Part P.

OUTLET DESIGN EXAMPLES

3-STAGE OUTLET

This example is also applicable when a portion of the first flush storm is infiltrated.

Area = 80,128 sf or 1.84 ac
First flush volume: 3,842 cf
Bankfull volume: 8,286 cf
100-year detention volume: 20,106 cf
(should include additional 20% volume if required infiltration is not provided)

Storage Provided

ELEVATION	AREA (SF)	DEPTH (FT)	VOLUME (CF)	TOTAL VOLUME (CF)
813.0	13,524	1	12,834	43,962
812.0	12,144	1	11,490	31,128
811.0	10,836	1	10,218	19,638
810.0	9,600	1	5,952	9,420
809.0	2,304	1	2,010	3,468
808.0	1,716	1	1,458	1,458
807.0*	1,200	0	0	0

* x_{bot}

Storage Elevations

First Flush $$\frac{810.0-809.0}{9{,}420-3{,}468}=\frac{x_{ff}-809.0}{3{,}842-3{,}468}$$ x_{ff} = 809.06

Bankfull $$\frac{810.0-809.0}{9{,}420-3{,}468}=\frac{x_{bf}-809.0}{8{,}286-3{,}468}$$ x_{bf} = 809.81

100-year $$\frac{812.0-811.0}{31{,}128-19{,}638}=\frac{x_{100}-811.0}{20{,}106-19{,}638}$$ x_{100} = 811.04

The allowable release rate is 0.15 cfs/acre

$$Q_{allow}=\left(0.15\frac{cfs}{acre}\right)(A)$$

$$Q_{allow}=\left(0.15\frac{cfs}{acre}\right)(1.84\ acres)$$

$$Q_{allow}=0.276\ cfs$$

3 STAGE OUTLET DESIGN EXAMPLE

FIRST FLUSH DISCHARGE

The first flush storm must be released in a minimum of 24 hours.

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

$$Q_{ff}^{min} = \frac{3{,}842}{(24hr)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$Q_{ff}^{min} = 0.0445\ cfs$$

A. To determine the appropriate size orifice to release the first flush volume, an average head value is used in the orifice equation.

$$h_{ave} = \frac{2}{3}(x_{ff} - x_{bot})$$

$$h_{ave} = \frac{2}{3}(809.06 - 807.00)$$

$$h_{ave} = 1.37\ ft$$

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

$$A_{ff} = \frac{0.0445\ cfs}{0.62\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(1.37\ ft)}}$$

$$A_{ff} = 0.0076\ ft$$

If the basin can be modelled as trapezoidal in shape, 2/3 of the total head is an acceptable approximation for the average head.

B. The number and size of orifices to meet the area requirements is variable, so many acceptable solutions are possible. In general, larger holes are preferable if multiple orifices can be used (to reduce incidences of clogging). For this example we chose a 1.00" diameter orifice (area = 0.0055 sf).

$$Maximum\ \#_{orif} = \frac{A_{ff}\ sf}{A_{orif}\ sf}$$

$$Maximum\ \#_{orif} = \frac{0.0076\ sf}{0.0055\ sf}$$

$$Maximum\ \#_{orif} = 1.40$$

C. The number of orifices used in the outlet design should be equal to or less than the calculated maximum number of orifices and may depend on allowable release rate and detention time conditions being met, so in this example we use one – 1.00" diameter orifice at elevation 807.00' (x_{bot}).

$$Q_{ff}^{act} = (0.62)(\#_{orif})(A_{orif}^{act})\sqrt{2gh_{ave}}$$

$$Q_{ff}^{act} = (0.62)(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(1.37\ ft)}$$

$$Q_{ff}^{act} = 0.0318\ cfs$$

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

$$T_{ff}^{act} = \frac{3{,}842\ cf}{(0.0318\ cfs)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$T_{ff}^{act} = 33.6\ hr$$

The actual detention time for one – 1.00" diameter orifice: Since T_{ff}^{act} is greater than 24 hours, the size and number of orifices meets the detention time criteria.

3 STAGE OUTLET DESIGN EXAMPLE

BANKFULL DISCHARGE

A. The bankfull storm must be detained between 36 and 48 hours. The first flush orifices should be checked to see if they are adequate or if additional orifices are necessary.

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

$$h_{ave} = \frac{2}{3}(809.81 - 807.00)$$

$$h_{ave} = 1.87 ft$$

$$Q_{bf} = (0.62)(\#_{orif})(A_{orif}^{act})\sqrt{2gh_{ave}}$$

$$Q_{bf} = (0.62)(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(1.87\ ft)}$$

$$Q_{bf} = 0.037\ cfs$$

$$T_{bf} = \frac{V_{bf}}{Q_{bf}}$$

$$T_{bf} = \frac{8{,}286\ cf}{(0.037\ cfs)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$T_{bf} = 62.0\ hr$$

B. Because the holding time exceeds the maximum allowable 48 hours, additional orifices are required. The release rate is approximated by considering two circumstances; the release rate when both the first flush and bank full orifices are contributing and the release rate when the water elevation is below the bank full orifice (which is set at the first flush elevation). Since the time for the first flush volume to release was calculated at 33.3 hours, the remaining volume (bank full volume – first flush volume) must be released so the total detention time falls between 36 and 48 hours. A target time of 44 hours was chosen in this case.

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

$$V_{rem} = 8{,}286\ cf - 3{,}842\ cf$$

$$V_{rem} = 4{,}444\ cf$$

$$T_{rem} = T_{target} - T_{ff}^{act}$$

$$T_{rem} = 44.0\ hr - 33.6\ hr$$

$$T_{rem} = 10.4\ hr$$

C. The volume release by one – 1.00" diameter orifice in 10.4 hours should be calculated

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

$$h_{ave}^{ff} = \frac{2}{3}(809.81 - 809.06) + (809.06 - 807.00)$$

$$h_{ave}^{ff} = 2.56\ ft$$

Q_{ff+bf} will be defined as the discharge through the first flush orifices when both the first flush and bank full holes are contributing.

$$Q_{ff+bf} = (0.62)(\#_{orif})(A_{orif}^{act})\sqrt{2gh_{ave}^{ff}}$$

$$Q_{ff+bf} = 0.62(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(2.56\ ft)}$$

$$Q_{ff+bf} = 0.044\ cfs$$

$$V_{ff+bf} = (T_{rem})Q_{ff+bf}$$

$$V_{ff+bf} = 10.4\ hr(0.044\ cfs)\left(\frac{3{,}600\ \text{sec}}{1\ hr}\right)$$

$$V_{ff+bf} = 1{,}632\ cf$$

3 STAGE OUTLET DESIGN EXAMPLE

BANKFULL DISCHARGE

D. The leftover volume will be released by the bankfull orifice(s). Vbf will be defined as the amount of water to be discharged by the bank full orifices in 10.4 hours.

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

$$V_{bf} = 4{,}444\ cf - 1{,}632\ cf$$

$$V_{bf} = 2{,}812\ cf$$

$$Q_{bf} = \frac{V_{bf}}{T_{rem}}$$

$$Q_{bf} = \frac{2{,}812}{(10.4\ hr)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$Q_{bf} = 0.075\ cfs$$

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

$$h_{ave}^{bf} = \frac{2}{3}(809.81\ ft - 809.06\ ft)$$

$$h_{ave}^{bf} = 0.50\ ft$$

$$A_{bf} = \frac{Q_{bf}}{0.62\sqrt{2gh_{ave}^{bf}}}$$

$$A_{bf} = \frac{0.075\ cfs}{0.62\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(0.50\ ft)}}$$

$$A_{bf} = 0.0213\ sf$$

A 1.75” diameter orifice has an area of 0.0167 sf

$$Maximum\ \#_{orif} = \frac{A_{bf}\ sf}{A_{orif}\ sf}$$

$$Maximum\ \#_{orif} = \frac{0.0213\ sf}{0.0167\ sf}$$

$$Maximum\ \#_{orif} = 1.27$$

E. The number of orifices used in the outlet design should be equal to or less than the calculated maximum number of orifices and may depend on allowable release rate and detention time conditions being met. In this example we use one – 1.75” diameter orifice at elevation 809.06’ (x_{ff}). The actual detention time for one – 1.75” diameter orifice:

$$Q_{bf}^{act} = (0.62)(\#_{orif})(A_{orif}^{act})\sqrt{2gh_{ave}^{bf}}$$

$$Q_{bf}^{act} = (0.62)(1)(0.0167\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(0.50\ ft)}$$

$$Q_{bf}^{act} = 0.059\ cfs$$

$$T_{bf}^{act} = T_{ff}^{act} + \frac{V_{rem}}{(Q_{ff+bf} + Q_{bf}^{act})\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$T_{bf}^{act} = 33.6\ hr + \frac{4{,}444\ cf}{(0.059\ cfs + 0.044\ cfs)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$T_{bf}^{act} = 45.6\ hr$$

Since T_{bf}^{act} is greater than 36 hours but less than 48 hours, the size and number of orifices meets the detention time criteria.

3 STAGE OUTLET DESIGN EXAMPLE

100 YEAR STORM (1% STORM)

Q_{allow}=0.276 cfs

A. Q_{allow} is a peak, or maximum, flow rate. Calculate the maximum flow passing through the first flush and bank full orifices using the total head, and subtract Qallow to determine the orifice size to release the 100-year storm volume.

$$Q_{ff} + Q_{bf} = 0.62(\#_{orif}^{ff})(A_{orif}^{ff})\sqrt{2g(x_{100} - x_{bot})} + 0.62(\#_{orif}^{bf})(A_{orif}^{bf})\sqrt{2g(x_{100} - x_{ff})}$$

$$Q_{ff} + Q_{bf} = 0.62(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(811.04 - 807.00)}$$

$$+ 0.62(1)(0.0167\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(811.04 - 809.06)}$$

$$Q_{ff} + Q_{bf} = 0.055\ cfs + 0.117\ cfs = 0.172\ cfs$$

$$Q_{100}^{max} = Q_{allow} - (Q_{ff} + Q_{bf})$$

$$Q_{100}^{max} = 0.276\ cfs - 0.172\ cfs$$

$$Q_{100}^{max} = 0.104\ cfs$$

$$A_{100}^{max} = \frac{Q_{100}^{max}}{0.62\sqrt{2g(x_{100} - x_{bf})}}$$

$$A_{100}^{max} = \frac{0.104\ cfs}{0.62\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(811.04 - 809.81)}}$$

$$A_{100}^{max} = 0.0189\ sf$$

The number and size of orifices to meet the area requirements is variable, so many solutions are possible. For this example we chose to use 1.75” diameter orifices (area = 0.0167 sf).

3 STAGE OUTLET DESIGN EXAMPLE

100 YEAR STORM (1% STORM)

$$Maximum\ \#_{orif} = \frac{A\ sf}{A_{orif}\ sf}$$

$$Maximum\ \#_{orif} = \frac{0.189\ sf}{0.0167\ sf}$$

$$Maximum\ \#_{orif} = 1.13$$

Therefore use one - 1.75” diameter orifice at elevation 809.81’ (x_{bf}).

B. Check to confirm that the allowable flow rate has not been exceeded by the actual number of orifices selected.

$$Q_{ff} + Q_{bf} + 0.62\#_{orif}A_{100}\sqrt{2gh_{tot}^{100}} < Q_{allow}$$

$$0.055\ cfs + 0.117\ cfs + 0.62(1)(0.0167\ ft)\sqrt{2\left(32.2\ \frac{ft}{sec^2}\right)(811.04 - 809.81)} < 0.276$$

0.264 cfs < 0.276 cfs

C. The 100-year storm volume has to discharge in less than 72 hours. The time can be approximated by considering two circumstances; the time for the basin to discharge the 100-year volume down to the bankfull elevation (when all three sets of orifices are contributing) in addition to the time to discharge when the bankfull volume remains (which was already calculated at 45.3 hours).

Q_{all} will be defined as the discharge through the first flush orifices when the first flush, bankfull, and 100-year holes are contributing.

$$h_{ave}^{all} = \frac{2}{3}(x_{100} - x_{bf}) + (x_{bf} - x_{bot})$$

$$h_{ave}^{bf} = \frac{2}{3}(811.04 - 809.81) + (809.81 - 807.00)$$

$$h_{ave}^{all} = 3.63\ ft$$

3 STAGE OUTLET DESIGN EXAMPLE

100 YEAR STORM (1% STORM)

$$Q_{all} = (0.62)(\#^{ff}_{orif})(A^{ff}_{orif})\sqrt{2gh^{all}_{ave}}$$

$$Q_{all} = 0.62(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(3.63\ ft)}$$

$$Q_{all} = 0.052\ cfs$$

D. Q_{bf+100} will be defined as the discharge through the bankfull orifices when the first flush, bankfull, and 100-year holes are contributing.

$$h^{bf}_{ave} = \frac{2}{3}(x_{100} - x_{bf}) + (x_{bf} - x_{ff})$$

$$h^{bf}_{ave} = \frac{2}{3}(811.04 - 809.81) + (809.81 - 809.06)$$

$$h^{bf}_{ave} = 1.57\ ft$$

$$Q_{bf+100} = (0.62)(\#^{bf}_{orif})(A^{bf}_{orif})\sqrt{2gh^{bf}_{ave}}$$

$$Q_{bf+100} = 0.62(1)(0.0167\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(1.57\ ft)}$$

$$Q_{bf+100} = 0.104\ cfs$$

E. The average discharge through the 100-year storm orifice(s) when the other orifice(s) are contributing should be determined.

$$h^{100}_{ave} = \frac{2}{3}(x_{100} - x_{bf})$$

$$h^{100}_{ave} = \frac{2}{3}(811.04 - 809.81)$$

$$h^{100}_{ave} = 0.82ft$$

$$Q^{100}_{ave} = (0.62)(\#^{100}_{orif})(A^{100}_{orif})\sqrt{2gh^{100}_{ave}}$$

$$Q^{100}_{ave} = (0.62)(1)(0.0167)\sqrt{2(32.2)(0.82)}$$

$$Q^{100}_{ave} = 0.075\ cfs$$

F. Check to confirm that the 100-year storm volume is discharged in less than 72 hours.

$$V_{rem} = V_{100} - V_{bf}$$

$$V_{rem} = 20{,}106\ cf - 8{,}286\ cf$$

$$V_{rem} = 11{,}820\ cf$$

$$T_{100} = T_{bf} + \frac{V_{rem}}{Q_{all} + Q_{bf+100} + Q^{100}_{ave}}$$

$$T_{100} = 45.6\ hr + \frac{11{,}820}{(0.052cfs + 0.104\ cfs + 0.075\ cfs)\left(\frac{3600\ sec}{1\ hr}\right)}$$

$$T_{100} = 45.6\ hr + 14.2\ hr = 59.8\ hr$$

$T_{100} \leq 72$ hr

59.7 hr ≤ 72 hr

Therefore, the design meets both the time of detention and the flow rate requirements.

OUTLET DESIGN EXAMPLES

2-STAGE OUTLET

In instances where the on-site infiltration is provided, the volume infiltrated will be equal to or greater than the first flush volume. This eliminates the need for first flush orifices, and the outlet structure can use a two-stage orifice system to discharge the required detention volumes.

Area = 80,128 sf or 1.84 ac
First flush volume: 3,842 cf
Bankfull volume: 8,286 cf
On-site infiltration requirement: 6,581 cf
100-year detention volume : 10,173 cf

ELEVATION	AREA (SF)	DEPTH (FT)	VOLUME (CF)	TOTAL VOLUME (CF)
811.0	10,836	1	10,218	24,366
810.0	9,600	1	7,528	14,148
809.0	5,455	1	4,174	6,621
808.0	2,893	1	2,447	2,447
807.0*	2,000	0	0	0

* X_{bot}

Storage Elevations

The bankfull volume to be detained consists of the calculated bankfull volume minus the volume infiltrated

Bankfull detained =8,286 cf – 6,581 cf
Bankfull detained = 1,705 cf

Bankfull $\frac{808.0-807.0}{2{,}447-0} = \frac{x_{bf}-807.0}{1{,}705-0}$ $x_{bf} = 807.70$

100-year $\frac{810.0-809.0}{14{,}148-6{,}621} = \frac{x_{100}-809.0}{10{,}173-6{,}621}$ $x_{100} = 809.47$

The allowable release rate is 0.15 cfs/acre

$$Q_{allow} = \left(0.15\frac{cfs}{acre}\right)(A)$$

$$Q_{allow} = \left(0.15\frac{cfs}{acre}\right)(1.84\ acres)$$

$$Q_{allow} = 0.276\ cfs$$

2 STAGE OUTLET DESIGN EXAMPLE

BANKFULL DISCHARGE

The bankfull storm must be detained between 24 and 36 hours on sites where the minimum required infiltration is achieved.

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

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

$$h_{ave} = \frac{2}{3}(807.70 - 807.00)$$

$$h_{ave} = 0.47\ ft$$

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

$$Q_{bf} = \frac{V_{bf}}{T_{bf}}$$

$$Q_{bf} = \frac{1{,}705\ cf}{24\ hr(\frac{3{,}600\ sec}{hr})}$$

$$Q_{bf} = 0.01974\ cfs$$

$$A_{bf} = \frac{0.01974\ cfs}{0.62\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(0.47\ ft)}}$$

$$A_{bf} = 0.0058\ ft$$

B. The number and size of orifices to meet the area requirements is variable, so many acceptable solutions are possible. In general, larger holes are preferable if multiple orifices can be used (to reduce incidences of clogging). For this example we chose a 1.00” diameter orifice (area = 0.0055 sf).

$$Maximum\ \#_{orif} = \frac{A_{bf}\ sf}{A_{orif}\ sf}$$

$$Maximum\ \#_{orif} = \frac{0.0058\ sf}{0.0055\ sf}$$

$$Maximum\ \#_{orif} = 1.06$$

C. The number of orifices used in the outlet design should be equal to or less than the calculated maximum number of orifices and may depend on allowable release rate and detention time conditions being met, so in this example we use one – 1.00” diameter orifice at elevation 807.00’ (x_{bot}).

The actual detention time for one – 1.00” diameter orifice:

$$Q_{bf}^{act} = (0.62)(\#_{orif})(A_{orif}^{act})\sqrt{2gh_{ave}}$$

$$Q_{bf}^{act} = (0.62)(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(0.47\ ft)}$$

$$Q_{bf}^{act} = 0.0188\ cfs$$

$$T_{bf}^{act} = \frac{V_{bf}}{Q_{bf}^{act}}$$

$$T_{bf}^{act} = \frac{1{,}705\ cf}{(0.0188\ cfs)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$T_{bf}^{act} = 25.6\ hr$$

2 STAGE OUTLET DESIGN EXAMPLE

100 YEAR STORM (1%) STORM

$$Q_{allow} = 0.276\ cfs$$

D. Q_{allow} is a peak, or maximum, flow rate. Calculate the maximum flow passing through the bank full orifices using the total head, and subtract Q_{allow} to determine the orifice size to release the 100-year storm volume.

$$Q_{bf} = 0.62(\#_{orif}^{bf})(A_{orif}^{bf})\sqrt{2g(x_{100} - x_{bot})}$$

$$Q_{bf} = 0.62(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(809.47 - 807.00)}$$

$$Q_{bf} = 0.043\ cfs$$

$$Q_{100}^{max} = Q_{allow} - Q_{bf}$$

$$Q_{100}^{max} = 0.276\ cfs - 0.043\ cfs$$

$$Q_{100}^{max} = 0.233\ cfs$$

$$A_{100}^{max} = \frac{Q_{100}^{max}}{0.62\sqrt{2g(x_{100} - x_{bf})}}$$

$$A_{100}^{max} = \frac{0.233\ cfs}{0.62\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(809.47 - 807.70)}}$$

$$A_{100}^{max} = 0.0352\ sf$$

E. The number and size of orifices to meet the area requirements is variable, so many solutions are possible. For this example we chose to use 1.5” diameter orifices (area = 0.0123 sf).

Therefore use two – 1.5” diameter orifices at elevation 807.70’ (x_{bf}).

$$Maximum\ \#_{orif} = \frac{A\ \ sf}{A_{orif}\ \ sf}$$

$$Maximum\ \#_{orif} = \frac{0.0352\ sf}{0.0123\ sf}$$

$$Maximum\ \#_{orif} = 2.86$$

F. Check to confirm that the allowable flow rate has not been exceeded by the actual number of orifices selected.

$$Q_{bf} + 0.62(\#_{orif}^{100})(A_{orif}^{100})\sqrt{2gh_{tot}^{100}} < Q_{allow}$$

$$0.043\ cfs + 0.62(2)(0.0123\ ft)\sqrt{2\left(32.2\ \frac{ft}{sec^2}\right)(809.47 - 807.70)} < 0.276$$

0.206 cfs < 0.276 cfs

G. The 100-year storm volume has to discharge in less than 72 hours. The time can be approximated by considering two circumstances; the time for the basin to discharge the 100-year volume down to the bankfull elevation (when both sets of orifices are contributing) in addition to the time to discharge when the bankfull volume remains (which was already calculated at 25.6 hours).

Q_{both} will be defined as the discharge through the bankfull orifices when the bankfull and 100-year holes are contributing.

2 STAGE OUTLET DESIGN EXAMPLE

100 YEAR STORM (1% STORM)

$$h_{ave}^{both} = \frac{2}{3}(x_{100} - x_{bf}) + (x_{bf} - x_{bot})$$

$$h_{ave}^{bf} = \frac{2}{3}(809.47 - 807.70) + (807.70 - 807.00)$$

$$h_{ave}^{both} = 1.88\ ft$$

$$Q_{both} = (0.62)(\#_{orif}^{bf})(A_{orif}^{bf})\sqrt{2gh_{ave}^{both}}$$

$$Q_{both} = 0.62(1)(0.0055\ sf)\sqrt{2\left(32.2\frac{ft}{sec^2}\right)(1.88\ ft)}$$

$$Q_{both} = 0.037\ cfs$$

A. The average discharge through the 100-year storm orifice(s) while the other orifice(s) are contributing should be determined.

$$h_{ave}^{100} = \frac{2}{3}(x_{100} - x_{bf})$$

$$h_{ave}^{100} = \frac{2}{3}(809.47 - 807.70)$$

$$h_{ave}^{100} = 1.18\ ft$$

$$Q_{ave}^{100} = (0.62)(\#_{orif}^{100})(A_{orif}^{100})\sqrt{2gh_{ave}^{100}}$$

$$Q_{ave}^{100} = (0.62)(2)(0.0123)\sqrt{2(32.2)(1.18)}$$

$$Q_{ave}^{100} = 0.133\ cfs$$

B. Check to confirm that the 100-year storm volume is discharged in less than 72 hours.

$$V_{rem} = V_{100} - V_{bf}$$

$$V_{rem} = 10{,}173\ cf - 1{,}705\ cf$$

$$V_{rem} = 8{,}468\ cf$$

$$T_{100} = T_{bf} + \frac{V_{rem}}{Q_{both} + Q_{ave}^{100}}$$

$$T_{100} = 25.6\ hr + \frac{8{,}468}{(0.037cfs + 0.133\ cfs)\left(\frac{3{,}600\ sec}{1\ hr}\right)}$$

$$T_{100} = 25.6\ hr + 13.8\ hr = 39.4\ hr$$

$$T_{100} \leq 72\ \text{hr}$$

$$39.4\ \text{hr} \leq 72\ \text{hr}$$

Therefore, the design meets both the time of detention and the flow rate requirements.