Survey of New England experience with drip dispersal of wastewater effluent

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ABSTRACT | While 95 percent of the U.S. experience with drip dispersal is outside New England, national experience dates back more than 20 years and covers areas of the country with comparable climatic conditions. The number and type of such systems recently installed in New England is presented along with present cost data to illustrate those situations in which drip dispersal may be cost-effective compared to other land-based effluent disposal systems. Drip dispersal is not always cost-effective, but several design aspects help the practitioner to identify cost savings.

KEYWORDS | Drip dispersal, drip irrigation, land disposal, septic tank effluent, mounded disposal system, groundwater recharge

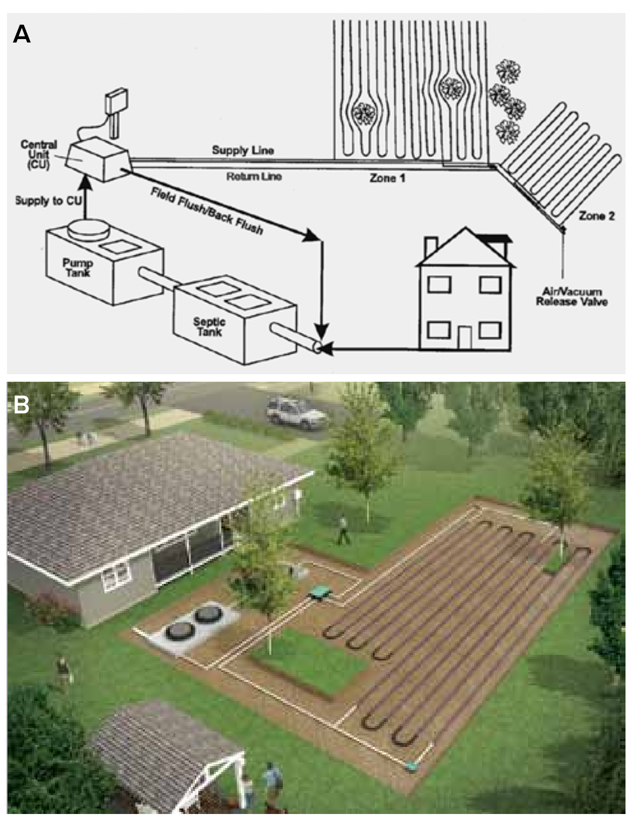

Figure 1. Elements of the typical drip dispersal system
Sources: (A) adapted from American Manufacturing, 2001; (B) Oakson, Inc., 2014

INTRODUCTION

Drip dispersal of wastewater effluent is widely used in the U.S., but it is only recently gaining popularity in New England. This paper documents the number and type of such systems recently installed in New England and presents cost data to illustrate situations in which drip dispersal may be cost-effective compared to other land-based effluent disposal systems.

WHY EFFLUENT RECHARGE IS IMPORTANT

Owners, operators, and design engineers must optimize wastewater management facilities in four areas:

- Wastewater collection
- Wastewater treatment
- Effluent disposal
- Residuals management

In our profession, most of the energy, innovation, and investment have occurred in the first three areas. However, wastewater effluent is increasingly recognized as a "resource," not a "waste requiring disposal," and we need to think more about ways to reuse it. Where surface water discharges are difficult to permit and where land is available, effluent recharge allows aquifer replenishment and polishing of effluent quality, either at the soil surface or in the subsurface. Irrigation with effluent can reduce other demands on surface water or groundwater sources. Drip dispersal of effluent offers several advantages over traditional land-based effluent disposal techniques and warrants consideration in many sites and applications.

DESCRIPTION OF DRIP DISPERSAL TECHNOLOGY

In simplest terms, drip dispersal is a form of subsurface discharge of effluent. Unlike a traditional subsurface leaching system, however, the discharge can be into the A or B soil horizons, often 6 to 12 inches (15 to 30 cm) below the ground surface, and the dispersal system may be placed directly into native soil, not into crushed stone. Effluent is distributed through 0.5-inch (1.27 cm) plastic tubing and enters the soil at evenly spaced "emitters." Often termed "drip irrigation," this technology is better named "drip dispersal" to distinguish it from the widespread agricultural practice of irrigating crops through tubing placed on the land surface.

The fundamental elements of a drip dispersal system are:

- Pretreatment
- Pumping station
- Control unit (including filtration and flow measurement)
- Distribution and dispersal tubing
- Flushing system

Figure 1 illustrates how these functions are configured in a typical system for a single- or multi-family home. Septic tank effluent is pumped through a control unit that includes an in-line filter, flow meter, solenoid valves, and control systems. At pre-set intervals, effluent enters the drip dispersal tubing at sufficient pressure to force it out the emitters. Occasionally the control unit opens and closes the appropriate valves so that the tubing can be flushed back to the septic tank. The in-line filtration and back-flushing limit the solids loading to the emitters so that plugging is not a problem, even with a septic tank as the sole pretreatment device. One of the tubing manufacturers implants a biocide-impregnated material in the emitter to impede bio-growth.

There are two techniques for installing drip tubing. The least expensive method is to plow the tubing directly into the native soil using a vibratory plow or trenching machine. Alternatively, the tubing can be manually laid on a prepared bed of sand, and then covered with fill and topsoil.

New England has two main drip dispersal systems—Perc-Rite and GeoFlow. The two suppliers of these systems furnished the information herein on U.S. and New England installations.

U.S. PRACTICES

Nationwide more than 10,000 systems are in place, and there are perhaps as many as 20,000 systems. Most serve single-family homes, but between 400 and 500 are larger than 1,000 gallons per day (gpd), or 3,785 liters per day (lpd), in capacity. The earliest systems date back to the early 1990s. More than 100 systems are larger than 10,000 gpd (37,854 lpd) across the country, more than 20 larger than 100,000 gpd (378,540 lpd), and a few larger than 1 million gpd (around 3.8 million lpd).

Table 1. Drip dispersal systems in place in New England in 2013

	Number of Systems	
State	**Smaller than 1,000 gpd***	**1,000 gpd and Larger**
Massachusetts	426	26
Maine	57	3
Vermont	36	1
New Hampshire	10	1
Connecticut and Rhode Island	Few	0
Total	**Approx. 530**	**31**

*3785 lpd

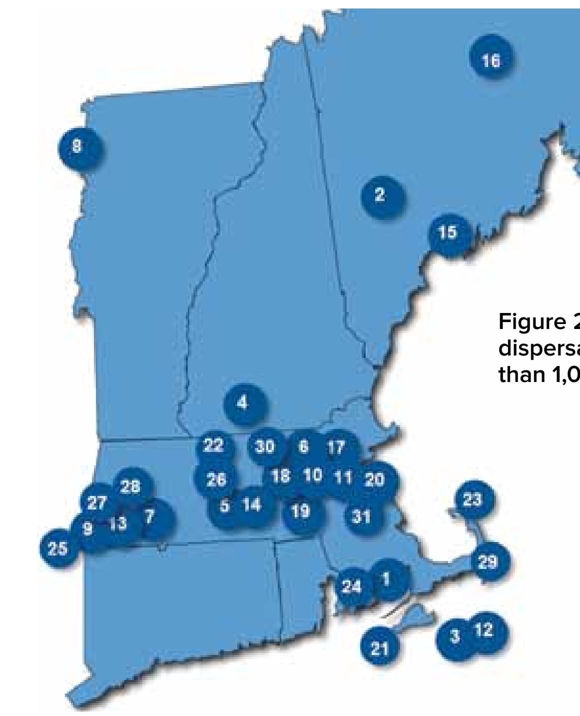

Figure 2. Location of drip dispersal systems larger than 1,000 gpd (3,785 lpd)

GeoFlow systems are primarily in Texas, California, Washington, and Arkansas. Most of the Perc-Rite systems are in the mid-Atlantic region (Pennsylvania, Virginia, and North Carolina) with a rapidly growing presence in the Northeast. Many drip dispersal systems are in place in the upper Midwest, with climates similar or more severe than New England, and these systems have operated year-round, even with relatively shallow burial.

NEW ENGLAND EXPERIENCE

A survey identified drip dispersal systems in New England. The survey focused on two system sizes: smaller than 1,000 gpd (3,785 lpd), assumed to be

| SURVEY OF NEW ENGLAND EXPERIENCE WITH DRIP DISPERSAL OF WASTEWATER EFFLUENT |

Table 2. State regulatory approval processes

State	Approval Status
Massachusetts	DEP approval letter covers flows less than 10,000 gpd (37,854 lpd)
	Design-specific review required for flows greater than 10,000 gpd (37,854 lpd)
	Design guidelines apply to flows greater than 10,000 gpd (37,854 lpd)
Maine	Wastewater code covers all flows
	Secondary effluent allowed by code
	DHHS approval letter required for septic tank effluent
Vermont	Secondary effluent allowed by code
	DEC approval letter required for septic tank effluent
	Design-specific review required for flows greater than 6,500 gpd (24,605 lpd)
New Hampshire	DES approval letter covers flows less than 2,000 gpd (7,571 lpd)
	Design-specific review required for flows greater than 2,000 gpd (7,571 lpd)
Connecticut	DPH approval pending for Perc-Rite for flows less than 5,000 gpd (18,927 lpd)
	Design-specific review required for flows greater than 5,000 gpd (18,927 lpd)
Rhode Island	DEM approval letter covers all flows

predominantly single- and multi-family housing, and 1,000 gpd (3,785 lpd) and larger. For this paper, the focus has been on those drip dispersal systems of 1,000 gpd (3,785 lpd) capacity and larger.

Table 1 summarizes the results of this survey. At the end of 2013, about 530 small drip systems were in place, and 31 systems were 1,000 gpd or larger. Approximately 80 percent of the small systems are in Massachusetts, and another 15 percent are in Maine and Vermont. Of the large systems, more than 90 percent are in Massachusetts and Maine (see Figure 2).

In 2008, only two drip dispersal systems were identified with a capacity of more than 1,000 gpd (3,785 lpd). Three more were built in 2009, and six to eight were installed each year since. The local suppliers report many new systems are in the planning and design stages, some of which may have been in the works for years and delayed due to economic conditions.

- **Seasonal vs. Year-round Use**. All but four of these systems are serving year-round facilities.
- **Pretreatment**. Of the 31 larger systems in New England, pretreatment is provided as follows:
  - Septic tank—12 systems
  - Sand filter—2 systems
  - Biological treatment—11 systems
  - Membrane bioreactor—4 systems

  The membrane bioreactor systems appear to have been selected for nutrient removal reasons, and not necessarily to achieve very low effluent suspended solids concentrations. Forty percent of these systems were designed to receive septic tank effluent.
- **Installation Methods**. More than half of these 31 large systems involve drip tubing that was plowed in, and the rest were placed on fill.
- **Loading Rates**. These 31 drip systems were designed with effluent loading rates between 0.2 and 1.5 gpd per sq. foot (8.2 – 61.3 lpd per sq. meter). Most of the systems have design loading rates of 0.60 to 0.75 gpd per sq. foot (24.4 - 30.1 lpd per sq. meter).
- **Burial Depth**. All the large systems identified are installed with 12 inches (30 cm) or less of final cover. The shallowest system has 6 inches (15 cm) of cover, and most fall in the range of 8 to 10 inches (20 to 25 cm).
- **National Comparisons**. Drip dispersal experience in New England is limited compared to the national scene. For systems smaller than 1,000 gpd (3,785 lpd), New England's 530 installations represent perhaps 3 percent of the national total. New England's 31 larger systems represent only 6 to 7 percent of the national totals. While 95 percent of the U.S. experience with drip dispersal is outside New England, national experience dates back more than 20 years and covers areas of the country with comparable climatic conditions.

REGULATORY ISSUES

Table 2 summarizes the regulatory issues for use of drip dispersal in New England. In those states which require product approval prior to a system being installed, drip dispersal systems have been approved in all states except Connecticut, where Perc-Rite's application is pending. Some states require special approval for drip systems receiving septic tank effluent. Most states require state review of design plans for systems larger than a few thousand gallons per day (approximately 1,000 to 3,000 gpd or 5,000 to 10,000 lpd).

The Massachusetts Department of Environmental Protection has provided detailed guidance related to drip dispersal in the May 2013 update to its "Guidelines for the Design, Construction, Operation and Maintenance of Small Wastewater Treatment Facilities with Land Disposal." This document devotes six pages to drip dispersal and covers pressure dosing, drip tubing, and zones, emitters, zone valves, soil conditions, and performance expectations. The allowable application rates for drip systems are 60 to 80 percent of those allowed for trench-type subsurface disposal systems when percolation rates are faster than 10 minutes per inch (2.5 cm), and 90 percent for 10 to 20 minutes per inch (2.5 cm). In tighter soils (those with slower than 20 minutes per inch (2.5 cm) percolation rates), drip systems are allowed higher loading rates, reflective of the relatively good performance experiences under those conditions.

Figure 3. Oak Bluffs effluent disposal site

COST FACTORS

Drip dispersal systems offer cost advantages over traditional effluent disposal systems when the tubing can be installed directly into native soils eliminating the cost of crushed stone and site restoration.

The ability to plow in the tubing can significantly reduce installation time which allows for beneficial use of the property faster than traditional bed construction. An example of this would be on a drip dispersal site that is a ball field and work must be completed between sports seasons.

Because of the shallow burial of the tubing, sites with relatively shallow depth to groundwater can be acceptable for drip systems at no cost or less cost for fill in a mounded system. This makes more sites available for drip disposal than can accommodate traditional systems. Further, since drip systems can be easily segmented into multiple zones, smaller sites are acceptable that may not be for traditional systems.

Depending on site and groundwater characteristics, reduced groundwater mounding can also be demonstrated due to the uniform application rate, evapotranspiration, the timed-dosing of the effluent being applied to the soil, and the ability to have long and linear drip fields.

For vegetated sites, installation of drip systems instead of traditional systems is often easier because less clearing and grading is required. Several successful systems in New England use wooded sites, where minimal clearing was needed. The avoidance of clearing saves money and results in sites more aesthetically pleasing (and thus more publicly acceptable) than sites with complete clearing and significant re-grading.

Shallow-burial drip dispersal systems should reduce irrigation costs on sites that require irrigation (such as ball fields). A similar argument can be made for fertilization. While these are benefits, it is unlikely that the drip dispersal system would provide for all irrigation and fertilization needs.

Aspects of drip dispersal systems can make them more expensive than traditional systems with piping and crushed stone beds or trenches. If the traditional system can be fed by gravity, it will have a cost advantage over drip systems which require pumping. If state regulations dictate a lower loading rate with drip systems, the overall site will be larger and likely entail more site work.

CASE STUDIES

To illustrate the relative importance of the various cost factors discussed above, three case studies were formulated and are presented herein.

Oak Bluffs Case Study

The first step in developing the case studies was to formulate a cost model based on actual costs for a completed project. The Oak Bluffs, Mass., effluent disposal system was selected for the base case in this cost model since it is a municipally owned, publicly bid project that represents a typical large subsurface disposal system. This project is considered a typical installation because it was installed in a large open area without any soil, site, or groundwater-related challenges.

The Oak Bluffs disposal system was designed for 360,000 gpd (1.29 million lpd) of tertiary effluent. It is under Ocean Park, a 7-acre (2.83 hectare) open space, and was constructed in 2001 and 2002. The system includes 28 effluent disposal beds, each 50 by 100 feet (15.2 by 30.48 meters), with 12 inches (30.48 cm) of crushed stone (see Figure 3). One set of four beds is used as a rotating reserve, and the design capacity is provided by the other 24 beds loaded at 3 gpd per square foot (120 lpd per square meter).

To develop the cost model, the contractor's schedule of values was aggregated into the most predominant categories of the project, including: mobilization, bed construction, piping, pumping systems, and site restoration. All elements were captured in one of these categories. The contractor's

Table 3. Cost evaluation for Oak Bluffs case study

	Leaching Bed @ 3 gpd/sf*	Drip Dispersal @ 3 gpd/sf	Drip Dispersal @ 1 gpd/sf**
Mobilization & site prep	90,000	80,000	90,000
Bed construction	450,000		
Drip tubing and installation		70,000	180,000
Pump station, controls, etc.	250,000	420,000	460,000
Piping	70,000	90,000	190,000
Site restoration	130,000	60,000	120,000
Total	**$990,000**	**$720,000**	**$1,040,000**
Savings with Drip Dispersal		(27%) $270,000	(-5%) -$50,000

*0.97 lpd/sm **0.32 lpd/sm

Figure 4. Drip dispersal system under construction at Quail Ridge in Acton, Mass.

pricing for each item was compared to the non-winning bids to account for any unbalanced bidding. Costs were adjusted for inflation through 2013.

The next step was to determine the cost for a comparable drip dispersal system for the same flow conditions to be installed on the same site. A preliminary design was prepared for a Perc-Rite system, including a bill of materials and a cost estimate for materials and installation. This cost information was combined with cost data for the site work, pumping systems, and ancillary work as determined by the unit prices as discussed above. This information was used to develop a construction cost estimate for a drip dispersal system with an application rate of 3 gpd per sq. foot (120 lpd per sq. meter)).

As shown in Table 3, this analysis indicates that a drip dispersal system could have been installed at a considerable cost savings compared with the actual cost of the traditional system, assuming both systems could have been built with the same application rate of 3 gpd per sq. foot (120 lpd per sq. meter). There was little experience with drip dispersal in New England at the time of the Oak Bluffs design, and no experience at this relatively high loading rate. For the stated assumptions, the drip dispersal system might have saved nearly 30 percent of the construction cost. Most of the savings stem from the markedly lower cost of tubing installation and for site restoration, compared with the construction of the subsurface leaching system. These major savings are offset somewhat by the added cost of the pumping and control systems.

To test the cost sensitivity to effluent loading rate, a companion cost estimate was prepared based on the drip system loaded at 1 gpd per sq. foot (40.7 lpd per sq. meter), as shown in the last column of Table 3. For this scenario, the drip system would have cost about 5 percent more than the system that was actually installed. (A major assumption in this alternate analysis is that municipal land could have been made available at no cost at the same site. Such land is not available, so this is a purely hypothetical analysis.)

Mounded System Case Study

Other cost factors were evaluated in the case study for a hypothetical mounded disposal system similar to the one at the Quail Ridge project in Acton, Mass. (see Figure 4). This case study was selected to evaluate the benefits of drip dispersal systems due to their lower profile when separation from groundwater is a controlling factor and earthwork can be reduced compared to a traditional system.

This case study compares a traditional subsurface leaching system and a drip dispersal system for a 50,000-gpd (189,270-lpd) design flow with an application rate of 3 gpd per sq. foot (120 lpd per sq. meter) where fill is required to meet the depth-to-groundwater requirements.

Table 4 presents the cost comparison for this case study. The cost model predicted a traditional system would cost approximately $620,000 compared to $500,000 for the drip system, which could be built with 15 inches (38.1 cm) less fill. Most of the cost savings (19 percent overall) relate to the lower cost of purchasing and placing the fill for the drip system, and the lower cost for tubing installation versus placement of crushed stone.

Wooded Site Case Study

Because of the installation flexibility afforded by drip dispersal systems, wooded sites offer potential cost savings. Since the drip tubing can be installed around potential obstacles such as trees, site preparation and restorations can be significantly reduced. Figure 5 shows how drip tubing can be installed with minimal clearing.

This final case study compared a traditional system and a drip dispersal system each sized for 30,000 gpd (107,340 lpd). The traditional leaching trench system was sized at 2 gpd per sq. foot (81.8 lpd per sq. meter), and would require substantial site clearing. The drip system was sized at 1 gpd per sq. foot (40.7 lpd per sq. meter), with the lower loading rate intended to account for the difficulties working around vegetation that would largely remain in place. While the drip dispersal system would require clearing and grubbing, and site restoration, the magnitude is greatly reduced compared to a traditional system. Table 5 presents the comparative cost estimate that indicates that the drip dispersal system could be installed for approximately 12 percent less.

CONCLUSIONS WITH RESPECT TO COST

Considering the above-noted costs and the results of these case studies, the conditions that are most favorable for drip dispersal systems are:

- Sites where native vegetation must be preserved
- High groundwater conditions
- Irregularly shaped sites
- Sites with steep slopes
- Projects with limited construction time
- Soils with low permeability.

Conversely, the least favorable conditions for drip systems are:

- Disturbed sites where earthwork costs are small
- Soils that allow high loading rates for traditional systems (such as rapid infiltration)
- Projects in states that require a high degree of pretreatment prior to drip dispersal
- Dual-use sites subject to heavy load, where shallow-burial drip tubing might be damaged

While the case studies all show favorable conclusions with respect to the costs of drip dispersal systems, they were formulated to do just that. Drip dispersal is not always cost-effective, but this study should help the practitioner to identify where cost savings may accrue.

CHALLENGES AND OPPORTUNITIES

Effluent recharge via drip dispersal is a viable technology for New England. With more than 500 installed systems of less than 1,000 gpd (3,578 lpd) in capacity, the single-family-home market is well established. While the experience in New England is limited to about 25 projects greater than 1,000 gpd in size installed in the last 5 years, the national experience dates back more than 20 years, including widespread use in climates comparable to New England. The regulatory setting is evolving, but five of the six New England states now approve drip dispersal systems.

As design engineers seek to avoid surface water discharges and prevent hydrologic imbalances, drip dispersal has an important role in decentralized wastewater management. Key advantages include easy installation, reduced need for extensive clearing, ability to easily segment the layout making smaller sites viable, and, often, reduced costs. Research is expected to demonstrate nutrient uptake as an additional advantage.

Table 4. Cost evaluation for hypothetical mounded system

	Leaching Bed	Drip Dispersal
Mobilization and site prep	39,000	39,000
Fill	293,000	190,000
Bed construction	49,000	
Drip tubing and installation		15,000
Pump station, controls, etc.	164,000	186,000
Piping	23,000	19,000
Site restoration	52,000	51,000
Total	**$620,000**	**$500,000**
Savings with drip dispersal		(19%) $120,000

Table 5. Cost Evaluation for Hypothetical Wooded Site

	Leaching Bed	Drip Dispersal
Mobilization and site prep	16,000	16,000
Clearing and grubbing	12,000	3,000
Bed construction	44,000	
Drip tubing and installation		43,000
Pump station, controls, etc.	139,000	145,000
Piping	21,000	19,000
Site restoration	53,000	24,000
Total	**$285,000**	**$250,000**
Savings with Drip Dispersal		(12%) $35,000

Figure 5. Wooded drip dispersal site in northern New England

ABOUT THE AUTHORS

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