

POSITION PAPER: Stone Specification

Albert Frick

Issue Being Addressed: Stone size diameter, uniformity and allowance or fines tolerance.

Rationale for Proposed Change: The size of stone and allowance for fines has always been a controversial issue. The author, in the spirit of attempting to put science back in regulations, looked into the effect of stone size diameter, uniformity and fines on the performance of a subsurface wastewater disposal system (see attached research).

The reality is that the lack of stone diameter uniformity does not significantly impact the void capacity for storage (6.3% variation). Hence, specific gradation table passing nominal size, sizes need not be as specific or demanding, in the author’s opinion, and would eliminate many issues regarding needlessly failing a septic system inspection for a characteristic that will not adversely affect the performance.

A cubic yard of stone is roughly one ton (2,000 lbs.). The current allowance of 2% fines passing a 200 sieve (i.e. silt and clay sized material equals 40 lbs.) that “dirtiness factor” allowing for the equivalent of a 40 lb. bag of limestone mixed into a cubic yard of stone is quite liberal and should easily be tolerable and acceptable. However, the typical visual inspection by a LPI with 40 lbs. of silt and clay intermixed with a cubic yard of stone will cause alarm (based on purely a visual observation and an apparent “dirtiness” appearance).

Furthermore, if the underlying backfill material is gravelly coarse sand (i.e. suitable backfill), and the fines are sand-sized material, then there is no potential for lowering the hydraulic conductivity. A greater concern would be silt and clay-sized fraction of fines. *(See attached study)*

Current Rule: Section 805.2.3

Proposed Rule:

Stone requirements: The disposal field stone shall be clean, uniform in size and free of fines, dust, ashes, or clay. It **and** shall conform to ~~one of the nominal~~ stone sizes listed in Table 800.1.

TABLE 800.1
Maximum Percent passing by weight

		Nominal Stone Size				
		2-1/2"	2"	1-1/2"	1"	3/4"
Sieve Size	4"	100	100	100	100	100
	3"	90	95	100	100	100
	2"	10	10	90	95	100
	1"	5	5	10	10	90
	3/4"	4	4	5	5	10
	1/2"	3	3	4	4	5
	1/4"	2 4	2	3	3	4
	#200	2	2	2	2	2

STORAGE CAPACITY OF STONE BED SEPTIC SYSTEMS RELATED TO DIAMETER OF STONE AND UNIFORMITY

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September 2004

Executive Summary: The *storage capacity* of a stone bed constructed of $\frac{3}{8}$ " dia, $\frac{3}{4}$ " dia, $1\frac{1}{2}$ " dia, $2\frac{1}{2}$ " dia, and evenly mixed (to $2\frac{1}{2}$ " dia) is 44.3%, 46.6%, 47.6%, 48.8%, and 42.5%, respectively. The larger the effective diameter of the stone, the larger the storage capacity, however, the increase is not significant. A non-uniform mixture of various stone sizes produced a 6.3% reduction in storage capacity.

The specific surface area of $\frac{3}{8}$ " dia, $\frac{3}{4}$ " dia, $1\frac{1}{2}$ " dia and $2\frac{1}{2}$ " dia is 100, 50, 25, and 15 square feet, respectively, per cubic foot of stone. The larger the effective diameter of the stone, the smaller the surface area. Square inches of surface area per cubic inch of aggregate can be expressed as $3/r$.

1 cubic foot of a stone leaching bed comprised of $1\frac{1}{2}$ " dia stone bed has 0.48 cubic feet of void space for storage of 3.6 gallons of wastewater, and has 25 square feet of surface area.

INTRODUCTION:

Many states, counties and municipalities throughout the United States have rules and regulations concerning the specification of stone size and uniformity of stone to be utilized in construction of leaching areas utilizing stone beds in septic systems.

Septic system designers, installers, septic system inspectors, project engineers, health officers, aggregate suppliers, regulatory agencies and septic system owners are concerned with proper specifications, design, construction, permitting and using septic systems.

Many septic systems have been designed with specified stone size and uniformity. Contractors have been ordered to remove and reconstruct with different stone size and uniformity at considerable expense. Is the effective diameter and uniformity of stone size important in providing adequate storage and treatment of wastewater? What is the effect on storage capacity of varying stone size and uniformity? This paper examines the physical storage capacity and surface area that is provided by stone leaching areas of various effective stone diameters and uniformity.

EXPERIMENTAL DESIGN:

Crushed stone aggregate was collected from a large supplier in the Portland, Maine area of the $\frac{3}{8}$, $\frac{3}{4}$, $1\frac{1}{2}$, and $2\frac{1}{2}$ -inch effective size (see Specification Sheet, Table 1).

Five new “*five gallon*” capacity plastic buckets were used as volume measurers. A Fairbanks digital electronic scale (measures to 0.1 lbs and 0.01 kilograms) was utilized for weight measurements. The “5 gallon” buckets were measured to have a volume of 5.51 gallons (0.73 cubic feet) when filled to the brim.

The five measuring containers were tared and filled to the brim with $\frac{3}{8}$, $\frac{3}{4}$, $1\frac{1}{2}$, $2\frac{1}{2}$ -inch effective diameter (an even mixture of $\frac{3}{8}$ to $2\frac{1}{2}$) and leveled off with a straight edge (see photos 2, 3, 4, 5, 6 and 7). The container with the varying stone sizes were then filled with water and reweighed (see Photo 8). The difference between the container of stone and the container with stone and water revealed the amount of water stored in the voids. The weight of the water was translated into volume and the storage capacity measured.

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Table 1: Analysis from Suppliers of Stone Utilized in Experiment

Blue Rock Industries								59 Main Street Westbrook, ME 04092 (207) 854-2561							
Location: WESTBROOK				Date: 5/12/04				Product: VARIOUS							
Subject: ANALYSIS				By: LAB				Project: ALBERT FRICK ASSOCIATES							
Lab No: N/A				Submitted by: S. MACDONALD											
Source of Material: WESTBROOK QUARRY (GRANITE STONE)				Date Sampled: VARIOUS											
Sampled from: STOCKPILE															
Remarks: ALL RESULTS ARE BASED ON YEARLY AVERAGES.															
Sieve (Sq. Mesh)	No. 1 2 1/2"	No. 2 1 1/2"	No. 3 3/4"	No. 4 3/8"	No. 5	No. 6	Specification								
	%	%	%	%											
	PASS	PASS	PASS	PASS											
*3"															
2 1/2"	100														
2"	95	100													
*1 1/2"		92													
1 1/4"															
1"	19	51	100												
3/4"	4	17	93												
5/8"	1.5	8	74												
1/2"		4	37	100											
*3/8"		2	8	89											
No. 3		1.2		41											
*No. 4			1	19											
No. 6															
*No. 8			1	4											
No. 10															
*No. 16				1.6											
No. 20															
*No. 30															
No. 40															
*No. 50															
No. 60															
No. 80															
*No. 100															
*No. 200		1.2	1.0	1.0											
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6									
	2 1/2"	1 1/2"	3/4"	3/8"											
	CR. STONE	CR. STONE	CR. STONE	CR. STONE											
	Gsb = 2.699	Gsb = 2.718	Gsb = 2.694	Gsb = 2.691											

Photo 1: Fairbanks digital scale utilized in experiment.

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RESULTS:

Table 2: Storage Capacity vs. Effective Stone Size

Effective Diameter of stone	$\frac{3}{8}$ "		$\frac{3}{4}$ "		$1\frac{1}{2}$ "		$2\frac{1}{2}$ "		Mixed ($\frac{3}{8}$ to $2\frac{1}{2}$)	
	lbs	kg	lbs	kg	lbs	kg	lbs	kg	lbs	kg
Weight of stone in 5.51 gal container	66.4	30.10	67.4	30.60	66.4	30.15	65.1	29.80	69.1	31.35
Weight of stone and water in 5.51 gal container	86.7	39.3	88.8	40.25	88.2	40.00	87.5	39.65	88.6	40.20
Weight of water in 5.51 gal container	20.3	9.20	21.4	9.69	21.8	9.87	22.4	10.14	19.5	8.83
Capacity of water	gals cu.ft									
	2.44		2.57		2.62		2.69		2.34	
Void Percentage	44.3%		46.6%		47.6%		48.8%		42.5%	
Storage capacity in gallons in 1 cu. ft. of stone bed	3.31 gals		3.49 gals		3.56 gals		3.65 gals		3.18 gal	

DISCUSSION/CONCLUSIONS:

There was a direct correlation between effective stone size diameter and void space (the larger the stone diameter, the greater the void space). There was a 4.5% difference in storage capacity between $\frac{3}{8}$ " and $2\frac{1}{2}$ " (see Table 2).

The mixture of various diameters produced the less storage capacity and reduced the capacity by 6.3%.

FOR EXAMPLE: A common 20' x 45' stone disposal bed built 12" deep with $1\frac{1}{2}$ " dia stone utilized in Maine specified for a common sandy loam glacial till soil, which comprises approximately 80% of the land area in the State of Maine, has storage capacity of approximately 3,200 gals:

$$(20' \times 45' \times 1' \text{ deep} = 900 \text{ cu. ft.} \times 3.56 \text{ gal/cu. ft.} = 3,204 \text{ gals})$$

Specific surface of the stone leaching areas comprised of various stone sizes is probably the outstanding characteristic that results from their size. Specific surface is the proportion of surface to unit volume of the aggregate. Specific surface can be expressed in sq. inches of surface area per cu. in. of aggregate. Specific surface is important because most chemical, physical and biological reactions occur at the surface.

The specific surface of a sphere is:

$$\frac{(\text{surface of a sphere})}{(\text{volume of a sphere})} = \frac{4 \pi r^2}{4/3 \pi r^3}$$

This can be cancelled to read: $\frac{3}{r}$

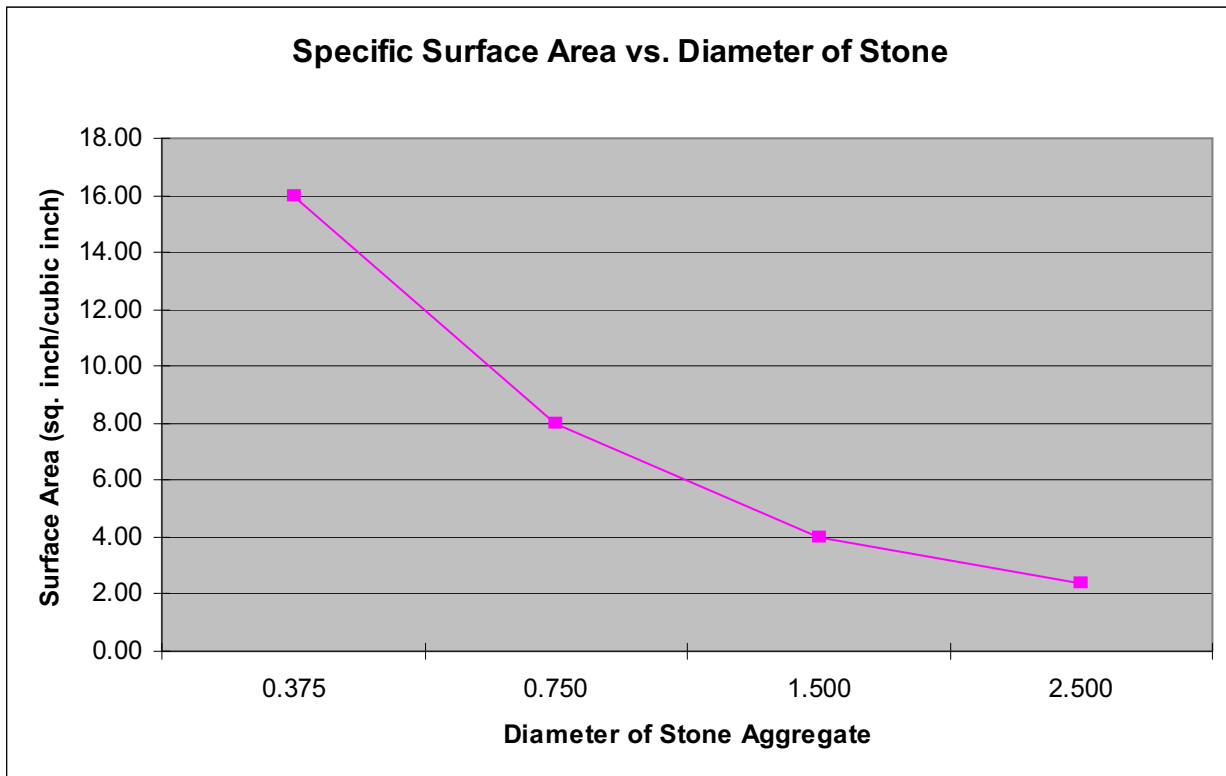
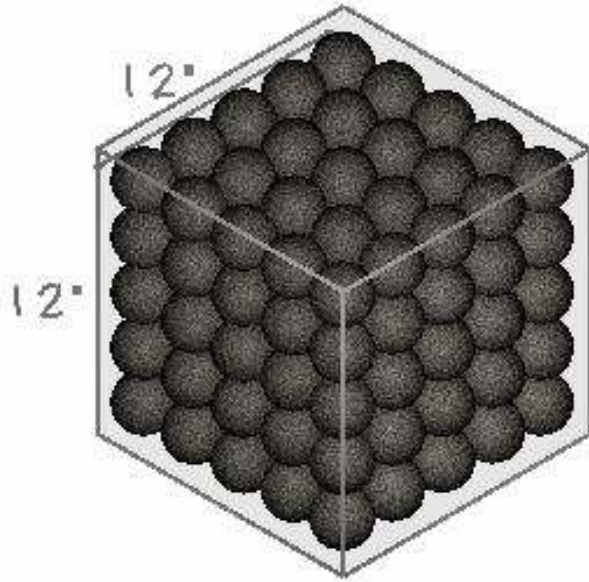


Figure 1: Specific surface area (diameter of stone versus surface area square inches per cubic inch of material)



2 1/2" Dia. Stone

Approximately 110 stones

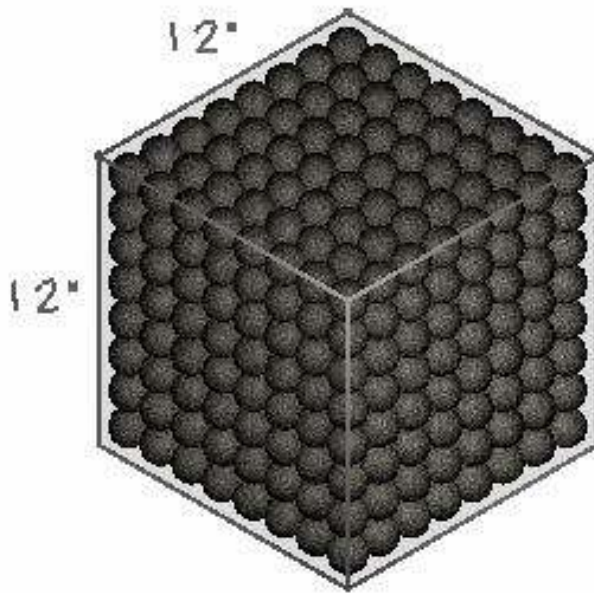
$$\text{Surface of sphere} = 4\pi r^2$$

$$r = 1.25$$

$$\frac{4 \times 3.14 (1.25)^2 \times 110 \text{ stones}}{144 \text{ sq. inches/sq. ft}}$$

$$\frac{2,158.75 \text{ sq. inches}}{144 \text{ sq. inches/sq. ft}}$$

= **15 sq. ft** of surface area per cubic foot of stone



1 1/2" Dia. Stone

Approximately 512 stones

$$\text{Surface of sphere} = 4\pi r^2$$

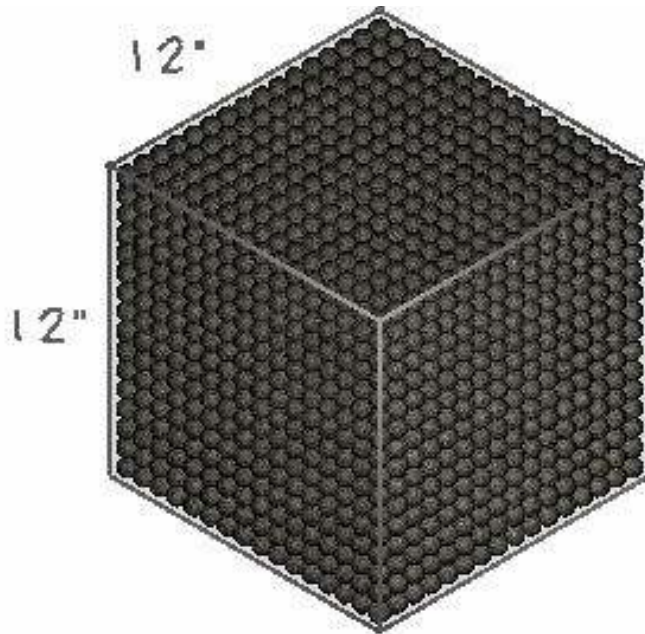
$$r = 0.75$$

$$\frac{4 \times 3.14 (0.75)^2 \times 512 \text{ stones}}{144 \text{ sq. inches/sq. ft}}$$

$$\frac{3,617 \text{ sq. inches}}{144 \text{ sq. inches/sq. ft}}$$

= **25 sq. ft** of surface area per cubic foot of stone

Figure 2a: Graphic representation of 1 1/2" and 2 1/2" dia. "stone" stacked in 1 foot cube to calculate theoretical surface area



3/4" Dia. Stone

Approximately 4,096 stones

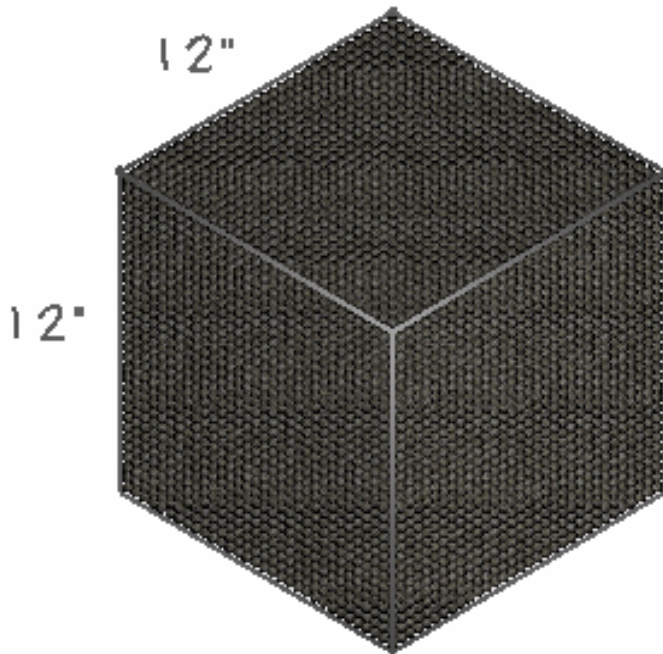
$$\text{Surface of sphere} = 4\pi r^2$$

$$r = 0.375$$

$$\frac{4 \times 3.14 \times (.375)^2 \times 4,096 \text{ stones}}{144 \text{ sq. inches/sq. ft}}$$

$$\frac{7235 \text{ sq. inches}}{144 \text{ sq. inches/sq. ft}}$$

= **50 sq. ft** of surface area per cubic foot of stone



3/8" Dia. Stone

Approximately 32,768 stones

$$\text{Surface of sphere} = 4\pi r^2$$

$$r = 0.1875$$

$$\frac{4 \times 3.14 \times (.1875)^2 \times 32,768 \text{ stones}}{144 \text{ sq. inches/sq. ft}}$$

$$\frac{14,469 \text{ sq. inches}}{144 \text{ sq. inches/sq. ft}}$$

= **100 sq. ft** of surface area per cubic foot of stone

Figure 2b: Graphic representation of 3/4" and 3/8" dia. "stone" stacked in 1 foot cube to calculate theoretical surface area

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Effective Diameter	$\frac{3}{8}$ "	$\frac{3}{4}$ "	$1\frac{1}{2}$ "	$2\frac{1}{2}$ "	Mixed ¹ ($\frac{3}{8}$ to $2\frac{1}{2}$)
Surface area (sq. ft.) in 1 cu. ft. of stone	100	50	25	15	48
Surface area in typical stone bed 20' x 45' x 1' sq. ft.	90,000	45,000	22,500	13,500	43,500

¹Based on a volume average of individual components.

Table 3: Surface Area Of Stone Vs. Effective Stone Size Diameter

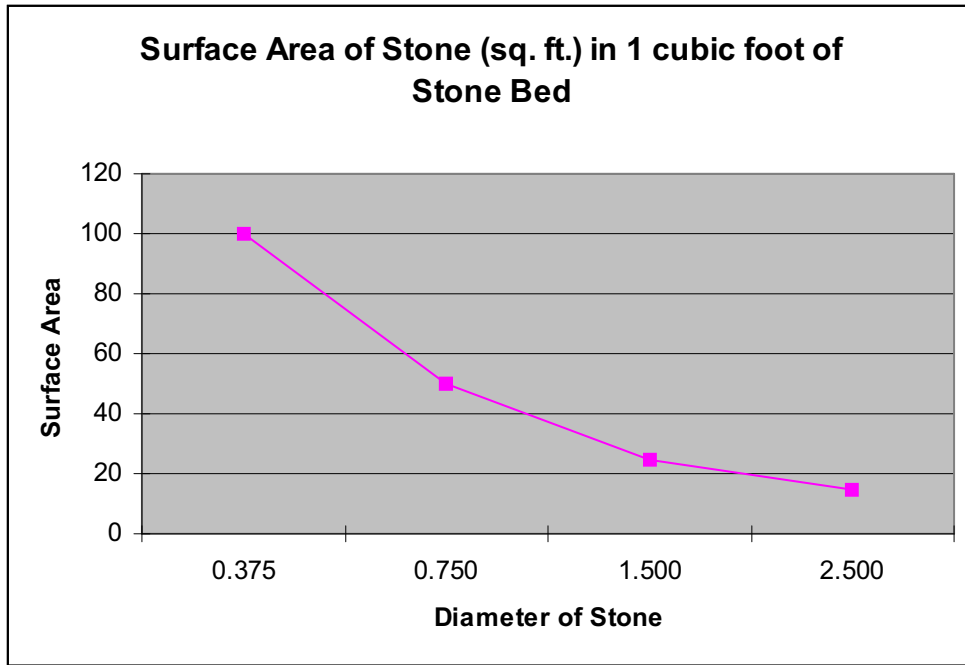


Figure 3: Calculated Square Feet of Surface Area per Cubic Feet of Stone Bed vs. Effective Stone Size Diameters

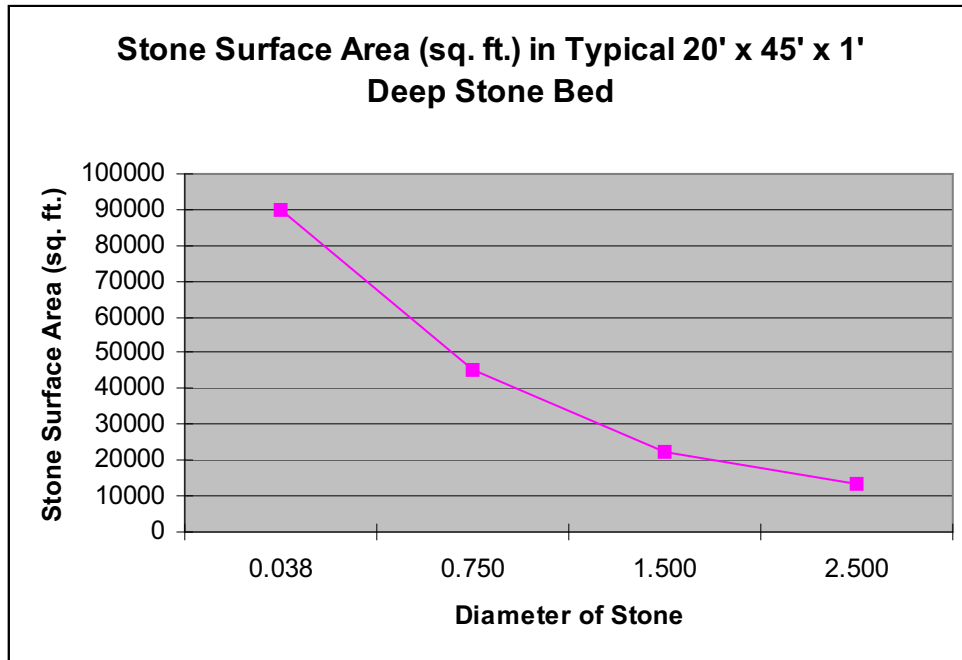


Figure 4: Calculated Square Feet of Surface Area in Typical Maine (medium large) 20' x 45' Stone Bed vs. Effective Stone Diameter

By reducing stone diameter from 1½" to ¾", it reduces storage capacity by 0.9% and doubles surface area. By reducing stone diameter from 1½" to ⅜", it reduces storage capacity by 3.3% and quadruples surface area. Hence, stone diameter has a much larger impact on disposal surface area than on disposal storage capacity.

While performing this experiment, authors noted silty residue washing from the stone particles (see Photos 9 & 10). Rock *flour* or silty residue in stone aggregate particles utilized for construction of septic systems may be a concern as a source of fine particles washing off the aggregate and forming a fine textured silty layer at the stone/soil surface thereby reducing permeability and should be examined.

However, a small percentage of coarse gravel or sandy particle mixed with stone aggregate should not significantly reduce storage and should not cause a fine textured horizon at the stone/soil interface if it was to wash down with use, so it does not appear to be a concern, since the coarseness of the particles would not necessarily cause a hydraulically restricted horizon in comparison to the typical backfill material.

Experience of authors in examining leaching areas comprised of stone beds has revealed that a biological coating of polysaccharides and organic material can be found on stone particles of older used stone beds. This material adheres to the surface of the stone. Hence, more surface area produces more storage area for biological matter, which would inherently reduce the amount of matter available to potentially clog the soil/stone interface.

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Photo 2: Stone samples of $\frac{3}{8}$ " dia, $\frac{3}{4}$ " dia, $1\frac{1}{2}$ " dia and $2\frac{1}{2}$ " diameter used in experiment.

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Photo 3: $\frac{3}{8}$ " dia stone sample.

Photo 4: $\frac{3}{4}$ " dia stone sample.

Photo 5: $1\frac{1}{2}$ " diameter stone sample.

Photo 6: $2\frac{1}{2}$ " diameter stone sample.

Photo 7: Mixed stone-25% by volume of dia of $\frac{3}{8}$ ", $\frac{3}{4}$ ", $1\frac{1}{2}$ " and $2\frac{1}{2}$ " diameter.

Photo 8: Adding water to container with stone to weight added water weight of voids.

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Photo 9: Typical silt residue from rock flour of crushing operation on stone aggregate after rinsing.



Photo 10: Residue from stone *dust* of silt size particle.