

APPENDIX H

Detention Basin Design Utilizing the Rational Method of Runoff Determination

The following procedure utilizing the Rational Method of Design has been adopted from the Erosion Control Manual of Oakland County, Michigan. This method has been revised to include the particular requirements of the Washtenaw County Drain Commissioner.

- A. Determine the acreage tributary to the detention basin and the composite runoff coefficient. The runoff coefficient must be based on the area and surface types tributary to the basin.

Example Extended Detention Pond Volume Calculations and Outlet Design

The following is an example for one method of extended detention pond design that meets the minimum standards of the Washtenaw County Drain Commissioner. More complex systems are preferred and shall be provided where feasible. The example is based on a 7.3 acre site with a runoff coefficient of 0.75. The release rate specified in the example is based on a pond which outlets to an existing watercourse that is adequate to effectively handle a concentrated flow of water from the proposed development.

$$C = 0.75$$

$$A = 7.3 \text{ Ac.}$$

The allowable release rate is 0.15 cfs/ac:

$$Q_a = \left(0.15 \frac{\text{cfs}}{\text{ac}}\right)(A)$$

$$Q_a = \left(0.15 \frac{\text{cfs}}{\text{ac}}\right)(7.3 \text{ ac})$$

$$Q_a = 1.10 \text{ cfs}$$

100-Year Flood Volume Required

$$Q_o = \frac{Q_a}{AC}$$

$$Q_o = \frac{1.10 \text{ cfs}}{(7.3 \text{ ac})(0.75)}$$

$$Q_o = 0.20 \frac{\text{cfs}}{\text{ac-imp}}$$

$$T = -25 + \sqrt{\frac{10312.5}{Q_o}}$$

$$T = -25 + \sqrt{\frac{10312.5}{0.2 \frac{\text{cfs}}{\text{ac-imp}}}}$$

$$T = 202.1 \text{ min}$$

$$V_s = \frac{16500T}{T + 25} - 40Q_oT$$

$$V_s = \frac{(16500)(202.1 \text{ min})}{202.1 \text{ min} + 25} - (40)\left(0.2 \frac{\text{cfs}}{\text{ac-imp}}\right)(202.1 \text{ min})$$

$$V_s = 13066.8 \frac{\text{cf}}{\text{ac-imp}}$$

$$V_t = V_s AC$$

$$V_t = \left(13066.8 \frac{\text{cf}}{\text{ac-imp}}\right)(7.3 \text{ ac})(0.75)$$

$$V_t = 71541 \text{ cf}$$

Bankfull Flood Volume

The bankfull storm is defined as the 24 hour, 1.5-year storm event:

$$V_{bf} = (2.25")\left(\frac{1'}{12"}\right)\left(\frac{43560 \text{ ft}^2}{1 \text{ ac}}\right)AC$$

$$V_{bf} = \left[(2.25")\left(\frac{1'}{12"}\right)\left(\frac{43560 \text{ ft}^2}{1 \text{ ac}}\right)\right](7.3 \text{ ac})(0.75) = (8170)(7.3)(0.75)$$

$$V_{bf} = 44731 \text{ cf}$$

First Flush Volume

The first flush storm is defined as the first 0.5" of rain over the entire watershed:

$$V_{ff} = (0.5")\left(\frac{1'}{12"}\right)\left(\frac{43560 \text{ ft}^2}{1 \text{ ac}}\right)AC$$

$$V_{ff} = \left[(0.5")\left(\frac{1'}{12"}\right)\left(\frac{43560 \text{ ft}^2}{1 \text{ ac}}\right)\right](7.3 \text{ ac})(0.75) = (1815)(7.3)(0.75)$$

$$V_{ff} = 9937 \text{ cf}$$

Storage Provided

Elevation	Area (sf)	Depth (ft)	Volume (cf)	Total Volume (cf)
94.0	28,960	1	26,640	80,080
93.0	24,320	1	22,240	53,440
92.0	20,160	1	18,000	31,200
91.0	15,840	1	13,200	13,200
90.0	10,560	1	0	0

Storage Elevations

First flush:

$$\frac{91.0 - 90.0}{13200 - 0} = \frac{x_{ff} - 90.0}{9937 - 0}$$

$$x_{ff} = 90.75(\text{approx. } 90.8)$$

Bankfull:

$$\frac{93.0 - 92.0}{53440 - 31200} = \frac{x_{bf} - 92.0}{44731 - 31200}$$

$$x_{bf} = 92.61(\text{approx. } 92.6)$$

100 year:

$$\frac{94.0 - 93.0}{80080 - 53440} = \frac{x_{100} - 93.0}{71541 - 53440}$$

$$x_{100} = 93.68(\text{approx. } 93.7)$$

Outlet Control Structure

First flush of runoff:

The *average* allowable release rate for runoff resulting from 0.5" of rain over watershed area in 24 hours:

$$Q_{ff} = \frac{V}{T_{24}}$$

$$Q_{ff} = \frac{9937_{cf}}{(24hr)\left(\frac{3600\text{ sec}}{1hr}\right)}$$

$$Q_{ff} = 0.115_{cfs}$$

Place openings in standpipe at bottom of basin (90.0):

To determine the appropriate size orifice to release the first flush volume, an average head value can be used in the orifice equation. If the basin is designed to be trapezoidal in shape, 2/3 of the total head is an acceptable approximation for the average head.

$$h_{ave} = \frac{2}{3}(elev._{ff} - elev._{bot})$$

$$h_{ave} = \frac{2}{3}(90.8 - 90.0)$$

$$h_{ave} = 0.53\text{ ft}$$

$$A = \frac{Q_{ff}}{0.62\sqrt{2gh_{ave}}}$$

$$A = \frac{0.115_{cfs}}{0.62\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(0.53\text{ ft})}}$$

$$A = 0.032_{sf}$$

The number and size of orifices to meet the area requirements is variable. In general larger holes are preferable, although multiple outlets should be used if possible. For this example, we will choose a 1.25" diameter orifice (which has an area of 0.0085 sf).

$$\# = \frac{0.032_{sf}}{0.0085_{sf}}$$

$$\# = 3.76$$

Therefore, use 3 – 1.25" diameter holes @ elev. 90.0

The detention time for 3 – 1.25" diameter holes is:

$$Q_{ff}^{new} = A_{ff}^{new}(0.62)\sqrt{2gh_{ave}}$$

$$Q_{ff}^{new} = (3)(0.0085_{sf})(0.62)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(0.53\text{ ft})}$$

$$Q_{ff}^{new} = 0.092_{cfs}$$

$$T_{ff}^{new} = \frac{V_{ff}}{Q_{ff}^{new}}$$

$$T_{ff}^{new} = \frac{9937cf}{(0.092cfs)\left(\frac{3600sec}{1hr}\right)}$$

$$T_{ff}^{new} = 30.0hr$$

Bankfull flood:

The bankfull flood must be detained 36-48 hours; check the discharge through the first flush orifice to see if additional holes are necessary:

$$h_{ave} = \frac{2}{3}(elev_{bf} - elev_{bot})$$

$$h_{ave} = \frac{2}{3}(92.6 - 90.0)$$

$$h_{ave} = 1.73$$

$$Q = 0.62A_{ff}\sqrt{2gh_{ave}}$$

$$Q = (0.62)(3)(0.0085sf)\sqrt{(2)\left(32.2\frac{ft}{sec^2}\right)(1.73ft)}$$

$$Q = 0.17cfs$$

$$T = \frac{V_{bf}}{Q}$$

$$T = \frac{44731cf}{(0.17cfs)\left(\frac{3600sec}{1hr}\right)}$$

$$T = 73.1hr$$

Because the holding time exceeds 48 hours, additional orifices in the standpipe are required. The release rate may be considered occurring in two phases; the release rate when both the ff and bf orifices are contributing, and the release rate when the water elevation is below the bf orifice (ff elevation). The time for the ff volume to release was calculated above, so the remaining volume (bf volume – ff volume) must be released so the total detention time does not exceed 36 – 48 hours.

A target detention time of 44 hours was chosen for this example.

$$V_{rem} = V_{bf} - V_{ff}$$

$$V_{rem} = 44731cf - 9937cf$$

$$V_{rem} = 34794cf$$

$$T_{rem} = T_{tot} - T_{ff}^{new}$$

$$T_{rem} = 44hr - 30.0hr$$

$$T_{rem} = 14.0hr$$

Volume through 3 – 1.25" diameter holes in 14.0 hours:

$$h_{ave}^{ff} = \frac{2}{3} (elev_{.bf} - elev_{.ff}) + (elev_{.ff} - elev_{.bot})$$

$$h_{ave}^{ff} = \frac{2}{3} (92.6 - 90.8) + (90.8 - 90.0)$$

$$h_{ave}^{ff} = 2ft$$

Q_1 will be defined as the discharge through the ff orifices when both the ff and bf holes are contributing.

$$Q_1 = 0.62A_{ff} \sqrt{2gh_{ave}^{ff}}$$

$$Q_1 = (0.62)(3)(0.0085sf) \sqrt{2 \left(32.2 \frac{ft}{sec^2} \right) (2ft)}$$

$$Q_1 = 0.18cfs$$

$$V_1 = T_{rem} Q_1$$

$$V_1 = (14.0hr) (0.18cfs) \left(\frac{3600sec}{1hr} \right)$$

$$V_1 = 9072cf$$

The leftover volume will be released by the bankfull orifice. V_2 will be defined as the amount of water to be discharged by the bf orifices in 14.0 hours.

$$V_2 = V_{rem} - V_1$$

$$V_2 = 34794cf - 9072cf$$

$$V_2 = 25722cf$$

$$Q_2 = \frac{V_2}{T_{rem}}$$

$$Q_2 = \frac{25722cf}{(14.0hr) \left(\frac{3600sec}{1hr} \right)}$$

$$Q_2 = 0.51cfs$$

$$h_{ave}^{bf} = \frac{2}{3} (elev_{.bf} - elev_{.ff})$$

$$h_{ave}^{bf} = \frac{2}{3} (92.6ft - 90.8ft)$$

$$h_{ave}^{bf} = 1.2ft$$

$$A_2 = \frac{Q_2}{0.62 \sqrt{2gh_{ave}^{bf}}}$$

$$A_2 = \frac{0.51cfs}{0.62 \sqrt{2 \left(32.2 \frac{ft}{sec^2} \right) (1.2ft)}}$$

$$A_2 = 0.094sf$$

A 2" diameter orifice has an area of 0.022 sf

$$\# = \frac{0.094 \text{ sf}}{0.022 \text{ sf}}$$

$$\# = 4.27$$

Therefore, use 4 – 2" diameter holes @ elev. 90.8

100-year flood:

$$Q_a = 1.10 \text{ cfs}$$

Q_a is a *peak* or maximum flow. Calculate the maximum flow passing through first flush and bankfull orifices, using the total head, and subtract from Q_a to determine the orifice size to release the 100-year storm volume:

$$Q_{ff} + Q_{bf} = 0.62 A_{ff} \sqrt{2gh_{tot}} + 0.62 A_{bf} \sqrt{2gh_{tot}^{bf}}$$

$$Q_{ff} + Q_{bf} = (0.62)(3)(0.0085 \text{ sf}) \sqrt{2 \left(32.2 \frac{\text{ft}}{\text{sec}^2}\right) (93.7 - 90.0)} + (0.62)(4)(0.022 \text{ sf}) \sqrt{2 \left(32.2 \frac{\text{ft}}{\text{sec}^2}\right) (93.7 - 90.8)}$$

$$Q_{ff} + Q_{bf} = 0.99 \text{ cfs}$$

$$Q_{100} = Q_a - (Q_{ff} - Q_{bf})$$

$$Q_{100} = 1.10 \text{ cfs} - 0.99 \text{ cfs}$$

$$Q_{100} = 0.11 \text{ cfs}$$

$$A_{100} = \frac{Q_{100}}{0.62 \sqrt{2gh_{100}}}$$

$$A_{100} = \frac{0.11 \text{ cfs}}{0.62 \sqrt{2 \left(32.2 \frac{\text{ft}}{\text{sec}^2}\right) (93.7 - 92.6)}}$$

$$A_{100} = 0.021 \text{ sf}$$

A 1" diameter orifice has an area of 0.0055 sf

$$\# = \frac{0.021 \text{ sf}}{0.0055 \text{ sf}}$$

$$\# = 3.82$$

Therefore, use 3 - 1" diameter holes @ elev. 92.6