewers. Again, all septic tank outlets must be above the hydraulic grade line. Since there are no high points or low points, air release valves and odor scrubbing systems are not required and potential for solids deposition is minimized.
- Septic tank effluent pump (STEP) sewers. Again sewer lines run with the lay of the land in this concept. This type of system is used when interceptor tank outlets are below the hydraulic grade line, so a pump is required to move effluent through the sewers. Since wastewater is pumped, line grade is irrelevant, making STEP sewers very easy to lay. The system may be designed with a pump tank at the outlet of each interceptor tank, or flow from several tanks may be routed through effluent gravity sewers to a collective pump tank. Pump size and pumping frequency are based on the daily flow rate through the pump tank and the total dynamic head against which it is pumped. This is determined by the flow rate, the length and size of pressure sewer, and elevation difference between the tank and the outlet.

The VGES and MGES concepts are collectively referred to as STEG (septic tank effluent gravity) systems. Wherever practical, MGES sewers should be employed exclusively, eliminating the complications imposed by the local high points allowed in the VGES concept.

Effluent Pump Stations

Where pumping is required in the collection system, generally the most cost efficient system would route effluent from several interceptor tanks through STEG sewers into a collective STEP tank—an effluent pump station. This moves the pump system off the lot and into an easement. It also allows the reliability of duplex pumps to be cost efficiently realized, and the pumps would be powered through a dedicated service drop for the effluent pump station instead of through house wiring. All this imparts greatest reliability and control by the wastewater management entity.

A typical design for an effluent pump station is shown in Figure 2. Larger scale collective management strategies might employ this "STEG/STEP" sewer system to accommodate any pumping found to be necessary in the collection system.



TYPICAL EFFLUENT PUMP STATION
FIGURE 2

Note in Figure 2 an allowance for surge storage. In a large system, more than one effluent pump station might feed into a pressure sewer line. If more than one pump were to come on at once, the higher flow rate would increase friction head losses and thus decrease the flow rate produced by each pump. In the worst case, if several pumps were to come on at once, one or more pumps might “deadhead” until other pumps turned off. To accommodate the potential for this situation, the practice is to design all effluent pump stations with an equalization volume (surge storage) equal to the flow expected in a specified time interval at the peak hour flow rate. This is in addition to the “emergency” storage volume above the alarm that would signal simultaneous failure of both pumps in the duplex pump system. Whether or not simultaneous pump operation may be an issue in a given system, this equalization volume also provides additional storage for times when power outages occur, so is recommended in any case.

Effluent Sewer Pipe Sizing

Effluent gravity sewer capacity is determined using the Hazen-Williams or Manning equation, with the latter generally found to be more conservative. The Manning equation can be used to calculate flow capacity as follows:

$$Q = VA = A(1.486/n)R^{2/3}S^{1/2}$$

where,
Q = flow rate (cfs)
V = flow velocity (ft/sec)
A = pipe cross-sectional area (sq. ft.)
n = Manning coefficient of roughness (dimensionless)
R = pipe hydraulic radius [diameter/4] (ft), and
S = pipe slope (ft/ft).

Design guidelines for small-diameter effluent gravity sewers suggest assuming a design flow rate of 0.6 gpm per connection. For larger generators, this criterion would be multiplied by the number of equivalent residential units represented by the flow source. Pipe sizing calculations would be performed for each segment of pipe in the effluent sewer system, based upon the number of connections that each carries and the slope available in that run, which is typically equal to the ground slope, so that trench depth is fairly uniform.

As an example, consider a segment that required a very low slope—presume 0.25%, essentially "flat", so it could traverse a considerable distance of flat ground without requiring deep burial by the end of the run. Performing the calculations using the actual I.D. of Sch. 40 pipe and an *n*-value of 0.013, it is seen that a 2" pipe can carry about 0.016 cfs, or about 7.3 gpm, accommodating about 12 houses. A 3" pipe can carry about 0.047 cfs, or about 21.1 gpm, accommodating about 35 houses. A spreadsheet chart can be readily created showing capacity vs. available slope as an easy to use design tool for effluent gravity sewers.

Note that these capacities assume open-channel flow. Capacity would increase if the line were surcharged. Some surcharging would be allowable using the cleanout/"breather" arrangement shown in Figure 1 without creating a backup into an interceptor tank. While the topography in a given situation may allow most effluent sewer runs to be 2" or 3" pipe, based on the size requirement obtained from these calculations, it remains to be determined what minimum size might be allowed by the state regulatory system, since existing rules do not typically address effluent sewer technology.

[to be continued …]
This paper will be expanded to further review design of effluent sewer systems and components.