URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

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TECHNICAL MEMORANDUM

FROM: Ken MacKenzie

SUBJECT: Water quality orifice sizing equation for rain gardens, sand filter basins, and permeable pavement systems

DATE: August 24, 2010

This memorandum describes the development of the equations to correctly size the orifice area and diameter required for twelve hour release of the EURV or WQCV for porous landscape detention, sand filters, and permeable pavement systems:

These equations were developed using the EPA Storm Water Management Model (SWMM) Version 5.0.018 and are valid for $0.5 \leq Y \leq 3$ and $2 \leq H \leq 8$, where Y is the depth of the surcharge volume above the filter media surface. This depth does not significantly affect the outcome within these given limits; therefore Y does not appear in the equations.

The SWMM model was set up with surcharge volumes (*Vol*) of 500, 1000, 3000, 6000, and 10000 cubic feet at surcharge depths (Y) of 0.5, 0.75, 1.0, 1.5, and 3.0 feet and depths to orifice (H) of 1, 2, 4, 6, and 8 feet, for a total of 125 conditions. Orifices were sized by trial and error to achieve the desired 12-hour drain time and the results were plotted. It was found that the effect of the surcharge depth (Y) on the orifice size was not significant except when the orifice depth (H) was very shallow. For this reason, the average orifice area (A_O) for each orifice depth (H) was chosen, as shown in Figure 1.

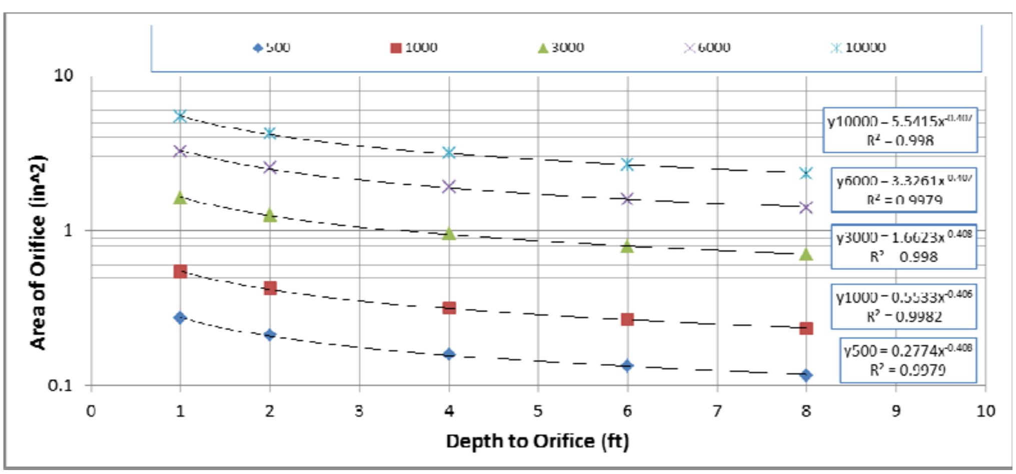

Figure 1: *Average orifice area (A_O) vs. depth to orifice (H) for five representative storage volumes (Vol) of 500, 1000, 3000, 6000, and 10000 cubic feet.*

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A power regression was analyzed on these plotted values. The general form of the equation for this regression is:

$$A_O = c_1 H^{-0.41}$$ ***Equation 1***

Values of coefficient c_1 were plotted vs. storage volume and the results are shown in Figure 2:

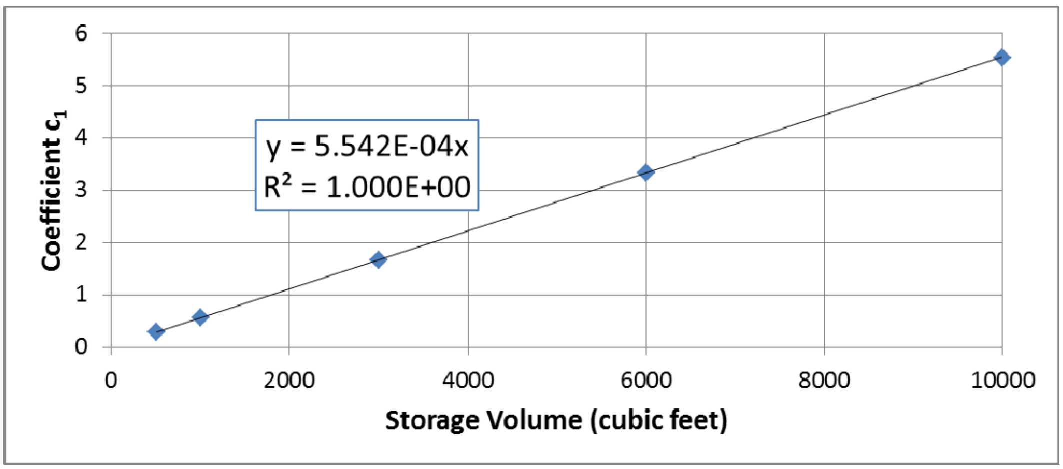

Figure 2: *Coefficient c_1 vs. storage volume*

It was found by linear regression that coefficient c_1 is equal to storage volume divided by 1804 (1/0.0005542), giving the final form of the equation. The full analysis may be found in the Excel workbook *PLD orifice sizing 20100824.xlsx*.

The final form of the equations to determine the orifice area and diameter required for twelve hour release of the EURV or WQCV for porous landscape detention, sand filters, and permeable pavement systems are:

$$A_O = \frac{Vol}{1804H^{0.41}}$$ ***Equation 2***

And:

$$D_O = \sqrt{\frac{Vol}{1414H^{0.41}}}$$ ***Equation 3***

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Where:

A_O = the orifice area, in inch^2;
D_O = the orifice diameter, in inches;
Vol = the storage volume, in feet^3;
H = the vertical distance from the centroid of the orifice to the bottom of the storage volume (surface of the filter media), in feet.

Example: Find the required orifice area and diameter to drain a rain garden with a surcharge depth of one foot and a WQCV of 5,000 cubic feet, with an orifice 3.5 feet below the media surface:

$$A_O = \frac{5000}{1804\left(3.5^{0.41}\right)} = 1.66 inch^2 \qquad D_O = \sqrt{\frac{5000}{1414\left(3.5^{0.41}\right)}} = 1.45 inch$$

For drain times other than twelve hours simply multiply the calculated orifice area by the ratio of 12 divided by that drain time.