# Technical Note

## TN 6.32 Manifold Sizing for StormTech® Chamber Systems

## Introduction

The design of subsurface chambers systems, as part of a site design, involves many site-specific and regulatory constraints that necessarily leave overall design responsibility with the consulting engineer. However, ADS offers assistance to the design engineer for the layout of chamber systems and the manifolds that connect the chambers to the drainage system. This technical document summarizes the methods ADS uses for calculating the size and configuration of manifolds for the StormTech chamber system.

StormTech Chamber manifolds are comprised of smooth interior pipes, fittings, injection molded and prefabricated manifold sections that align with the proper spacing of the chamber rows. The use of common pipe components enables the engineer to apply straightforward hydraulic equations to size the manifold system.

The primary manifold design objectives are: 1) to convey the peak flows to and from the chamber system without causing an unacceptable backwater and 2) to preclude scour of foundation stone under the chamber system. ADS assumes the maximum allowable water surface elevation is at full storage (top of open graded cover stone). The design engineer may choose to design for a higher maximum water surface elevation. Since the relationship between the inflow hydrographs, outlet control, time to peak and accumulated storage are site specific and complex, ADS assumes that the peak inlet flow occurs when there is no water in the chambers. This is the worst-case condition for scour. ADS assumes that the chambers are full when the peak outlet flow occurs.

## Inlet Manifolds

Inlet manifold design can be broken down into three parts. First, determine the flow capacity of the main trunk. Then, determine the flow capacity & scour potential of each stub. Finally, compare the two values and choose the lesser of the two.

### *Inlet Trunk Sizing*

Design of the main trunk is determined by using the equation for the orifice of a short tube. In general, StormTech chamber systems are laid level with minimal length between the manhole and the location of the first stub. In this case, the short tube will be the controlling condition. Flow in the main trunk is reduced after each stub and headlosses in the balance of the trunk do not control.

The equation for an orifice of a short tube[1] is:

$$Q = Ca\sqrt{2gh}$$

Where,

Q = maximum flow through the orifice $cfs$ $\left(\frac{m^3}{s}\right)$

C = 0.75 [unitless coefficient of discharge]

a = area of manifold trunk $ft^2$ $(m^2)$

g = 32.2 $\frac{ft}{s^2}$, $\left(9.8\ \frac{m}{s^2}\right)$

h = head over center of orifice $ft$ $(m)$

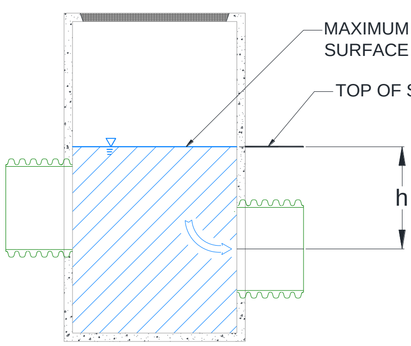



**Figure 1**
**Head for Orifice of a Short Tube Equation**

The value of “h” is dependent on the size, invert, and configuration of the selected manifold. Chamber size and cover may limit the manifold sizes available. Ultimately, a manifold is considered acceptable when the values for both “a” and “h” produce a value of Q greater than the required inlet flow. Values of “h” are typically based on standard StormTech components. Standard stub inverts can be found on the Technical Specification corresponding to the chamber model.

The design engineer may apply a greater value for “h” if it is not limited by the maximum water surface elevation being set at the top of stone.

### *Inlet Stub Sizing*

Inlet stub flows have been calculated by evaluating the stub connection as a circular broad crested weir[2]. The flow through the stub can be calculated using the following equations:

$$Q = C_d {d_0}^{2.5} g^{0.5} f(\theta)$$

$$C_d = 0.93 + 0.10 \frac{H_1}{L}$$

Where,

$C_d$ = discharge coefficient [unitless dimension]

L = length of weir in the flow direction $ft\ (m)$

g = $32.2\ \frac{ft}{s^2}$, $\left(9.8\ \frac{m}{s^2}\right)$

$H_1$ = energy head $ft\ (m)$

$d_0$ = stub diameter $ft\ (m)$

f($\theta$) = shape factor for the control section

The shape factor can be interpolated from Table 1 and varies based on the energy head. The energy head is assumed to not exceed the diameter of the stub.

**Figure 2**

**StormTech Manifold as a Broad-Crested Weir with Circular Cross Section**

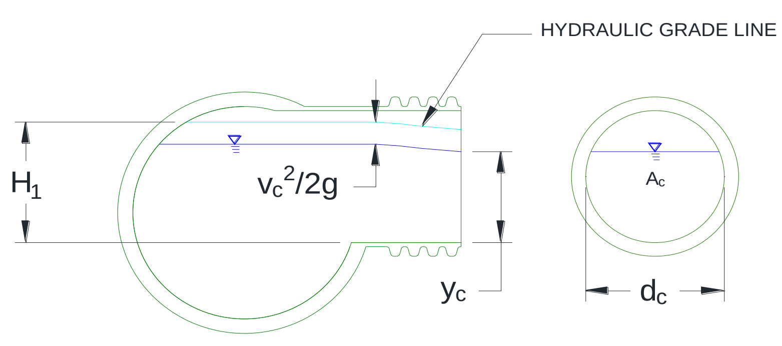


**Table 1**

**Ratios for Determining the Discharge Q of a Broad-Crested Weir with a Circular Control Section[2]**

| $\frac{H_1}{d_c}$ | f($\theta$) | $\frac{H_1}{d_c}$ | f($\theta$) | $\frac{H_1}{d_c}$ | f($\theta$) |
|---|---|---|---|---|---|
| 0.0668 | 0.0027 | 0.4926 | 0.1311 | 0.9502 | 0.4189 |
| 0.0803 | 0.0039 | 0.5068 | 0.1382 | 0.9674 | 0.4314 |
| 0.0937 | 0.0053 | 0.5211 | 0.1455 | 0.9848 | 0.444 |
| 0.1071 | 0.0068 | 0.5354 | 0.1529 | 1.0025 | 0.4569 |
| 0.1206 | 0.0087 | 0.5497 | 0.1605 | 1.0204 | 0.4701 |
| 0.1341 | 0.0107 | 0.5641 | 0.1683 | 1.0386 | 0.4835 |
| 0.1476 | 0.0129 | 0.5786 | 0.1763 | 1.0571 | 0.4971 |
| 0.1611 | 0.0153 | 0.5931 | 0.1844 | 1.0759 | 0.5109 |
| 0.1746 | 0.0179 | 0.6076 | 0.1927 | 1.0952 | 0.5252 |
| 0.1882 | 0.0214 | 0.6223 | 0.2012 | 1.1148 | 0.5397 |
| 0.2017 | 0.0238 | 0.6369 | 0.2098 | 1.1349 | 0.5546 |
| 0.2153 | 0.027 | 0.6517 | 0.2186 | 1.1555 | 0.5698 |
| 0.2289 | 0.0304 | 0.6665 | 0.2276 | 1.1767 | 0.5855 |
| 0.2426 | 0.034 | 0.6814 | 0.2368 | 1.985 | 0.6015 |
| 0.2562 | 0.0378 | 0.6964 | 0.2461 | 1.221 | 0.618 |
| 0.2699 | 0.0418 | 0.7114 | 0.2556 | 1.2443 | 0.6351 |
| 0.0736 | 0.046 | 0.7265 | 0.2652 | 1.2685 | 0.6528 |
| 0.2973 | 0.0504 | 0.7417 | 0.275 | 1.2938 | 0.6712 |
| 0.3111 | 0.055 | 0.757 | 0.2851 | 1.3203 | 0.6903 |
| 0.3248 | 0.0597 | 0.7724 | 0.2952 | 1.3482 | 0.7102 |
| 0.3387 | 0.0647 | 0.7879 | 0.3056 | 1.3777 | 0.7312 |
| 0.3525 | 0.0698 | 0.8035 | 0.3161 | 1.4092 | 0.7533 |
| 0.3663 | 0.0751 | 0.8193 | 0.3268 | 1.4432 | 0.7769 |
| 0.3802 | 0.0806 | 0.8351 | 0.3376 | 1.48 | 0.8021 |
| 0.3942 | 0.0863 | 0.8511 | 0.3487 | 1.5204 | 0.8293 |
| 0.4081 | 0.0922 | 0.8672 | 0.3599 | 1.5655 | 0.8592 |
| 0.4221 | 0.0982 | 0.8835 | 0.3713 | 1.6166 | 0.8923 |
| 0.4361 | 0.1044 | 0.8999 | 0.3829 | 1.6759 | 0.9297 |
| 0.4502 | 0.1108 | 0.9165 | 0.3947 | 1.7465 | 0.9731 |
| 0.4643 | 0.1174 | 0.9333 | 0.4068 | 1.8341 | 1.0248 |
| 0.4784 | 0.1289 | | | | |

In addition to determining the hydraulic capacity of the stub, the velocity of flow down the chamber must be checked to ensure that the scour velocity of the stone is not exceeded. Scour velocity is based on the critical shear stress of the bedding material which is dependent on particle size. The No. 57 stone is used for the analysis since the particle diameter of the material is the smallest allowed in StormTech material guidance. Permissible shear velocity and shear stress can be found in Table 2.

**Table 2**

**Permissible Shear Velocity & Shear Stress for Various Types of Materials[2]**

| Material | Clear Water | | Water Transporting Colloidal Silts | |
|---|---|---|---|---|
| | U $\left[\frac{ft}{s}\right]$ | $\tau_0\left[\frac{lb}{ft^2}\right]$ | U $\left[\frac{ft}{s}\right]$ | $\tau_0\left[\frac{lb}{ft^2}\right]$ |
| Fine sand, colloidal | 1.50 | 0.027 | 2.50 | 0.075 |
| Sandy loam, noncolloidal | 1.75 | 0.037 | 2.50 | 0.075 |
| Silt loam, noncolloidal | 2.00 | 0.048 | 3.00 | 0.11 |
| Alluvial silts, noncolloidal | 2.00 | 0.048 | 3.50 | 0.15 |
| Ordinary firm loam | 2.50 | 0.075 | 3.50 | 0.15 |
| Volcanic ash | 2.50 | 0.075 | 3.50 | 0.15 |
| Silt clay, very colloidal | 3.75 | 0.26 | 5.00 | 0.46 |
| Alluvial silts, colloidal | 3.75 | 0.26 | 5.00 | 0.46 |
| Shales and hardpan | 6.00 | 0.67 | 6.00 | 0.67 |
| **Fine gravel** | **2.50** | **0.075** | **5.00** | **0.32** |
| Graded loam to cobbles when noncolloidal | 3.75 | 0.38 | 5.00 | 0.66 |
| Graded silts to cobbles when colloidal | 4.00 | 0.43 | 5.50 | 0.80 |
| Coarse gravel, noncolloidal | 4.00 | 0.30 | 6.00 | 0.67 |
| Cobbles and shingles | 5.00 | 0.91 | 5.50 | 1.10 |

Typically, ADS assumes 9” (230mm) of ponded water in the MC series and 6” (150mm) of ponded water in the SC series when the peak flow occurs. Additionally, StormTech ignores losses from the impact loses from the jet exiting the stub, the expansion loses as the water frays outward, and the friction losses caused by the corrugations. In larger stub diameters and flows there is the potential for a hydraulic jump to form. Scour lengths have been determined to ensure that the jump occurs before the end of the scour fabric.

**Table 2**

**Permissible Shear Velocity & Shear Stress for Various Types of Materials[2]**

| Stub Diameter $in\ (mm)$ | Inlet Flow Rate per Stub per Chamber Model $cfs\ \left(\frac{L}{s}\right)$ LP-160 | SC-310 | SC-740/DC-780 | MC-3500 | MC-4500 |
|---|---|---|---|---|---|
| 6 (150) | 0.37 (10.4) | 0.43 (12.1) | 0.43 (12.1) | 0.43 (12.1) | 0.43 (12.1) |
| 8 (200) | 0.74 (20.9) | 0.89 (25.1) | 0.89 (25.1) | 0.89 (25.1) | 0.89 (25.1) |
| 10 (250) | NA | 1.32 (37.3) | 1.56 (44.1) | 1.56 (44.1) | 1.56 (44.1) |
| 12 (300) | NA | 2.07 (58.5) | 2.30 (65.0) | 2.48 (70.1) | 2.48 (70.1) |
| 15 (375) | NA | NA | 2.80 (79.2) | 3.50 (99.0) | 3.50 (99.0) |
| 18 (450) | NA | NA | 2.80 (79.2) | 5.50 (155.6) | 5.50 (155.6) |
| 24 (600) | NA | NA | 2.80 (79.2) | 8.50 (240.5) | 9.50 (268.8) |

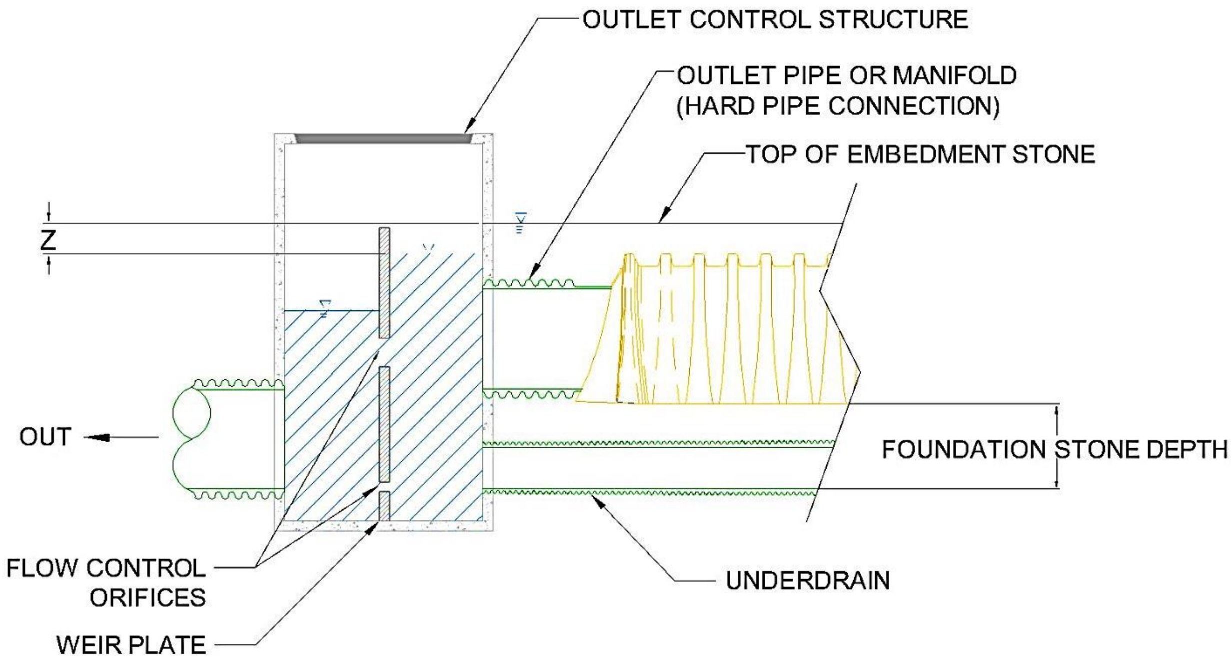
## Outlet Manifolds

The purpose of the outlet manifold "hard-pipe connection(s)" is to ensure that there are free-flooding conditions between the StormTech chambers and the outlet control structure. The outlet manifold must be able to pass the design peak outlet flow rate from the chamber system to the outlet control structure.

The premise for the ADS sizing approach is that the outlet control structure has caused the chambers to be full when the peak outlet flow occurs. Essentially, the outlet control structure has impeded flow and caused a backwater in the StormTech chambers. This premise is appropriate for most flow attenuation systems and also simplifies the design. Since the chambers are assumed to be full, the allowable flow through the chamber row is the full chamber flow area multiplied by the acceptable scour velocity. However, when the design intent is to maximize storage in the chambers, the outlet structure would cause a high tailwater and driving head would be small. Under the low driving head scenario, pipe flow is more constricting than chamber row flow.

The outlet manifold sizing then becomes full pipe flow which is dependent upon driving head, headlosses at the pipe entrance, friction losses in the pipes, fitting losses (if a manifold) and exit losses. This is solved by a simple application of the energy equation and the Darcy-Weisbach equation for piping connecting two reservoirs; the upstream reservoir elevation being the maximum water surface elevation in the chamber system and the downstream reservoir elevation being the water surface elevation caused by the outlet control (see Figure 3).

**Figure 3**
**Outlet Connections (Reservoir-to-Reservoir Connection)**




The formulas to be used are:

Energy Equation[4]

$$\frac{p_1}{\gamma} + \alpha\frac{{v_1}^2}{2g} + z_1 = \frac{p_2}{\gamma} + \alpha\frac{{v_2}^2}{2g} + z_2 + h_l$$

Where,

$\frac{p}{\gamma}$ = Pressure head $ft\ (m)$

$\alpha\frac{v^2}{2g}$ = Velocity head $ft\ (m)$,

$\alpha$ = kinetic energy correction factor (typically set to 1)

$z$ = Elevation $ft\ (m)$

Darcy-Weisbach Formula[4]

$$h_f = f\frac{Lv^2}{D2g}$$

Where,

$h_f$ = Headlosses in pipe $ft\ (m)$

$L$ = Length of pipe $ft\ (m)$

$D$ = Pipe diameter $ft\ (m)$

$f$ = resistance coefficient

$\frac{v^2}{2g}$ = Velocity head $ft\ (m)$

Colebrook Formula[5]

$$\frac{1}{\sqrt{f}} = 2.0 \log\left(\frac{\frac{\varepsilon}{D}}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$

Where,

$f$ = Headlosses in pipe

$D$ = Pipe diameter $ft$ $(m)$

$Re$ = Reynolds number

$\frac{\varepsilon}{D}$ = equivalent relative roughness

$\varepsilon$ = equivalent absolute roughness

Headlosses in transitions and fittings can be calculated using the formula[4]:

$$h_L = K\frac{v^2}{2g}$$

Where,

$K_e$ = 0.5 for square edge inlet pipe[4]

$K_E$ = 1.0 for re-entrant (pipe into outlet control[4] structure)

$K_L$ = 2.0 for branched tee (manifold tee)[7]

ADS solved the energy equation and the Darcy-Weisbach equation based on a driving head of 0.25 feet (76mm). The losses included are: 1 square edge inlet, 1 tee, 1 outlet and ≤ 50 ft of pipe. Suggested maximum flow rates manifold diameter as shown in Table 4. When the required pipe size exceeds the maximum allowable stub diameter that can connect to the chamber end cap a reducing manifold is required allowing for smaller individual connections to the end caps that feed the larger required manifold trunk. The number of stubs required for the reducing manifold is obtained by dividing the required outlet flow rate by the maximum allowable outlet flow rate per stub from Table 4. Size-on-size manifolds only require a single connection to meet the maximum allowable outlet flow per diameter.

**Table 4**

**Maximum Allowable Outlet Flow Rate per Stub Diameter**

| Stub Diameter $in$ $(mm)$ | Maximum Allowable Outlet Flow Rate $cfs$ $\left(\frac{L}{s}\right)$ |
|---|---|
| 6 (150) | 0.4 (11.3) |
| 8 (200) | 0.7 (19.8) |
| 10 (250) | 1.0 (28.3) |
| 12 (300) | 2.0 (56.6) |
| 15 (375) | 2.7 (76.4) |
| 18 (450) | 4.0 (133.2) |
| 24 (600) | 7.0 (198.2) |
| 30 (750) | 11.0 (311.4) |
| 36 (900) | 16.0 (453.0) |
| 42 (1050) | 22.0 (622.9) |
| 48 (1200) | 28.0 (792.8) |

**Figure 4**

**Determining Maximum Allowable Outlet Flow for Reducing Manifolds**

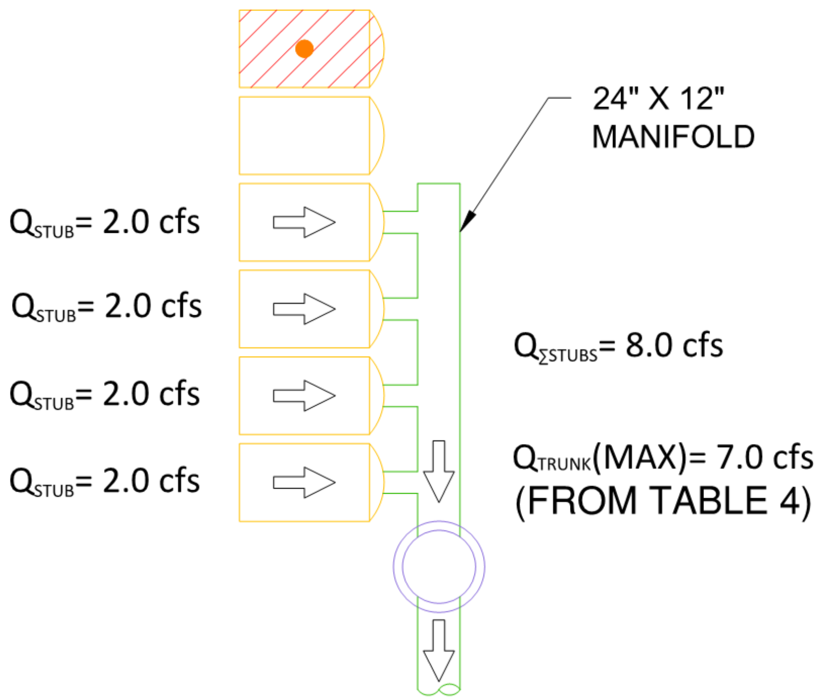


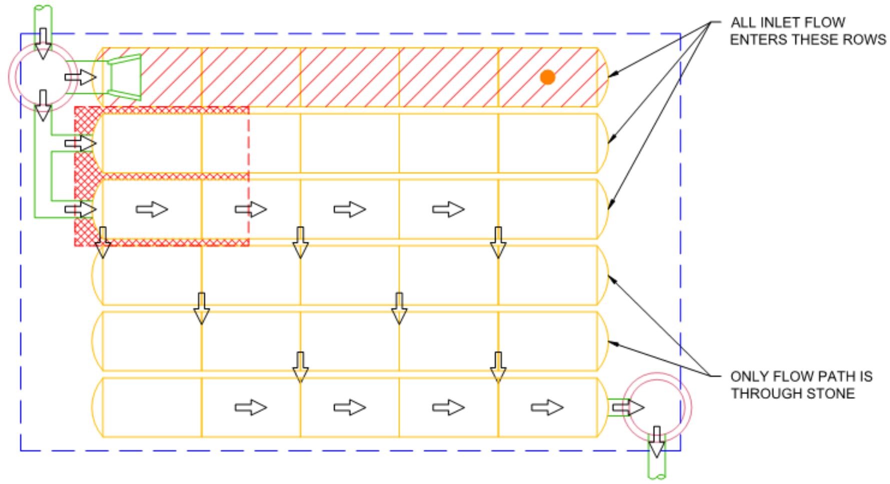

Figure 4 shows how the maximum allowable outlet flow is determined for a reducing manifold. In this case the four 12" stubs provide 2.0 $cfs$ $(56.6\ \frac{L}{s})$ each for a total of 8.0 $cfs$ $(226.4\ \frac{L}{s})$ . These stubs will feed the trunk which has a maximum allowable outlet flow of 7.0 $cfs$ $(198.1\ \frac{L}{s})$ (see Table 4). The lesser of these two values should be chosen. Therefore, the maximum allowable outlet flow for this example is 7.0 $cfs$ $(198.1\ \frac{L}{s})$ . If only three 12" stubs were provided (for a total of 6.0 $cfs$, $169.8\ \frac{L}{s}$) then 6.0 $cfs$ $(169.8\ \frac{L}{s})$ would be the maximum allowable outlet flow.

## Manifold Configuration

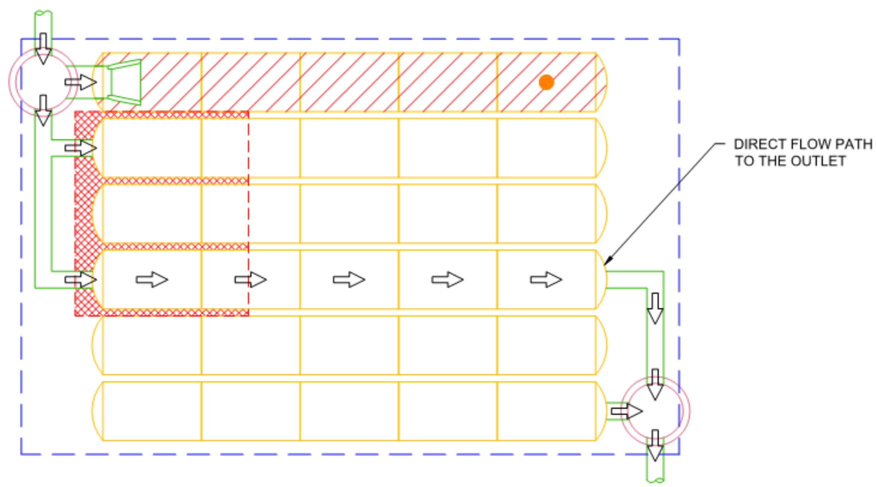
In addition to conveying the peak flow rates, StormTech manifolds are designed to distribute water across the chamber system and provide a direct flow path from inlet to outlet. For wider beds, manifold stubs are spaced out over the available rows. Spread configurations help prevent conditions where lateral flow through the embedment stone limits the distribution across the system. Figure 5 shows an example of two manifold configurations; one where flow is limited by lateral flow through the embedment stone and one where flow has a direct path from inlet to outlet.

**Figure 5**

**Flow Path through StormTech Systems based on Manifold Configuration**




**Flow forced through foundation stone**




**Free flow through chamber row**

The aggregate used for StormTech's chambers have permeability's (Darcy *k* values) that range from $0.1\ \frac{ft}{s}$ $\left(0.03\ \frac{m}{s}\right)$to $1.6\ \frac{ft}{s}\left(0.49\ \frac{m}{s}\right)$ (No. 57 and No. 3 respectively) [6]. StormTech has estimated the flow through the stone beneath the chambers (one direction) as:

**Table 5**

**Estimate Flow Rates Through Stone by Gradation and Chamber Model**

| Stone Gradation | Darcy "k" | Flow by Chamber $cfs\ \left(\frac{L}{s}\right)$ LP-160 | SC-310 | SC-740 | MC-3500 | MC-4500 |
|---|---|---|---|---|---|---|
| #3 | 1.6 | 2.28 (64.5) | 3.04 (86.0) | 4.17 (118.0) | 6.67 (188.7) | 4.25 (120.2) |
| #357, 4, 467, 5 | 0.6 | 0.85 (24.0) | 1.14 (32.2) | 1.60 (45.2) | 2.50 (70.7) | 1.60 (45.2) |
| #56, 57 | 0.1 | 0.14 (3.9) | 0.19 (5.3) | 0.26 (7.3) | 0.42 (11.8) | 0.27 (7.6) |
| *Disclaimer: The hydraulic performance of manifolds for detention systems is dependent upon many variables including but not limited to; headwater and tail water conditions, the inflow hydrograph and headloss through the piping system. StormTech has used assumptions to simplify the manifold design process. The design engineer for the project must verify that the assumptions and calculations are appropriate for the specific application.* | | | | | | |


[1] Brater, E.F. and King, H. W., Handbook of Hydraulics for the Solution of Hydraulic Engineering Problems, 6th ed., McGraw-Hill, New York, 1976

[2] Bos, M. G., Discharge Measurement Structures 3rd ed. International Institute for Land Reclamation and Improvement, 1990.

[3] Chang, H. H., Fluvial Processes in River Engineering. Krieger Publishing Company, 2008.

[4] Cassidy, J.J, Chaudhry, M.H., and Roberson, J. A., Hydraulic Engineering, 1st ed., Houghton Mifflin, Boston, 1988

[5] Gerhart, P.M., Gross, R.J., and Hochstien, J.I. Fundamentals of Fluid Mechanics, 2nd ed., Addison-Wesley, New York, 1992

[6] Cedergren, H.R., Seepage, Drainage, and Flow Nets, 3rd ed., John Wiley & Sons, New York, 1989

[7] Munson, B.R., Okiishi, T.H., and Young, D.F., Fundamentals of Fluid Mechanics, 5th ed., John Wiley & Sons, Danvers, 2006