



## Vegetative Filters for Dairy Waste

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A vegetative filter is a grassy area that receives rainfall runoff from an open livestock feedlot. The vegetative filter separates nutrients from the lot runoff and provides an infiltration area for the runoff water so that no discharge occurs.

In order for the vegetative filter to work properly, it is necessary to separate solids from the runoff ahead of the vegetative filter and divert roof water and clean water runoff from above the feedlot and the vegetative filter area. Solids are separated in a concrete settling basin, or in an earthen impoundment basin or a terrace. A uniformly sloping vegetative fil-

ter area with less than 10 percent slope is desirable.

### Sizing a vegetative filter

The filter area is based on the larger requirement of the nutrient loading to occur on the area or the area soil infiltration rate. M121-H, Vegetative Filter Worksheet, gives a step-by-step outline for sizing the vegetative filter and a holding basin. You may find the worksheet on pages 55 and 56 of Missouri Manual 121, *Design Guidelines for Animal Waste Management for Concentrated Animal Feeding Operations*.

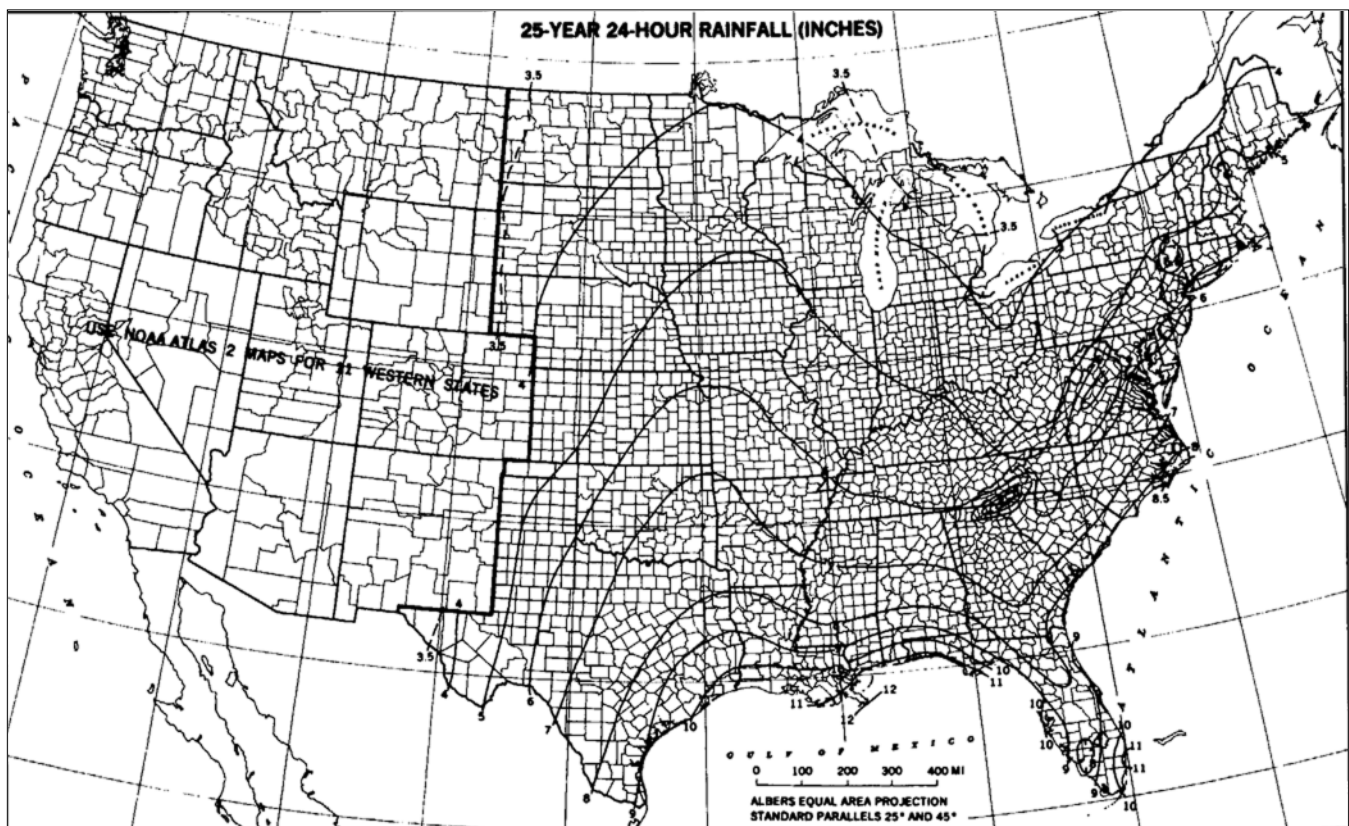


Figure 1. The expected 25-year, 24-hour rainfall in inches.

## Soil infiltration basis

For sizing the filter based on infiltration rate, the infiltration rate of the soil at the vegetative filter must exceed the rate of application of the liquid effluent. Also, the available water-holding capacity of the soil must equal or exceed the volume of liquid to be applied. Therefore, it is usually necessary to impound the runoff to reduce the rate of application and, possibly, to allow application when the filter area is not saturated.

The size of a storage basin should be adequate to store the runoff expected from the feedlot for a 25-year, 24-hour storm, plus storage capacity for a minimum of 180 days manure production, expected rainfall and influent from other sources. The manure production (solids volume) includes the manure expected to be settled out between cleaning cycles plus silt from any dirt lots.

For earthen lot areas, the value of 2,800 cubic feet per acre per year should be used to calculate the amount of manure and silt solids that would come off the lot area. For concrete lot areas, the amount of manure generated, the percent solids going to the settling basin and the desired days of storage should be used to size the settling basin. Dairy cattle produce about 10.4 pounds of manure solids per day per 1,000 pounds of body weight, see Missouri Manual 121, Table 10.

The 25-year, 24-hour rainfall varies from 5.5 inches in extreme northeast Missouri to 7 inches in extreme southwest Missouri, see Figure 1. The runoff for 180 days storage is 60 percent of the expected 365-day runoff. To reduce the storage requirement, systems have been designed to apply the runoff to the vegetative filter by gravity during the storm through a gated distribution pipe.

## Nutrient loading basis

The nutrient loading basis sizes the area of the filter based on the conservative or intensive approach to nitrogen application.

The conservative approach is based on applying not over 100 pounds of nitrogen per acre per year. Missouri guidelines call for sizing the vegetative filter based on 7,000 pounds of dairy cow equivalents per acre of filter area.

The intensive approach adjusts the filter area calculated using the conservative approach to accommodate the expected nitrogen uptake by the removed forage, see Table 1.

Referring to Table 1, it is obvious that by removing 4 tons of orchard grass per year and taking advantage of the intensive approach, the filter can be one-half the size calculated by the conservative approach (200 pounds of nitrogen per year vs. 100

Crop	Annual Yield (tons per acre)	Nitrogen Removed (pounds per acre)
Blue grass	2.0	52
Fescue	5.0	275
Fescue	3.0	165
Orchard grass	4.0	200
Orchard grass	2.5	125
Reed canary grass	6.0	359

Table 1. Nitrogen removal capabilities of various grasses with forage removed each year.

pounds per year). Using these guidelines, pages 4 and 5 illustrate the two approaches to sizing filters.

## Pretreatment required

A solids separation/settling structure is recommended to reduce the nutrient loading on the vegetative filter and to prevent the accumulation of manure solids, wasted feed, debris and other materials on the upper areas of the vegetative filter. Solids may be separated by screening or by settling in a basin or terrace. These methods require a storage basin to permit applying the runoff at a slower rate.

## Limitations

Usually, vegetative filters are used to correct an existing problem, especially with small operations. These systems can become expensive to construct and may require considerable labor and management.

The filter area should slope between 0.5 percent and 10 percent. Slopes flatter than 0.5 percent create problems with leveling and maintenance to prevent ponding on the filter area. Slopes greater than 10 percent reduce filter effectiveness and may cause erosion.

For uniform application, the filter must be constructed with a similar slope in the direction of flow and a flat section perpendicular to the flow. Occasionally, the natural grade will be satisfactory for uniform sheet flow without grading. The maximum filter width for sheet flow is 200 feet. Adjust the length to achieve the necessary area while maintaining 200 feet or less sheet flow length.

Typically, the distribution pipe may be laid on the backslope of a terrace or diversion.

## Removing wastewater

Pumping and gravity flow are the usual methods to remove settled wastewater from the basin and transport it to a vegetative filter. In selecting a pump, you must consider the solids content of the water, in addition to the necessary pressure and flow rate. The pump intake should be screened to keep out solids

larger than the pump will handle. For uniform application, the pressure and flow rate must be matched to the distribution system.

If long-term storage of liquid is intended, you should provide some provision to contain runoff from a 25-year, 24-hour rainfall. For example, if an automatic pumping or gravity drainage system maintains the liquid level at a set point, provide storage above that point for storing the runoff from a 25-year, 24-hour storm. Distribution over the vegetative filter will be more uniform if trickle flows are not permitted, such as a maintaining a set pressure head on the distribution system during discharge onto the filter area.

The usual distribution method is a gated pipe operating at a few pounds per square inch pressure, see Figure 2. A computer program to aid in the design of gated-pipe systems is available from Agricultural Engineering Extension at the University of Missouri – Columbia.

For gravity flow systems, a screened basin outlet is customary. The outlet should be designed to drain out the full depth of the basin for dewatering the solids. Debris, bedding and manure solids may clog the outlet screen. Periodically clean the screen to allow full flow and complete dewatering. There are two types of outlets, the perforated riser pipe and the porous dam. [MWPS-18, Livestock Waste Facilities Handbook](#), has more details.

The vegetative filter area should be planted to a grass such as fescue, orchard grass, blue grass or reed canary grass. Maintain the grass between three to 24 inches. Livestock should not be allowed on the filter area. Equipment used to remove the forage should only be on the filter area when sufficiently dry to not make tracks or ruts.

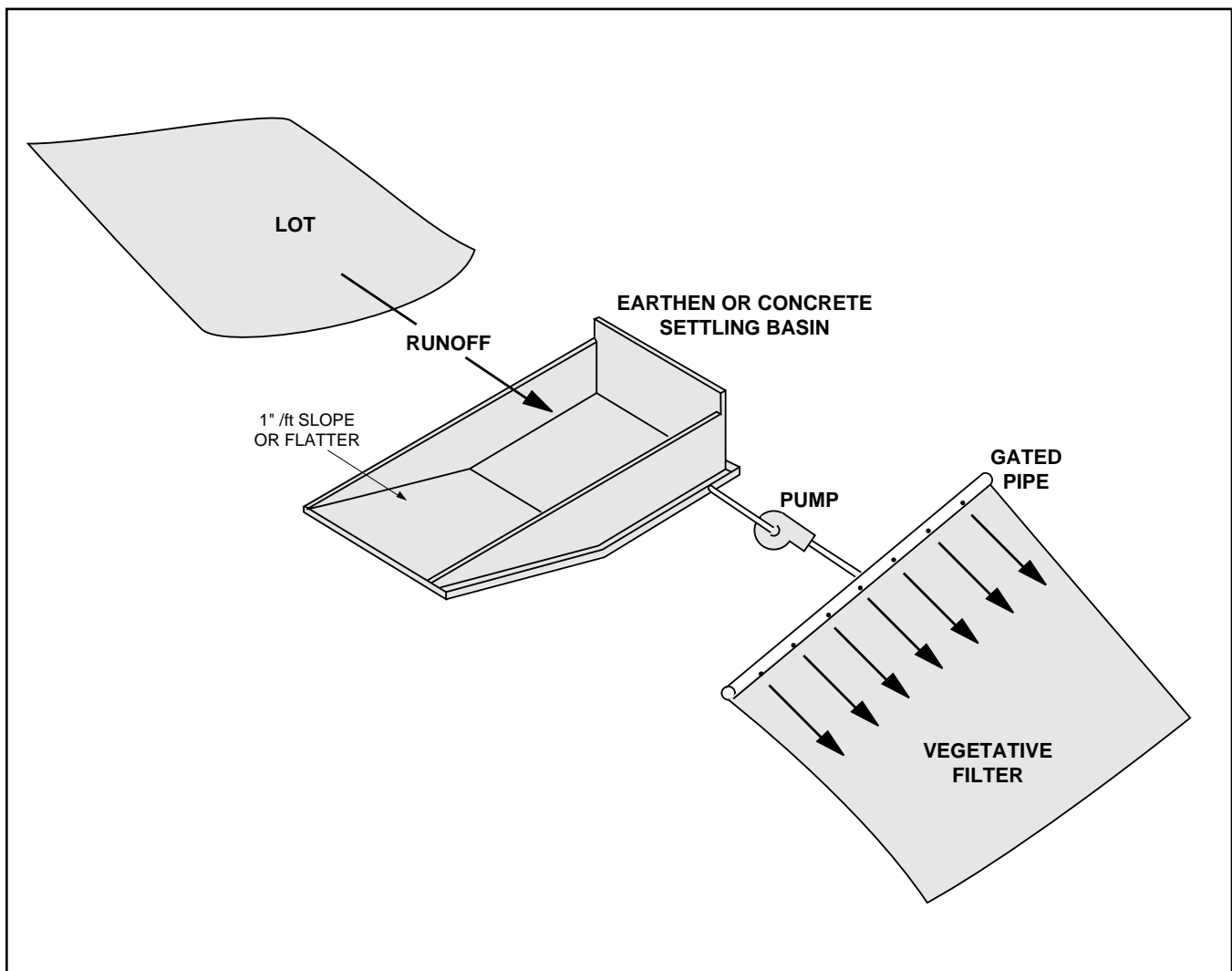


Figure 2. A schematic of an open-lot runoff control/distribution system that uses a pump to convey liquid from the settling basin to the gated-pipe distribution system at the vegetative filter area.

## Preliminary filter size: Soil infiltration basis

Calculate the required vegetative filter area for 30 1,400-pound cows spending 50 percent of the time on a 250- by 250-foot dirt lot in central Missouri. The 25-year, 24-hour rainfall is 6 inches. Assume 365 days storage of solids. From the county soil survey, the soil permeability at the vegetative filter area is 0.2 inches per hour. The following procedure is from the Vegetative Filter Worksheet, M121-H, see pages 55-56, in the Missouri Manual 121.

### 1. Lot runoff volume:

Lot area x rainfall\* x 0.8\*\* ÷ 12 inches/foot = lot runoff volume

\*Rainfall from Figure 1.

\*\*This assumes 80 percent of rainfall runs off the dirt lot. (Use 100 percent runoff for concrete lot.)

$$\underline{250 \times 250} \text{ (feet}^2\text{)} \times \underline{6} \text{ (inches)} \times 0.8 \div 12 \text{ inches/foot} = \underline{25,000} \text{ (feet}^3\text{)}$$

### 2. Solids volume(for earth lot):

Lot area x 2,800 x days storage ÷ 365 days/year x time cows on lot\* = solids volume

\*Proportion of time cows spend in open lot.

$$\underline{250 \times 250/43,560} \text{ (acres)} \times 2,800 \times \underline{365} \div 365 \text{ days/year} \times \underline{0.50} = \underline{2,009} \text{ (feet}^3\text{)}$$

### 3. Other sources (milking parlor wastes, etc.):

From other sources(feet<sup>3</sup>/day) x days storage = other sources

$$\underline{0} \text{ (feet}^3\text{/day)} \times \underline{0} \text{ (days)} = \underline{0} \text{ (feet}^3\text{)}$$

### 4. Total volume:

Lot runoff volume + solids volume + other volume = total volume

$$\underline{25,000} \text{ (feet}^3\text{)} + \underline{2,009} \text{ (feet}^3\text{)} + \underline{0} \text{ (feet}^3\text{)} = \underline{27,009} \text{ (feet}^3\text{)}$$

Use this volume to size settling/storage basin.

### 5. Preliminary filter size:

$$\frac{\text{Total liquid runoff volume} \times 12 \text{ inches/foot}}{(T^* \times \text{soil infiltration rate}) - \text{rainfall}^{**}} = \text{filter area, feet}^2$$

\*T=hours to empty the basin, either by pumping or gravity draining.

Note: If the product of time to empty the basin and the soil infiltration rate is less than the rainfall value from Figure 1, the filter area will be negative. For low infiltration rates, the time to empty the basin must be large but not more than 48 hours.

\*\*Data from Figure 1.

$$\frac{25,000 \text{ (feet}^3\text{)} \times 12 \text{ inches/foot}}{(48 \text{ (hours)} \times 0.2 \text{ (inches/hour)}) - 6 \text{ (inches)}} = \underline{83,333} \text{ (feet}^2\text{)} = \text{acres}$$

$$\frac{83,333 \text{ feet}^2}{43,560 \text{ ft}^2\text{/acre}} = 1.9 \text{ acres}$$

## Preliminary filter size: Nutrient loading basis

### Conservative approach:

Calculate the required vegetative filter for 30 1,400-pound cows spending 50 percent of the time on a 250-by-250 foot dirt lot in central Missouri. The 25-year, 24-hour rainfall is 6 inches. To size a vegetative filter to apply 100 pounds of plant available nitrogen per acre, the guidelines for dairy cows are for seven 1,000-pound animal equivalents per acre. This assumes about 10 percent of the nitrogen will be plant available based on: 50 percent loss in the open lot, 50 percent removal in the settling basin, 50 percent loss on the surface after land application and a 20 percent denitrification loss, see Missouri Manual 121, Table 11. The following procedure is from M121-H, Vegetative Filter worksheet, see Missouri Manual 121, page 2.

Total animal weight ÷ 1,000 pounds ÷ 7 1,000 pounds A.E.\*/acre x percentage lot time = conservative filter size (acres)

$$\frac{30 \times 1,400 \text{ pounds}}{1,000 \text{ pounds}} \div 7 \frac{1,000 \text{ pounds A.E.*/acre}}{1,000 \text{ pounds A.E.*/acre}} \times 0.50^{**} \text{ (lot time)} = \underline{3} \text{ (acres)}$$

\*Animal equivalent.

\*\*Proportion of time cows spend in open lot.

### Intensive approach:

Adjust the filter size calculated using the conservative approach to accommodate the expected nitrogen removal by the crop, as shown below. Calculate the filter area assuming that 4 tons per acre of orchard grass hay will be removed from the filter area annually, requiring 200 pounds of nitrogen per acre.

$$\text{Filter size (see above)} \times \frac{100 \text{ pounds/acre nitrogen}}{\text{pounds of nitrogen (from Table 1)}} = \text{intensive filter size}$$

$$\underline{3} \text{ (acres)} \times \frac{100 \text{ pounds/acre nitrogen}}{200 \text{ pounds nitrogen (from Table 1)}} = \underline{1.5} \text{ (acres)}$$

For your applications, see the blank worksheet on page 6.

## Final vegetative filter size:

Use the larger of the sizes from the soil infiltration basis, the conservative loading basis or the intensive nutrient loading basis.

Vegetative filter size = 3 acres (based on the conservative nutrient loading approach)

For your applications, see the blank worksheet on page 7.

# Worksheet to calculate vegetative filter size

Facility name \_\_\_\_\_ Date \_\_\_\_\_

The following procedure is from M121-H, Vegetative Filter Worksheet (Reference pages 55-56 in Missouri Manual 121).

## 1. Lot runoff volume:

A. Earth lots:

\_\_\_\_\_ feet<sup>2</sup> lot area \_\_\_\_\_ \* inches rainfall x 0.8\*\* ÷ inches/foot = \_\_\_\_\_ feet<sup>3</sup>

B. Concrete lots:

\_\_\_\_\_ feet<sup>2</sup> lot area \_\_\_\_\_ \* inches rainfall ÷ inches/foot = \_\_\_\_\_ feet<sup>3</sup>

\*Rainfall from Figure 1.

\*\*This assumes 80 percent of rainfall runs off dirt lot.

## 2. Solids volume:

A. Earth lots:

Lot area \_\_\_\_\_ acres x 2,800 x \_\_\_\_\_ days storage ÷ 365 days per year x \_\_\_\_\_ \* = \_\_\_\_\_ feet<sup>3</sup>

B. Concrete lots:

Total pounds of animal \_\_\_\_\_ 1,000 pounds x 10.4\*\* pounds total solids per day 0.0521 x \_\_\_\_\_ \* storage x \_\_\_\_\_ \* = \_\_\_\_\_ feet<sup>3</sup>

\*Proportion of time cows spend in open lot.

\*\*For dairy cattle, total solids per day = 10.4 pounds per day per 1,000 pounds weight.

## 3. Other sources (milking parlor wastes, etc.):

Other sources \_\_\_\_\_ feet<sup>3</sup> x \_\_\_\_\_ days storage = \_\_\_\_\_ feet<sup>3</sup>

Total volume:

Sum of 1A + 1B + 2A + 2B + 3 = \_\_\_\_\_ feet<sup>3</sup>

Use this volume to size settling/storage basin.

## 5. Preliminary filter size: Soil infiltration basis

$$\text{Filter area feet}^2 = \frac{\text{Total liquid runoff volume (feet}^3\text{)* x 12 inches foot}}{(\text{ } T^{**} \text{ x x Soil infiltration rate (inches/hour)) - } \text{ inches rainfall}^{***}} = \text{ } \text{feet}^2$$

$$\frac{\text{ } \text{feet}^2}{43,560 \text{ ft}^3/\text{acre}} = \text{ } \text{acres}$$

\*Total liquid runoff volume = Sum of volumes 1A + 1B + 3.

\*\*T = hours to empty the basin, either by pumping or gravity drainage.

\*\*\*Rainfall from Figure 1.

Note: If the product of time to empty the basin and the soil infiltration rate is less than the rainfall value from Figure 1, the filter area will come out negative. Therefore, for low infiltration rates, the time to empty the basin must be large. It is recommended that the time to empty the basin not exceed 48 hours.

## 6. Preliminary filter size: Nutrient loading basis

### A. Conservative approach

(Based on the application of 100 pounds of plant available nitrogen per acre per year.) This assumes that 10 percent of the nitrogen will be plant available, based on: 50 percent loss in the open lot, 50 percent removed in the settling basin, 50 percent lost on the surface after land application and 20 percent denitrified.

$$\frac{\text{ } \text{Total pounds of animal} \div 1,000 \text{ pounds} \div 7.0 * 1,000 \text{ pounds A.E.*/acre x } \text{ }^{**}}{\text{ }^{**}} = \text{ } \text{acres}$$

\*7.0 = number of 1,000 pound animal equivalents per acre for dairy cows, Missouri Manual 121, Table 11.

\*\*Proportion of time cows spend in open lot.

### B. Intensive approach

(This is based on the nitrogen removal capabilities of various grasses in Table 1).

The intensive approach to sizing a vegetative filter adjusts the filter size calculated using the conservative approach to accommodate the expected nitrogen removal by the crop.

$$\text{ } \text{acres from 6A x } \frac{100 \text{ pounds nitrogen per acre}}{\text{ } \text{pounds nitrogen from Table 1}} = \text{ } \text{acres}$$

## 7. Final vegetative filter size

Use the larger of the sizes from steps 5 and (6A or 6B).

Vegetative filter size =  $\text{ } \text{acres}$

# References

1. Missouri Manual M121, *Design Guidelines for Animal Waste Management for Concentrated Animal Feed Operations*. Second edition, July 1989. Missouri Department of Natural Resources-Water Pollution Control Program, P.O. Box 176, Jefferson City, MO 65102.

2. *MWPS-18, Livestock Waste Facilities Handbook*. 1985. Midwest Plan Service, Iowa State University, Ames, IA 50011.

3. Schneider, John H.; Susan B. Harrison and Paul B. Freeze. 1993. No Discharge Gated Pipe Distribution of Feedlot Runoff. ASAE Paper No. 93-4566. St. Joseph, Mich.

4. MU Publication M115, *Animal Waste Management-Planning and Designing Guidelines*. 1979. University of Missouri, Columbia, Mo. 65211



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