The “Secret” Life of Pressure Sewers

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Abstract

The paper will include background of pressure sewer technology, applications that are commonplace with some example case studies, along with several little known applications that are presently “secrets” to the average practitioner. These less well known applications could be a literal “gold mine” of ideas to developers, regulators and engineers.

1.0 Introduction

1.1 History of Pressure Sewers

- ASCE sponsored project (mid 60’s) inspired by Professor Gordon M. Fair of the Harvard School of Public Health (Fair 1968)
- Development (1963-6) at General Electric of world’s first prototype grinder pump Field test of first pressure sewer system (1969-70) by Environment One Corp. in cooperation with NYDEC and the US EPA (Carcich 1972)
- Introduction of first commercial grinder pump at WEF (then WPCF) Annual Conference in Boston, 1969
- Other EPA-sponsored demonstration projects (early 70’s) in Pennsylvania (Mekosh 1973), Oregon (Eblen 1978) and Indiana (Sanson 1973)
- Earliest projects approved by state regulatory agencies (1970-72) in Indiana, New York, Ohio, Texas, Virginia
- Federal Construction grant eligible (c. 1970’s) as an Alternative Technology
- Adopted (early 1980’s) into “Ten States Standards” as well as most individual state guidelines
- Considered by most progressive consulting engineers (by middle 1980’s) to be a routine solution to certain design situations
- Currently (late 90’s) in general use throughout the U.S., Canada, Scandinavia, and being introduced into Australia and Japan

2.0 Well-Known Applications for Pressure Sewers

2.1 Failing Septic Tanks in Existing Subdivisions

The biggest building boom in American history began immediately following the second World War. This boom, epitomized by William Levitt at his Levittowns on Long Island and in southeastern Pennsylvania, provided a first home to millions of homecoming GI’s. Many of these subdivisions in all parts of America were carved out of raw land adjacent to existing cities and towns. Most provided only streets, electricity and telephones. Such niceties as curbs and gutters, street lights, fire protection, and especially public sewers and water supply were notable by their absence. Into this breach was thrown an old technology, developed early in the 20th century by agricultural engineers for use on the farm; namely, septic tanks and soil absorption systems. Out in the country land was abundant. So long as the well was prudently located up hill and on the other side of the house there was no problem. A little odor or a soft spot in the middle of a field far from habitation was no cause for concern. Limited use of such septic systems had also been made in some city neighborhoods with large lots, prime soil conditions and careful operation (limited loading and frequent pump outs). In retrospect, septic tanks when brought to town were a very poor choice on these small "postage stamp sized" lots. Nonetheless, in the rush to provide critically needed homes, millions of septic tanks were built.

By the late 50's the Public Health Service, who were conducting on behalf of FHA serious studies in the field and in labs at the Taft Sanitary Engineering Center, reported that over 24 million septic systems were in service. Further that they were failing on average in 11 years — far less than the twenty or thirty year term of the typical VA or FHA mortgage loan. These same USPHS studies showed that over 50 percent of the available building land in the U. S. was unsuitable for septic tank systems (Coulter 1957 and Bendixen 1951). Despite these facts, and because of continuing tremendous pressure from the public and the home building and real estate industries, several million more septic tanks were installed. Even today the stock is growing, albeit at a drastically lower rate. The sad fact that failing septic tanks are a ubiquitous feature of many, many American suburbs today makes it clear that they have been grossly misused.

Happily, there are several alternative solutions to this need for affordable, dependable, safe sewers in the places where Americans live. One of the most successful and widely used systems is ***pressure sewers powered by grinder pumps.*** Most public health officials, developers, consulting engineers, contractors, and public works personnel have had at least some experience with pressure sewers during the thirty years since their introduction. Hundreds of thousands of homes that once suffered from marshy, odorous children's play yards, lake water quality degradation, and even hepatitis and E-coli epidemics caused by septic tank failures are today the proud owners of successful grinder pump pressure sewer systems. These are in everyday use in subdivisions or other neighborhoods all over the country.

2.2 New Developments with Slow Rate of Buildout

In the typical "second home" community all the lots are platted, roads built, and some community facilities put up initially in order to begin selling lots. This represents a large "up front" investment at the start of the project. Since only a few houses are actually built and occupied each year, resulting in a proportionally small revenue stream, the "up front" cost of gravity sewers is often prohibitive. On the other hand, if pressure sewers and grinder pumps are chosen, all of the small diameter shallow buried pressure piping system can be installed initially at very low cost per foot. The ***grinder pumps***, which comprise the majority of capital cost, ***need be bought and installed only as each house is built***. This is especially critical in providing affordable sewers initially to the first few houses — often scattered throughout a large tract far from their nearest neighbor.

2.3 Projects with Wide Lots and Consequent High Cost per Dwelling Unit
The cost difference between gravity and pressure sanitary sewers is a function of the pipe size, depth, and the necessity to "survey" gravity sewers into the ground. Once installed, it becomes necessary to maintain this precise grade throughout the working life of a gravity sewer. Pressure sewer pipes, besides being smaller and shallower, need not be laid on a precise grade, but can indeed often go over hill and dale at a nominally constant shallow depth dictated by the local frost penetration depth or, in very mild climates, by the need for protection from mechanical damage. Since these costs are assessed to benefited properties on a dollars per front foot basis, the cost advantage for pressure sewers increases rapidly as lots become wider.

2.4 Difficult Terrain such as Undulating and Very Steep
In steep terrain, especially on up hill runs, gravity sewers very quickly become too deep to be feasible. The only answer is to put at least one pumping station on each significant uphill reach. Gravity can usually be used on the downhill sections, but the capacity of pump stations become successively larger as the piping progresses toward the ultimate discharge point. Pressure sewers can be designed to work successfully in either situation. A useful analogy to water system hydraulics can be drawn which shows that appropriate attention must be paid to the need for air and vacuum release valves at significant high points in the profile, as well as at the beginning of long downhill runs discharging to atmosphere. The ability to construct sewers that follow hill and dale not only makes development affordable, but has also preserved natural rolling topography and trees. Examples include Clifton Country Knolls, New York, and Avalon near Lenoir City, Tennessee.

2.5 Rocky soil conditions Rock can be one of the most costly and difficult factors in construction. In the case of gravity sewers with their wide trenches, excavated to precise grade and alignment, and going inexorably deeper with each foot of length, the price per foot can easily becomes orders of magnitude greater than in normal soil. Bid prices as high as $500 per running foot have been submitted for 10" gravity sewers in solid rock. In most cases, however, contractors decline to bid altogether, or submit only on alternatives such as pressure, vacuum or STEP systems. The fact that these alternatives require dramatically narrower and shallower trenches makes them feasible in places like ***solid rock*** where ***gravity*** is ***literally impossible***.

2.6 High Groundwater Levels
Locations with high groundwater, whether seasonal or year round, present other challenges in both construction and operation of gravity sewers. During construction, the work site must be de-watered by generous use of pumps and well points distributed along the proposed trench route, and powered 24 hours a day. Such de-watered soil can be very unstable and potentially dangerous to work in. Therefore continuous shoring and bracing are usually required. Even if these obstacles are overcome by expenditure of much money, care and effort, there remains the necessity to successfully operate the completed gravity sewer for the next 40 or 50 years. Consider that once the de-watering pumps are shut down and the ground water returns the sewer must operate in what is tantamount to a submerged condition — this without causing infiltration and or inflow, both notorious enemies of overall water quality goals.

2.7 Lakeside or Oceanfront Properties
One of the most desirable properties, sought out by millions and millions of humans around the world, is “a place beside the water.” It doesn’t really matter if it’s a pond, a creek, a lake or reservoir, river front, an estuary or an ocean. People will do almost anything to live on the water. The topographical features which create these precious water bodies are dominated by the fact that ***the land*** almost always ***slopes down toward the shore***. So, when these millions and millions of humans use the sanitary fixtures in their waterfront property, where does the wastewater naturally try to go? YES! — (we all know) — down to or toward the waterfront. It is very expensive, environmentally damaging, and seldom entirely satisfactory to put gravity sewers in such waterfront locations.

Since they must be down slope from the houses, they cause the disturbance, degradation and sometimes destruction of the most important feature of waterfront properties; namely, the “front yards” facing the shore. In some cases land is so precious and the demand so great that tiny cabins are crowded against each other, and literally pressed down as close as they dare to the water. Ever hear of a camp up on stilts and literally hanging out over the water? Of course you have! Not altogether a choice place for gravity sewers and, obviously, not very desirable for good septic tank operation either. The pressure sewer has been a real hero in these waterfront situations, because it takes the wastewater ***uphill and away*** from the beautiful water body that everyone loves and wants to protect for future generations. Examples of highly successful waterfront projects abound. A few might include: Puget Sound, Washington (Mayhew 1999); Weatherby Lake, Missouri (Gray 1975); Lake Worth, Texas (Head 1998); three towns on Oneida Lake, New York (Wetsel 1995); Fairfield Glade, Tennessee (Gray 1991); Quaker Lake, Pennsylvania (Milnes 1978); and Groton, Connecticut (Almquist 1991).

2.8 Lots on the “Wrong Side” - Sewer must go under a Stream or Highway
Sometimes, property is developed in a strip all along one side of a highway, road or stream. Often there are highly desirable, perhaps isolated, building lots on the

“wrong side of the street.” Until pressure sewers came along, these choice lots were listed as “unbuildable” and might be ignored for decades with a casual, “That’s too bad.” Pressure sewers bored under the stream or highway using a trenchless technology (see sect. 3.1 below) or carried overhead on a bridge crossing make such difficult sites easily accessible to whatever sewers already serve the strip community.

2.9 Very Low Basements such as Houses at End of Existing Gravity Sewer
It is always desirable, and sometimes absolutely mandatory that public sewers be deep enough to serve fixtures at, or just under, the basement floor level. It often happens that when a gravity sewer is designed to serve a certain area, the basements of houses at the ends of the served streets end up just level with the sewer. If such streets are later extended “further out into the country,” the new houses will be too low to have basement sewer connections. The answer is to put grinder pumps in or next to these basements and create a pressure sewer district that can pump into the nearest gravity pipe or pumping station with available capacity for the additional flow.

3.0 Little Known Applications for Pressure Sewers

3.0 Flat Land
Contrary to common knowledge, flat land is not necessarily an easy or inexpensive place to sewer. There is no doubt that in conventional gravity sewer construction, shallow trenches are the least expensive, but all flat land trenches are not necessarily shallow. In fact the only way that sewers in perfectly flat terrain can be kept shallow is by the frequent use of lift stations. The profile of such a sewer can accurately be likened to a saw tooth, more specifically a rip saw, with long down ramps (gravity runs) interrupted by nearly vertical sections (lift stations). Considering that much flat land is coastal — such as in Florida — the water table tends to be high and unless gravity sewers are kept above the normal water table, the problems of underwater construction plus a permanent threat of infiltration can be enormous. On the other hand, pressure sewers are, both by definition and in practice, water tight and virtually leak free. They need never go deeper than the maximum frost penetration depth. In our example of Florida, where there is no frost penetration, the pressure sewers need be only 18” to 24” deep — whatever is required to protect them from mechanical damage.

3.1 Applications of “Trenchless” Technology During the past decade a whole new industry described broadly as Trenchless Technology has come into being. Like most new ideas, it takes a long time and lots of field experience for a new technology to find its niche. In the process, there are bound to be some unfortunate misapplications through honest lack of knowledge or over-eager selling. Even one such bad application gives any new technology a “black eye” that must be overcome by perhaps a dozen “success stories.” Each setback slows down the time for eventual recognition and general adoption of something which may be really worthwhile if not truly revolutionary. Consider how many people need to learn about a new development before it becomes commonplace. How many seminars, ads, demonstrations, conference papers, magazine articles, and recommendations of colleagues does it take to convince us we should “try something new”?

In the author’s opinion, that describes the situation today with Trenchless Technology. It has been through its growing pains, many variations exist, and there is a sizeable body of success stories waiting to be heard. In other words, proven trenchless methods exist which are the answer to many supposedly “unanswerable questions,” like, “How can I lay a pipeline through established residential properties with no damage to flower gardens, shrubs, hundred year old trees, tennis courts, patios and you name it?” Such a capability not only makes quick work of installing pressure sewers, but has found useful application in most other utilities including water, gas, electric, TV and optical cable. Trenchless methods were used to install pressure sewers on the historic 17th-century palace grounds at Drottningholm, Sweden, nearly a decade ago (Environment One 1988).

3.2 Indoor Installations

As strange as it sounds to us today, when flush toilets were first invented, they were installed in the outhouse (Ierley 1999). Now more than a century later, the flush toilet and other convenient water using fixtures are firmly ensconced as not only necessities, but beautiful adjuncts to the modern American home. However, we still seem to have a residual mental block from those days, which whispers, “anything to do with sewage goes out in the yard.” Too bad, because grinder pumps, properly designed for the purpose, are much more appropriately located in the basement than outside. Consider the modern, proven, grinder pump was designed as a major appliance, safe, quiet, and unobtrusive in appearance. It has been repeatedly tested and approved by Underwriters Laboratories (UL) as free from fire and electrical hazards; and certified by the National Sanitation Foundation (NSF), co-sponsors of this Conference, for compliance with applicable plumbing and health requirements.

The ***advantages of indoor installation of grinder pumps*** include all of the following:

- easier to install since deep excavation is not needed — this not only saves money, but avoids need for huge excavating machinery in the yard
- safer because the “attractive nuisance” of a deep hole out in the yard is eliminated. On some models, the lid can be removed by taking out two or three bolts, exposing an open shaft through which a curious child could tumble down into raw sewage.
- protected from the weather and vandalism
- much easier and safer to service in all kinds of weather, but particularly in winter when even finding the pump outside can be a real challenge

- interior drain, waste, vent piping can be routed directly to the pump inlet all inside the building reduces the pump cost because no extension tube or access way to the surface is used
- reduces engineering and installation costs since there is no need to site the pump at a specific place in the yard; no conduit or weather-tight boxes, nor any frantic, last minute, cries for a longer or shorter access way

3.3 Elimination of Infiltration/Inflow

Pressure sewers are constructed of pressure pipe and leak tested to the same AWWA standards used for potable water supply; thus, they are, for all practical purposes, watertight. This eliminates most infiltration problems so characteristic of old gravity sewers. Since there are no elements corresponding to access manholes, the inflow from street runoff is also virtually eliminated. In a pressure sewer system, the only element potentially vulnerable to I/I problems is the gravity house sewer connection to the grinder pump inlet. If indoors, as in section 3.2 above, there is none!! Since this is usually constructed using modern PVC pipe with solvent welded joints and is often a single length of 4" pipe, there is little chance for the massive joint infiltration that was commonplace when two foot sections of clay pipe with bell and spigot joints were used. New collection systems consisting entirely of pressure lines fed by grinder pumps have been shown to be entirely free of extraneous water flows. It has also been well documented that the per capita contribution falls in the range of 30 to 70 gal/cap/day if infiltration and/or inflow is rigorously excluded. This has profound and obviously desirable effects on treatment plant capacity, cost and performance. One classic instance of this has been documented in a paper by Lynn Palmer (Palmer 1993). The towns of Sharpsburg and Keedysville, Maryland, include the site of the historic civil war battle of Antietam Creek. A new completely pressure collection system with individual grinder pumps serving each house was constructed about ten years ago. This system, including nearly ten miles of pressure house laterals and an equal length of main line, plus several more miles of force main, transports the wastewater to a new secondary plant using an oxidation ditch. Flow measuring and recording instrumentation enabled plant personnel to obtain and analyze daily flow data, per capita contribution and the effects of separately recorded rainfall events. There was shown to be ***absolutely no correlation between*** recorded ***plant flow and major rainfall events*** in the same watershed.

3.4 Suitable Soil Uphill or Far Away

It is sometimes necessary for an isolated single home to provide its own plan for pollution free wastewater disposal. Suppose a house is beautifully sited on a desirable lot that slopes down to a waterfront vista, boat dock or beach. Many reasons suggest the desirability of locating a septic tank, and certainly its absorption field, up and away from the waterfront. In fact the only justification for going down slope is that ***gravity leads nowhere else***. If the gravity-only constraint is thrown off (by adopting the use of a grinder pump), the possibilities open up to a near smorgasbord of desirable ideas.

If there is a public sewer up the driveway along the main road, it can be reached at distances of up to two miles, or at elevations higher by over a hundred feet. If there is a place with suitable soil for the absorption field (positive results on the 'perc test'), it can be far away and at a greatly higher elevation. This will undoubtedly mean the source of any potential leaching is sited farther and farther away from the waterfront. With sufficient separation, the likelihood of lake contamination can virtually be eliminated. These possibilities can often be made more feasible by cooperation with one or more neighbors into a quasi homeowners association in which some of the same techniques are applied to your little private self-help pressure sewer system. This can be an excellent stopgap measure, far better than doing nothing while waiting expectantly for something to happen at a larger municipal or district level.

4.0 Conclusions

- Pressure sewers using grinder pumps were first adopted early in the 1970's by a few visionary engineers and regulatory agencies who, faced with the virtually insurmountable problems posed by the helter-skelter adoption of septic tanks in the suburbs, felt that the potential gains justified the risk of being a pioneer.
- It has taken three decades, corresponding to nearly 60% of this author's working life, for pressure sewers to begin to take their proper place within the public health engineering field. For indeed today there are hundreds of thousands of grinder pumps in routine daily operation in projects ranging in size from a single pump to many with thousands of pumps. The skeptics have been pleasantly surprised as decades of operating experience pile up with O&M costs equal to or less than original estimates.
- Even with general adoption in every state and a new generation of consulting engineers who don't even remember when there weren't pressure sewers, there are still a few applications and variations which are not generally considered. These include more general application of trenchless technology, indoor installations, use as a weapon in the fight against infiltration and inflow, application in flat land, and as an excellent stop gap measure to fight waterfront pollution one house at a time by re-siting absorption fields ***"up, up and away!"*** from the water's edge.

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