HANCOCK
ASSOCIATES

July 6, 2015

Mr. Jeffrey Ribeiro
Regulatory Officer I
Cape Cod Commission
3225 Main Street, PO Box 226
Barnstable, MA 02630

Subject: SpringHill Suites by Marriott, 556 Main Street, Falmouth, MA

Dear Mr. Ribeiro:

An analysis of groundwater mounding due to the proposed stormwater system at 556 Main Street in Falmouth, as requested in the letter by Neal M. Price of the Horsley Witten Group, Inc., dated June 30, 2016, has been performed and is described herein. Potential impact that the stormwater system will have on the water tables on abutting properties is also analyzed. The proposed stormwater system includes three systems of subsurface "R-Tanks" which will provide stormwater detention and promote infiltration. The three systems are referred to as 1PA, 1PB, and 1PC on the design plans and in the Stormwater Report. A groundwater mounding analysis was performed for each of these systems. The estimated seasonal high groundwater at systems 1PA, 1PB, and 1PC is 4.4', 3.1', and 3.8', respectively. We would like to note that, since the bottom of these systems is at elevation 10.10' and the separation to groundwater is greater than 4', a mounding analysis is not required per the Massachusetts Stormwater Regulations. Elevations are on vertical datum NGVD 29.

The groundwater mounding was analyzed using a spreadsheet created by the U.S. Geological Survey (USGS) which solves the Hantush equation, a method suggested in Mr. Neal's letter. The completed spreadsheets are attached. The spreadsheet references 7 variables including initial thickness of saturated zone (hi(0)), and recharge rate (R). The depth of bedrock in Falmouth and the surrounding area is described as at least 200 feet in the USGS document, "Bedrock Topography of Western Cape Cod". A depth of 100 feet is used for the initial thickness of saturated zone, as a conservative estimate. For the purpose of these calculations the recharge rate (variable "R" in the spreadsheet) was determined using the peak volume in the "R-Tank" systems during the 10-Year storm event, generated by the Hydrocad Model. The recharge rate calculations are as follows:

1PA:
10-Year Storm Volume = 4,562 Cubic Feet
System Area = 2,543 Square Feet
10-Year Storm Depth = 1.79 Feet
R = 1.79 Feet / 1.5 Days = 1.19 Feet/Day

1PB:
10-Year Storm Volume = 2,513 Cubic Feet
System Area = 1,262 Square Feet
10-Year Storm Depth = 1.99 FT
R = 1.99 FT / 1.5 Days = 1.33 FT/Day

1PC:
10-Year Storm Volume = 3,152 Cubic Feet
Pond Area = 1,562 Square Feet
10-Year Storm Depth = 2.25 Feet
R = 2.25 Feet / 1.5 Days = 1.50 Feet/Day

The mounding elevations at various distances from the centroid of the "R-Tank" systems are below.

		"R-Tank" System		
		System 1PA	System 1PB	System 1PC
Estimated Seasonal High Groundwater Elevation		4.4'	3.1'	3.8'
Mounding Elevation at Distance from Centroid of System	0 Feet	4.87	3.589	4.289
	20 Feet	4.80	3.465	4.165
	40 Feet	4.65	3.346	4.046
	50 Feet	4.60	3.305	4.005
	100 Feet	4.48	3.183	3.883
	120 Feet	4.46	3.158	3.858

The closest structure to the systems, on abutting properties, is the Dunkin Donuts business to the north. That structure, a slab foundation, is approximately 40' away from 1PB at the closest point, with a mounding height of 0.224' (2.7"). The next closest structure is the house at 6 Lantern Lane, about 50' away from 1PA. The mounding height at that house will be 0.204' (2.5"). This house has a basement, probably at elevation 10.0' except under the garage. The septic system on that property is closer to 1PC (about 60' away). Mounding height at the septic system would be 0.107' (1.3"). The house at 7 Morse Pond Road is greater than 300' from the proposed location of 1PA. The mounding height at that location will be less than 1 inch. We believe that the groundwater mounding that will result from the proposed stormwater system is negligible and will have no negative impact on the surrounding properties.

Please do not hesitate to contact me should you have any additional questions or concerns. I can be reached at 978-777-3050 or via email at kcruz@hancockassociates.com.

Sincerely,
Hancock Associates

Katherine A. Cruz, PE
Project Manager

cc: Falmouth Hospitality LLC

"R-Tank" System 1PA

This spreadsheet will calculate the height of a groundwater mound beneath a stormwater infiltration basin. More information can be found in the U.S. Geological Survey Scientific Investigations Report 2010-5102 "Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins".

The user must specify infiltration rate (R), specific yield (Sy), horizontal hydraulic conductivity (Kh), basin dimensions (x, y), duration of infiltration period (t), and the initial thickness of the saturated zone (hi(0), height of the water table if the bottom of the aquifer is the datum). For a square basin the half width equals the half length (x = y). For a rectangular basin, if the user wants the water-table changes perpendicular to the long side, specify x as the short dimension and y as the long dimension. Conversely, if the user wants the values perpendicular to the short side, specify y as the short dimension, x as the long dimension. All distances are from the center of the basin. Users can change the distances from the center of the basin at which water-table aquifer thickness are calculated.
Cells highlighted in yellow are values that can be changed by the user. Cells highlighted in red are output values based on user-specified inputs. The user MUST click the blue "Re-Calculate Now" button each time ANY of the user-specified inputs are changed otherwise necessary iterations to converge on the correct solution will not be done and values shown will be incorrect. Use consistent units for all input values (for example, feet and days)

use consistent units (e.g. feet & days **or** inches & hours)

Input Values

1.1900	*R*	**Recharge (infiltration) rate (feet/day)**
0.280	**Sy**	**Specific yield, Sy (dimensionless, between 0 and 1)**
12.00	**K**	**Horizontal hydraulic conductivity, Kh (feet/day)***
22.500	**x**	**1/2 length of basin (x direction, in feet)**
15.000	**y**	**1/2 width of basin (y direction, in feet)**
1.500	**t**	**duration of infiltration period (days)**
100.000	**hi(0)**	**initial thickness of saturated zone (feet)**

100.474	**h(max)**	**maximum thickness of saturated zone (beneath center of basin at end of infiltration period)**
0.474	**Δh(max)**	**maximum groundwater mounding (beneath center of basin at end of infiltration period)**

Conversion Table

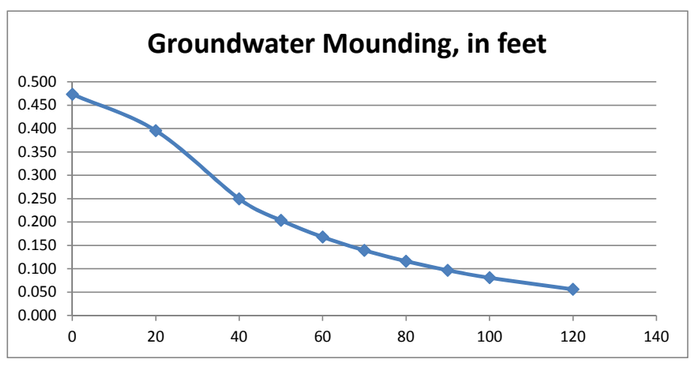
inch/hour	**feet/day**
0.67	1.33
2.00	4.00

hours	**days**
36	1.50

In the report accompanying this spreadsheet (USGS SIR 2010-5102), vertical soil permeability (ft/d) is assumed to be one-tenth horizontal hydraulic conductivity (ft/d).

Ground-water Mounding, in feet	**Distance from center of basin in x direction, in feet**
0.474	**0**
0.396	**20**
0.250	**40**
0.204	**50**
0.168	**60**
0.139	**70**
0.116	**80**
0.097	**90**
0.081	**100**
0.056	**120**

Re-Calculate Now



Disclaimer

This spreadsheet solving the Hantush (1967) equation for ground-water mounding beneath an infiltration basin is made available to the general public as a convenience for those wishing to replicate values documented in the USGS Scientific Investigations Report 2010-5102 "Groundwater mounding beneath hypothetical stormwater infiltration basins" or to calculate values based on user-specified site conditions. Any changes made to the spreadsheet (other than values identified as user-specified) after transmission from the USGS could have unintended, undesirable consequences. These consequences could include, but may not be limited to: erroneous output, numerical instabilities, and violations of underlying assumptions that are inherent in results presented in the accompanying USGS published report. The USGS assumes no responsibility for the consequences of any changes made to the spreadsheet. If changes are made to the spreadsheet, the user is responsible for documenting the changes and justifying the results and conclusions.

"R-Tank" System 1PC

This spreadsheet will calculate the height of a groundwater mound beneath a stormwater infiltration basin. More information can be found in the U.S. Geological Survey Scientific Investigations Report 2010-5102 "Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins".

The user must specify infiltration rate (R), specific yield (Sy), horizontal hydraulic conductivity (Kh), basin dimensions (x, y), duration of infiltration period (t), and the initial thickness of the saturated zone (hi(0), height of the water table if the bottom of the aquifer is the datum). For a square basin the half width equals the half length (x = y). For a rectangular basin, if the user wants the water-table changes perpendicular to the long side, specify x as the short dimension and y as the long dimension. Conversely, if the user wants the values perpendicular to the short side, specify y as the short dimension, x as the long dimension. All distances are from the center of the basin. Users can change the distances from the center of the basin at which water-table aquifer thickness are calculated.
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use consistent units (e.g. feet & days **or** inches & hours)

Input Values

1.5000	*R*	**Recharge (infiltration) rate (feet/day)**
0.280	**Sy**	**Specific yield, Sy (dimensionless, between 0 and 1)**
12.00	**K**	**Horizontal hydraulic conductivity, Kh (feet/day)***
12.000	**x**	**1/2 length of basin (x direction, in feet)**
21.000	**y**	**1/2 width of basin (y direction, in feet)**
1.500	**t**	**duration of infiltration period (days)**
100.000	**hi(0)**	**initial thickness of saturated zone (feet)**

100.471	**h(max)**	**maximum thickness of saturated zone (beneath center of basin at end of infiltration period)**
0.471	**Δh(max)**	**maximum groundwater mounding (beneath center of basin at end of infiltration period)**

Conversion Table

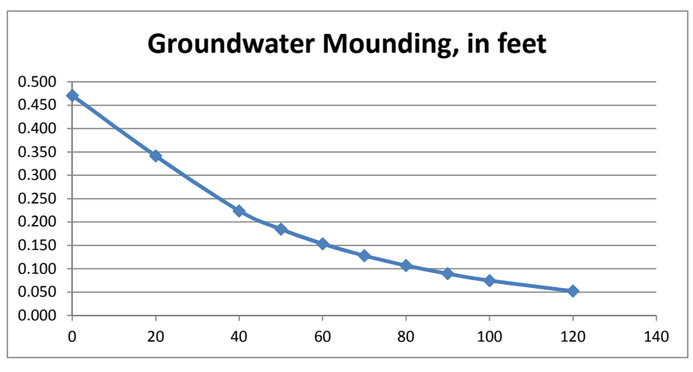
inch/hour	**feet/day**
0.67	1.33
2.00	4.00

hours	**days**
36	1.50

In the report accompanying this spreadsheet (USGS SIR 2010-5102), vertical soil permeability (ft/d) is assumed to be one-tenth horizontal hydraulic conductivity (ft/d).

Ground-water Mounding, in feet	**Distance from center of basin in x direction, in feet**
0.471	**0**
0.341	**20**
0.224	**40**
0.185	**50**
0.153	**60**
0.128	**70**
0.107	**80**
0.089	**90**
0.075	**100**
0.052	**120**

Re-Calculate Now



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"R-Tank" System 1PB

This spreadsheet will calculate the height of a groundwater mound beneath a stormwater infiltration basin. More information can be found in the U.S. Geological Survey Scientific Investigations Report 2010-5102 "Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins".

The user must specify infiltration rate (R), specific yield (Sy), horizontal hydraulic conductivity (Kh), basin dimensions (x, y), duration of infiltration period (t), and the initial thickness of the saturated zone (hi(0), height of the water table if the bottom of the aquifer is the datum). For a square basin the half width equals the half length (x = y). For a rectangular basin, if the user wants the water-table changes perpendicular to the long side, specify x as the short dimension and y as the long dimension. Conversely, if the user wants the values perpendicular to the short side, specify y as the short dimension, x as the long dimension. All distances are from the center of the basin. Users can change the distances from the center of the basin at which water-table aquifer thickness are calculated.
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use consistent units (e.g. feet & days **or** inches & hours)

Input Values

1.3300	*R*	**Recharge (infiltration) rate (feet/day)**
0.280	**Sy**	**Specific yield, Sy (dimensionless, between 0 and 1)**
12.00	**K**	**Horizontal hydraulic conductivity, Kh (feet/day)***
11.000	**x**	**1/2 length of basin (x direction, in feet)**
29.500	**y**	**1/2 width of basin (y direction, in feet)**
1.500	**t**	**duration of infiltration period (days)**
100.000	**hi(0)**	**initial thickness of saturated zone (feet)**

100.489	**h(max)**	**maximum thickness of saturated zone (beneath center of basin at end of infiltration period)**
0.489	**Δh(max)**	**maximum groundwater mounding (beneath center of basin at end of infiltration period)**

Conversion Table

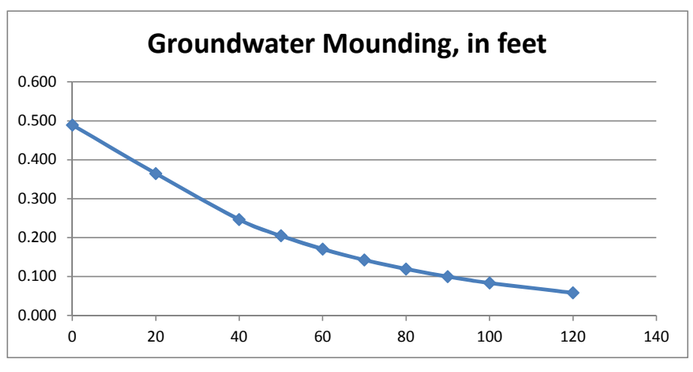
inch/hour	**feet/day**
0.67	1.33
2.00	4.00

hours	**days**
36	1.50

In the report accompanying this spreadsheet (USGS SIR 2010-5102), vertical soil permeability (ft/d) is assumed to be one-tenth horizontal hydraulic conductivity (ft/d).

Ground-water Mounding, in feet	**Distance from center of basin in x direction, in feet**
0.489	**0**
0.365	**20**
0.246	**40**
0.205	**50**
0.171	**60**
0.143	**70**
0.119	**80**
0.100	**90**
0.083	**100**
0.058	**120**

Re-Calculate Now



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