- The gravel flow spreader should be a minimum of 12 inches deep and 12 inches wide.
- The surface of the gravel layer should be placed at least 1 inch below the surface of the contributing impervious area.
- Gravel flow spreaders should use gravel that meets the specification for shoulder ballast listed in Section 9-03.9(2) of the WSDOT *Standard Specifications* (see Table RT.02.2).
- If there are concerns that water percolated within the gravel flow spreader may exfiltrate into the highway prism, impervious geotextiles can be used to line the bottom of the flow spreader.
- When feasible, the specified gravel should be composed of calcitic or dolomitic limestone to buffer runoff pH and improve dissolved metals removal through the filter strip by ion exchange, precipitation, and sorption.
- Energy dissipaters are needed for filter strips where a slope drops suddenly, such as in a terraced filter strip system or over a retaining wall. Energy can be adequately dissipated at the base of a drop slope section by using a rock pad consisting of 4- to 8-inch quarry spalls.

Table RT.02.2. Shoulder ballast specification for gravel flow spreaders.

Sieve Size	Percent Passing
2.5 inches	100
¾ inch	40–80
¼ inch	5 maximum
#100	0–2

Design Method

1. **Determine the runoff treatment design flow (Q_{WQ}).** In western Washington, the design flow for runoff treatment is the flow rate derived from a continuous model such as MGSFlood, WWHM, or KCRTS that calculates the flow rate from the drainage basin below which 91 percent of the average annual runoff volume occurs. In eastern Washington, the design flow rate is determined based on the peak 10-minute intensity for the design storm, which is the 6-month, short duration event. See Chapter 4 for criteria and hydrologic methods.

   Western Washington flow rate adjustment. In western Washington, design flow rates are calculated using a continuous simulation model. Most of the performance research on filter strips and biofiltration BMPs has been conducted on filter strips that used event-based designs. The 91st percentile flow event (as calculated by the continuous model) tends to be less than the estimated 6-month, 24-hour event flow rate in most cases.

The ratio between the 91st percentile flow event and the estimated 6-month, 24-hour flow rate varies with location and percent of impervious area in the modeled drainage basin. When designing filter strips in western Washington, multiply the on-line water quality design flow rate by the coefficient k[1] given below to apply the 9-minute residence time criterion.

Western Washington Design Flow Coefficient for Biofilters

$$k = 1.41\ (P_{72\%,\ 2\text{-yr.}}) - 0.052$$

where: $P_{72\%,\ 2\text{-yr}}$ = 72 percent of the 2-year, 24-hour precipitation depth (in.)

Note: The 6-month, 24-hour precipitation event can be estimated at 72 percent of the 2-year, 24-hour precipitation event if 6-month, 24-hour precipitation data are not available.

In eastern Washington, no design flow rate adjustment is needed, since the 6 month, 24 hour flow rate is calculated directly using SBUH-based models such as StormSHED.

The vegetated filter strip design flow rate then becomes:

$$Q_{vfs} = kQ_{wq}$$

2. **Calculate the design flow depth at Q_{vfs}.** The design flow depth is calculated based on the width of the filter strip (same as the length of the pavement edge contributing runoff to the filter strip) and the longitudinal slope of the filter strip parallel to the direction of flow. Design flow depth is calculated using a form of Manning's equation:

$$Q_{vfs} = \frac{1.49}{n} W y^{5/3} s^{1/2} \qquad \text{(RT.02-1)}$$

where: Q_{vfs} = vegetated filter strip design flow rate (cfs)

n = Manning's roughness coefficient. Manning's n can be adjusted by specifying soil and vegetation conditions at the project site, as specified in Table RT.02.1

y = design flow depth (ft), also assumed to be the hydraulic radius = 1.0 inch maximum = 0.083 feet

W = width of the filter strip parallel to the pavement edge (ft)

s = slope of the filter strip parallel to the direction of flow (ft/ft). Filter strip slopes should be greater than 2 percent and less than 15 percent. Filter strip slopes should be made as shallow as is feasible by site constraints. Gently sloping filter strips can produce the required residence time for runoff treatment using less space than steeper filter strips.

[1]Derived by calculating the linear regression of the ratios of the 91st percentile flow event at 15 minute intervals (determined by MGSFlood) vs. 72% of the 2 year, 24 hour event (determined by the rational method) at each of the major continuously-operating rain gauges in Western Washington.

Rearranging equation RT.02-1 to solve for y yields:

$$y = \left[\frac{nQ_{vfs}}{1.49Ws^{1/2}} \right]^{3/5} \qquad \text{(RT.02-2)}$$

If the calculated depth y is greater than 1 inch, either adjust the filter strip geometry or use other runoff treatment BMPs.

3. **Calculate the design flow velocity passing through the filter strip at the vegetated filter strip design flow rate.** The design flow velocity (V_{WQ}) is based on the vegetated filter strip design flow rate, the width of the filter strip, and the calculated design flow depth from step 2:

$$V_{WQ} = \frac{Q_{vfs}}{Wy} \qquad \text{(RT.02-3)}$$

where: V_{WQ} = design flow velocity (ft/sec)

y = design flow depth (ft, from equation RT.02-2)

4. **Calculate the filter strip length.** The length of the filter strip is determined by the residence time of the flow through the filter strip. A 9-minute (540-second) residence time is used to calculate filter strip length:

$$L = TV_{WQ} = 540V_{WQ} \qquad \text{(RT.02-4)}$$

where: L = filter strip length (ft)

T = time (sec)

V_{WQ} = design flow velocity (ft/sec, from equation RT.02-3)

A minimum length of 8 feet is recommended in order to ensure that the long-term effectiveness of the filter strip will occur.

5. **Calculate the runoff storage capacity provided by compost-amended vegetated filter strips or engineered roadside embankment subcourse.** If design Option 1 is chosen for the project (Table RT.02.1), the area of the filter strip can be modeled as "grass" land cover on the underlying soil type in MGSFlood or an equivalent continuous simulation model. If Options 2, 3, or 4 (compost-amended filter strips) or an engineered roadside embankment is chosen as a runoff treatment option, the surface area of these BMPs can be modeled as "pasture" on the underlying soil type. If additional storage layers, such as trenched underdrains, are used for conveyance to a flow control facility, the drain or trench can be modeled as an infiltration trench to account for water losses within the drain or trench. Additionally, the storage volume within drains or trenches can be used as live storage if orifices are included as a design element in the riser used to drain the trenches. Calculating the infiltration and storage capacity of conveyance underdrains can significantly reduce the size of a detention pond needed for flow control (properly designed filter strips as