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LONGEVITY OF CONVENTIONAL GRAVEL AND REDUCED AREA CHAMBER DISTRIBUTION SYSTEMS INSTALLED IN THE TOWN OF CUMBERLAND, MAINE 1975 TO 1988

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Abstract

Over 1100 Maine Subsurface Wastewater Disposal Systems Applications were reviewed and categorized by system type and age. The longevity study was limited to the 404 systems that were at least 20 years old. System failure was established by the application for a replacement system. Fifty-five systems (13.6%) were replaced. The systems were categorized by drainfield location and type (in-ground trench or bed and above-ground trench or bed). Systems were further categorized by drainfield design (chamber vs. conventional gravel). Chambers installed during the timeframe of the study were constructed of concrete. In Maine, chambers are allowed up to a 50% reduction in size, based on the assumption of greater efficiency. While the age at failure and the percent failure were more favorable for reduced area chamber systems, the statistical analysis of the data revealed no significant difference between the two at the 5% level. However, the analysis did reveal that soil conditions have an important effect upon the tendency to fail when systems were designed with the Maine loading rate table in effect at the time. Review of other longevity studies documents the difficulties in the design and interpretation of longevity research.

Introduction

Previous field studies of longevity of chamber and gravel drainfield systems concentrated on young systems (less than 10 years old). The purpose of this paper is to assess longevity of older systems (over 20 years old) by measuring the relative "propensity to fail" (failure rate) and "age at failure" of gravel and reduced area chambers installed in the period of 1975 to 1987 in the Town of Cumberland, Maine under the State of Maine code. Because the quality of the local codes, regulatory practice and the skill of local designers and installers affect longevity performance, the results of this analysis may not necessarily be replicated in other jurisdictions.

Maine, unlike most other states, included sizing criteria for chambers in the body of the code very early in the modern era. The first modern era codes in most other states established drainfield design criteria for gravel filled trenches and beds. Other drainfield technology was considered an alternate to the codified stone filled drainfield and was typically approved under alternate approval processes. When promoters of new technology approached regulators, they were frequently required to support claims that the recommended sizing of the technology would result in equal or greater longevity than the benchmark stone design. Because the technology was new, they were unable to document relative longevity by failure analysis and had to rely on

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other methods. With over 30 years of history, chamber technology is no longer new and relative gravel and chamber system failure rate and longevity can be measured.

In July 1974 the Maine Subsurface Wastewater Disposal Rules first authorized the use of 50% reduced area chamber systems. “The Rules allows [sic] a reduction in the size of the disposal area when chambers are utilized. The rationale for the allotted reduction in disposal area is that leaching chambers provide an unmasked interface between the effluent and the soil.” (Maine Department of Human Services, 2001)

The chamber design creates a subsurface open-bottom area. Three generations of materials have been used in chamber installations in Maine; wood Vee-plank, concrete and plastic. The primitive Vee-plank (wood planks) design was used extensively beginning in the late 1940’s and was phased out by the beginning of this study period. Concrete chambers were introduced in the mid 1970’s and plastic chambers in the late 1980’s. All chambers installed in Maine during the study period were concrete. The concrete chamber dimensions were commonly 4 feet wide, 8 feet long and 1 foot high with overflow and air exchange ports in the side and end walls. In the late 1980’s the plastic chamber was introduced. (Maine Department of Human Services, 2001)

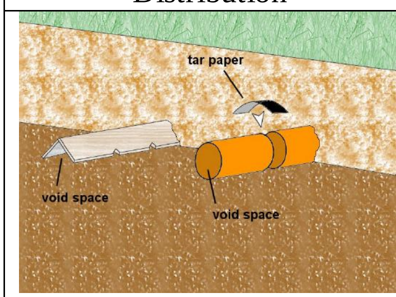
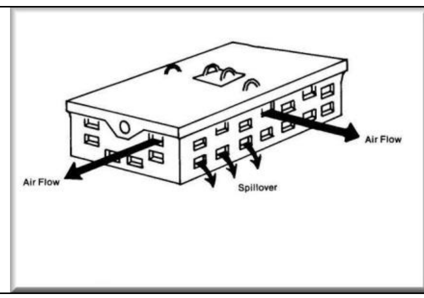
Vee-Plank Site Constructed Chamber and Tile Distribution	Concrete Chamber	Plastic Chamber
		

Figure 1- Three generations of Chambers utilized in Maine

<u>Town Dispersal System Design</u>

The 1974 Maine code focused on the bed design because of the difficulty of constructing trenches in areas with shallow bedrock.[5] As a result, ninety-eight percent of the Town of Cumberland installations evaluated were beds. Fill was frequently used because of slopes or shallow soils. The size of the gravel beds was determined by a codified loading rate table. The chamber design simply replaced gravel in a 50% reduced area bed (Martin 2004).

Based on a review of permits, gravel bed design was typically 12 inches of gravel overlying native soil or fill, covered with two inches of straw or hay and 8-14 inches of approved fill. A 4 inch distribution pipe was installed approximately one inch below the top of the gravel. Gravel beds were assigned design area credits based on bottom area.

[5] Based on interview with Russ Martin, Director of Maine’s Subsurface Wastewater Program.

Gravel trench design criteria assigned 3 square feet of area credit per lineal foot of trench. The trenches were typically 2 feet wide with 18 inch sidewalls. No area credit was assigned to the trench bottom. [6]

Based on the review of permits, chamber systems were typically placed on native soil or fill and covered with 6 to 12 inches of approved fill. The 4 x 8 chambers were assigned 32 square feet of area credits for both beds and trenches. All but one of the chamber systems were beds.

Appendix 1 is the Maine loading rate table in effect in 1978. The loading rate tables contained 11 soil conditions based on textural classes, 9 of which were utilized for conventional systems. The 9 textures were grouped into six drainfield sizing categories designated "small" to "extra large." Each group's loading rate was expressed as square feet per gallon of design flow. For example, the loading rate for the classification "Medium" was 2.6 square feet per gallon design flow. The soil condition portion of the table classified site conditions based on vertical separation to a limiting condition and provided design instructions for the various conditions. Design flow was 90 gal/day per bedroom. This was significantly less that than the 120-150 gpd used in many states, resulting in smaller drainfields than in those other states.

Maine loading rate tables evolved over the time period of the study. Appendix 2 contains tables that document the evolution of gravel and chamber distribution system area requirements for various soil groups. Specific comments on the individual tables are:

- The chamber column in the July 1974 table reflects area credits assigned to two specific manufactured products. The values in the gravel trench and bed columns include sizing ranges that allowed the designer to factor in individual household and site characteristics.
- The June 1975 table added more detail relative to sizing for gravel systems and became more generic relative to chambers as multiple manufacturers emerged. The chamber area as a percent of gravel varied from 44.4% to 59%, averaging 50.5%.
- The May 1978 table was more detailed and specified the loading rate requirements as square feet per gallon design flow. The chamber area as a percent of gravel varied from 48.84% to 53.8%, averaging 50.1%.

Efficacy of Longevity Analysis Techniques

System longevity is commonly defined as time from installation to hydraulic failure – usually defined as sewage at the ground surface or backing into the structure. Designers, installers and regulatory policy makers are interested in the longevity of specific designs for both public health and liability reasons.

Gravel drainfields are the benchmark design for the distribution of septic tank effluent in most state codes. State gravel sizing practices have evolved with empirical evaluation over the last half century. Where regulators and designers noticed early system failure in general or in a specific set of site conditions, the regulatory agency normally decreased the loading rate to resolve the problem. While alternate technology is also subject to empirical evaluation, it takes

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[6] Ibid, Martin

an extended period to assess the technology. Chambers, in use for over 30 years, are not new technology.

Nationally, almost all state regulatory agencies have accepted some level of area reductions for alternate drainfield designs, from chambers to drip distribution. The agencies are generally interested in the treatment and longevity of the alternate design relative to the conventional gravel design when making approval determinations.

To support claims of chamber infiltrative efficiency, a number of studies have been conducted that were intended to assess the relative longevity of chamber and gravel drainfield designs. The research techniques included field surveys of installed systems, test center studies and studies that attempted to predict longevity based on ponding development in trench systems.

A field longevity evaluation protocol requires trained personnel, appropriate classification of system design, a clear definition of failure, a defined inspection technique, knowledge of changes in design requirements, information on installation and replacement dates and a statistically valid approach. Statistical validity involves determination of adequate sample size for statistical significance, appropriate classification of sites studied (avoiding apples/oranges aggregation), appropriate hypothesis development, consideration of the influence of independent variables and random selection in the case of a sample survey.

Test center studies frequently apply very aggressive loads and flows to induce early biomat formation and ponding to reduce the duration of the evaluation. To the greatest extent possible protocols should mimic common field installation conditions and the results should be calibrated by field surveys of failures.

The primary evaluation methods are listed below along with comments: Individual studies may utilize a mix of these methods. Longevity studies require accurate measurement of installation and the time of failure. Failure rate studies require the date of installation and a method to timely determine system failure occurrence. Periodic physical evaluation of all systems improves the clarity of both evaluations. One-time surveys lack the clarity because they identify failures than may in fact have occurred years earlier.

1. Site evaluation – Physical evaluation of sites for system failure, combined with a record review, is the optimum method of determining both time to failure and failure rate. The evaluation can consist either of evaluation of all systems or of a random sampling.

2. Evaluation by examination of records – While less expensive than field surveys, this method adds error involving bias in reporting system failure and is dependent on the consistency and quality of record keeping. Most jurisdictions have not systematically identified system failures with periodic inspection of all systems. Instead they rely on homeowner initiated repairs and neighbor complaints. This method introduces major reporting bias in that failures are often not reported at all or in a timely manner. This reporting bias explains large gaps in failure detection between this method and field surveys. Nevertheless, this method has merit if the purpose is to determine relative performance of subpopulations such as gravel

and chamber designs, assuming that owners and neighbors are no more or less likely to report failures of gravel systems than chamber systems.

3. Longevity prediction through trench ponding development – This approach is new and in early protocol development stage. The method has been attempted in field and test center studies. It is also complex in critical areas because of the number of variables that affect longevity.

The studies reported below provide information on future protocol designs for both field and test center evaluations.

Review of Longevity Studies

Five examples of previous longevity or protocol evaluation studies are reported here. The focus of the first two studies conducted by NSF International (NSF) at the Massachusetts Alternative Septic System Test Center (MASSTC) and the University of Minnesota (U of M) Water Resources Center was to develop or implement a protocol intended to estimate relative longevity of various drainfield designs by analysis of ponding development in trenches. Ponding development analysis was intended to shorten the 20-30 year period normally needed do a more complete failure analysis. The other three reported studies involve failure rate studies of relatively young installed systems in Oregon, North Carolina and Maine.

NSF/MASSTC Study

This is a Method 3 test center evaluation – evaluation of ponding development. NSF and the Wastewater Treatment Technology Joint Committee (Joint Committee) conducted an evaluation of a possible NSF protocol and standard intended to measure the relative longevity and treatment of gravel and gravelless drainfield technology. The evaluation was conducted over 20 months beginning in February of 2006. The evaluation of the protocol development is the subject of a paper presented at the 2007 ASABE Conference on Small Community Sewage Systems.[7]

The chamber system was utilized as a stand-in for all gravelless systems. Five trench cells each were constructed for the control (gravel) and chamber drainfield technology in ASTM C 33 (Standard Specification for Concrete Aggregate Material) sand. Chamber cells were half the area of gravel cells. Gravel cells were loaded at 1.48gal/ft^2/day. Chambers were loaded with the same volume. All cells were underlain by an impermeable membrane below the sand to allow collection and evaluation of the wastewater for treatment. Two feet of vertical separation were maintained below the drainfield. Ponding heights were measured in each cell at observation ports located at the 1/3 and 2/3 points of the trench length, separated by about 8 feet in gravel and by about 4 feet in chamber cells.

[7] Corry is a member of the NSF Wastewater Technology Joint Committee and a participant in a number of subcommittee discussions regarding the protocol. The progress and circumstances of the MASSTC center evaluation was subject of briefings at the annual Joint Committee meetings in September of each year. The meetings were open to the public.

Heufelder et al 2007 reported ponding height differences in gravel trenches between the two observation ports and speculated that "…biomat material within the gravel in the proximal end of the trenches forms dams or bridges to prevent the equilibrating of liquid level in the entire trench as occurs in the gravelless trenches."

Heufelder (2007) indicated the importance of uniform construction techniques and the necessity of assigning the technologies randomly to the cells. The gravel and chamber cells were installed in blocks of five adjacent cells rather than randomly being assigned to cells. The blocks were constructed during different times of the day using similar techniques and the same source of ASTM C33 sand. The soil report indicated that "Significant differences in the percentage of water drained at different tensions occurred between the longer [gravel] and the shorter cells [chamber]. There were no differences in soil porosity, grain size distribution, particle size distribution and bulk density. Therefore, the observed variation in pore size distributions probably occurred during placement and compaction of the sandy fill material in the test cells." With respect to random placement of the cells, the report indicates "The longer test cells (cells 1-5) were also constructed earlier in the day than the shorter cells (cells 6-10). Hence, the treatments (gravel-laden vs. gravelless trenches) were not randomly applied to the test cells and do not represent completely independent observations." The study report to NSF recommended that the cell assignment be randomized.

The results of the protocol evaluation remain under review by NSF and the NSF Wastewater Technology Joint Committee

University of Minnesota (U of M) Study

This was a combination Method 1 and 3 evaluations – physical site evaluation, record review and measurement of ponding development. The study titled "Field Comparison of Rock-Filled and Chambered Trench Systems**"** was reported at the 2007 NOWRA Annual Conference. The paper described an unsuccessful attempt to estimate longevity of gravel and reduced area chamber drainfields by measuring ponding progression in sequentially loaded trenches in Minnesota. Infiltrator Systems Inc (ISI) co-funded the study with the University of Minnesota and was provided a copy of the database and was allowed to comment on draft reports.[8] The U of M authors controlled the content.

The study initially involved site evaluation of 189 gravel and chamber trench systems age 5-10 years (90 chamber and 99 gravel systems).[9] Similar numbers of sites for each technology were selected in three soil hydraulic permeability classifications (slow, medium and fast) and in 7 geographically dispersed counties. The systems were all drop box sequentially loaded conventional systems serving homes. Ponding data were collected in the spring of 2006 from only the distal observation port on each trench.[10] The average trench length was 68 ft for gravel

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[8] Corry, as an ISI employee, and Nelson, as a statistical consultant to ISI, along with other ISI staff, participated in the review of the drafts of U of M study. They were provided U of M draft reports and the databases that were used in the study.

[9] Information from the January 2, 2007 database that was provided by the University of Minnesota..

[10] At the time of the MN protocol development, the MASTC documentation on differential ponding levels between the proximal and distal observation ports was not available. The lack of proximal ponding observation likely affected the calculations of the ponding area utilized in gravel trenches.

and 57 ft for chambers.[11] Ponding development was measured on the basis of ”ponding area utilized”, defined as the percent of total trench volume occupied by ponded wastewater. A trench with 12 inches of gravel and ponded to 6 inches was considered to have used 50% of its area used.

Because site evaluation determines drainfield sizing, a re-evaluation of site soil conditions was conducted by a U of M team member at most sites in order to verify the original loading rate classification. The U of M soil evaluation classification differed from that found on the site permit on 58% of 153 sites where both the original site evaluation and the U of M classification were listed.[12]

A number of circumstances and decisions significantly reduced the utility of the study relative to its intended purpose.

- Christopherson (2007) reported that the systems were too immature to conduct a longevity analysis with "…nearly 60% of the systems visited during the study of the ages 5 -10 years did not have any ponding observed." As a result, "These results should not be used to predict system longevity."
- The design of the gravel systems varied significantly in areas critical to the study: reduced area drainfields, variation in sidewall height and depth of infiltrative surface. In Minnesota, the standard conventional design is a drop-box sequential loaded gravel trench system with the overflow pipe elevated 6 inches above the trench bottom, with the area determined by the number of bedrooms and the loading rate table. The Minnesota code allows gravel drainfield downsizing up to 40% with an elevated overflow pipe that is 24 inches above the trench bottom, with prorated area reductions for shorter pipe elevations (12 inch – 20%, 18 inch - 34%).[13] All but two of the gravel systems had pipe elevations of 6, 12 or 18 inches. Review of the database indicated major differences in ponding development in these three gravel designs. For example, systems with 6, 12, and 18 inch overflow pipes displayed in-trench ponding in 30%, 39% and 90% of the sites, respectively.[14] Instead of disaggregating the unique gravel designs in the report statistics, Christopherson (2007) reported that 27 (64% of 42 ponded systems) gravel systems with ponding heights greater than 6 inches were deleted from the database. The result of the deletions reduced the percent of trench area utilized by ponding from 11.4% [15] to the 4.3% reported in the NOWRA paper. Christopherson (2007) reported chamber percent used at 15.8%.
- Since ponding levels were not measured at the proximal end of the trench, any ponding elevation differences between the proximal and distal ends of the trench were not recorded. A measurement of no ponding at the distal end of the trench was recorded as zero ponding for the trench.

[11] Table 5, Christopherson et al., 2007)

[12] Information from the March 2007 database provided by the University of Minnesota. This information was not reported in the paper but was reported during the presentation of the paper at the January 2008 SW On-Site Wastewater Conference in Laughlin, Nevada.

[13] State of Minnesota Rules, Chapter 7080 Subp2C.(1)b

[14] Calculated from the January 2, 2007 database provided by the university

[15] Ibid

Oregon Study[16]

This is a Method 1 study – visual inspection and review of records. King and Hoover published a paper in 2002 that compared failure rates between gravel and 50% reduced area systems in Oregon. King (2002) reported that "reduced area" was calculated by the chamber open bottom area compared to a 24 inch wide gravel trench. The exposed bottom area of the chamber design was 50% of the basal area of the gravel trenches. The study included a total of 198 chamber and 191 gravel sites in two climates and three soil conditions. The sites were selected through a random, stratified process and were physically inspected by the authors in conjunction with state and county regulatory officials. The systems were 2.9 to 5 years old with an average age of approximately 4 years. Failure was defined as surface discharge of sewage. The study concluded that "…there were no statistically significant differences in failure rates between the technologies…"

North Carolina Study[17]

This is a Method 1 study – physical inspection and record review. R.L. Uebler et al of the North Carolina Department of Environment and Natural Resources published a longevity study of gravel, chamber and expanded polystyrene bundles. Uebler (2006) reported that the size of the installations included 36 inch wide gravel trenches, chambers with an approximate width of 34 inches, and three expanded polystyrene bundles approximately 36 inches in combined width. Chambers and expanded polystyrene were installed with a 25% trench length reduction relative to gravel trenches. Chambers included in the survey were produced by 4 companies. A total of 912 systems, evenly divided between technologies were included in the study. The sites selected were located in three soil groups in 3 counties and three distinct physiographic regions. System ages were from 2 to 12 years old. The conclusion of the paper relative to reduced area chambers was that the failure performance of reduced area chambers relative to gravel trenches was not " … significantly different at a 95% confidence level."

2001 Maine Study[18]

This was a Method 2 study – evaluation of records. Dix and Hoxie published a paper in 2001 of the State of Maine failure rates for two classifications of systems: "all systems" and 50% reduced area "chamber systems." The paper compared failure rates by year of installation (1984 – 1994). The "chamber system" classification included both concrete and plastic chambers. Because 62% of the permits were missing information on the original installation (type of system or date installed), the number of reported failures underestimated total failures. The authors estimated total failure numbers by multiplying the reported failures by the factor of total reports divided by complete reports for each year. The average adjustment factor to estimate actual failures from reported failures was 2.66. The conclusion of the study was: "Comparing systems less than 10 years of age for the two technologies," the authors estimated "… the cumulative

[16] The Oregon protocol design was under the supervision of the Oregon Department of Environmental Quality. The study was made to gain acceptance for Infiltrator Systems Inc reduced area chamber designs.
[17] The North Carolina study was conducted and controlled by the state. The study was funded primarily by the state with various manufacturers funding the remainder.
[18] The study was funded by ISI. Dix was an employee of ISI.

failure of all systems at between 1.56% and 4.13% and for chambers at between 1.92% and 4.99%."

Analysis of Longevity and Failure Rate of Gravel and Reduced Area Chamber Systems in the Town of Cumberland, Maine[19]

Statistical Terms Used

This analysis contains terms and deploys statistical processes new to some members of the onsite industry audience. Definitions and explanations follow:

Type III Sums of Squares and Means Squares are obtained for a test of significance of each factor adjusted for the effects of the other factors in the model. Adjusted means for levels of a significant factor may then be compared to determine where the actual differences exist.

Propensity for failure – Response data are given values of 0 for lack of failure and 1 for failure and an analysis of variance run on this response data. The F-values should not be considered exact due to some distributional problems with the error term. Averages of this response are then obtained for each level of a factor such as Soil Condition. The larger the average, the greater the propensity for failure. Generally the averages will be in the range of 0 to 1.

Odds of an event – number of failures divided by number of lack of failures.

Odds ratio - The ratio of two odds which is calculated by dividing the odds in one group of observations by the odds in another group of observations, e. g. Group 1 = Gravel and Group II = Chamber.

Logit in logistic regression – natural log of an odds ratio. The logit has some desirable properties that the odds ratio doesn't so therefore it is used extensively.

Method

This is a Method 2 study - evaluation of records. Town of Cumberland plumbing permit records were available from 1974 to the present, filed in permit number order, not by address. This required a review of all plumbing permits to determine onsite installation and replacement activity at a site. The target population of installed systems was those age 20 and older. All chambers installed in this period were constructed of concrete.

To verify that designers took advantage of the allowed area reduction, the chamber area reductions were calculated from permit applications using two methods:

- Comparison of gravel and chamber system areas by unique sets of site conditions – Permits contained information on installed system size, the number of bedrooms, the soil profile (texture) and condition (depth to a limiting condition). For each unique combination of factors that controlled sizing (number of bedrooms, soil profile and condition) the size of

[19] This study was funded by ISI. Corry was an employee of ISI during much of the study development.

gravel and chamber systems as listed on the permits was averaged. The average chamber bed area was 53% of the average gravel bed area.

- Calculation of gravel sizing for chamber permits - The gravel design area was calculated for chamber applications based on the information contained on the permits. The resultant gravel area was then divided by the chamber area on the permit. The average chamber area was 55% of the gravel design area.

Permit records were excluded from the study database for the following reasons:

- Only records of conventional gravel drainfields and chambers installed directly on soil were included. Some designers preferred to place chambers on a bed of gravel; however, if this was done, "…the system must be sized as a conventional stone bed." (Maine Department of Human Services, 2001) Because the focus of this study is distribution media installed directly on the trench or bed bottom, chambers installed on stone beds are not included.
- Because evaluation focused on household conventional systems, engineered, cluster and commercial systems were excluded.
- Where the street address of the initial system could not be determined from Town records.
- Where the system was replaced by municipal sewer or was replaced or modified because of an alteration or addition to the home.

The resultant database contained 404 records; 341 gravel and 63 chamber systems. Variables included in the database were: date installed, soil profile, soil condition, area in square feet, system type (gravel or chamber), system design (bed or trench) and (primarily above or below ground), age in years as of January 1, 2008 of existing systems, and date the drainfield was replaced for failed systems. Other variables such as the number of bedrooms, design flows, tank size, and drainfield area were recorded but were not used in the analysis either because data were missing on many permits or because the item was highly correlated with another variable.

Three independent variables were analyzed: soil profile (texture), soil condition (vertical separation to bedrock or groundwater) and drainfield media (rock and reduced area chamber drainfields).

Appendix 1 is the State of Maine loading rate table in effect in 1978. Soil profile consisted of 9 categories of texture which were assigned to five infiltration rate groups (small, medium, medium large, large and extra large) for drainfield sizing calculations. Soil condition categorized sites relative to depth to bedrock (A 1,2,3 = vertical separation to bedrock) and groundwater vertical separation (B = >48 inches, C = 15-48 inches, D = 7-15 inches, E = 0-7 inches)

For purposes of statistical analysis textural group (of which there were five levels) was utilized as a variable. The five soil condition categories were combined into three groups with group 1 = A category, group 2 = B and C categories and group 3 = D category. There were no sites in the E category. Categories B and C were combined as restrictions were the same (see Appendix 1).

Failure rate analysis based on record review of systems installed 20-32 years ago should be closer to reality than a record review of younger systems because of the increased likelihood that the failure would be reported with property turnover and homeowner/neighbor discontent with a persistent failure problem. Further, assuming no failure reporting bias between gravel and chamber systems, it is reasonable to compare statistics of equal age designs.

The results are presented as descriptive statistics and analysis of variance. The dependent variables are “time to failure” and “propensity to fail”. Also, related to the propensity to fail, is a logit transformed dependent variable which is used in the logistic regression. Analysis of variance (ANOVA) measures the relationship between multiple independent variables and the dependent variable. Arithmetic and adjusted means can differ because the independent variables are usually correlated to some extent so the effects of one factor need to be adjusted for the effects of others in the model

Results

Caveat - It is likely that these statistics under-report actual failures because of reporting bias inherent in traditional enforcement of regulation of failed systems: homeowner self reporting, neighbor complaints and discovery during voluntary home inspections for real-estate sales.

In Table 1 is presented basic descriptive statistical information on the systems installed during the study period. The arithmetic mean for the percent failure (propensity to fail) and age at failure are presented for the two design options.

Table 1 – Descriptive statistics of gravel and reduced area chamber systems installed from 1975 to 1987

	Reduced Area Chamber			Gravel		
Year	Installed	Failed	Age in years at replacement	Installed	Failed	Age in years at replacement
1975	1			12	3	9.9, 18.0, 32.8
1976	1			12	4	18.9, 22.7, 25.1, 27.7
1977	3	1	27.4	28	8	4.0, 6.8, 11.2, 11.3, 13.9, 14.3, 17.1, 18.9
1978	0			36	6	9.8, 10.4, 13.7, 20.2, 21.5, 24.4
1979	5			29	8	8.4, 11.4, 14.4, 15.0, 15.4, 19.4, 22.3, 23.1
1980	10	5	3.7, 11.4, 13.3, 15.5, 20.3	18	4	8.0, 8.7, 17.7, 23.0
1981	0			20	3	3.0, 16.2, 24.6
1982	4			17	2	1.0, 21.7
1983	5	1	16.7	30	0	
1984	6			27	3	1.8, 2.3, 10.0
1985	12			36	3	5.5, 7.5, 19.5
1986	10			39	1	18.9
1987	6			37	3	8.2, 13.9, 17.2
Totals	63	7	Percent failed: 11.1%. Average age at failure: 15.5 years	341	48	Percent failed: 14.1% Average age at failure: 14.8 years

Gravel system failures display the expected effect of age. Systems installed in the five year period of 1975-79 have a 25% failure rate while those installed in the five year period 1983-87 have a 6% failure rate.

Five of the ten chamber systems installed in 1980 failed, accounting for seventy-one percent of chamber system failures (5 of 7). A permit review of the five failures showed that two were adjacent lots and a second pair was in close proximity to each other.

In Table 2 is reported the assignment of soil profile textural classifications in the five Maine drainfield sizing classifications.

Table 2 – Maine loading rate table assignment of soil textural classes to loading rate classifications.

Maine Soil Profile Classification	Drainfield Sizing Classification
6	Small
4, 5	Medium
2, 3, 7	Medium Large
1,8	Large
9	Extra Large

Analysis of variance indicates that "age at failure" is significantly related to the variables soil profile and soil condition at the .05 level. The performance of gravel and reduced area chamber systems was not significantly different at the .05 level. Comparison of ages at failure (data includes only failed systems):

Table 3 – Analysis of variance for "age at failure"

Source	Degrees of freedom	Type III Sum of Squares	Type III Mean Squares	F
Profile Group	4	594.57	148.64	3.27*
Soil Condition	2	260.52	130.26	2.86 NS
Gravel vs. Reduced Area Chamber	1	59.11	59.11	1.30 NS
Error	47	2138.13	45.49	
Contrast Soil Condition 1 and 2 vs. Soil Condition 3		196.08	196.08	4.31*
Significant at .05 * Significant at .01 ** NS = Not significant.				

The adjusted means for age at failure are presented in Table 4. Whereas the chamber mean was higher than that for gravel, the difference was not significant at the .05 level.

Table 4 – Adjusted means for age at failure

Soil Profile group	Adjusted Mean	Soil Condition	Adjusted Mean	Drainfield Media	Adjusted Mean
Small	17.99	1	15.82	Chamber	16.73
Medium	12.69	2	17.00	Gravel	12.85
Medium large	21.26	3	11.56		
Large	9.32				
Extra large	12.70				

ANOVA evaluation of propensity for failure (Table 5) indicates that neither soil condition nor system type was significant relative to propensity for failure. Note that the F value for gravel vs. reduced area chambers is 0.00.

Table 5 - ANOVA for propensity for failure

Source	Degrees of freedom	Type III Sum of Squares	Type III Mean Square	F
Profile Group	4	3.005	.751	6.81**
Soil Condition	2	.345	.173	1. 56NS
Gravel vs. Chamber	1	.000414	.000414	0.00NS
Error	396	43.72	.110	
Significant at .05 * Significant at .01 ** NS = Not significant.				

The following table reports the adjusted means for propensity for failure. Note the large adjusted mean for the Small System category, meaning that failure is more apt to occur in this category than in the others.

Table 6 – Summary table, ANOVA adjusted means for propensity to fail

Soil Profile group	Adjusted Mean	Soil Condition	Adjusted Mean	Drainfield Media	Adjusted Mean
Small	.297	1	.194	Chamber	.128
Medium	.072	2	.147	Rock	.125
Medium Large	.077	3	.0380		
Large	.079				
Extra Large	.104				

The greater propensity for failure of textural class 6 (small system) was recognized by the State of Maine. They have increased the square foot area per gallon design flow from 1.3 to 2 ft^2/gal in more recent codes. (Maine Subsurface Waste Water Disposal Rules, 2005)

Table 7 - Logits and Odds Ratio

Variable	Logit Regression Coefficient Estimate	Odds ratio = e to the logit power
Intercept	-6.3895	0.002
Profile group Small vs. Extra Large	1.0634	2.896
Profile group Medium vs. Extra Large	-0.4677	0.626
Profile group Medium Large 2 vs. Extra Large	-0.4066	0.666
Profile group Large 1 vs. Extra Large	-0.4052	0.667
Soil condition group 1 vs. 3	5.0207	151.606
Soil Condition group 2 vs. 3	4.5647	95.828
Gravel vs. reduced area chamber	.00363	1.004

From Table 7, it is concluded that the Soil Profile group (Small) and one Soil Condition group (3) dominate the failure response of systems Soils in these groups are much more likely to fail than those in other groups with the loading rate tables in place during the period. With an odds ratio of 1.008, both gravel and reduced area chamber systems are equally likely to fail

Conclusion

The Maine study has provided an opportunity to evaluate longevity of systems in a way that previous studies have not. Analysis of data for "age at failure" and "propensity to fail" of gravel and reduced area chamber systems in Maine age 20 years and older indicate that reduced area chambers outperform gravel design in both areas. However, the differences are not statistically significant.   Soil profile and soil condition affected longevity when combined with the loading rate tables in use at the time. Soils in the Small System class are more apt to fail that those in other textural classes. Soil condition groups 1 and 2 are more apt to fail than group 3. The Maine Division of Health Engineering recognized this issue through empirical evidence and adjusted the loading rate tables where disproportionately higher levels of system failure were occurring.

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Appendix 1- Maine 1978 loading rate table, as implemented by the Town of Cumberland

TABLE 6-1

SOIL PROFILE and CONDITION versus DISPOSAL AREA SIZE

PARENT MATERIAL	SOIL PROFILE	TEXTURAL CLASSIFICATION and DESCRIPTIONS	SOIL CONDITIONS: SHALLOW to BEDROCK A BEDROCK I less than 10"	II +10" – −15"	III between (15-40")	DRAINAGE: B WELL DRAINED Ground Water Table greater than 40"	C MODERATELY WELL DRAINED Ground Water Table between (40" to 15")	D SOMEWHAT POORLY DRAINED Ground Water Table between (−15" to 6")	E VERY POORLY DRAINED Ground Water Table less than 6"	DISPOSAL AREA RATING SEC. 12
GLACIAL TILL	1	Silt loam soils which tend to become more more compact with depth and may have a restrictive layer. Angular coarse fragments may be present.		4	2	1	1	3	4	LARGE
GLACIAL TILL	2	Loam to sandy loam soils. Angular coarse fragments may be present.		4	2	1	1	3	4	MEDIUM LARGE
GLACIAL TILL	3	Loam to sandy loam soils with a restrictive layer at depths of (12" - 30"). Angular coarse fragments may be present.		4	2	1	1	3	4	MEDIUM LARGE
GLACIAL TILL	4	Sandy loam to loamy sand. Soils derived from ablation till. Coarse fragments (angular or rounded) may be present.		4	2	1	1	3	4	MEDIUM
STRATIFIED DRIFT	5	Loam to sandy loam soils overlying stratified fine and medium sands. Rounded coarse fragments may be present.		4	2	2	2	3	4	MEDIUM
STRATIFIED DRIFT	6	Loamy sand soils overlying stratified coarse sands and gravel. Round coarse fragments may be present.		4	2	2	2	3	4	SMALL
MIXED ORIGIN	7	Loamy sand to sand overlying a restrictive layer of silt to silty clay which occurs at a depth of 15 inches or greater. Coarse fragments may be present in upper horizons but usually absent in lower horizons.		4	2	1	1	3	4	MEDIUM LARGE
LACUSTRINE MARINE	8	Loam to fine sand overlying firmer silt loam to silt. A restrictive layer may be present. Coarse fragments usually absent. Stratified lenses of very fine sand, silts and clays may be present in the substratum.		4	2	1	1	3	4	LARGE
LACUSTRINE MARINE	9	Silt loam soils overlying firm silt loams to silty clays exhibiting a restrictive layer. Fragments are usually absent.		4	2	1	1	3	4	EXTRA LARGE
ORGANIC	10	Soils are composed of organic materials in various stages of decomposition.								
ALLUVIAL, DUNE, BEACH	11	Variable in texture. Exhibiting very little weathering. Deposited in flood plain, sandy dune or beach environment.				(5)	(5)			SEC. 11.F 11.G

ALL SYSTEMS PERMITTED

Note 1 See 11.C.2.a for Separation Distances.

Note 2 See 11.C.2.b for Separation Distances.

Severe Limitations REPLACEMENT SYSTEMS MAY BE PERMITTED (Sec.15)

Note 3 See 15.A for Replacement System Variance by LPI. See 11.C.2.a & 11.C.2.b for Separation Distances.

Very Severe Limitations REPLACEMENT SYSTEMS MAY BE PERMITTED if no alternative. NEW SYSTEMS NOT PERMITTED.

Note 4 See 15 for Replacement System Variance with Department Review. See 11.C.2d for Separation Distances.

Extremely Severe Limitations. SYSTEMS NOT PERMITTED

Note 5 See 11.F for Coastal Sand Dune limitations. See 11.G for Flood Plain limitations.

DIS[POSAL AREA RATING	BED AREA	CHAMBER AREA	TRENCH LENGTH
Small	1.3 sq ft/GPD	0.7 sq ft/GPD	0.4 lin ft/GPD
Medium	2.6 sq ft/GPD	1.3 sq ft/GPD	0.9 lin ft/GPD
Medium Large	3.3 sq ft/GPD	1.7 sq ft/GPD	1.1 lin ft/GPD
Large	4.1 sq ft/GPD	2.0 sq ft/GPD	1.4 lin ft/GPD
Extra Large	5.0 sq ft/GPD	2.5 sq ft/GPD	1.7 lin ft/GPD

Appendix 2 - Letter on History of Gravel and Chamber Sizing in Maine

The following three tables list the early sizing criteria for trenches, beds, and concrete chambers. The so-called Type A was the ameration chamber 45 SF per unit and the Type F was the flowdiffusor 32 SF per unit.

July 1974

Soil Class	Trenches (LF)	Beds (SF)	Chamber A(SF)	Chamber F (SF)
Very Small	84	250	180	160
Small	100-133	300-400	225	192
Medium	166-200	500-600	360	320
Medium Large	233-300	700-900	495	480
Large	Not Permitted	1200-1500	Not Permitted	Not Permitted
Extra Large	Not Permitted	Not permitted	Not permitted	Not permitted

June 1975

Soil Class	Trenches (LF)	Beds (SF)	Chambers (SF)
Very Small	65	300	177
Small	85	400	204
Medium	185	800	355
Medium Large	250	1000	477
Large	Not Permitted	1400	Not Permitted
Extra Large	Not Permitted	Not Permitted	Not Permitted

May 1978

Soil Class	Beds (SF/GPD)	Chambers (SF/GPD)
Small	1.3	0.7
Medium	2.6	1.3
Medium Large	3.3	1.7
Large	4.1	2.0
Extra Large	5.0	2.5

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