EN:PLAST TECHNOLOGY

ShockDrain™

• ROLL • RESOLVE • RECYCLE

DRAINAGE CAPACITY & TIME TO DRAIN DESIGN MANUAL

TABLE OF CONTENTS

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

USED ABBREVIATIONS

cfs	cubic feet per second
cm	centimeter
ft	foot / feet
fps	foot per second
hr	hour
in	inch
m	meter
mil	one thousandth of an inch
sec	second

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

1. INTRODUCTION

ShockDrain is a shock attenuation and synthetic aggregate technology designed for the use beneath synthetic turf designed to achieve optimum advanced artificial athlete performance. Additionally, the technology delivers high fluid and air transmissivity and low thermal gradient between sub-grade and turf.

ShockDrain embodies En-Plast technology's innovative design concept which revolves around three pillars:

1) *Structural stability*; where **ShockDrain** is an integral part with sub-base. The bottom square structure transfers vertical load to base at 360 degrees, the force reduction control to perform as a surface to athletes, and the high-friction angle subbase to pad.

2) *Top-Surface Integrity*; as **ShockDrain** is resilient to thermal cycles and play stress forces. It provides true expansion and contraction joints to combat thermal movements in hot or cold climates, and neutral frost cycles to transfer zero forces to top-surface. **ShockDrain** has highfriction angle turf-pad maintains field configuration integrity under the life of the field. The braced vertical pillar ribs of **ShockDrain** control playing stressors and provide impact attenuation and energy restitution optimizers. **ShockDrain** grants zero-line movements above ground.

3) *Drainage Performance*; the cross-section ribs and perforation of **ShockDrain** facilitate vertical and horizontal drainage, quick time for lateral drainage, and flash infiltration, turf-to-pad.

This design procedures manual focuses on the Drainage Performance of **ShockDrain** and the technical background on Input Parameters selection and the Design Calculations performed to determine the drainage capacity, and time to drain for a sportfield application. In such application, a typical section consists of, from top down, turf & fill cover layer, **ShockDrain**, 6-inch leveling stone, a separation geotextile layer, and then the prepared subgrade.

In some cases, the leveling stone is required to work as a storage and drainage layer in conjunction with the **ShockDrain**, in this case, the **ShockDrain** is perforated at the bottom layer to allow for continuation of the water flow vertically through and into the leveling stone. In some other cases, the **ShockDrain** is sufficient by itself for drainage and the stone layer is considered only for

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

leveling with a minimum thickness of 6 inches. The design procedures presented in the following sections will determine the drainage capacity requirement of the drainage system in consideration.

2. INPUT PARAMETERS

All the design steps and procedures presented in this manual are available on our website https://enplast.us/ where the designer can interactively input project-specific data and run sensitivity analysis with the design parameters for different system components. The design procedures presented in the following sections follow a design example of a sportfield system using **ShockDrain** in the city of Houston, TX.

2.1 Field Conditions

The first set of input parameters pertains to the sportfield conditions. Typically sport fields have a gentle slope with a value between 0.5% to 1% directed towards an edge drain to facilitate the infiltration and quick removal of the rainfall water from the ground. Figure 1 shows a typical section of a sportfield cover using **ShockDrain**. The field conditions also include the runoff coefficient, C which is an indication of the portion of rainfall that runoff the field cover and does not infiltrate into the ground. Table 1 lists the required input parameters of field conditions with an explanation of each parameter and the values considered for this example.

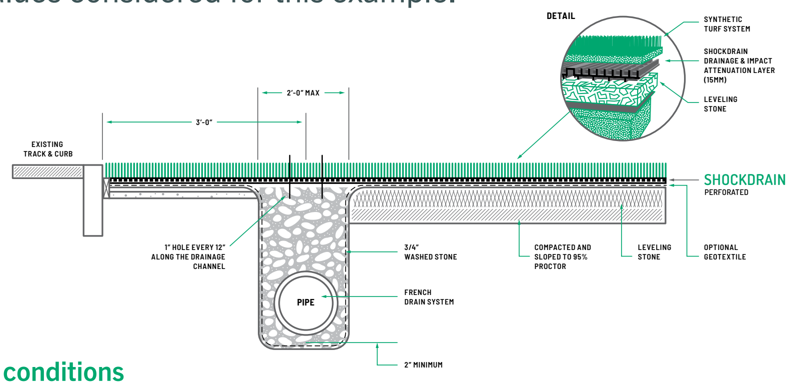


Figure 1: Typical Sports Field Section Using ShockDrain

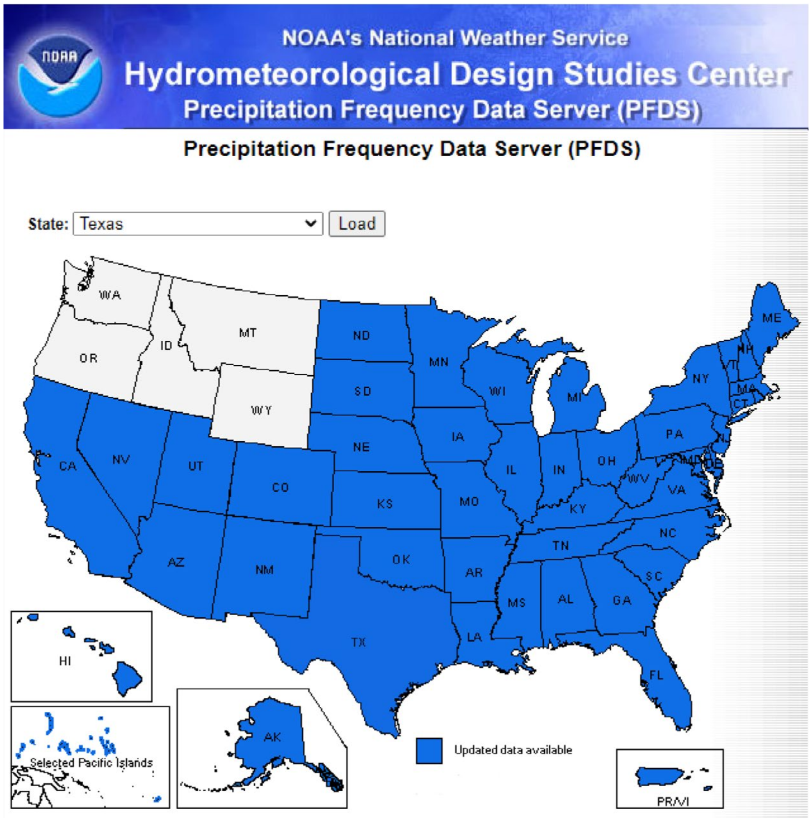
Table 1: Input parameters for field conditions

Input Parameter	Value	Units	Comments
Drainage length (length of the slope), ***L***	100	ft	Length of the field from the crest or center
Field width, ***W***	400	ft	Length of the field parallel to the edge drain
Gradient, ***s***	0.5	%	Slope of the field towards the edge drain
Runoff coefficient, ***C***	0.4	-	1 is all runoff, 0 is no runoff

2.2 Rainfall Properties

The second set of input parameters pertains to the rainfall properties at the location of the sport-field under design. The design engineer will select the rainfall event frequency and duration that the drainage system of the sportfield will be designed to handle. This type of selection depends on several factors including the design life of the sportfield, how often it will be maintained and how fast the water needs to be drained. The website of NOAA (National Oceanic and Atmospheric Administration) National Weather Services: Precipitation Frequency Estimate https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_printpage.html?lat=29.7583&lon=-95.3755&data=depth&units=english&series=pds provides the rainfall intensity at the location of interest, and the desired rainfall frequency and duration.

Figure 2: Selection of the sportfield location state, NOAA National Weather Services: Precipitation Frequency Estimate http://hdsc.nws.noaa.gov/hdsc/pfds



First, the user needs to select the state as shown in Figure 2, the click on "Load". The user will be prompted to a second screen, as shown in Figure 3, which shows a zoom in of the state with three different options to locate the site of the sportfield; 1) by latitude and longitude, b) by the closest station to the location, and c) by the address of the sportfiled. Once the location is determined, a red cross cursor will show identifying it on the map.

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

Figure 3 also shows that the type of data that the user is interested in showing for the location, there are two selections; 1) precipitation depth (inch), and 2) precipitation intensity (inch/hour). For the purpose of the design procedures of **ShockDrain** drainage capacity, precipitation intensity is selected. Figure 4 shows the precipitation intensity of the selected location at various rainfall event frequency and duration. For this example, a frequency of 1 in 10 years is selected and a duration of 2 hour or 60-min. The intensity corresponding to the event is 3.22 inch/ hour.

Figure 3: Selection of the sportfield location and data type, NOAA National Weather Services: Precipitation Frequency Estimate http://hdsc.nws.noaa.gov/hdsc/pfds

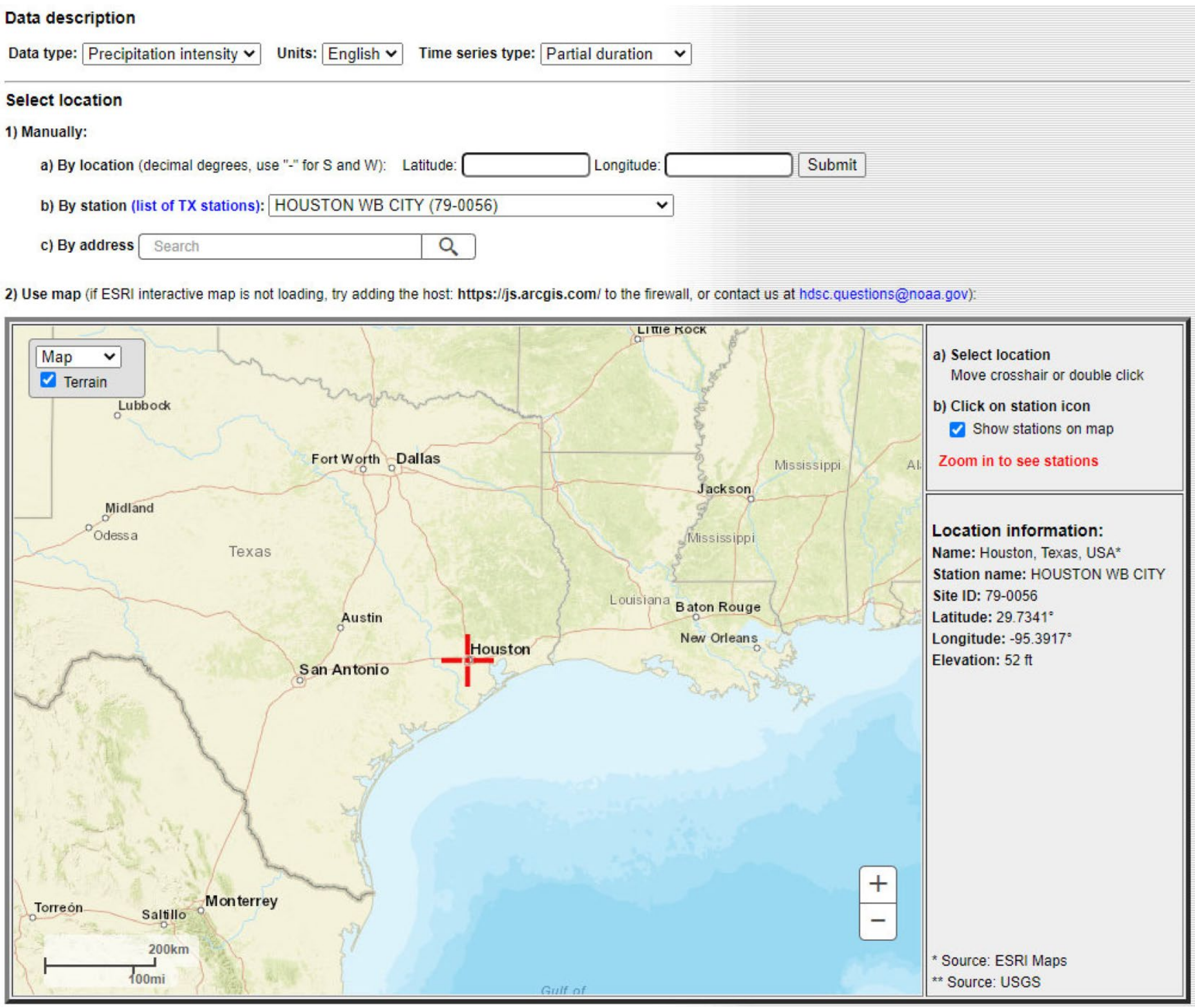


Figure 4: Precipitation intensity at various rainfall event frequency and duration, NOAA National Weather Services: Precipitation Frequency Estimate

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.498 (0.377-0.658)	0.585 (0.446-0.764)	0.726 (0.553-0.953)	0.845 (0.634-1.13)	1.01 (0.733-1.39)	1.14 (0.804-1.60)	1.27 (0.875-1.84)	1.41 (0.949-2.10)	1.61 (1.05-2.48)	1.77 (1.12-2.79)
10-min	0.788 (0.596-1.04)	0.928 (0.707-1.21)	1.15 (0.878-1.52)	1.34 (1.01-1.79)	1.61 (1.17-2.21)	1.82 (1.29-2.57)	2.03 (1.40-2.94)	2.24 (1.51-3.34)	2.53 (1.64-3.90)	2.75 (1.74-4.34)
15-min	1.00 (0.761-1.33)	1.18 (0.898-1.54)	1.46 (1.11-1.91)	1.69 (1.27-2.25)	2.01 (1.46-2.76)	2.26 (1.60-3.19)	2.52 (1.74-3.66)	2.80 (1.88-4.17)	3.19 (2.07-4.91)	3.49 (2.21-5.52)
30-min	1.45 (1.09-1.91)	1.68 (1.29-2.20)	2.07 (1.58-2.72)	2.39 (1.80-3.19)	2.84 (2.06-3.88)	3.17 (2.24-4.47)	3.53 (2.43-5.12)	3.93 (2.64-5.86)	4.52 (2.94-6.97)	5.00 (3.17-7.90)
60-min	1.90 (1.44-2.51)	2.23 (1.70-2.91)	2.77 (2.11-3.64)	3.22 (2.42-4.29)	3.85 (2.79-5.26)	4.33 (3.05-6.09)	4.84 (3.34-7.02)	5.45 (3.67-8.13)	6.37 (4.14-9.83)	7.14 (4.52-11.3)
2-hr	2.29 (1.74-3.00)	2.80 (2.12-3.57)	3.56 (2.72-4.63)	4.25 (3.21-5.62)	5.25 (3.83-7.15)	6.07 (4.31-8.50)	6.98 (4.84-10.1)	8.07 (5.45-11.9)	9.74 (6.35-15.0)	11.2 (7.10-17.5)
3-hr	2.50 (1.91-3.26)	3.13 (2.36-3.94)	4.06 (3.11-5.25)	4.93 (3.73-6.50)	6.23 (4.57-8.47)	7.32 (5.23-10.3)	8.58 (5.96-12.3)	10.1 (6.81-14.9)	12.4 (8.08-18.9)	14.3 (9.14-22.5)
6-hr	2.88 (2.21-3.73)	3.74 (2.81-4.60)	4.96 (3.81-6.34)	6.14 (4.68-8.04)	7.96 (5.89-10.8)	9.55 (6.87-13.3)	11.4 (7.96-16.3)	13.6 (9.21-19.9)	16.9 (11.1-25.7)	19.8 (12.7-30.8)
12-hr	3.31 (2.56-4.26)	4.40 (3.30-5.32)	5.90 (4.56-7.48)	7.38 (5.66-9.59)	9.68 (7.21-13.0)	11.7 (8.48-16.2)	14.1 (9.88-20.0)	16.9 (11.5-24.6)	21.2 (13.9-32.0)	24.9 (16.0-38.5)
24-hr	3.80 (2.95-4.85)	5.12 (3.85-6.12)	6.93 (5.39-8.72)	8.74 (6.73-11.3)	11.5 (8.66-15.5)	14.1 (10.2-19.4)	17.0 (12.0-23.9)	20.4 (13.9-29.4)	25.4 (16.8-38.2)	29.8 (19.1-45.8)
2-day	4.33 (3.39-5.50)	5.95 (4.48-7.01)	8.14 (6.36-10.2)	10.4 (8.03-13.3)	13.8 (10.5-18.5)	17.0 (12.5-23.4)	20.6 (14.6-28.8)	24.4 (16.8-35.0)	29.9 (19.8-44.5)	34.3 (22.2-52.5)
3-day	4.73 (3.72-5.98)	6.49 (4.92-7.64)	8.90 (6.98-11.1)	11.3 (8.80-14.4)	15.1 (11.5-20.1)	18.5 (13.6-25.4)	22.3 (15.9-31.1)	26.3 (18.1-37.6)	31.9 (21.2-47.3)	36.3 (23.5-55.4)
4-day	5.06 (3.99-6.38)	6.89 (5.25-8.12)	9.40 (7.40-11.7)	11.9 (9.28-15.1)	15.7 (12.0-21.0)	19.3 (14.2-26.3)	23.2 (16.5-32.2)	27.2 (18.8-38.7)	32.8 (21.8-48.5)	37.3 (24.2-56.7)
7-day	5.82 (4.61-7.30)	7.72 (5.95-9.13)	10.4 (8.22-12.8)	13.0 (10.2-16.4)	16.9 (13.0-22.4)	20.5 (15.2-27.8)	24.4 (17.4-33.8)	28.5 (19.7-40.4)	34.1 (22.8-50.3)	38.6 (25.1-58.5)
10-day	6.48 (5.14-8.08)	8.42 (6.55-9.99)	11.2 (8.89-13.8)	13.8 (10.9-17.4)	17.9 (13.7-23.5)	21.4 (15.9-28.9)	25.3 (18.1-34.9)	29.4 (20.4-41.5)	35.0 (23.4-51.4)	39.5 (25.7-59.6)
20-day	8.59 (6.86-10.6)	10.6 (8.45-12.8)	13.7 (11.0-16.8)	16.5 (13.0-20.6)	20.5 (15.7-26.6)	23.9 (17.7-31.9)	27.5 (19.8-37.6)	31.3 (21.9-44.1)	36.7 (24.7-53.6)	41.0 (26.8-61.5)
30-day	10.4 (8.33-12.8)	12.5 (10.1-15.1)	15.8 (12.8-19.4)	18.7 (14.8-23.3)	22.8 (17.4-29.3)	26.0 (19.3-34.4)	29.4 (21.2-40.0)	33.0 (23.1-46.3)	38.1 (25.7-55.5)	42.2 (27.7-63.1)
45-day	13.0 (10.5-16.0)	15.3 (12.5-18.6)	19.1 (15.5-23.3)	22.2 (17.7-27.5)	26.4 (20.3-33.8)	29.7 (22.1-39.1)	32.9 (23.8-44.7)	36.3 (25.5-50.8)	41.0 (27.7-59.5)	44.6 (29.3-66.5)
60-day	15.4 (12.4-18.9)	17.9 (14.6-21.8)	22.1 (18.0-26.9)	25.4 (20.3-31.4)	29.9 (23.0-38.1)	33.2 (24.8-43.6)	36.4 (26.4-49.3)	39.6 (27.9-55.3)	43.9 (29.7-63.5)	47.1 (31.0-69.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

Table 2 lists the required input parameters for the rainfall event of an interest with an explanation of each parameter and the values considered for this example.

Table 2: Input parameters for rainfall properties

Input Parameter	Value	Units	Comments
Rainfall frequency, ***f***	100	year	Average recurrence interval of the design rainfall event
Event duration, ***t***	1.0	hr	Duration of the rainfall which the drainage system needs to designed for
Intensity, ***I***	3.22	in/hr	Intensity of the rain for the selected event given by Figure 4

2.3 ShockDrain Properties

The third set of input parameters pertains to the engineering properties of **ShockDrain** which could be selected from the technical datasheet of the product. Table 3 lists the required input parameters for the **ShockDrain** properties that affect the calculations of its drainage capacity, with an explanation of each parameter and the values considered for this example. Test results that show the performance properties of **ShockDrain** are presented in Appendices A though C.

Table 3: Input parameters for ShockDrain properties

Input Parameter	Value	Units	Comments
Thickness, D_1	580	mils	Thickness of the product as measured by a caliber
Transmissivity, ***TRANS***	4.33E-02	m^3/sec.m	The transmissivity is the ability of the product to transmit a volume of water in a given time. It is equal to the hydraulic conductivity times the thickness measured at a given slope/gradient. Use this Table for the Transmissivity value that corresponds to the project's slope.
Effective porosity, n_1	0.65	-	Volume of voids percent to the total volume which will enable the water to flow through

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

2.4 Leveling Stone

The fourth and last set of input parameters pertains to the leveling stone which is typically placed underlying **ShockDrain**. The hydraulic properties of the stone could be obtained from the vendor. Otherwise, there are some typical values in the literature correlated to the median size of the stone. Table 4 lists the required input parameters for the leveling stone which affect the calculations of its drainage capacity and whether or not it will be needed in conjunction with **ShockDrain** to optimize the drainage performance of the system under the design rainfall event with an explanation of each parameter and the values considered for this example.

Table 4: Input parameters for leveling stone layer

Input Parameter	Value	Units	Comments
Hydraulic conductivity, k_2	1.0E-02	cm/sec	Represents how fast the water can flow through the leveling stone voids.
Thickness, D_2	0.83	ft	Average thickens of the stone as placed in the field.
Effective porosity, n_1	0.4	-	Volume of voids percent to the total volume which will enable the water to flow through
Initial degree of saturation, ***IS***	40	%	Represents the percent of voids occupied by water initially before the system be in operation. 100% is fully saturated

3. DESIGN CALCULATIONS

3.1 Drainage Capacity

The drainage capacity of **ShockDrain** in a sportfield application can be sufficient to convey all of the infiltrating flow from a design rainfall event. However, as stated earlier, in some cases and during heavy rainfall events, additional performance assessment is needed and the leveling stone will be needed to help in water storage as will be shown in the following design calculations. The infiltrated flow into the drainage system is equivalent to the rain flow minus the runoff flow.

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

Darcy's law for laminar flow:

$$\boldsymbol{Q = k.i.A} \qquad \textbf{Eq (1)}$$

Where, Q is the flow rate in (cfs), k is coefficient of permeability in (fps), i is the hydraulic gradient, and A is the cross sectional area in (ft^2)

Applying Darcy's law on vertical inflow of water into **ShockDrain**, the infiltrated flow rate Q_{in} per unit width:

$$Q_{in} = (1 - C)\,(I)(1)(L.1) \qquad \textbf{Eq (2)}$$

Where, C (-) is the runoff coefficient (Table 1), I (in/hr) is the rain intensity (Table 2), and L (ft) is the drainage length (Table 1)

Water storage in the leveling stone *ST* per unit width:

$$ST = \frac{n_2.(L.1).D_2}{T}\,.(1 - IS) \qquad \textbf{Eq (3)}$$

Where, n_2 (-) is the effective porosity (Table 4), D_2 (ft) is the thickness of the leveling stone (Table 4), T (hr) is the rainfall event duration (Table 2), and IS (-) is the initial saturation (Table 4)

To calculate the lateral drainage outflow per unit width into the edge drain for **ShockDrain:**

$$Q_{out1} = TRANS.s \qquad \textbf{Eq (4)}$$

Where, *TRANS* (m^3/s.m) is the transmissivity of **ShockDrain** (Table 3), s (-) is the gradient of the flow/ slope (Table 1).

To calculate the lateral drainage outflow per unit width into the edge drain for the leveling stone**:**

$$Q_{out2} = k_2.s.D_2 \qquad \textbf{Eq (5)}$$

Where, k_2 (cm/s) is the hydraulic conductivity of the leveling stone (Table 4)

The drainage factor of safety FS_{drain}

$$FS_{drain} = \frac{ST + Q_{out1} + Q_{out2}}{Q_{in}} \qquad \textbf{Eq (6)}$$

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

Substituting in Eq (2), $Q_{in} = (1 - 0.4)\ (\frac{2.12}{12})\ (100) = 16.10\ \ ft^3/hr.ft$

Substituting in Eq (3), $ST = \frac{0.4.(100)(0.83)}{1}\ (1 - 0.4) = \ 19.92\ \ ft^3/hr.ft$

Substituting in Eq (4), $Q_{out1} = (4.33e - 02)(3.281)^2(3600)(0.005) = 8.39\ \ ft^3/hr.ft$

Substituting in Eq (5), $Q_{out2} = (1.0e - 02)\ (\frac{3600}{30.48})\ (0.005)(0.83) = \ 0.005\ \ ft^3/hr.ft$

Substituting in Eq (6), $FS_{drain} = \frac{19.92+8.39+0.005}{16.10} = \mathbf{1.76}\ \ \mathbf{OK}$

An acceptable drainage factor of safety is typically higher than 1.25 ($FS_{drain} > 1.25$). The above calculations resulted in FS_{drain} =1.76 which is acceptable. It should be noted that the **ShockDrain** main contribution is towards the lateral drainage towards the edge drain, whereas the leveling stone contributes towards the storage within its thickness.

3.2 Time to Drain

The time to drain calculations rely mainly on the hydraulic conductivity of the medium through which the water is flowing. Also, an important factor is the drainage length. In this manual, time to drain is calculated based on the FHWA equation presented in FHWA (1992).

$$t = T_{50}.m \qquad \textbf{Eq (7)}$$

Where, *t* (hr) is the time to drain, T_{50} (-) is time factor for 50% drainage, and m (-) is the "m" factor. For T and m, please see below.

The time factor for 50% drainage T_{50} is determined by a regression equation developed based on a FHWA (1992) chart:

$$T_{50} = 0.2426\,.\,S_1^{-0.7028} \qquad \textbf{Eq (8)}$$

Where, S_1 (-) is the slope factor

$$S_1 = \frac{L.s}{D} \qquad \textbf{Eq (9)}$$

Where, L (ft) is the drainage length (Table 1), s (-) is the is the gradient of the flow/ slope (Table 1), and D (ft) is the thickness of the drainage medium (Table 3 & 4).

The "m" factor is determined by the following equation:

$$m = \frac{n\,L^2}{k\,D} \qquad \textbf{Eq (10)}$$

Where, n (-) is the effective porosity of the drainage medium (Table 3 & 4), and k (ft/hr) is the hydraulic conductivity of drainage medium (Table 3 & 4).

To calculate the time to drain for the **ShockDrain:**

Substituting in Eq (9), $S_1 = \frac{(100)(0.005)}{\frac{580}{1000\ (12)}} = 10.34$

Substituting in Eq (8), $T_{501} = 0.2426\ (10.34)^{-0.7028} = 0.047$

Substituting in Eq (10), $m_1 = \frac{(0.65)(100)^{\,2}}{(4.33e{-}02)(3.281)^2(3600)} = 3.874$ hours

Note, $(\boldsymbol{k})(\boldsymbol{D})$ is equal to ***TRANS***

Substituting in Eq (7), $t_1 = 0.047(3.874) = \mathbf{0.182\ hours}$

To calculate the time to drain for the **leveling stone** *without* **ShockDrain:**

Substituting in Eq (9), $S_2 = \frac{(100)(0.005)}{0.83} = 0.602$

Substituting in Eq (8), $T_{502} = 0.2426\ (0.60)^{-0.7028} = 0.35$

Substituting in Eq (10), $m_2 = \frac{(0.4)(100)^{\,2}}{(1.0e{-}02)(\frac{3600}{30.48})\ (0.83)} = 4080.32$ hours

Substituting in Eq (7), $t_2 = 0.35\ (4080.32) = \mathbf{1428.1\ hours}$

3.3 Conclusion

The presence of **ShockDrain** on the sportfiled significantly improve and enhance the drainage performance of the field. **ShockDrain** main contribution is towards the quick removal of the rain-water towards the edge drain. The leveling stone by itself is not capable of this quick removal as shown in the above example when calculating the time drain; comparing **1428.1 hours** with only the leveling stone to **0.182 hr** with the presence of **ShockDrain**. **ShockDrain** also contributes to the overall drainage factor of safety as shown above (**FS_{drain}** = **1.76**) and helps the drainage sys-tem maintains a satisfactory and acceptable factor of safety against drainage overload.

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us

4. REFERENCES

1. FHWA , 1992, FHWA-SA-92-008
2. Giroud, J.P. Designing with Geotextiles. Definitions of Properties and Design. 1985, pp 266 –292.
3. Koerner, Robert M. 2005. Designing with Geosynthetics, 5th Ed. New Jersey: Pearson Prentice Hall.
4. NOAA National Weather NOAA National Weather Services: Precipitation Frequency Estimate, http://hdsc.nws.noaa.gov/hdsc/pfds
5. US Army Corps of Engineers, Slope Stability, Engineering and Design Manual. EM 1110-2-1902, October 31, 2003.

En-Plast Headquarters 17510 Carlsway Rd | Houston, TX 77073 (281) 821-7700 | info@en-plast.us | www.en-plast.us