FLUTe™ Flexible Liner Underground Technologies, LLC

Vertical Wells Under Landfills and Buildings

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Purpose

This short paper is a description of the installation of Water FLUTe systems beneath landfills and buildings for monitoring purposes. This particular technique requires that the horizontal passages be constructed prior to the construction of the building or landfill above the monitoring wells. This technique is only especially useful if the passages are sufficiently long to prohibit the installation of pumping or head measurement systems by other means and the advantages of the Water FLUTe design are not preferred. However, for low flow formations, this is expected to be the preferred method.

The Water FLUTe design

Figure 1 shows a horizontal passage with a Water FLUTe system in place. The horizontal portion is a pipe of 4 inches or more in diameter and the vertical well portion can be cased or uncased as the situation requires. If cased, the vertical casing contains screens at several elevations for sample collection. However, the annulus between the casing and hole wall must be sealed between the screened intervals much like an ordinary cased screened well.

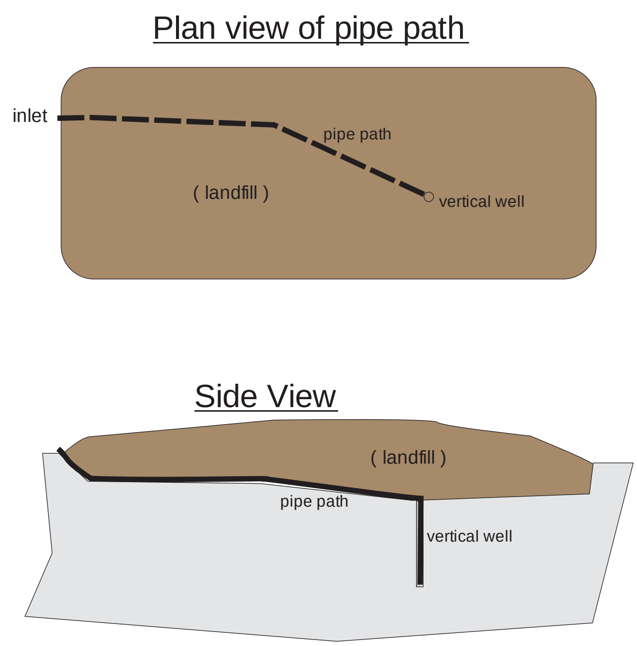


Fig. 1. Typical path beneath landfill/building

The FLUTe installation has several advantages:

1. The liner can be installed by propagation of the liner by eversion through the horizontal or sloped sections and through various turns in sweep elbows.
2. The liner contains all of the water in the well volume inside the liner, so that water does not need to be purged.
3. The sampling system can fill very slowly into the PVDF tubing system without concern of loss of contaminants or aeration as is the case for a slowly filling open casing or other kinds of tubing (e.g., LDPE).
4. The system is removable for repair or replacement.
5. The system allows sample collection and head measurements at several elevations in an open borehole while the entire hole is sealed by the liner.
6. Vadose pore gas sampling intervals can be included in the Water FLUTe system.

This basic design has been installed in numerous wells beneath a Lowe's hardware store in NJ to allow sampling and water table measurements in preexisting wells. Multi-level sampling has not been done beneath buildings or landfills, but is well within the capability of the FLUTe systems. All vertical installations of Water FLUTe systems include multi-level sampling intervals.

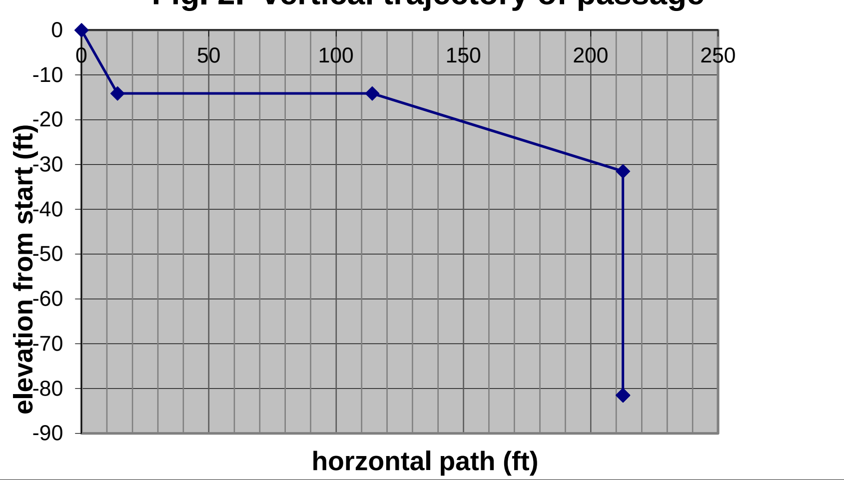
There are certain issues associated with this kind of installation. They are:

1. Is the driving head in the liner sufficient for propagating through the horizontal, sloped and vertical sections of the path (e.g., how many turns are allowed)?
2. How is the air trapped ahead of the everting liner to be removed so as to not stop the liner propagation?
3. How is the water beneath the liner to be removed if the flow in the formation is too slow to allow it to be displaced by the liner.
4. How can the head at each elevation be measured if one can not simply lower an electric water level meter down the pump tube as in the usual Water FLUTe installation?
5. How does one address the situation of extremely slow recharge rates from the formation?
6. Will the sampling system components withstand the contamination expected?
7. Will the liner be degraded by the leachate that may be encountered? If so, what is the recourse for liner damage?
8. What are the disadvantages of vadose sampling intervals or water sampling intervals in the horizontal sections of the piping?
9. Will the piping be strong enough to withstand the landfill load?

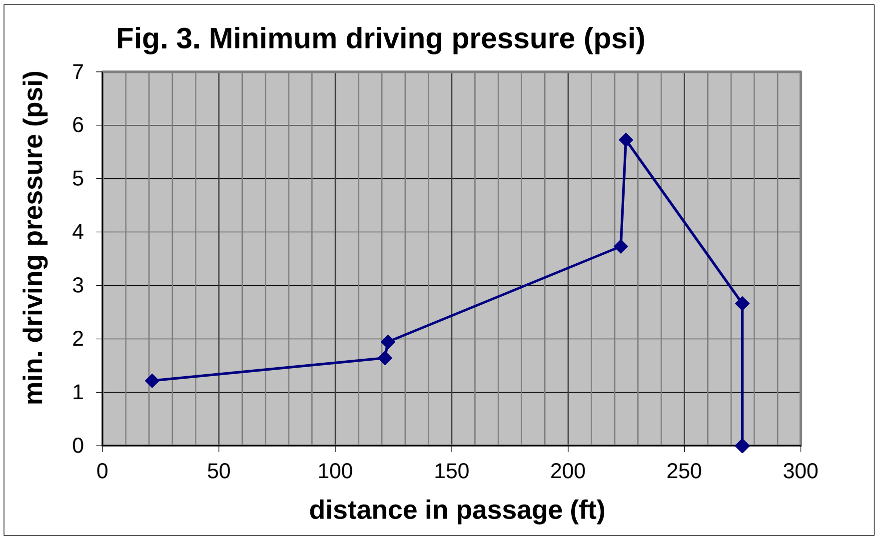
These questions are addressed hereafter.

The pipe trajectory of Fig. 1 was calculated with a FLUTe model which predicts the driving head/pressure needed to drive a liner into place through a tortuous passage made up of straight sections and elbows. The trajectory defined for this calculation was a section of 20 ft at 45 degrees downward, then horizontal for 100ft, a 45 degree turn to the right, sloped downward at 10 degrees for 100 ft, then turning into a vertical well for 50 ft. The path is shown in side view in Figure 2.

Fig. 2. vertical trajectory of passage



The driving pressure required as a function of length along the pipe is shown in Fig. 3. At each turn, the friction increases abruptly. In the downward slope, gravity eases the driving pressure needed. The conditions of this calculation were: Tubing bundle weight of 1 lb/ft, a friction coefficient of 0.3, a liner length of 270 ft with liner friction coefficient of 0.3, liner weight of 0.2 lb/ft. and minimum eversion pressure of 0.5 psi. The liner is 6 inches in diameter. If the liner and piping was of only 4 inch diameter, the peak driving pressure would be 12.2 psi instead of 5.7 psi at 223 ft. This model can address any passage of various pipe diameters, lengths, angles of turn, and upward or downward slope. It accounts for the varying fraction of the tubing bundle in the borehole with the liner propagation. The model includes friction, gravity, and drag in each turn. Tubing buoyancy is also included, but not tubing stiffness effect on drag. In that respect, this is a minimum driving pressure. Temperature can have a significant effect on the tubing stiffness.



Regarding the issues listed, the first is addressed by the model just described. It may be necessary to erect a scaffold at the entrance to provide sufficient driving pressure for the liner installation. The use of warm water can reduce the effect of liner and tubing stiffness in cold weather.

The second issue, air or water trapped ahead of the liner requires a tube to be emplaced with the liner, or prior to the liner installation, to remove any air or water trapped ahead of the liner. That is part of the liner design.

The water table at each port can be obtained in several ways: 1) if the water table is less than 20 ft below the liner wellhead, a well measured vacuum can be applied to each sampling tube to bring the water to the surface, allowing a calculation of the water table depth. 2) Otherwise, a transducer can be emplaced in the system for each port to measure the head at each port. There are several pressure measurement designs available including the FLUTe ACT system. 3) A third less precise method is to use the known tubing geometry for a calculation of the water table from the volume of sample water produced with a stroke of the pump system.

Extremely slow recharge rates are less concern in the Water FLUTe system because the tubing is all polyvinyldene fluoride (PVDF) which has a very low reactivity with the sample water. It is similar to PTFE (Teflon). If desired, the hardware of the sampling system can be stainless steel instead of the standard brass, Teflon and stainless steel. It is not uncommon to wait a day between the purging of the system and the sample collection.

It is not known what the leachate may contain, so it is not possible to assess the potential damage to the liner. If that is a concern, the liner can be cast full of a grout so that destruction of the thin liner is not a concern. However, there can be pH effects of a grout filled liner, albeit probably less than a grouted casing with grout in the formation.

Vadose gas sampling ports can be included in the liner system. However, it should be considered whether those screened intervals in the casing may be flooded and what effect that may have on the liner relative to the liner interior pressure which provides the liner seal. In piping, the liner can be sized to fit nearly perfectly in the pipe, so the interior pressure need not be very high above the exterior formation pressure.

The piping used must be of sufficient strength and well supported in a strong granular material (e.g., angular sand) to withstand the vertical landfill load. That should be a significant feature of the engineering design of the landfill. Slope stability is also important if the bed is not horizontal

Conclusion

The ability of the everting flexible liner to traverse crooked piping paths and the ability to carry instrumentation into such passages is a unique capability. Also, the fact that there is no need to purge the borehole water because it is entirely inside the liner increases the advantage of the Water FLUTe system, especially in low flow formations. The only indefinite feature of the method is the question of damage to the liner from potential leachate composition. Because the system is removable, and the system can be cast full of grout using the tubing normally emplaced in the tubing bundle, that may not be a serious concern.

Prior experience with this geometry in much smaller diameter piping than 6 inch adds to our confidence in this approach to landfill monitoring. However, there are other FLUTe designs for monitoring beneath landfills which may be of use for fifty to several hundred years. Those designs should also be considered.

For questions about FLUTe methods, see the web site, www.flut.com, under *publications* and *unique applications*. You can also contact FLUTe at 1-888-333-2433 or 1-505-852-0128 or Carl Keller at carl@flut.com.