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Evaluation of Stormwater Management System Mounding Analysis

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1 Introduction

The purpose of this document is to ensure that any mounding analysis required in a Stormwater Management System Report is performed in an accurate and scientifically defensible manner. If the inputs are valid, then the output of the model will be sufficiently accurate for the purposes of the report.

There is no expectation that the user of this document be a groundwater hydrologist; however, the user conducting the analysis should demonstrate a basic understanding of mounding analysis concepts and required inputs.

The MA DEP Stormwater Handbook Volume 3 requires a mounding analysis using the Hantush method (Hantush, 1967) when the base of a proposed stormwater detention BMP is less than four (4) feet above Estimated Seasonal High Groundwater and the system must attenuate a 10-year or greater storm OR when the detention BMP is adjacent to a contaminated site as specified in Volume 3. The purpose is to demonstrate that the detention BMP will drain within 72 hours after the storm ends and thus be ready for the next storm event.

Most likely, engineers designing the stormwater management system will be using a computer model to perform the mounding analysis. The model implementation can be in the form of a commercial application or a publicly available Excel workbook **as long as the model produces a water table recession hydrograph depicting exponential declin**e as required in the Massachusetts Stormwater Handbook, Volume 3, page 29, Paragraph 1 (MA DEP, 2008). A recession hydrograph is a height versus time plot.

A simplified checklist for mounding analysis review is provided in Section 4.

2 Inputs

Regardless of the model, the inputs have to include the following <u>at a minimum</u>:

R - The recharge or infiltration rate.

Sy- Specific Yield or Effective Porosity.

Kh - Horizontal hydraulic conductivity.

L - Detention system length (some models may require half the length).

W - Detention system width (some models may require half the width).

t - Duration of infiltration (should be 24 hours).

h - Initial Saturated Thickness of the aquifer.

2.1 Recharge Rate (R)

Fetter (2001) defines recharge rate as:

$$R = \frac{Q}{A}$$

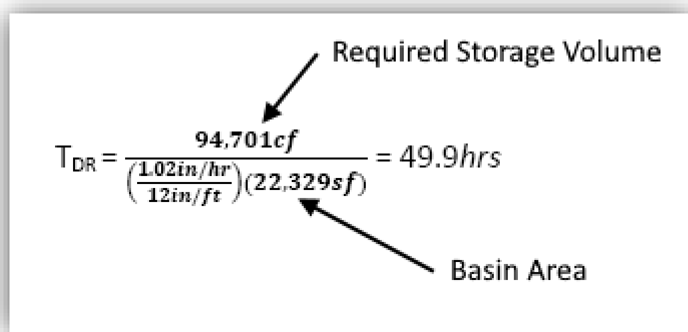
Parameter	Definition	Units	Description
R	Recharge Rate	Length/time – usually ft/d	Calculated recharge rate
Q	Discharge Rate	$Length^3$/time - usually ft^3/d	Total volume to be discharged divided by time over which infiltration will occur.
A	Basin Area	$Length^2$ – usually ft^2	Bottom area over which infiltration will occur

This information is extracted from the report as follows:

For each detention basin where a mounding analysis is to be performed, obtain the Required Storage Volume and Bottom Area value for the basin. These values will be used to calculate the Discharge Rate (Q).

These values are found in the portion of the report where Standard 3, Stormwater Recharge is calculated and Drawdown Calculations are displayed. The portion of the report where this information is found will vary. If in doubt, request this information from the applicant.

The drawdown calculation for the basin may look something like the following or be in a tabular format:



In all cases, the value for "time over which infiltration will occur" will always be one (1) day, as discussed in Section 2.5.

For example, if the Required Storage Volume for the basin is 94,701 ft^3 and the bottom area of the basin is 22,329 ft^2, Recharge Rate (R) is:

Q = 94,701 ft^3 / 1 day = 94,701 ft^3 day.

A = 22,329 ft^2

R = 94,701 ft^3 day / 22,329 ft^2 = 4.24 ft/d

If there is more than one detention system for a project, you only need to get these values from detention systems for which the mounding analysis is required.

A "Rawls Rate" from the Stormwater Handbook Volume 3 is not a recharge rate. A "Rawls Rate" is a hydraulic conductivity value for a given soil type obtained from laboratory tests (Rawls, 1982). A Rawls Rate cannot be used for a mounding analysis as it does not reflect the volume of recharge or the bottom area of the system. See Section 2.3 for further explanation.

2.2 Specific Yield or Effective Porosity (Sy)

The following are acceptable values for Sy:

- Sand and Gravel: 0.25
- Sand: 0.30
- Loamy Sand: 0.25
- Sandy Loam: 0.20
- Loam: 0.10
- Silt Loam: 0.05
- Silty Clay Loam: 0.02

These values were obtained on Johnson (1967). Effective porosity values in Rawls (1982) do not reflect drainable porosity from a groundwater hydrology perspective and should not be used in a mounding analysis.

2.3 Hydraulic Conductivity (Kh)

Hydraulic conductivity (K) is a measure of the ability of a porous medium to transmit water (Fetter, 2001).

K is defined as:

$$K = -\frac{Q}{\left(\frac{\mathrm{dh}}{\mathrm{dl}}\right) A}$$

Parameter	Definition	Units	Description
K	Hydraulic Conductivity	Length/time – usually ft/d	Measure of the ability of water to flow through a porous medium
Q	Discharge Rate	$Length^3$/time - usually ft^3/d	Total volume to be discharged divided by time through a given cross-sectional area.
(dh/dl)	Hydraulic Gradient	Length/Length – unitless	Change in the height of the water column over a specific length
A	Area	$Length^2$ – usually ft^2	Cross-sectional area through which flow is occurring

A mounding analysis requires a horizontal hydraulic conductivity (Kh).

There are several ways to obtain a Kh value:

1. Field permeameter test, which is used to obtain a vertical hydraulic conductivity (Kv). The test must be performed at a depth equal to the proposed bottom elevation of the detention system.

   Depositional processes cause a vertical anisotropy in any unconsolidated sediment. In New England, glacial outwash, glacio-lacustrine deposits and glacial till are all depositionally anisotropic. Therefore, Kh is derived using the following convention:

   Sand or coarser material: Kh = Kv x 5

   All other material: Kh = Kv x 10

2. Single-well Aquifer or Slug test of a monitoring well, which is used to directly obtain Kh.

3. Estimates from grain size distribution analysis (Devlin, 2015).

NOTE: A "Rawls Rate" from the Stormwater Handbook Volume 3 is not a substitution for a hydraulic conductivity derived from field permeameter test.

2.4 Detention System Dimensions (L and W)

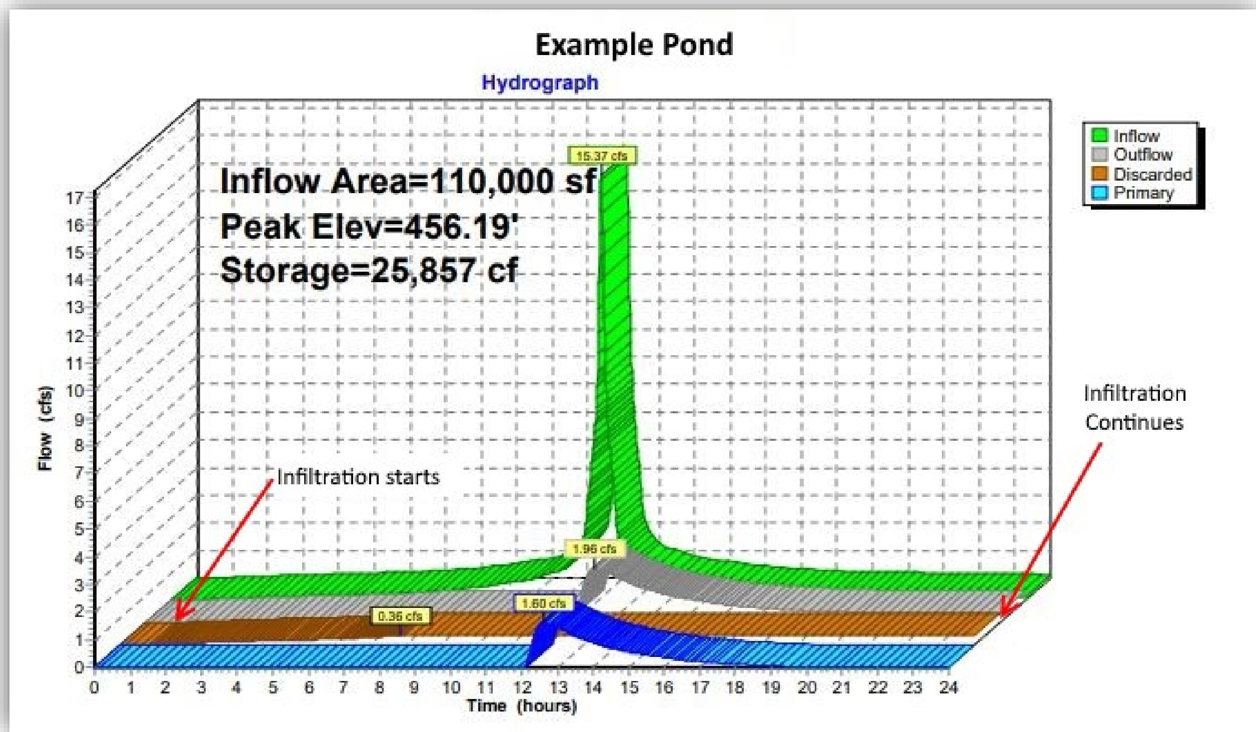
If the detention BMP is a subsurface infiltration basin, the dimensions of the BMP from the plans submitted with the NOI will be used to define these values. The values should be close to the basin area obtained from the recharge calculation.

If the BMP is an irregularly shaped detention basin, use the square root of the basin area obtained from the recharge calculation or a rectangular approximation that has the same basin area and orientation.

2.5 Duration of infiltration (t)

t = 24 hours or 1 day.

It does not matter if infiltration starts 12 hours into the storm. HydroCad hydrographs do not show when infiltration ends after the storm ends, as shown in the following example hydrograph. Also note that flow from the detention system also continues after the storm ends. For the purposes of the model, infiltration continues for 24 hours total time by convention.



2.6 Initial Saturated Thickness of the aquifer (h)

Initial Saturated Thickness is derived by subtracting the elevation of the base of the aquifer below the basin from Estimated Seasonal High Groundwater (ESHGW) elevation.

ESHGW should be provided in the report narrative. This value is required in order to determine the bottom elevation of the detention BMP.

The base of the aquifer will be one of these values:

- Test pit or boring surface elevation minus depth to bedrock.
- Test pit or boring surface elevation minus depth to clay layer.
- Test pit surface elevation minus depth to the elevation of hard pan (dense till).
- Test pit or boring surface elevation minus depth to deepest test pit or boring if no exploration reaches bedrock, clay or hardpan (dense unweathered till).
- **Boring** surface elevation to depth of first instance of very dense soil, determined by blow counts greater than 50 per foot for the interval between 0.5 to 1.5 feet of a 2-foot split spoon sample.

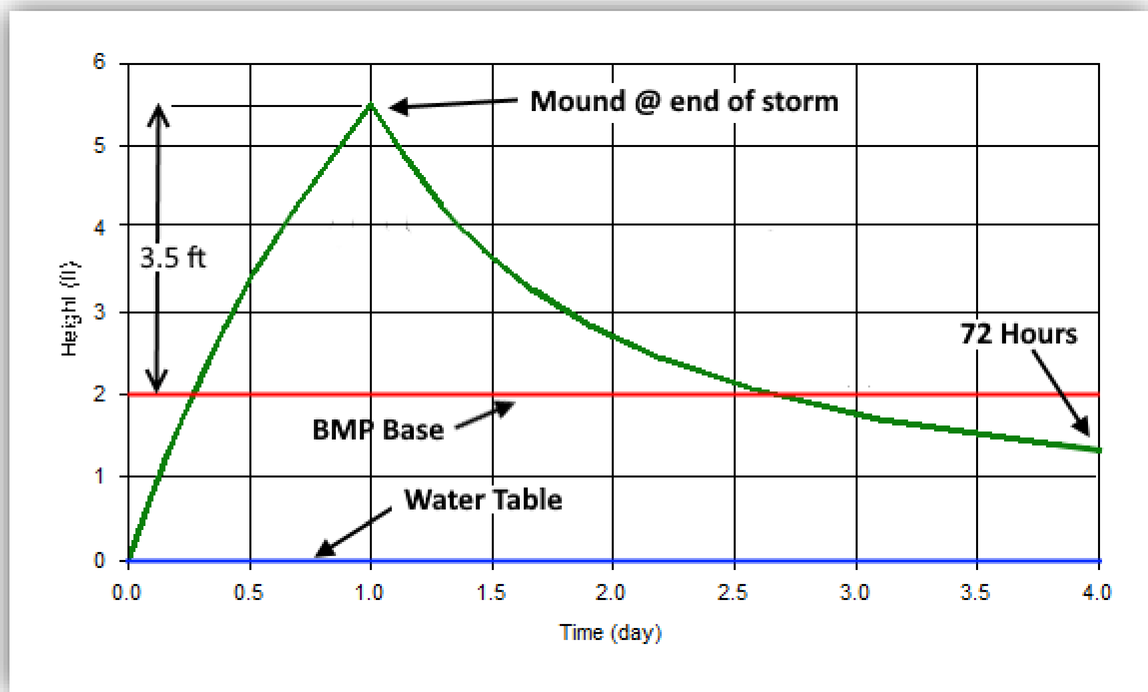
3 Hantush Model Result

The whole point of this exercise is to determine the elevation of the mound underneath the approximate center of the detention BMP 72 hours after the end of the design storm event.

This elevation needs to be less than the bottom elevation of the detention BMP. The mound elevation is the height of the modeled mound under the center of the detention BMP plus ESHGW elevation at 72 hours after the end of the storm.

If the model output is simply the mound elevation at the end of the storm event, the result is not acceptable. The applicant must use a model that shows that the basin will be drained within the 72-hour post-storm time frame as required by the regulations. The Stormwater Handbook requires **“a water table recession hydrograph depicting exponential decline.”**

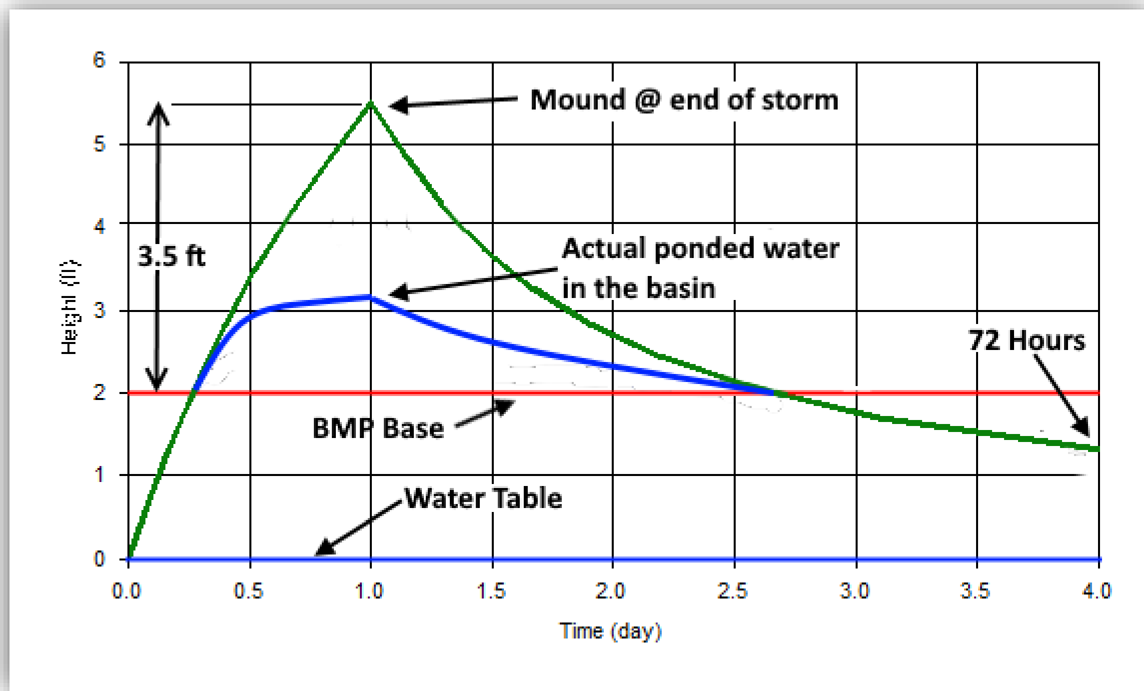
The annotated illustration below, produced by a mounding analysis computer application, shows the decay of a mound beneath the center of a detention BMP. At 4 days (72 hours post storm), the mound height is approximately 0.5 feet below the BMP base, indicating that the BMP is ready to receive the next storm. Note, the actual output is just the green curve.



Note that the mound elevation above the system base is NOT the height of the water in the basin. Effective porosity has to be taken into account. Assuming an effective porosity of 30%, the actual water level above the BMP base at 24 hours is:

3.5 feet x 0.30 = 1.05 feet

The estimated ponded surface water elevation is illustrated below:



4 Simplified Checklist

Y	N	Section	Item
		2.1	Is the recharge volume equal to the "Discarded" from the report?
		2.1	Is the surface area of the detention basin correct?
		2.1	Is the recharge rate equal to the "Discarded" value divided by the basin surface area?
		2.2	Is the Specific Yield (Sy) aka Effective Porosity correct?
		2.3	Was a valid method (permeameter, slug test, grain-size) used to derive Kh?
		2.4	Are the dimensions (x, y) of the detention basin valid?
		2.5	Is the duration of infiltration 24 hours (1 day)?
		2.6	Is the estimated elevation of the base of the aquifer correct?
		2.6	Is the initial saturated thickness equal to ESHGW minus the aquifer base elevation?
		3	Does the model show the mound elevation at 72 hours?
			Are the units of length and time consistent for all values of model input?

5 References

Devlin, J.F. 2015, HydrogeoSieveXL: an Excel-based tool to estimate hydraulic conductivity from grain size analysis. Hydrogeology Journal, DOI 10.1007/s10040-015-1255-0 (https://kuscholarworks.ku.edu/handle/1808/21763)

Fetter, C.W., 2001, Applied Hydrogeology, Fourth Edition.

Hantush, M.S., 1967, Growth and Decay of Ground-Water Mounds in Response to Uniform Percolation, Water Resources Research, 3: 227-34.

Johnson, A.I., 1967, Specific Yield--Compilation of Specific Yields for Various Materials, USGS WSP 1662-D, https://pubs.usgs.gov/wsp/1662d/report.pdf.

Rawls, W.J. et al, 1982, Estimation of Soil Water Properties, Transactions of the ASAE Vol. 25, No. 4, pp 1316 – 20.